EL-CELL®
electrochemical test equipment

User manual

Version 1.21

EL-Software

Software for PAT series battery tester

Dear user,

Thank you for choosing our battery testers and EL-Software.

EL-Software is the control software for our PAT series battery testers (PAT-Tester). It allows you to plan, perform, monitor, and evaluate your electrochemical experiments, as well as the general control of the PAT-Tester.
We wish you successful and pleasant work with our software.

Your EL-CELL Team

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Disclaimer

The software and the manual have been created with the utmost care. However, no guarantee can be given that the software, the data supplied, or the manual are error-free. Since changes were made to the software after the manual went to press, the facts or procedures described in the manual may differ from the software.

1 Table of Contents

2 General information

2.1 About this user manual

2.1.1 General notes

Read the documentation

Please read this manual to familiarize yourself with the EL-Software client before using it.

Whom is this user manual intended for?

This user manual is intended for laboratory personnel and researchers involved in battery materials research.

Obtaining the latest documentation and further training material

Please also take advantage of the information and video tutorials we provide on the manufacturer's website at https://el-cell.com/support/el-cell-software/el-software. Here you can also view and download the latest version of this user manual

2.1.2 Conventions used

Example	Description
Click	Press and release the left mouse button once.
Double-click	Press and release the left mouse button twice in quick succession.
Ctrl+C	On the keyboard: press Ctrl and C keys simultaneously.
Activate/deactivate the checkbox	Select/deselect the checkbox by mouse click to activate/deactivate the function behind it.
(1)	Numbers in brackets in the text refer to a corresponding number in an example image. 1

2.2 What is EL-Software?

EL-Software is the control software for all PAT series battery testers (PAT-Tester). The software consists of the following three independent software components:

- EL-Software Client
- EL-Software Server
- EL-Software Controller

2.2.1.1 EL-Software Client

The EL-Software Client is a stand-alone software for end users that provides a graphical interface for controlling and working with PAT-Testers. In addition, the EL-Software Client is also used to display and edit data stored on the EL-Software Server.

The EL-Software Client can be installed as many times as required. A client can only connect to a single EL-Software Server. If required, multiple client installations can be run in parallel, each connecting to a different server.

2.2.1.2 EL-Software Server

The EL-Software Server serves as the central interface between the EL-Software Client and the PAT-Testers. This component manages the connected PAT-Testers, and contains the databases in which measurement data, experiments, test scripts and the like are stored.

2.2.1.3 EL-Software Controller

The EL-Software controller is installed on each PAT-Tester for direct control. Among other things, it enables communication and access to the individual test channels of a device.

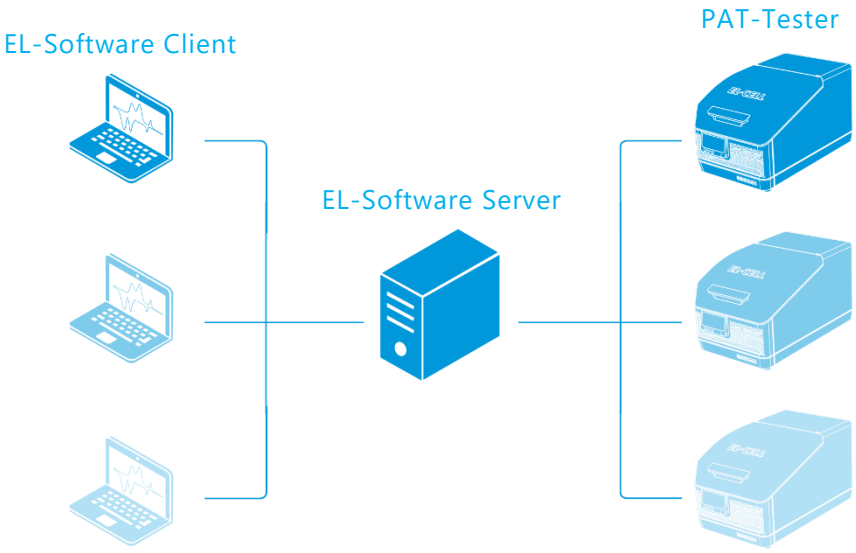
2.3 System requirements

PLEASE NOTE
EL-Software is a scalable software designed for simultaneous operation with multiple PAT-Testers. The hardware requirements result from the number of test channels used simultaneously, as well as the measurement data generated by the measurement protocols used, and is thus variable depending on the application**. The hardware requirements mentioned on the following pages should therefore only be regarded as a guideline for operating a system with up to 16 test channels.**

2.3.1 System setup

2.3.1.1 Basic structure

The overall system for operating a PAT-Tester consists of at least the components PAT-Tester, EL-Software Server and EL-Software Client. Communication between the components takes place via an existing network.



In principle, for small setups with individual test channels, it is possible to run the EL-Software Server and Client on the same computer. However, this requires the constant operation of this computer in order to be able to store measurement data properly. In addition, performance may be degraded if too many parallel processes are running on the computer.

We, therefore, recommend running the EL-Software client and server components on separate physical computers.

2.3.2 Network configuration

The PC running the EL-Software Server requires a permanent Ethernet connection with at least 1 GBit to the connected PAT-Tester. It is strongly recommended to use an Ethernet router for these connections. **A direct connection between the Ethernet ports of the PC and the PAT-Tester is not supported.** The client PCs only need a network connection to the server application. They do not require a connection to the PAT-Tester devices.

PLEASE NOTE
All devices require an IPv4 address that has been dynamically assigned via DHCP. Please contact our technical support if you have any questions**.**

2.3.2.1 Required port forwardings

If you use a firewall, port forwardings must be set up for the following ports:

EL-Software Server:

- TCP: 4711
- UDP: 1900

PAT-Tester:

- TCP: 4712, 1883, 22
- UDP: 1900

2.3.3 Hardware-requirements for EL-Software Server

Minimum hardware requirements for the server PC running the EL-Software server component:

- CPU: Intel i7-7700k (4 Cores / 8 Threads, 4,2 GHz) or similar Intel Xeon or AMD64 processor
- RAM: 8 GB
- File storage: 512 GB SATA-SSD
- System availability must be ensured during ongoing measurements.
- Hardware virtualization is supported
- 1 Gbit LAN connection to the PAT-Tester via Ethernet switch

2.3.4 Software-requirements for EL-Software Server

Minimum software requirements for the installation and operation of the **EL-Software Server**:

- Windows Server 2016 or 2019, Windows 10 version 1809 or later, or Linux Ubuntu 18.04 (for dedicated server use only)

2.3.5 Hardware requirements for EL-Software Client

Minimum hardware requirements for the server PC running the **EL-Software Client**:

- CPU: Up to date x86/AMD64 processor
- RAM: 4 GB
- File storage: 200 MB HDD
- Hardware virtualization is supported
- Screen with at least 1366 x 768 pixel screen resolution

2.3.6 Software requirements for EL-Software Client

Windows 10 Version 1809 or newer

3 Installing EL-Software

3.1 General information about the new installation

You can download the current installation file of EL-Software from the EL-CELL website. This installation file contains all components of EL-Software: the EL-Software Server, the EL-Software Client, and the EL-Software Controller. The latter component is only for updating the already installed software on a PAT-Tester.

In case of a new installation, you have to install the EL-Software Server first. If you have purchased your PAT-Tester as part of an appliance package, the EL-Software Server is already pre-installed.

It is also possible to install EL-Software Server and Client in the same process. This is useful for small setups with few test channels, where both the server and the client are to be installed on the same computer. In all other cases, we recommend installing the EL-Software Server on the dedicated server PC first and then setting up the EL-Software Clients on the other devices.

Once the EL-Software Server has been installed, there are two ways for you to perform a new installation of the EL-Software Client: via the installation file downloaded from the website or via the installed EL-Software Server itself. We recommend the latter method. It offers the advantage of automatically installing the software version compatible with the server.

If you want to reinstall the EL-Software Server, or even when setting up the server and client on the same computer, please continue with **chapter 3.1.1**

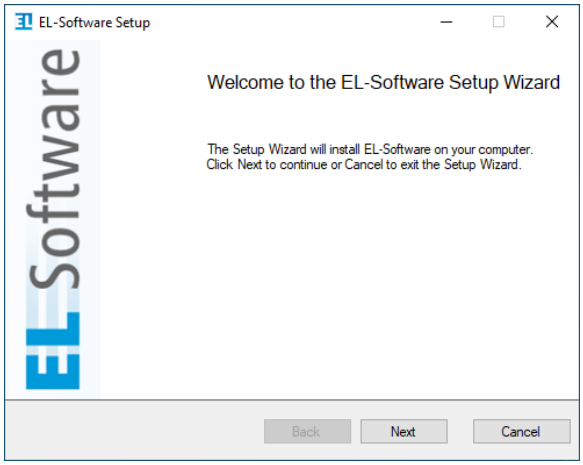
If you already have an installed EL-Software Server and want to install only the EL-Software Client, please continue with **chapter 3.1.2**

3.1.1 New installation of EL-Software

Follow these steps to install the EL-Software client and server components on the same computer running Microsoft Windows.

1. Download the latest installation file from the el-cell.com website:

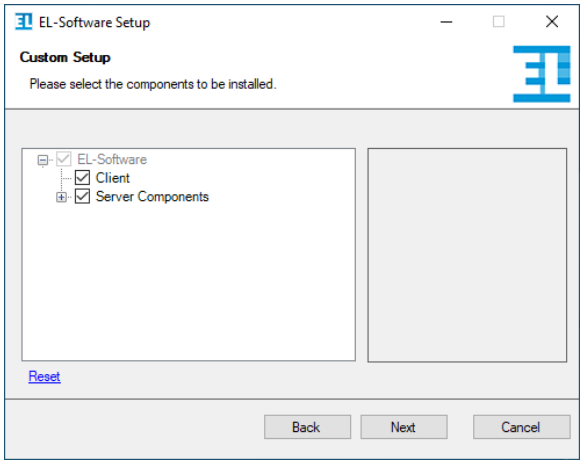
2. Double-click the downloaded .msi file to run it. The setup wizard will open to guide you through the installation process. Click "Next" to continue.



3. Select the components you want to install, and then select “Next” to continue.

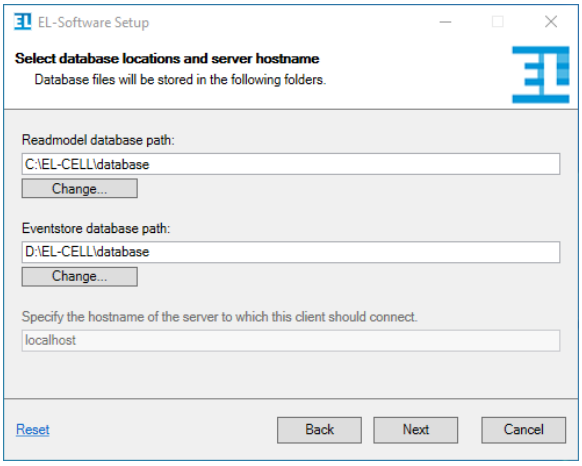
Client: Check the Client box to install the EL-Software Client.

Server components: Check the box to install EL-Software Server. Set both check marks if you want to install the server and client on the same system.

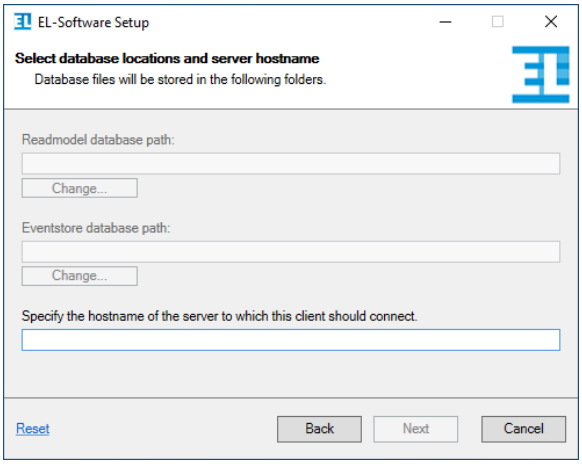


4. Depending on which components you want to install, further information will now be requested.

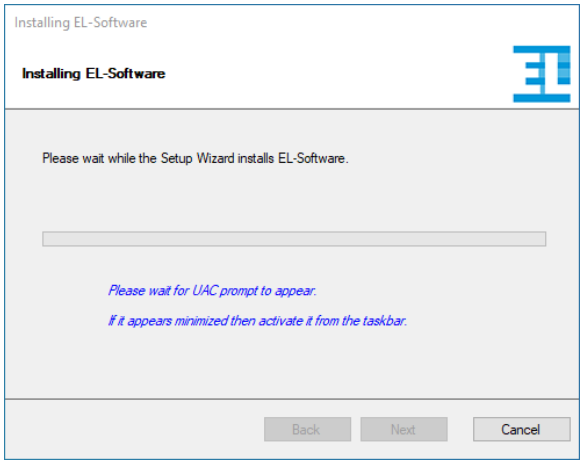
   a. **Server installation:** Select the file locations for the databases. We recommend saving each database to its own physical drive. After that, click "Next" to continue.



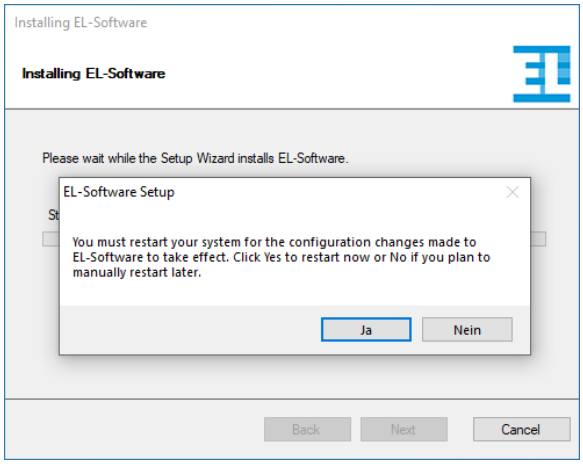
   b. **Client installation:** Enter the hostname of the server to which the client should connect. An EL-Software Client can only be connected to a single EL-Software Server at a time. Then click on "Next" to continue.



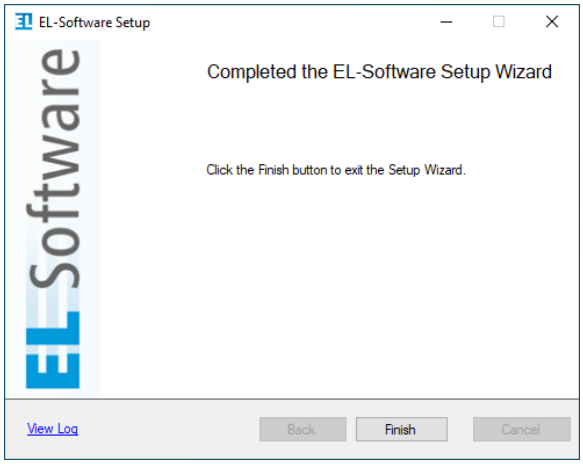
5. The installation of the software will now be performed. Confirm the Microsoft Windows User Account Control (UAC) message to confirm the process.



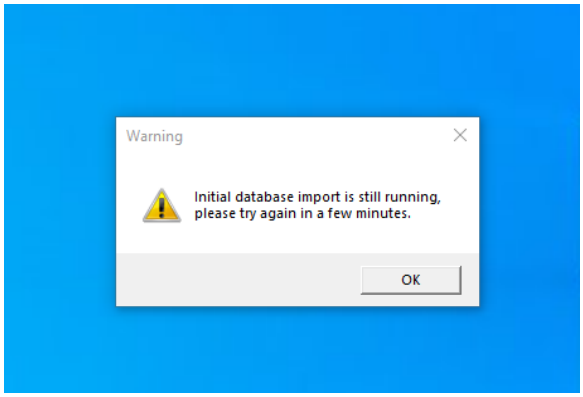
6. Once the installation is complete, you must restart the computer before you can run EL-Software. Confirm with "Yes" to perform the restart as soon as you finish the setup wizard. To perform the restart at a later time, click "No".



7. Click “Finish” to exit the wizard.



8. If you have installed the EL-Software Server, the databases will be set up after the restart. This process may take several minutes before you can use the software.



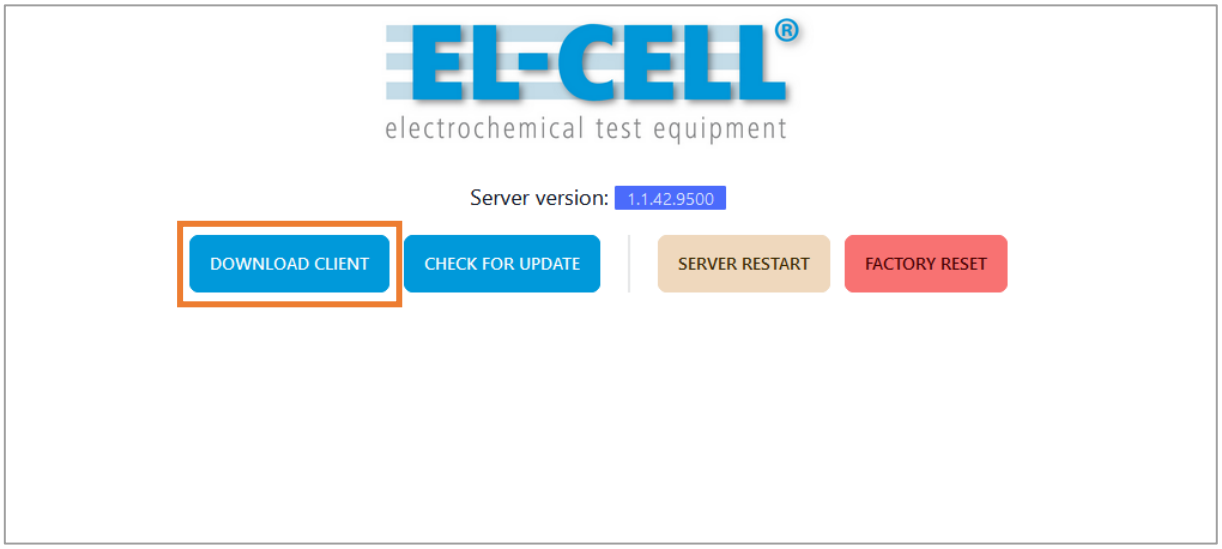
3.1.2 Reinstalling the EL-Software Client via the EL-Software Server

If the EL-Software server has already been installed, the installation of the client component can be retrieved directly from the server. This has the advantage that the client is already configured correctly during installation.

Carry out the following steps to perform the installation.

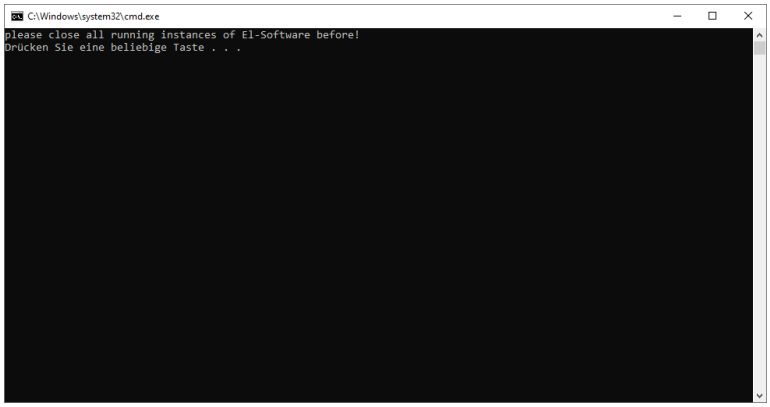
1. Open a web browser and call up the web interface of the EL-Software Server. By default, this can be reached via the address **192.168.10.20:4711**. If you have given the EL-Software Server a different IP address, use this IP address instead and add the port specification **:4711**.

2. The graphical user interface of the EL-Software Server opens. Click on "Download Client".



3. Double-click the downloaded .bat file and confirm the execution in the system dialog.

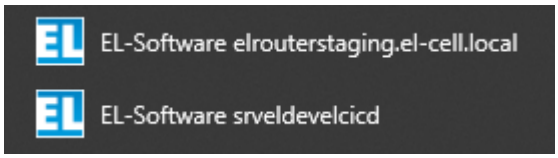
4. A system input window opens. Press any key to start the installation.



5. The installation will now be performed, and the EL-Software Client will be started automatically afterward.

3.1.2.1 Parallel installation of the EL-Software Client

In principle, it is possible to run out several client installations in parallel on one system, provided that several EL-Software servers are also available. Each client is permanently assigned to a server. The assignment can be seen from the entry in the Windows Start menu; the name of the respective hardware server appears there behind "EL-Software" unless the server and client are located on the same device, or the EL-Software was installed via the .msi Installer. In these cases, the server name is not displayed.



Example showing two EL-Software Clients installed on the same system

4 Updating EL-Software

4.1 General information about updating the software

With an existing Internet connection, a software update can be called up and executed directly via the web interface of the EL-Software server.

Without an existing Internet connection, it is possible to read in and execute an installation file located on a USB stick, for example, in order to update the server component.

Once the EL-Software Server has been updated, it provides the new software versions for the EL-Software Client and EL-Software Controller on the network. This does not require an existing Internet connection. It is, therefore, necessary to always update the EL-Software Server first when a new software version is released.

The update of the EL-Software Client is performed automatically as soon as it is restarted.

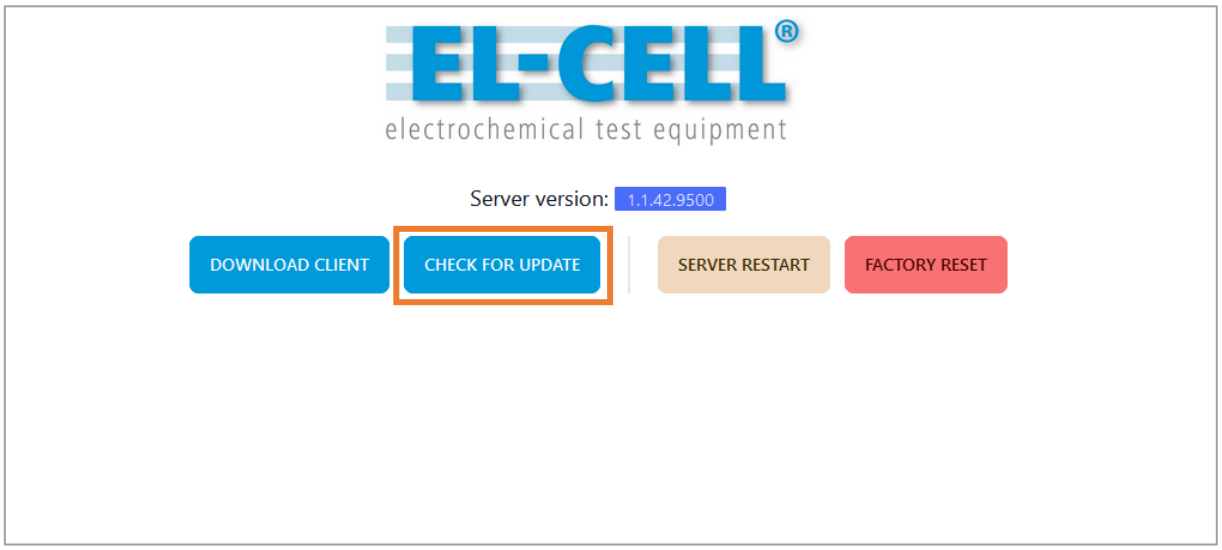
The update of the EL-Software Controller on a connected PAT-Tester is controlled via the program interface of the EL-Software Client. You can find out more about this in **chapter 7.1.2.**

PLEASE NOTE
When updating the EL-Software server, all databases are deleted and then recreated. The stored measurement data are not affected by this and are preserved.

4.2 Updating the EL-Software Server

Open a web browser and call up the web interface of the EL-Software Server. By default, this can be reached via the address **192.168.10.20:4711**. If you have given the EL-Software Server a different IP address, use this IP address instead and add the port specification **:4711**.

The graphical user interface of the EL-Software Server opens. Click on "Check for Update".



1. **If you are connected to the Internet**, you will immediately be offered the option of performing the update under "Automatic Update", provided that a new version is available.

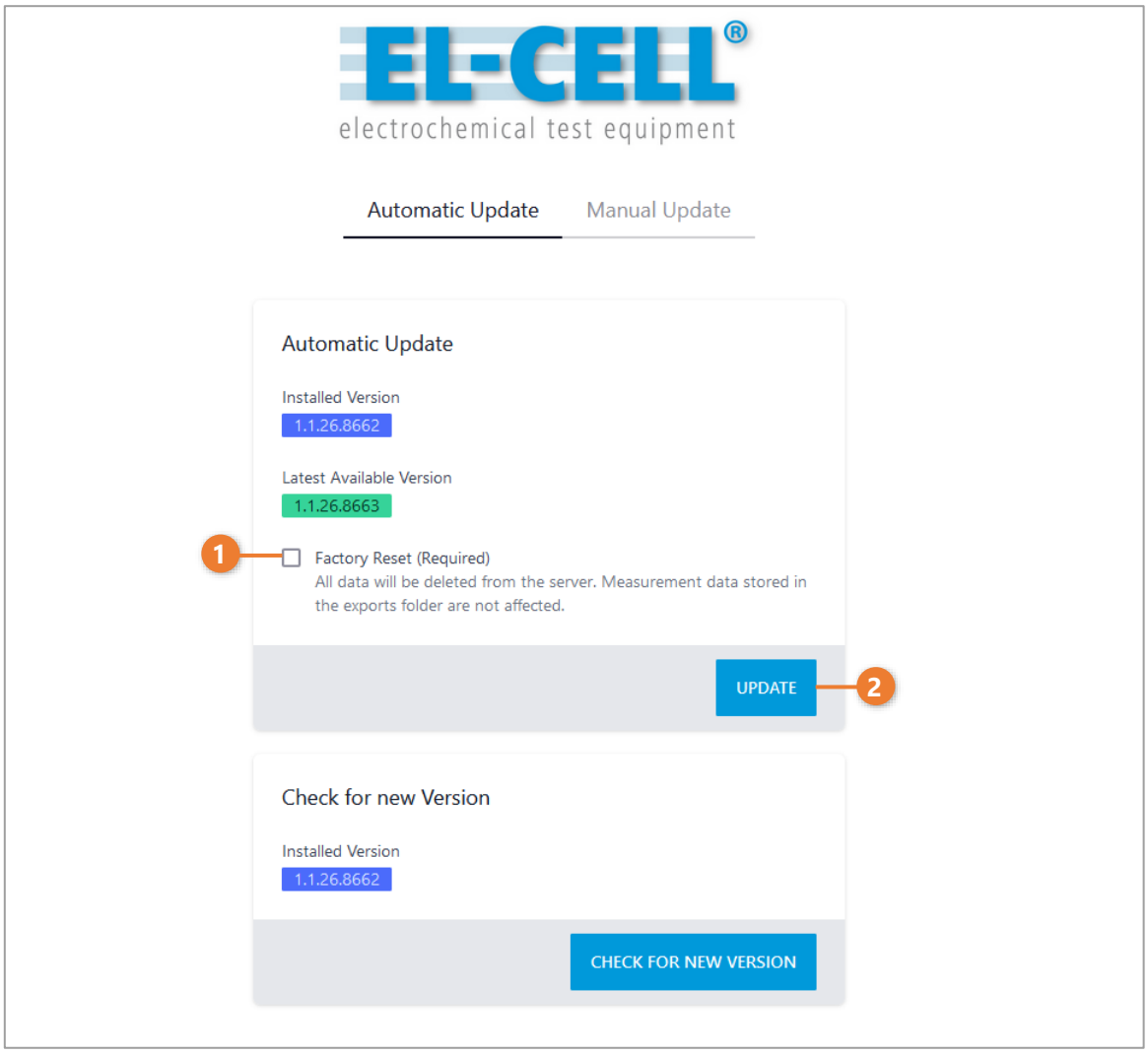
   To perform an update, you must first check the "Factory Reset" (1) box. This means that all databases are reset to factory settings. The existing measurement data in the Exports Order will be retained.

2. Now click on "Update" (2) to start the update process.

PLEASE NOTE

While the update is in progress, do not reload the web page or click on navigation elements. This can lead to error messages.

Therefore, wait until the update is done and the message appears that the page is now reloading.



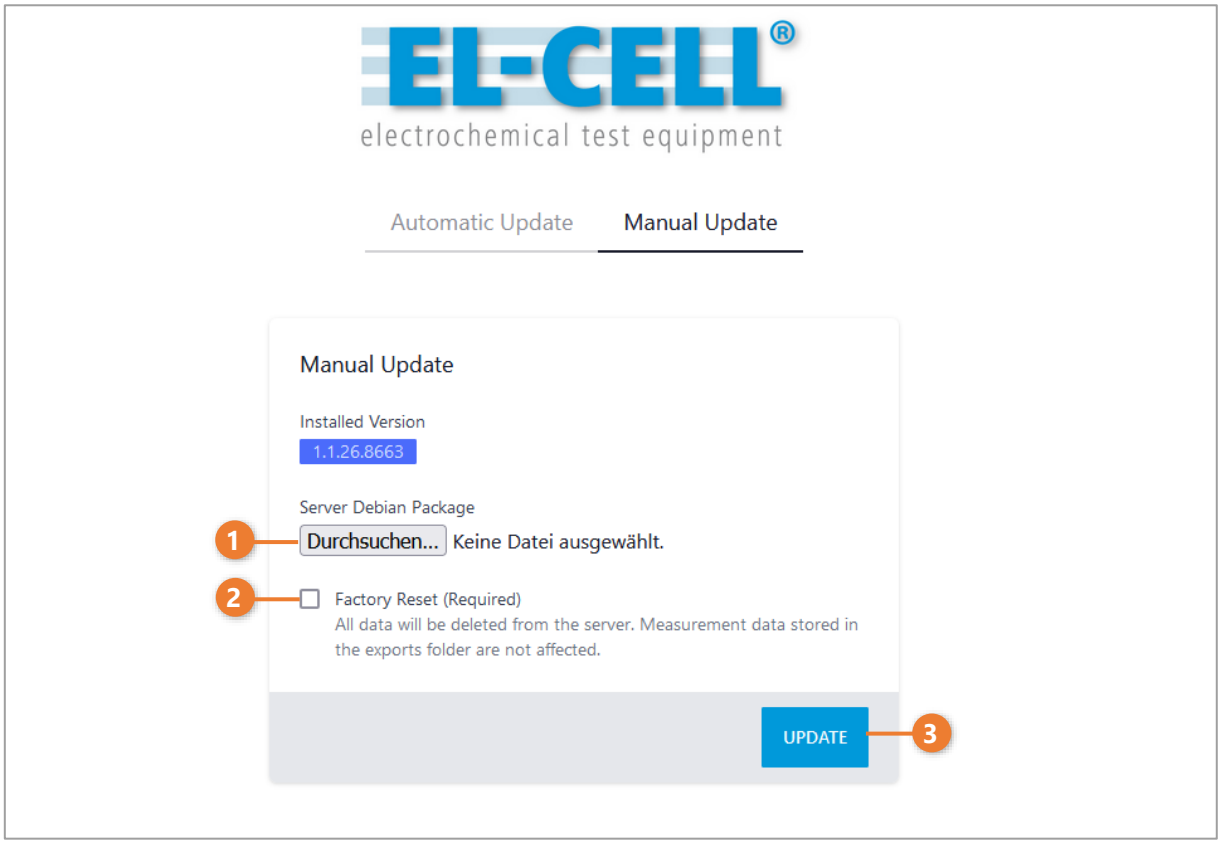
3. **Without an existing Internet connection**, you have the option of executing an installation file in *.deb* format, which you have previously downloaded from the EL-Cell website and saved on a USB stick, for example. To do this, switch to the "Manual Update" tab Here you can select the installation file (1).

   To perform the update, you must now check the box "Factory Reset" (2). This means that all databases will be reset to factory settings. The existing measurement data in the Exports Order will be retained. Now click on "Update" (3) to start the update process.

PLEASE NOTE

While the update is in progress, do not reload the web page or click on navigation elements. This can lead to error messages.

Therefore, wait until the update is done and the message appears that the page is now reloading.



4.3 Updating the EL-Software Client

Each time the EL-Software Client is started, the version is automatically checked and an update is performed if necessary. Afterwards the client starts automatically.

5 Removing the EL-Software Client

The EL-Software Client is uninstalled differently depending on the source from which it was obtained (EL-Cell website or EL-Software Server).

5.1 Required steps if installed via the EL-Software Server

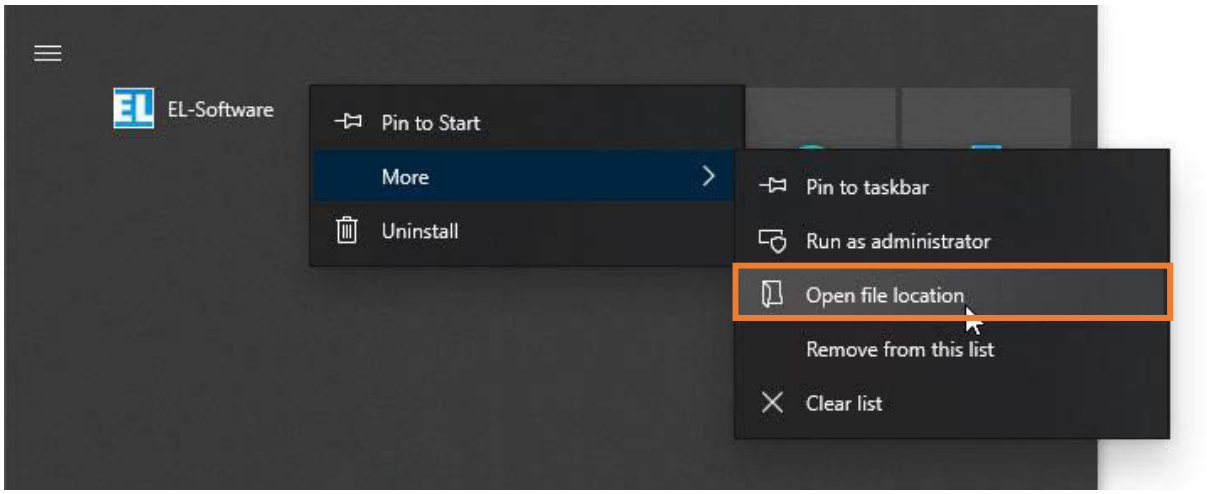
If the EL-Software Client was obtained and installed via the EL-Software Server, it must be removed by deleting the installation folders. To determine the location of these folders, proceed as follows.

1. Open the Windows Start menu via the taskbar or the Windows key.

2. Click with the right mouse button on the entry of the installed EL-Software Client.

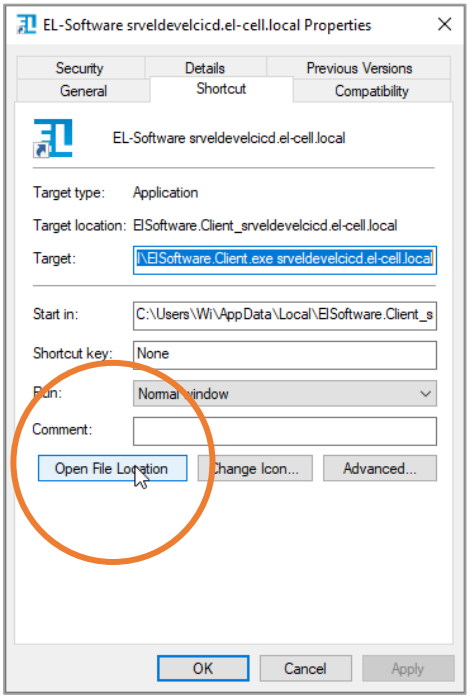
PLEASE NOTE
It is possible to install the EL-Software client multiple times on the same system. Each installation is connected to a different server. The name of the connected server is specified in the entry behind "EL-Software".

3. Go to "More" in the context menu and select "Open file location".

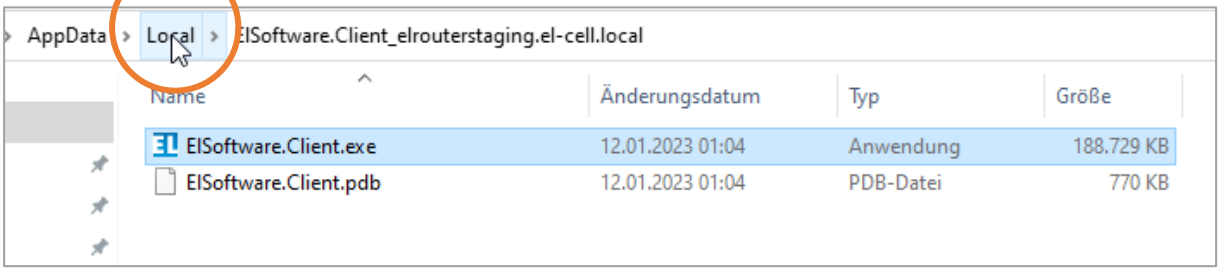


4. A file explorer window opens with the EL-Software Client shortcut. Select it with the right mouse button and click "Properties" in the context menu.

5. Now select "Open file path".



6. A new File Explorer window opens. Navigate one level higher by clicking on "Local" in the Explorer folder path.



7. Now delete the entire folder. It has the same name as the entry in the Windows start menu. This will uninstall the EL software client.

5.2 Required steps if installed via the .msi installer

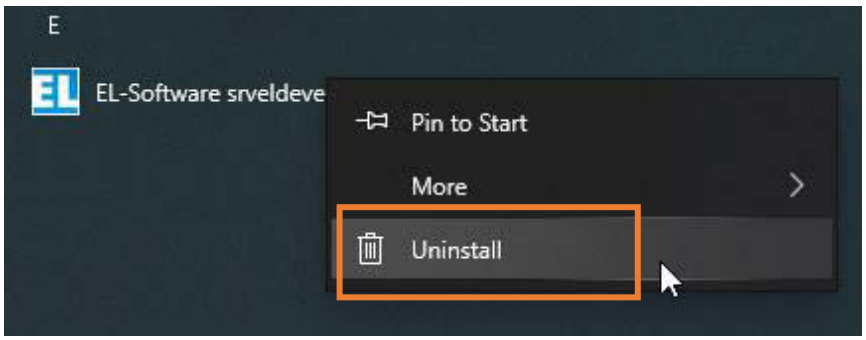
If you have installed the EL-Software Client via the *.msi* installation file offered as download on the EL-Cell website, you have to uninstall it via the Control Panel.

1. Open the Windows start menu via the taskbar or the Windows key

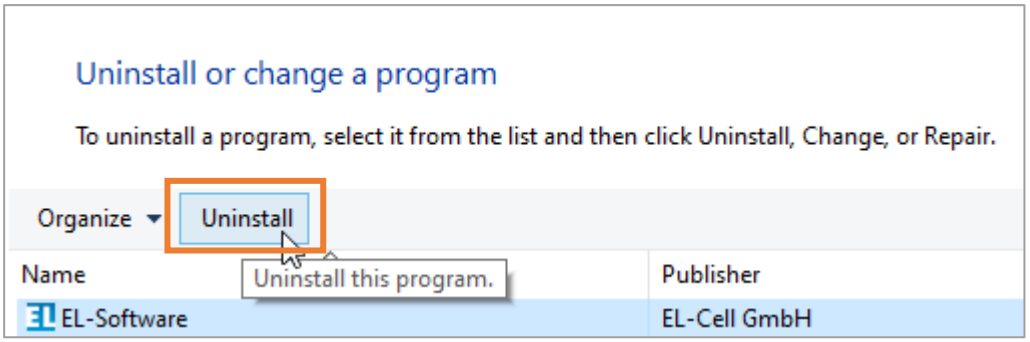
2. Click with the right mouse button on the entry of the installed EL-Software Client

PLEASE NOTE
It is possible to install the EL-Software Client multiple times on the same system. Each installation is connected to a different server. The name of the connected server is specified in the entry behind "EL-Software".

3. Select the option „Uninstall".



4. The Windows system dialog opens with a list of the installed programs on the client PC. Select the EL-Software Client entry and click Uninstall. This will remove the program from the client PC.



6 EL-Software Client

6.1 General information about the EL-Software Client

The EL-Software Client enables the control of one or more PAT-Testers, and the planning, execution and evaluation of electrochemical experiments. The EL-Software Client only provides the graphical interface to communicate with the EL-Software Server and the PAT-Testers. The client itself does not store any data.

Basic operation concepts

The basic concept behind the design and operation of EL-Software follows the experiment-centric approach. Since EL-Software is designed for high-throughput experiments, that means with many test channels on several battery testers, the focus lies on the experiment with its cell groups. This approach differs from the usual approach, which focuses on direct control of individual test channels. When working with EL-Software, it is therefore irrelevant in which test channel or battery tester a test cell is operated, as the cell groups are considered as a whole. This greatly simplifies cell management during the experiment. For practical work with EL-Software, this means the following principles:

- Each experiment requires at least one cell group with at least one test cell
- Test scripts are assigned to the cell group
- The experiment can extend over several battery testers, depending on the number of cells in the cell groups. To ensure effective cell management in larger experiments, individual test cells can be conveniently accessed via the cell group.
- For small experiments with a few cells, access to individual cells can also be made directly via the test channel.

Other special features of EL-Software are:

- The integrated database with all cell components used for efficient planning of experiments
- The recording of the cell composition used. This is used for later evaluation and logistical planning of experiments. The possibility of generating quantity lists of the required components can reduce the effort required for assembly
- The recording of the life cycle of the test cells used. As soon as a test cell has been assembled, a so-called *cell build* is generated. This is a virtual container that stores related data (cell composition, experiments performed) in the database to simplify later evaluations.
- The network-based design of EL-Software makes it possible to access battery testers, measurement data and experiments from any location.

6.2 Basic functions

6.2.1 Starting and ending the program

The EL-Software Client is started from the Windows Start menu. To close the client, close the program window by clicking on the "X" in the upper right corner of the window frame.

PLEASE NOTE

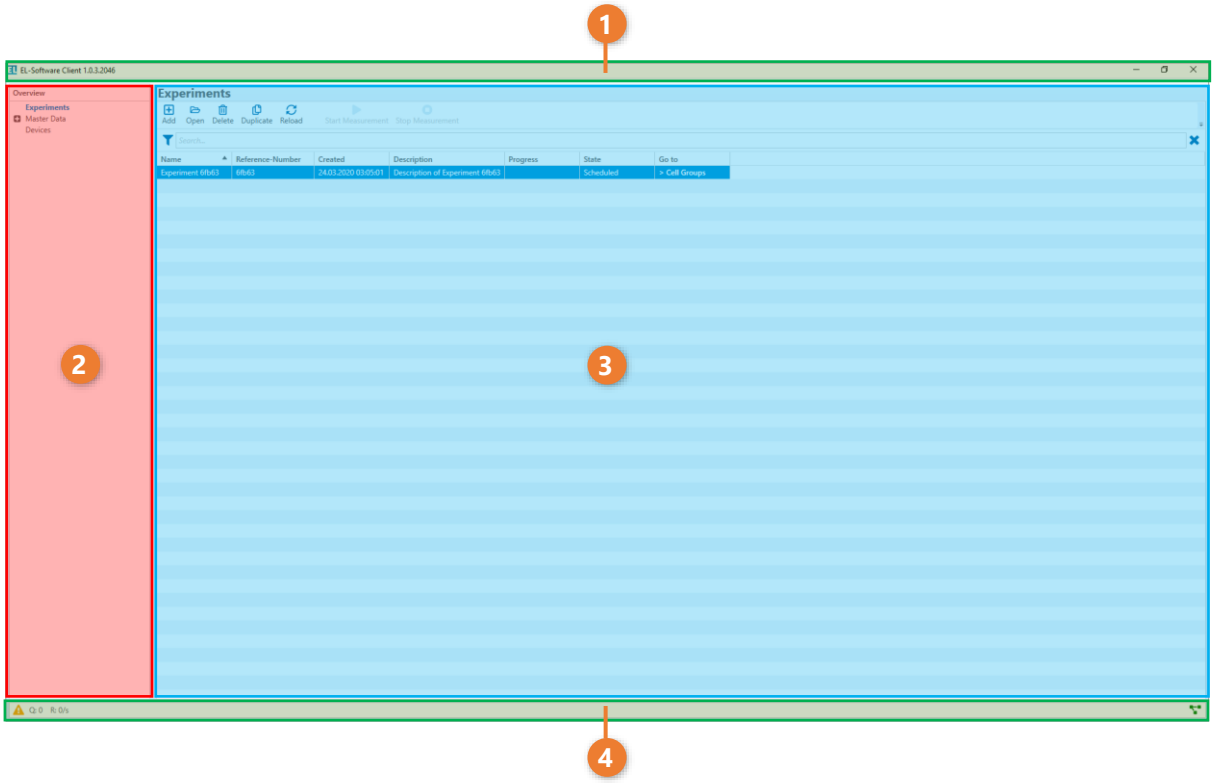
The EL-Software Client only provides the graphical user interface and allows access to the EL-Software Server and the associated battery testers. When exiting the client, running experiments are not affected.

6.2.2 Full screen and window mode

The EL-Software Client always starts in window mode. The size of the program window can be changed as desired by dragging the window frame. Using the controls in the upper right corner you can minimize the window (1), as well as switch between full screen and window mode (2).

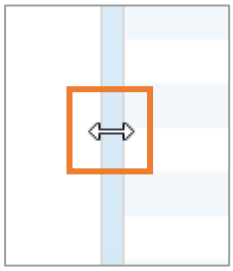
6.3 Layout of the user interface

The graphical user interface (GUI) of the EL-Software Client is divided into several areas. It is divided into the header bar (1), the tree view (2), the content area (3), and footer bar (4).



6.3.1 Changing the width of the interface areas

You can change the width of the divider between areas to hide or widen areas. To do this, move the mouse to the divider between two areas until the mouse pointer changes. By holding down the left mouse button, you can now change the width of the areas.

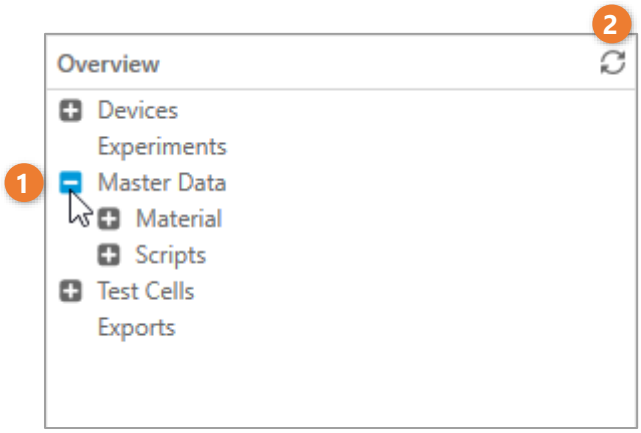


6.3.2 The areas of the graphical user interface

6.3.2.1 Header bar

The header bar shows the version number and creation date (1) of the installed EL-Software Client on the left and offers the operating system's own controls (2) for controlling the window mode and for exiting the client on the right.

6.3.2.2 Tree view



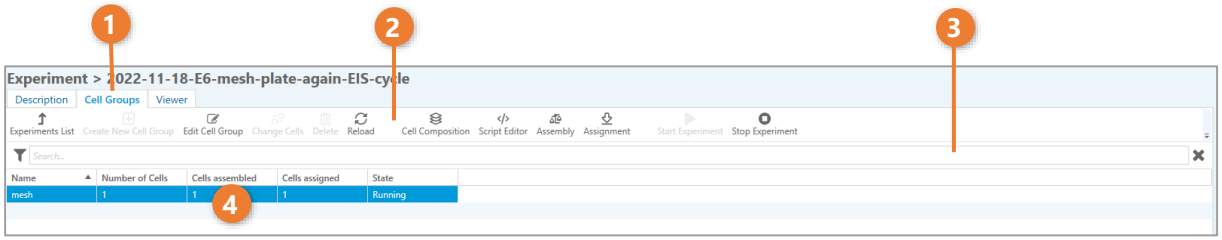
The tree view allows you to navigate to all main menu items as well as their sub-items.

You can expand or hide the entries by clicking on the plus or minus sign (1) in front of each entry. By clicking on the entry itself, the display of the content area changes to the selected entry.

Clicking the icon (2) in the upper right corner reloads the view and collapses all entries.

6.3.2.3 Content area

The content area shows the contents of the respective entry selected in the tree view.



1. Tab navigation

Depending on the currently selected main area, the content area may have additional views that can be accessed via tab navigation.

2. Menu bar

The menu bar offers buttons for all functions available in this view.

3. Search bar

The contents of the data area can be searched and filtered via the search bar. The display of the content is thereby reduced to matching elements by full text search. Click on the "X" to the right of the search bar or delete the search term to cancel the filter.

4. Data area

The data area displays all information of the selected view. It can contain several subareas depending on its complexity.

6.4 Main menu items in EL-Software

The contents and functions of EL-Software are summarized in several main menu options and accessible via the tree view.

6.4.1 Devices

The main menu item "Devices" is used to manage all PAT-Testers connected to the EL-Software Server. New devices can be connected to the server here.

6.4.2 Experiments

"Experiments" is used to manage, create and monitor experiments and their associated cell groups.

6.4.3 Master Data

The "Master Data" menu option is used to manage all cell components and test scripts required to perform the experiments.

6.4.4 Test Cells

The menu item "Test Cells" lists all test cells used in the experiments. In addition, a history of all experiments performed with each cell is recorded here.

7 Working with EL-Software

The following chapters serve as a quick introduction to working with EL-Software and describe the usual processes within the software.

7.1 Controlling the PAT-Tester via EL-Software

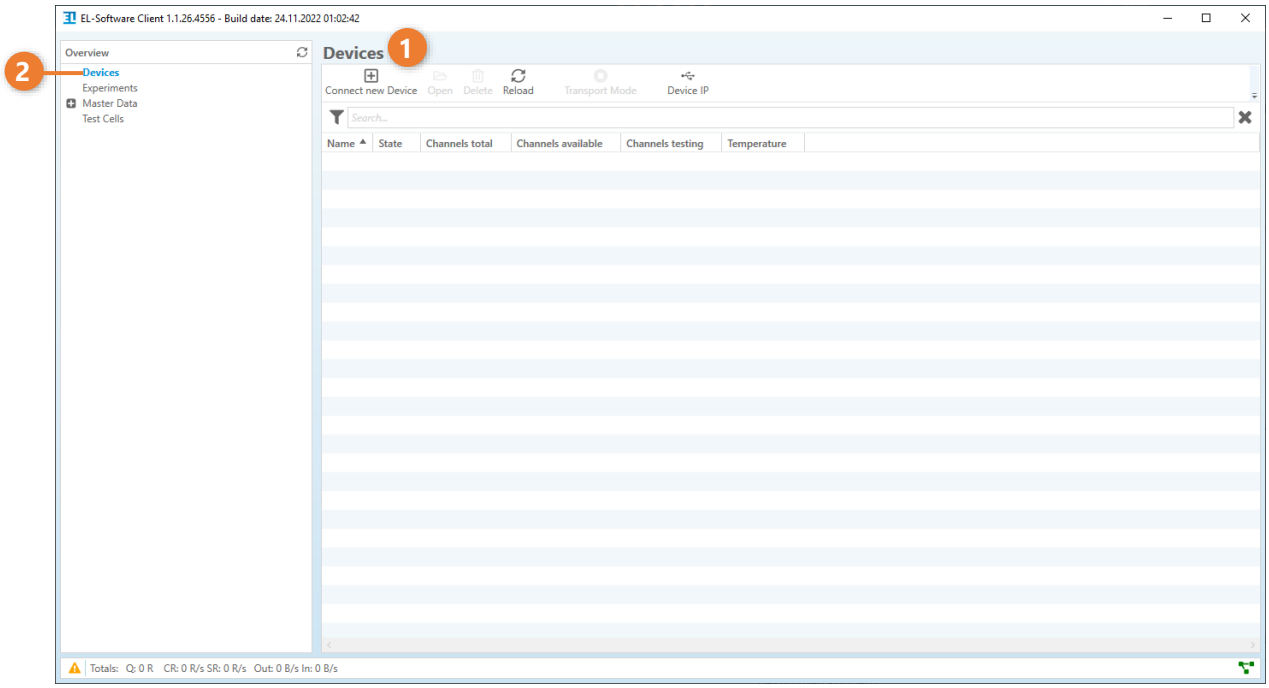
Each PAT-Tester must first be connected to the EL-Software Server before operation. The PAT-Tester can then be controlled via EL-Software and transmit measurement data to the server. Any number of PAT-Testers can be connected to the same EL-Software Server. However, a single PAT-Tester cannot be connected to several servers at the same time.

7.1.1 Connecting the PAT-Tester to the EL-Software Server

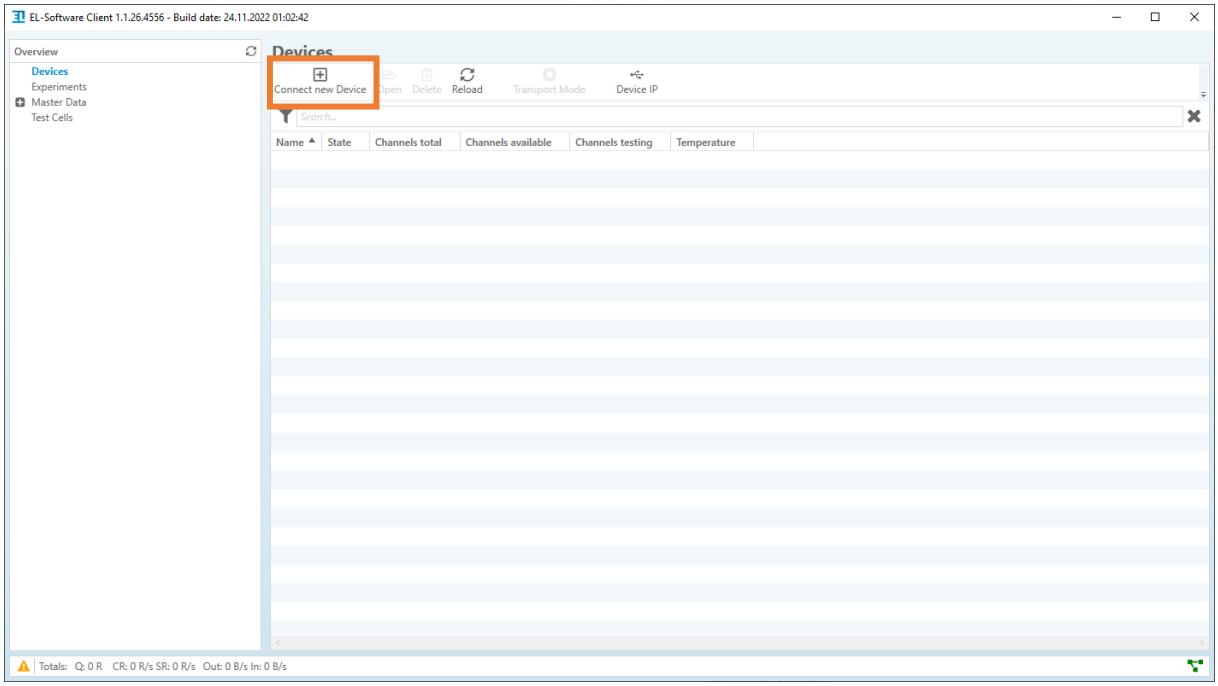
To connect a PAT-Tester to the server, perform the following steps.

1. Make sure that the PAT-Tester and the computer on which the EL-Software Server has been installed are turned on and connected to the same network via LAN.

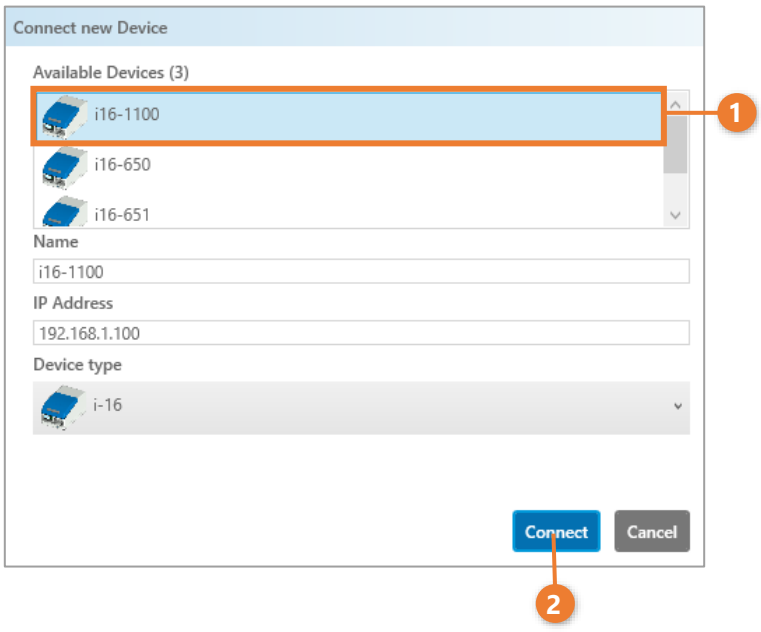
2. Start the EL-Software Client. It should display the menu item "Devices" (1) by default. Otherwise select "Devices" in the tree view (2).



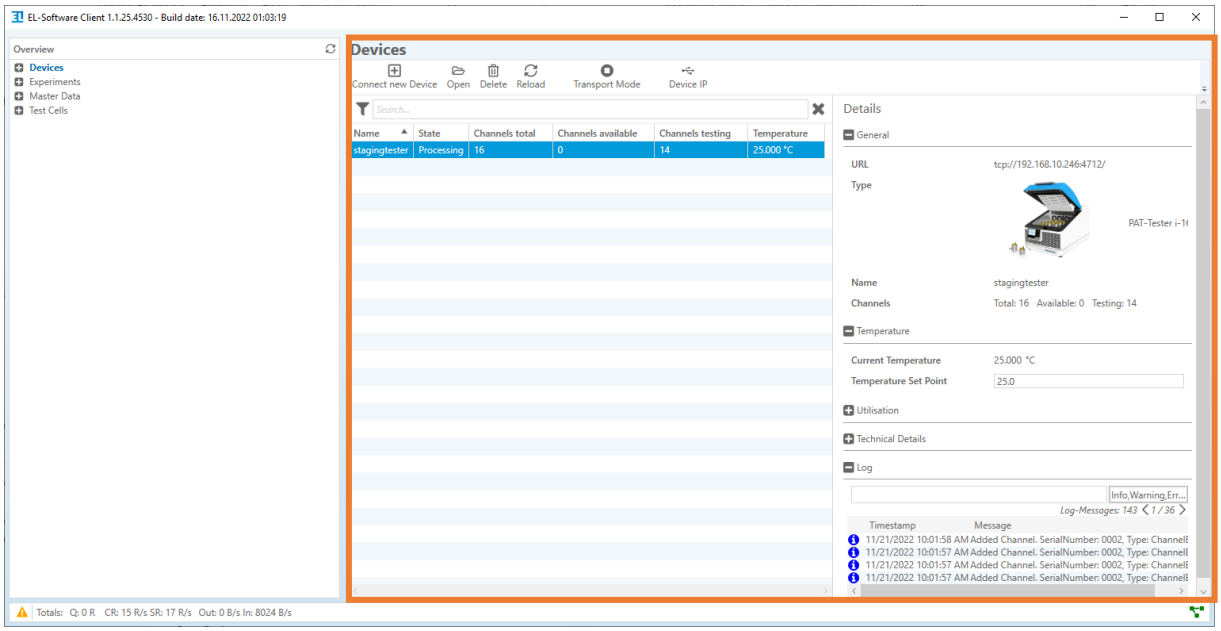
3. Click “Connect new Device” in the menu bar.



4. A dialog window will open listing all PAT-Testers currently available on the network. Select the PAT-Tester in the list (1) that you want to connect to the EL-Software Server and then click on "Connect" to connect it (2).



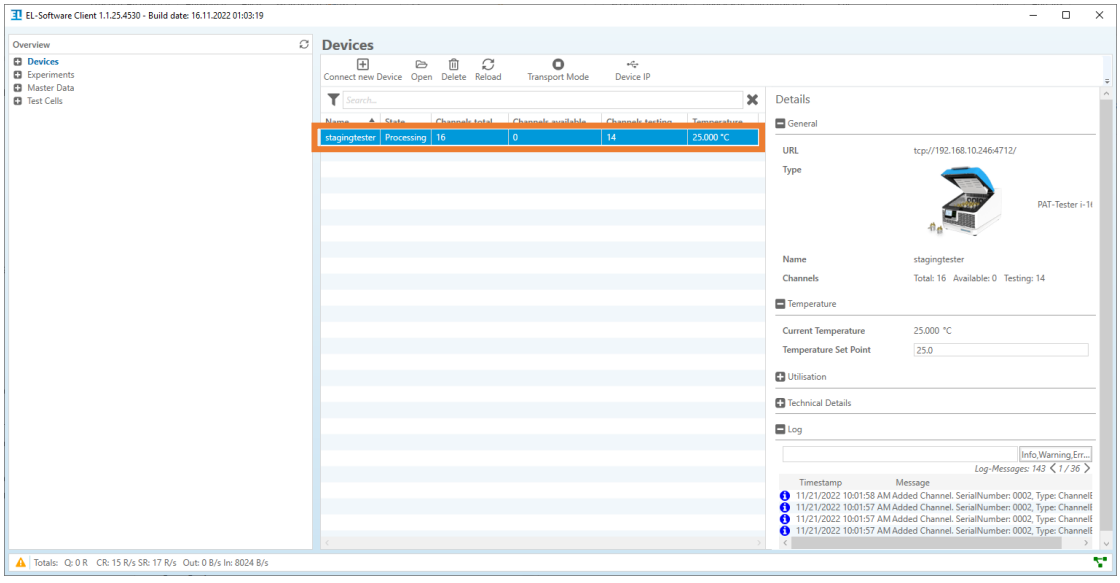
5. The PAT-Tester appears in the list view as a device. It is now connected and can be used.



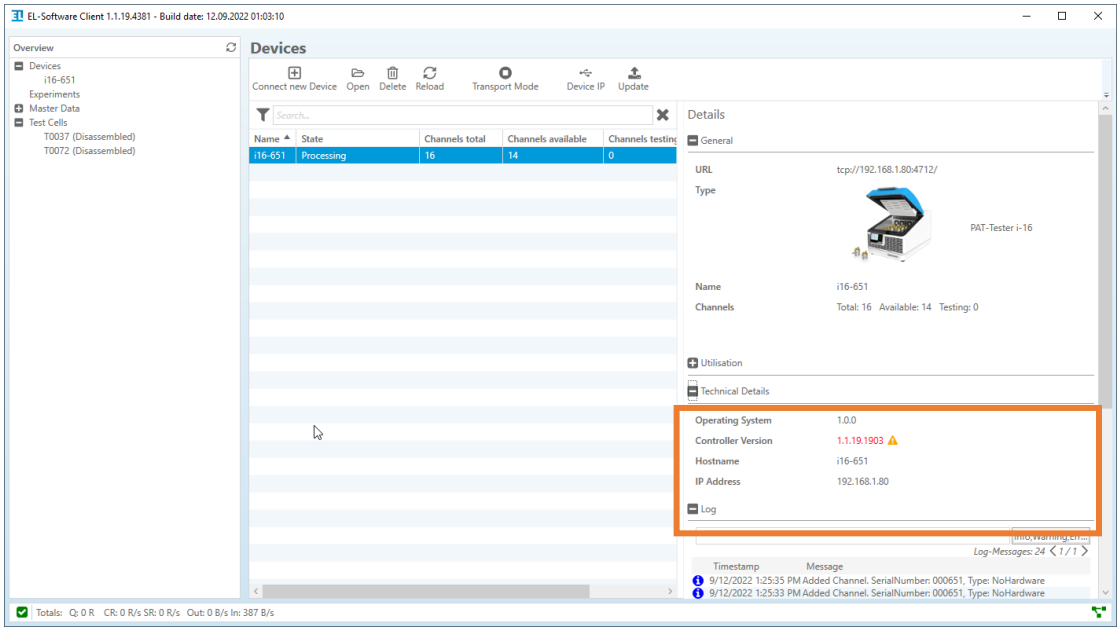
7.1.2 Updating the EL-Software Controller

The EL-Software Controller is the operating software installed on each PAT-Tester. It can be updated via the device list view under "Devices". To do this, follow the steps below:

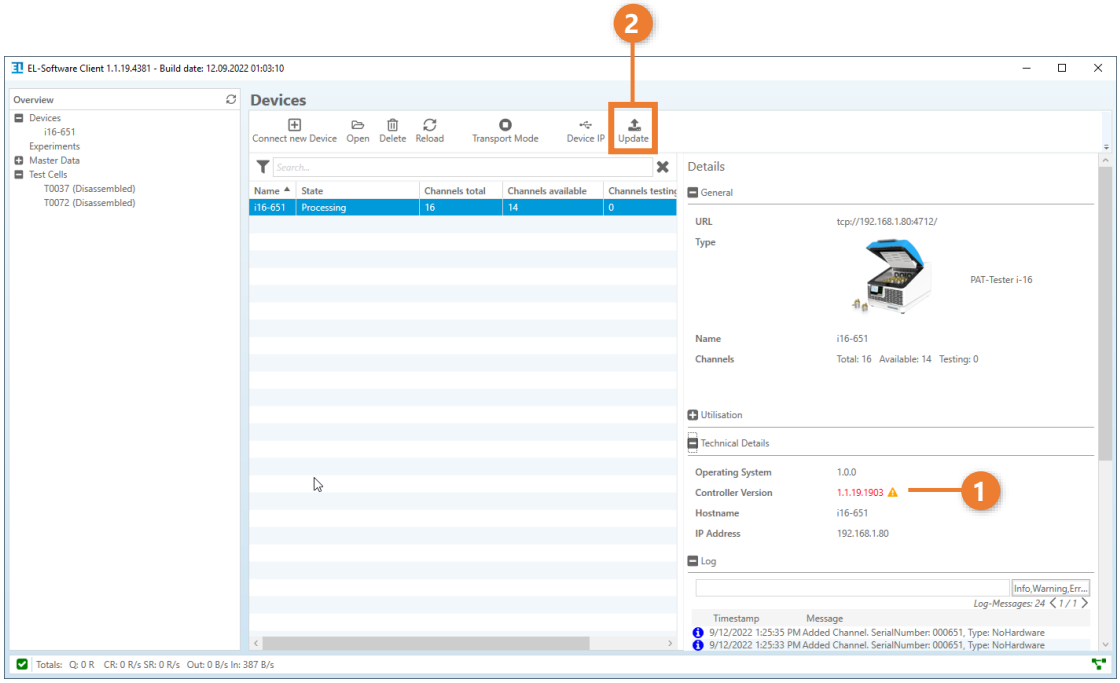
1. Call up the menu item "Devices" and click on the list entry of the PAT-Tester.



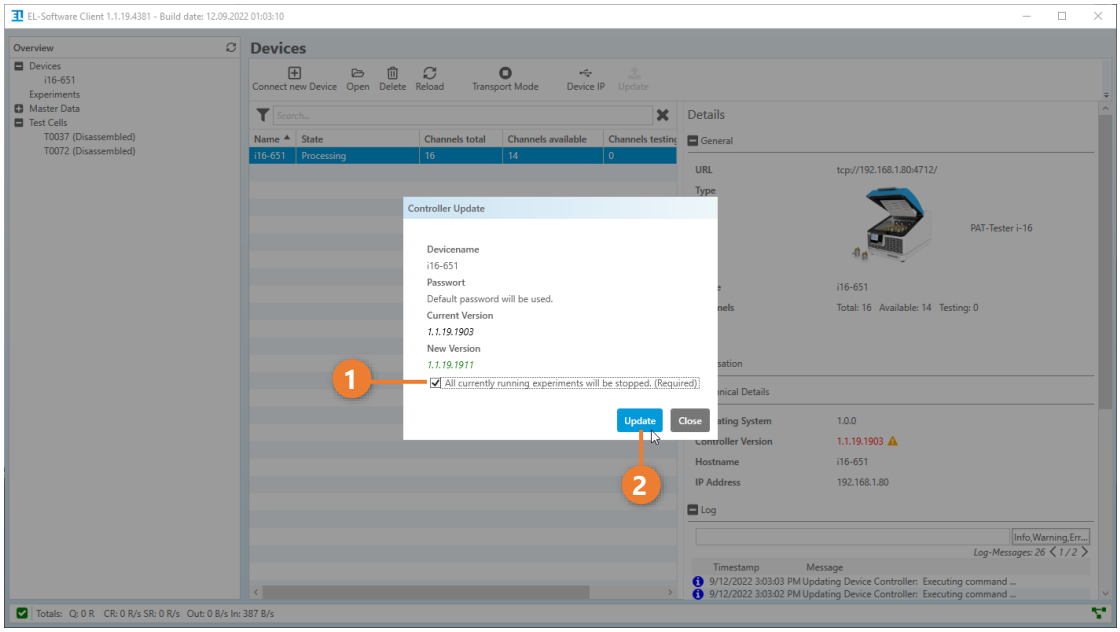
2. In the "Details" column on the right, all relevant information of the device is displayed. Expand the "Technical Details" menu option to check the installed software version.



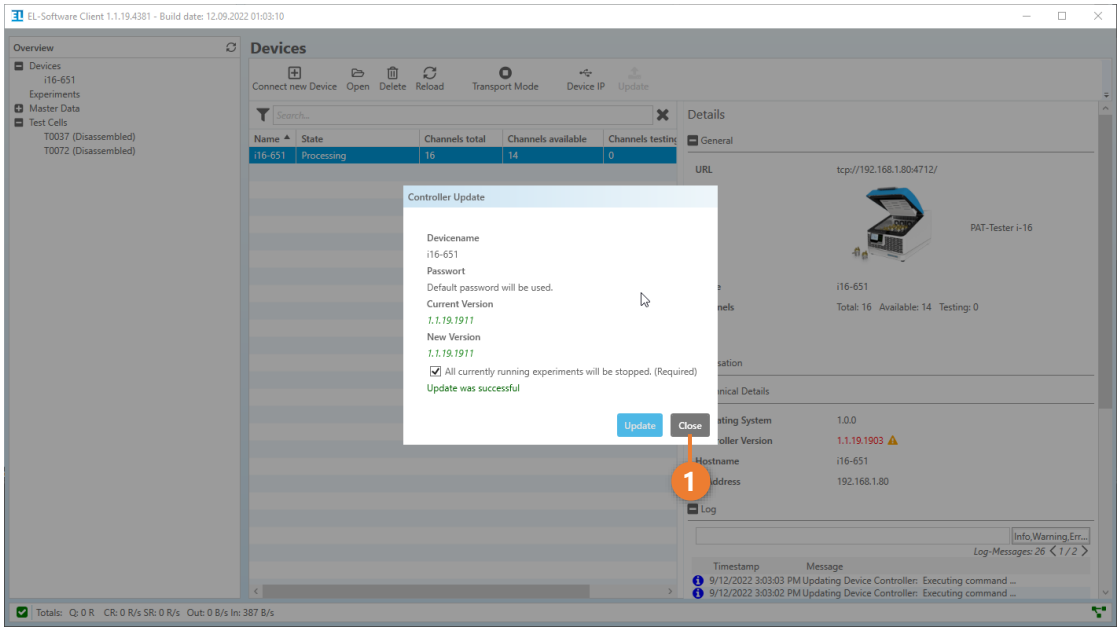
3. An outdated software version of the EL-Software Controller is displayed in red (1). Click on "Update" in the menu bar to start the update dialog (2).



4. When updating the EL-Software Controller, all running experiments on this device will be stopped. Check the box to confirm (1) and then click on "Update" (2) to start the process.



5. The software update is now performed on the device. After successful completion of the process, the corresponding message is displayed and the current version number now corresponds to the new version. Click on "Close" to exit the dialog box.

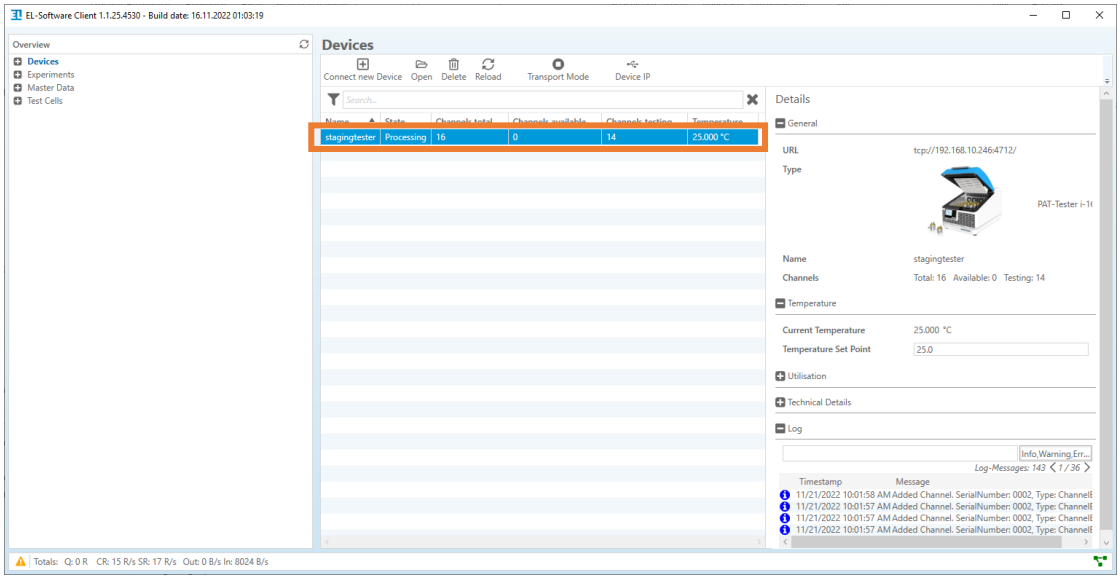


7.1.3 Changing the IP address of a PAT-Tester

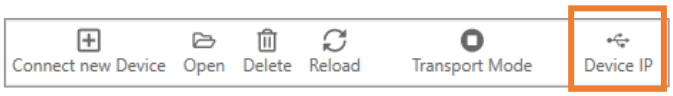
Perform the following steps to change the IP address of a PAT-Tester.

PLEASE NOTE
You need a formatted (Fat32 or NTFS) USB stick to perform these steps.

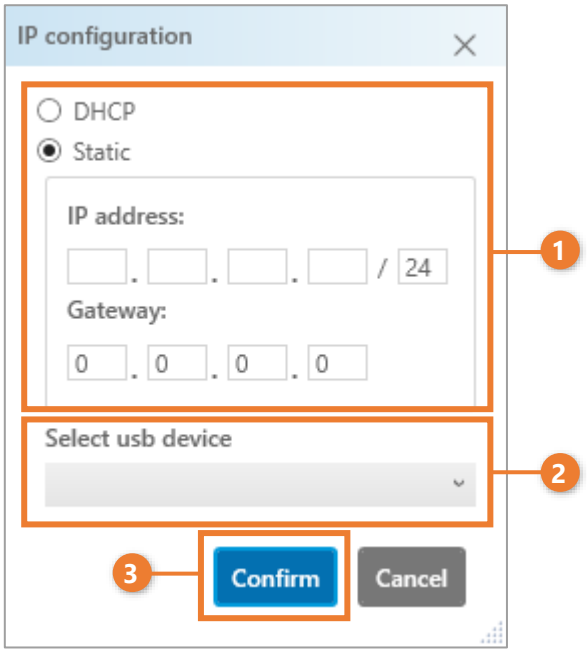
1. Call the menu item "Devices" and click on the list entry of the PAT-Tester.



2. Then click on the "Device IP" button in the menu bar



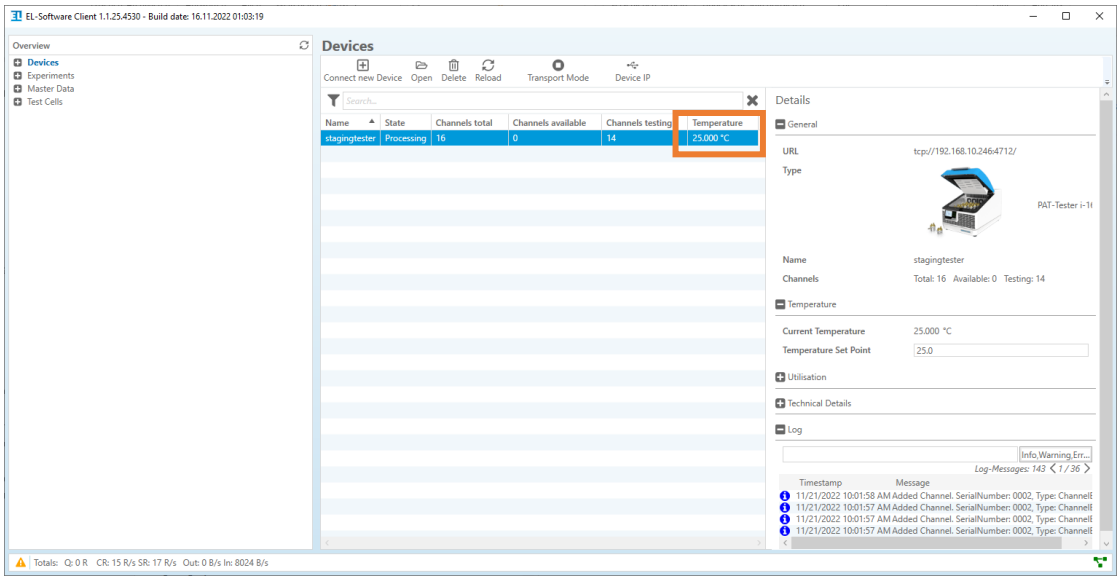
3. A dialog window opens where you can enter the new IP address. Select the USB stick on which the new network configuration is to be saved. Finally click "Confirm" to execute the operation and exit the dialog.



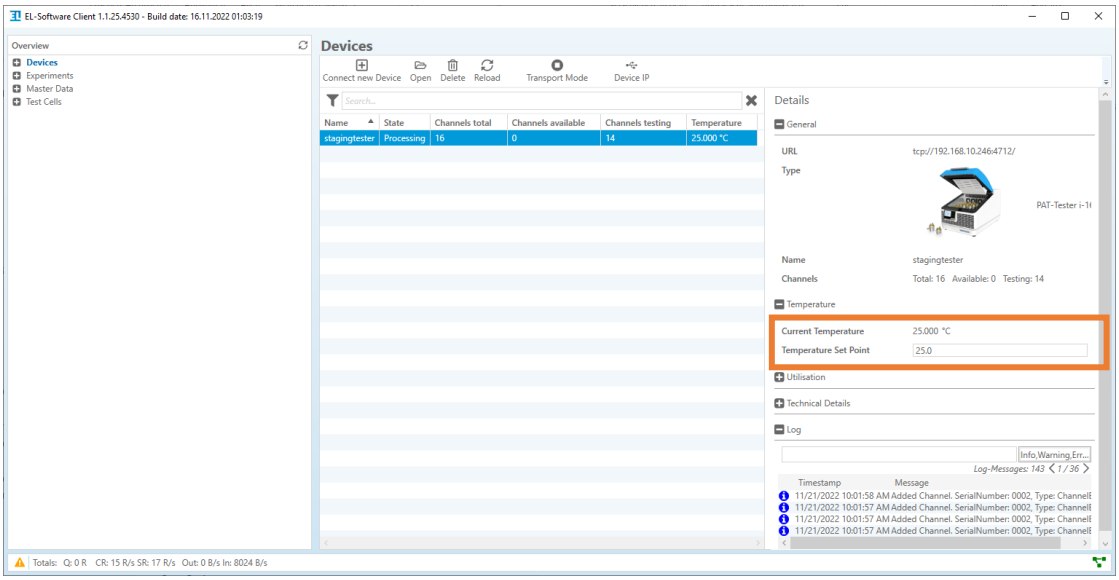
4. Connect the USB stick to the PAT-Tester. The network configuration is automatically transferred to the device and a reboot is performed. After that, the new IP address is set in the device.

7.1.4 Setting the temperature of the cell chamber inside the PAT-Tester-i-16

1. Call up the "Devices" menu item and click on the list entry of the PAT-Tester. The actual temperature of the cell chamber is displayed in the temperature column.



2. In the device details, the actual temperature is displayed as well as the set target temperature. 25°C is preset as the standard temperature. As soon as you enter a different value in the input field, this is transferred to the PAT-Tester as the new set temperature and the heating or cooling process is started.



7.1.5 Monitor system load

You can monitor the current load of all connected PAT-Testers in EL-Software. The values can provide information on whether the server hardware used is sufficient to record the data points generated in the current measurements. The following values are recorded:

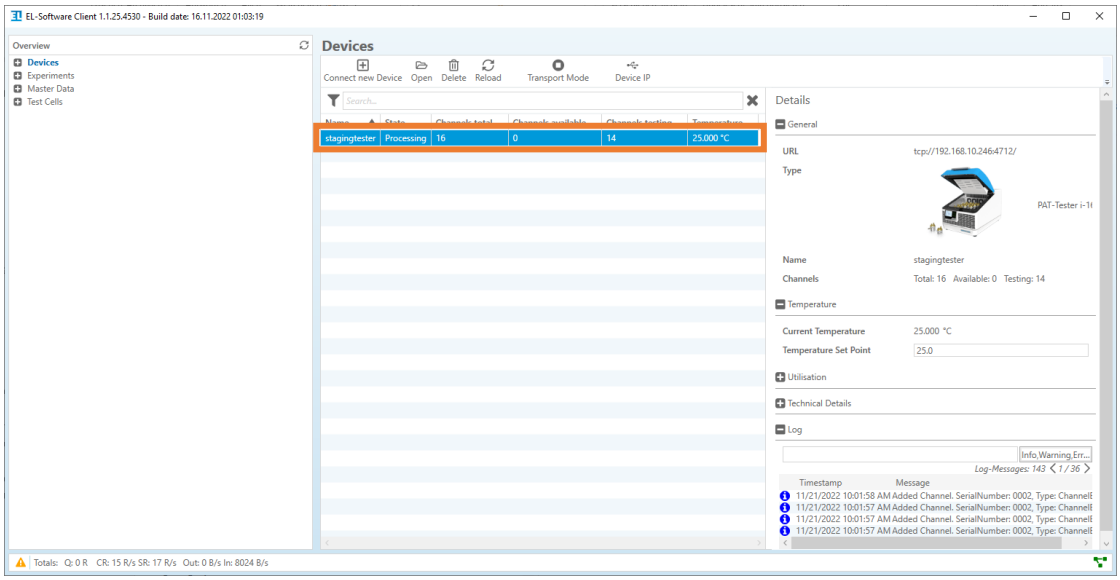
Parameter	Shortcut	Description
Queue	Q	Data packets that have been created but not yet transferred to the server
Controller Rate	CR	Speed at which the controller processes incoming messages of the test channels
Server Rate	SR	Speed at which the server processes incoming messages from the controller.
Bytes sent	OUT	Data currently sent by the tester in bytes per second
Bytes received	IN	Data currently received from the server in bytes per second

7.1.5.1 Monitoring the utilization of the overall system

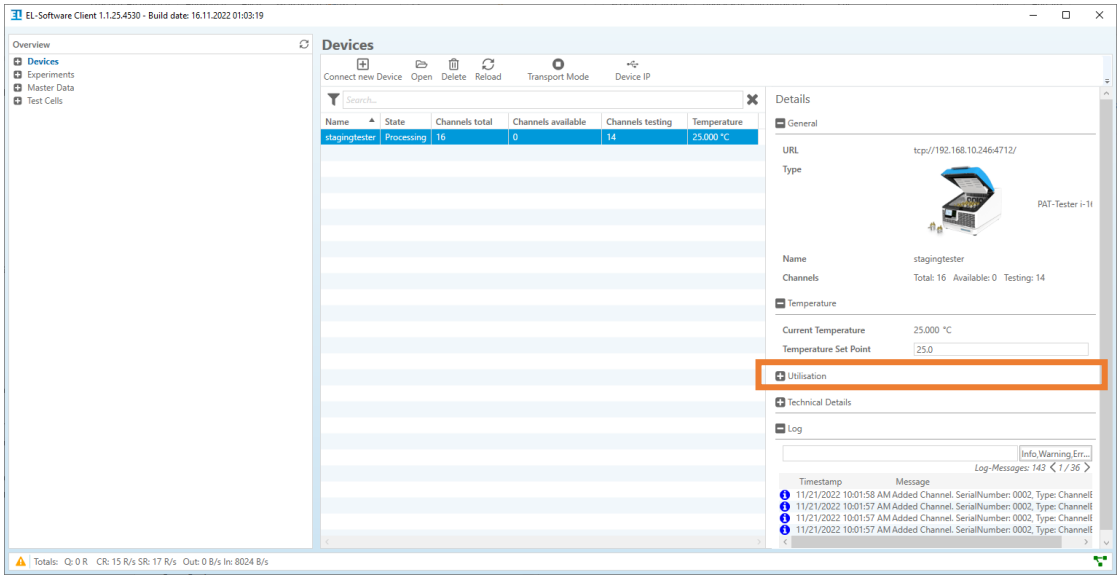
In the footer bar of the EL-Software Client, the summarized values of all connected PAT-Testers are permanently displayed. As soon as a value enters a critical range, a warning symbol appears in front of the entries, otherwise a check mark is displayed.

7.1.5.2 Monitoring the utilization of a single PAT-Tester

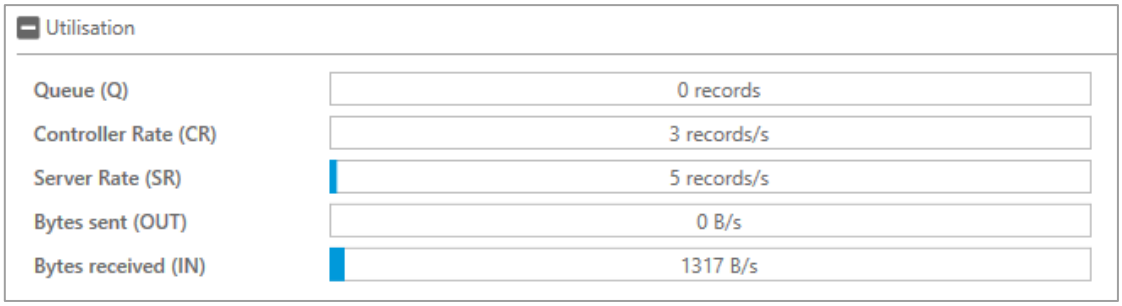
1. To do this, call up the "Devices" menu item and select a PAT-Tester from the overview table.



2. Expand the item "Utilisation" in the device details.



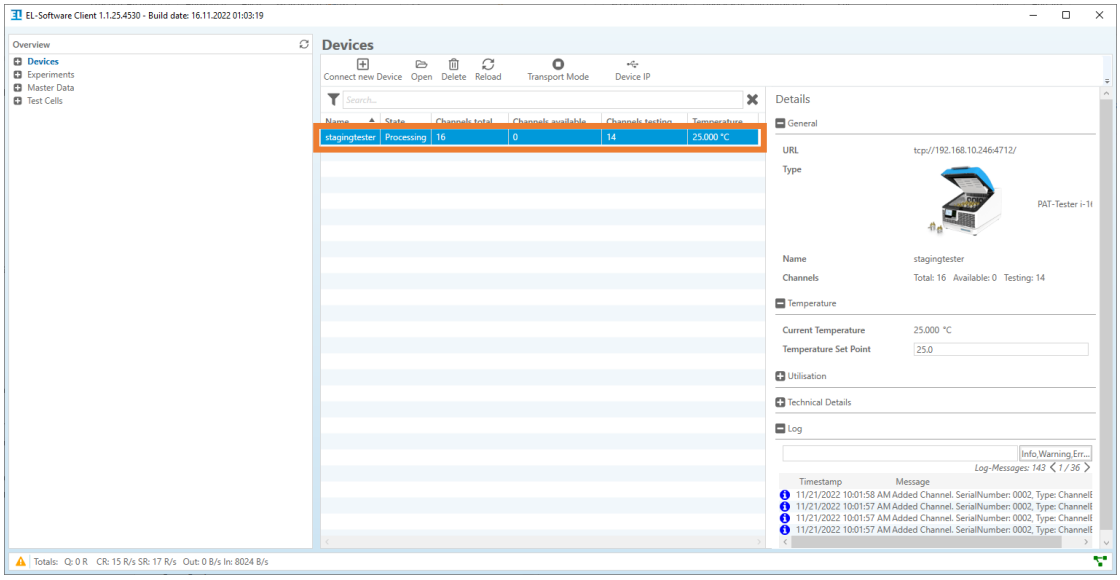
3. All relevant parameters are listed here.



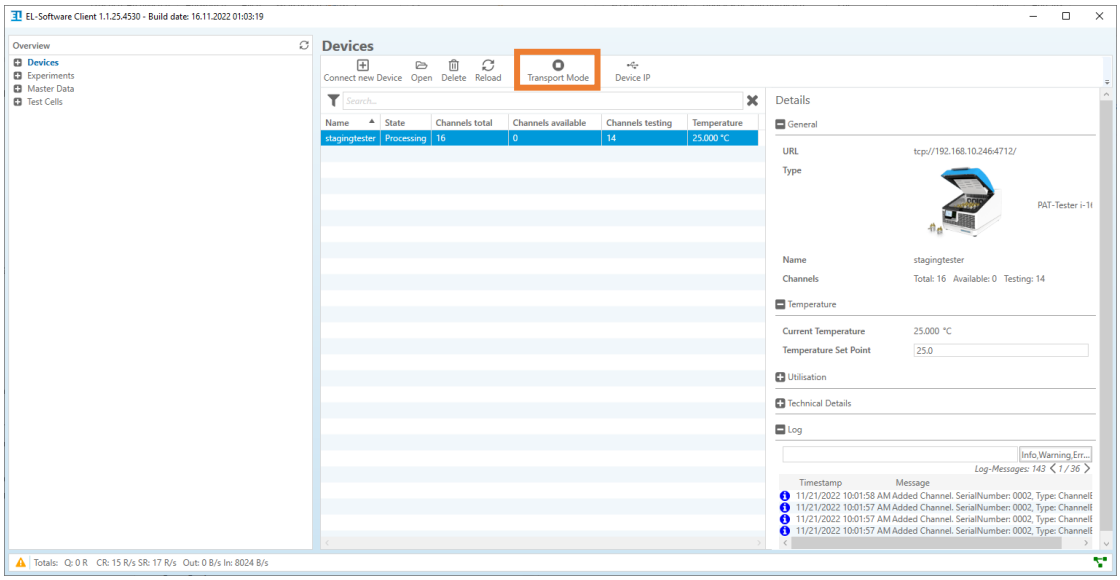
7.1.6 Transport mode

The PAT-Tester's transport mode safely shuts down the control computer inside. The PAT-Tester can then be disconnected from the power supply.

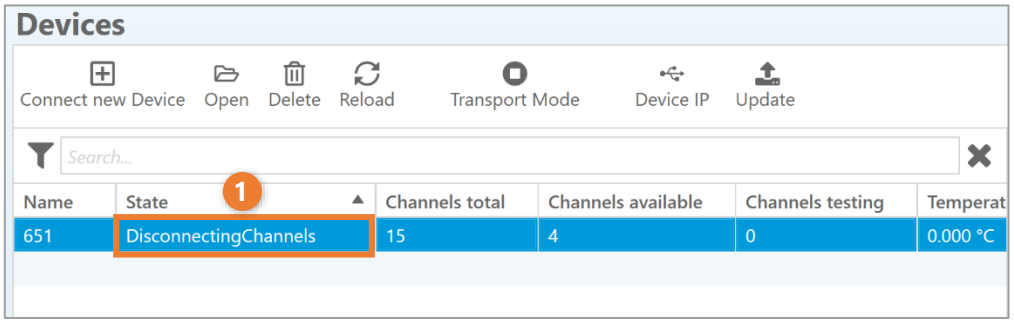
1. To do this, call up the "Devices" menu item and select a PAT-Tester from the overview table.

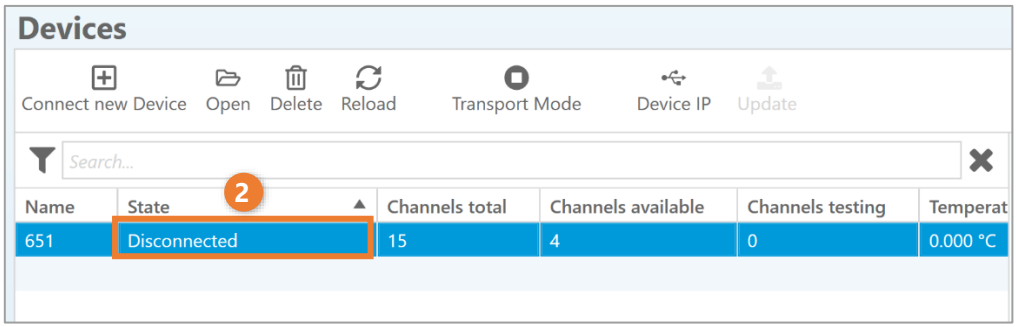


2. Click on the "Transport Mode" button. The internal control computer shuts down.



3. The status "DisconnectingChannels" (1) followed by "Disconnected" (2) is displayed in the list entry of the PAT-Tester. Wait approx. one minute to ensure that the control computer has been shut down safely. After that you can disconnect the PAT-Tester from the power supply.





7.2 Creating an experiment

In the following subchapters you will learn how to work with experiments in EL-Software.

7.2.1 General information about the workflow

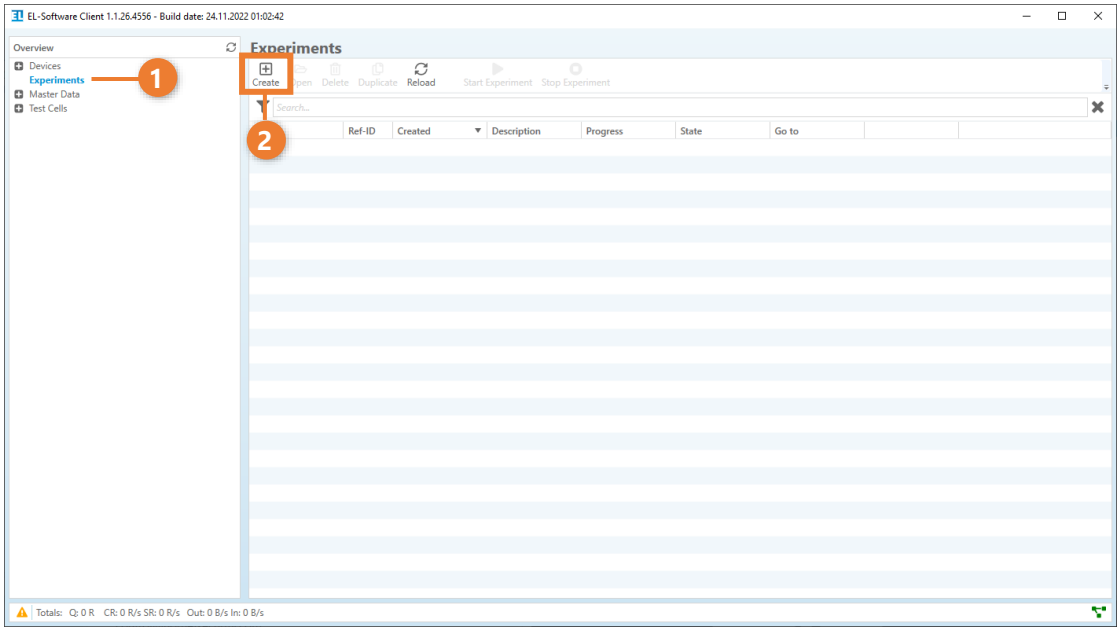
Creating an experiment in EL-Software requires various work steps, which partly depend on each other. EL-Software supports you in this process by enabling certain functions only once all the required conditions have been met.

The workflow includes the following steps:

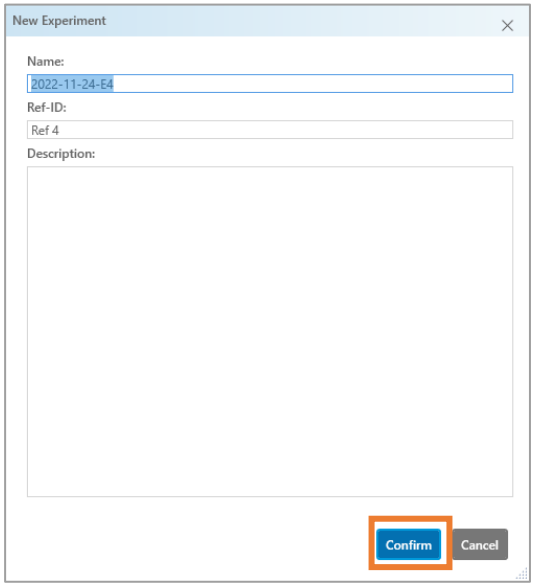
- Create an experiment
- Create one or more cell groups
- Assign test cells to the cell groups
- Record the cell composition if required
- Assign one or more test scripts to the cell groups
- Record the electrode weights of the test cells
- Assign the test cells to the test channels of the PAT-Testers
- Start the experiment

7.2.2 Creating an experiment

1. Click the "Experiments" menu item in the tree view (1). Then click on "Create" to create a new experiment (2).



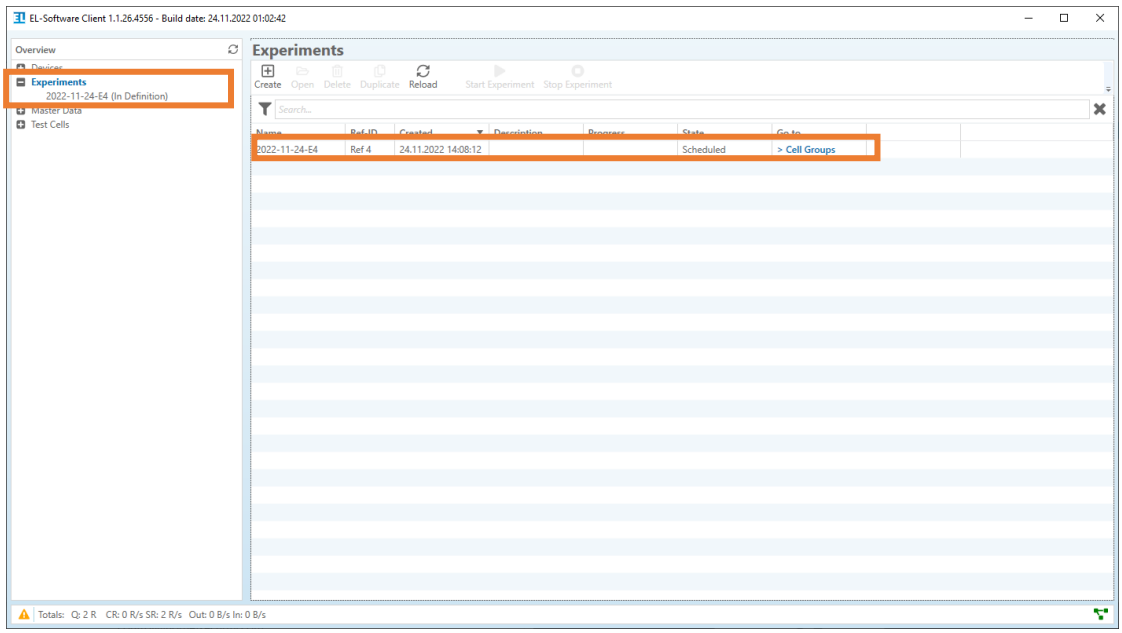
A dialog box opens. Here you can enter information about the experiment, or continue with the pre-filled values. Click on "Confirm" to create the experiment.



PLEASE NOTE

Each experiment needs a unique name and a unique reference ID (Ref-ID).

2. The experiment is now created and appears as an entry in the list and in the tree view.

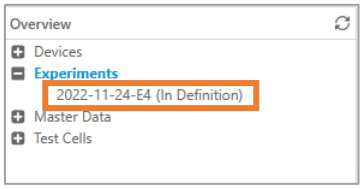


7.2.3 Creating a cell group and assigning test cells

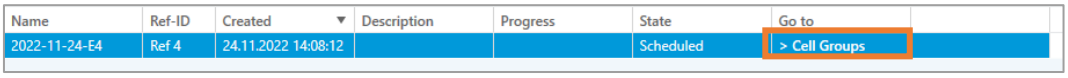
Each experiment requires at least one cell group with at least one assigned test cell.

1. Open the experiment in which you want to create the cell group. There are several ways to do this. You can either...

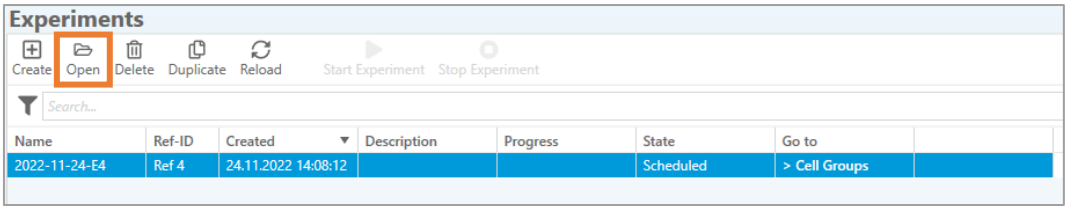
   a. ... click on the experiment in the tree view



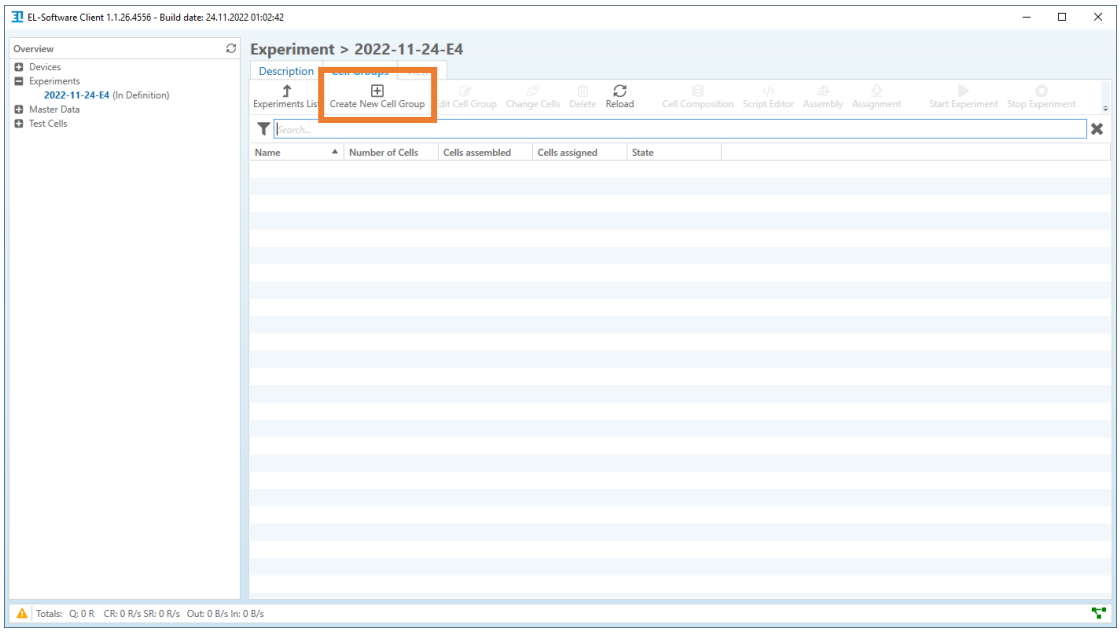
   b. ... select the experiment in the list under "Experiments" and click on the link at the end of the entry



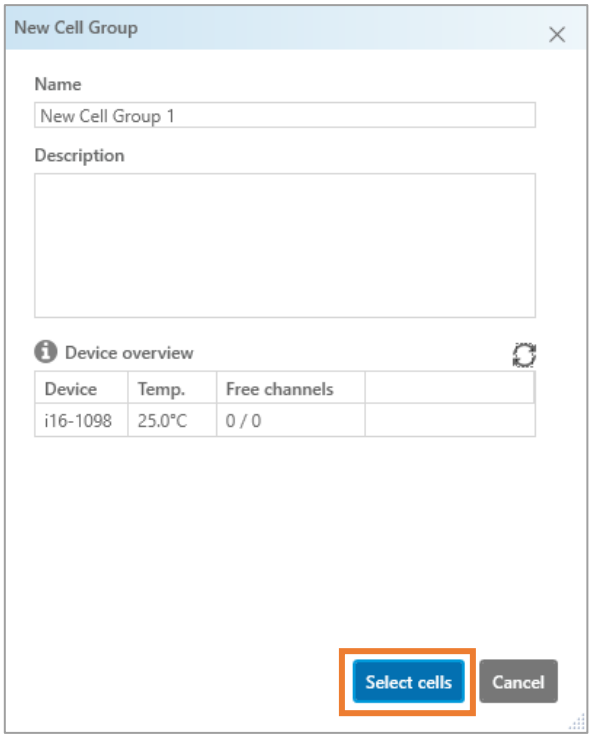
   c. ...or select the experiment in the list under "Experiments" and then click on "Open" in the menu bar



2. The experiment opens and the cell group list is displayed. Click on "Create New Cell Group".



3. The dialog box for creating the cell group opens. You can change the information here or use the pre-filled name for the new cell group. Click on "Select cells" to continue.



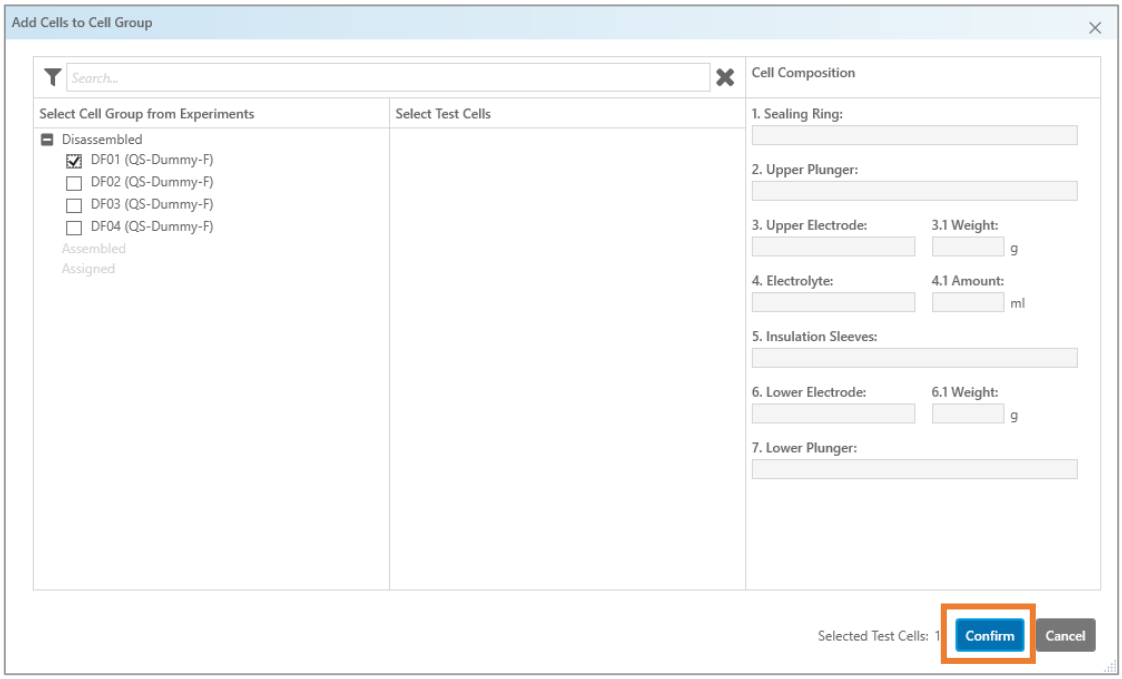
4. The dialog for cell assignment opens. Here you can add individual cells or cells of other cell groups to the new cell group. To do this, set the check mark for the respective test cells. **At least one test cell must be selected**.

   Then click on "Confirm" to create the cell group.

PLEASE NOTE

1. You can also change the cell assignment afterward.

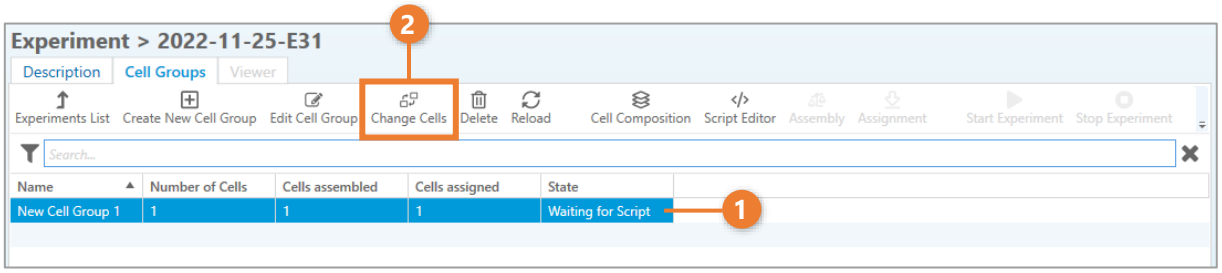
2. You can reuse cells that have already been used in other experiments. When you select such a cell, only cells that have the same composition and chemistry are automatically offered for selection, provided that these specifications have been defined in the system. This helps to avoid misassignments and speeds up the selection process.



7.2.3.1 Adding test cells to an existing cell group

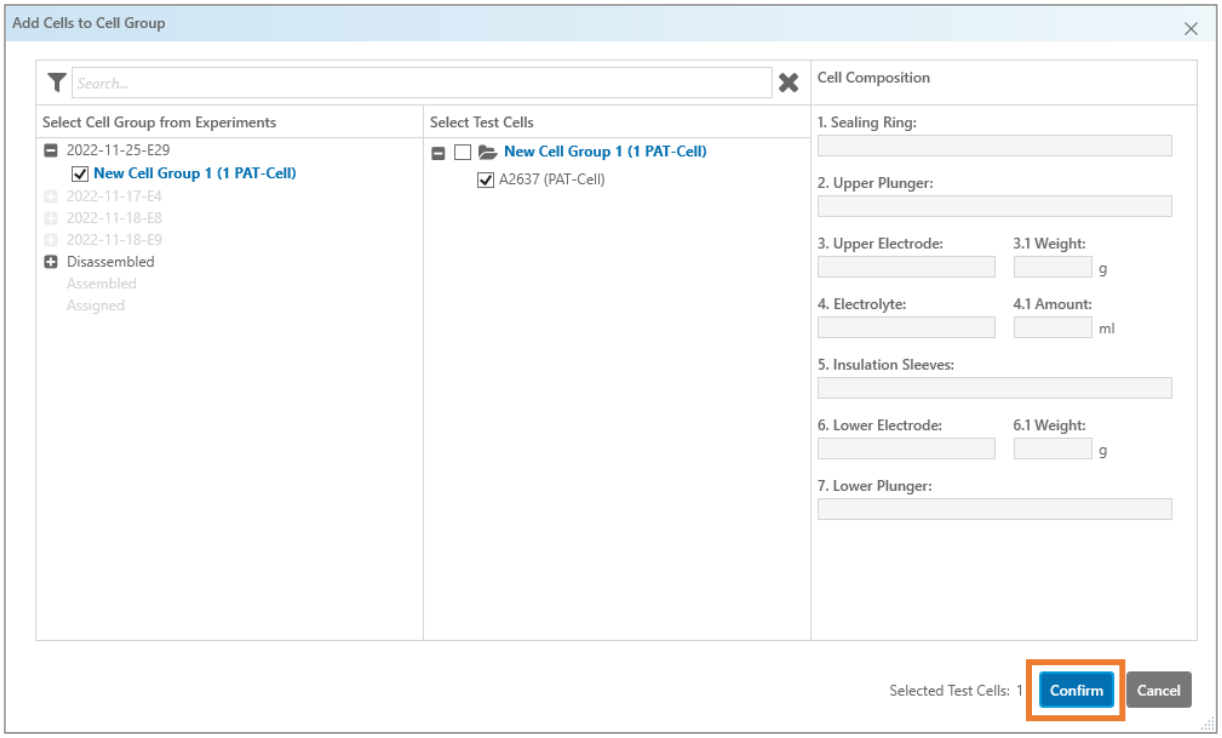
You can add or remove the test cells from an already-created cell group.

1. To do this, select the cell group in the list (1) and then click on "Change Cells" in the menu bar (2).



2. The dialog window opens. You can now remove assigned test cells again or add others. Only test cells that are either not yet assembled or that have the same cell composition and are therefore compatible can be added. All other cells are not selectable.

   Afterward, click on "Confirm".

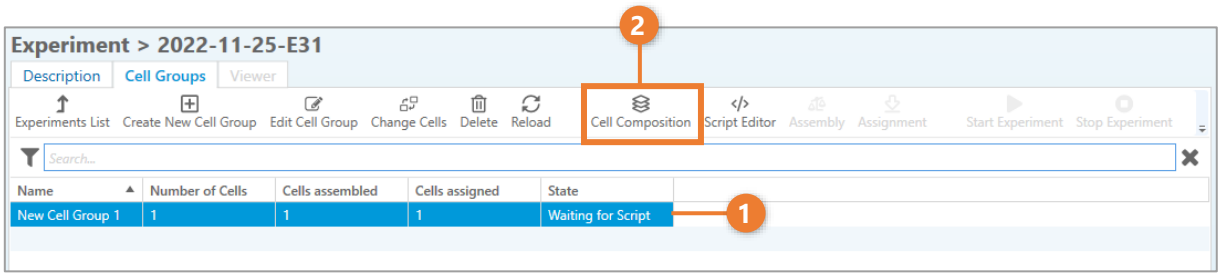


7.2.4 Determining the composition of the test cells

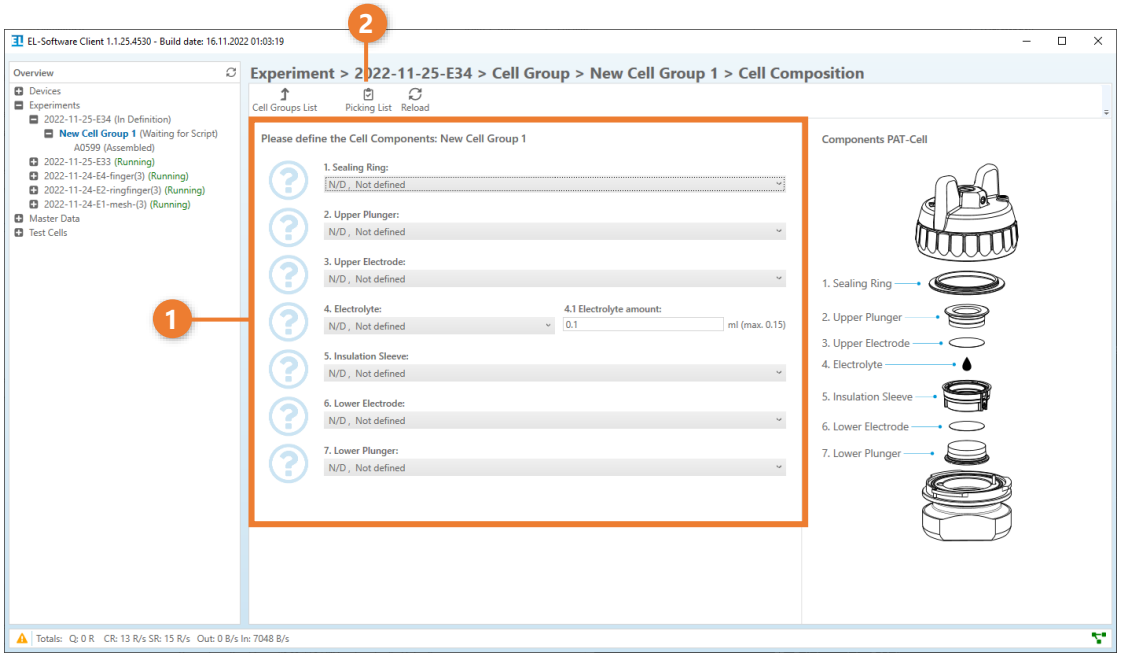
Once a cell group has been created in an experiment, the "Cell Composition" item becomes selectable. Here you can define the composition of all cells in a cell group. This information is stored in the database. It is not necessary to perform the experiment, but it offers several advantages:

- Based on the cell composition, a parts list can be created in which the required components are clearly listed. This simplifies the preparation of the experiment.
- The data can be viewed for later evaluation.
- Using the data, it is easier to check the cells for compatibility when creating cell groups. This can be helpful if cells with the same composition are to be reused in subsequent experiments.

1. Open the list view of the cell groups. Select a cell group from the list (1) and click on "Cell Composition" in the menu bar (2).



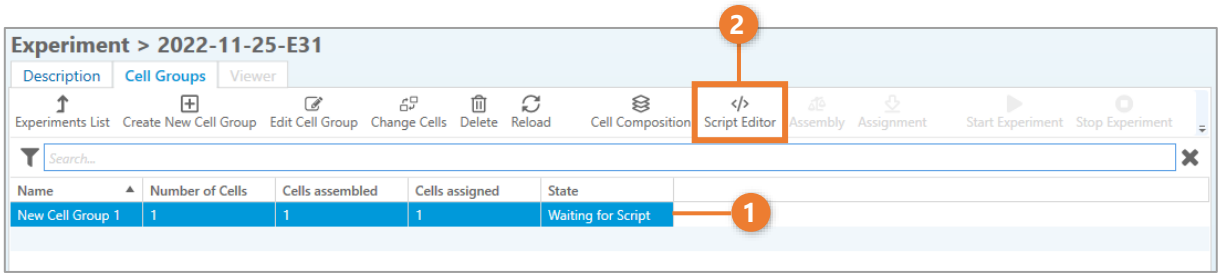
2. Select the components used in the cells of this cell group in this experiment (1). You can also create a parts list of the required components in PDF format by clicking on "Picking List" (2) in the menu bar.



7.2.5 Assigning a script

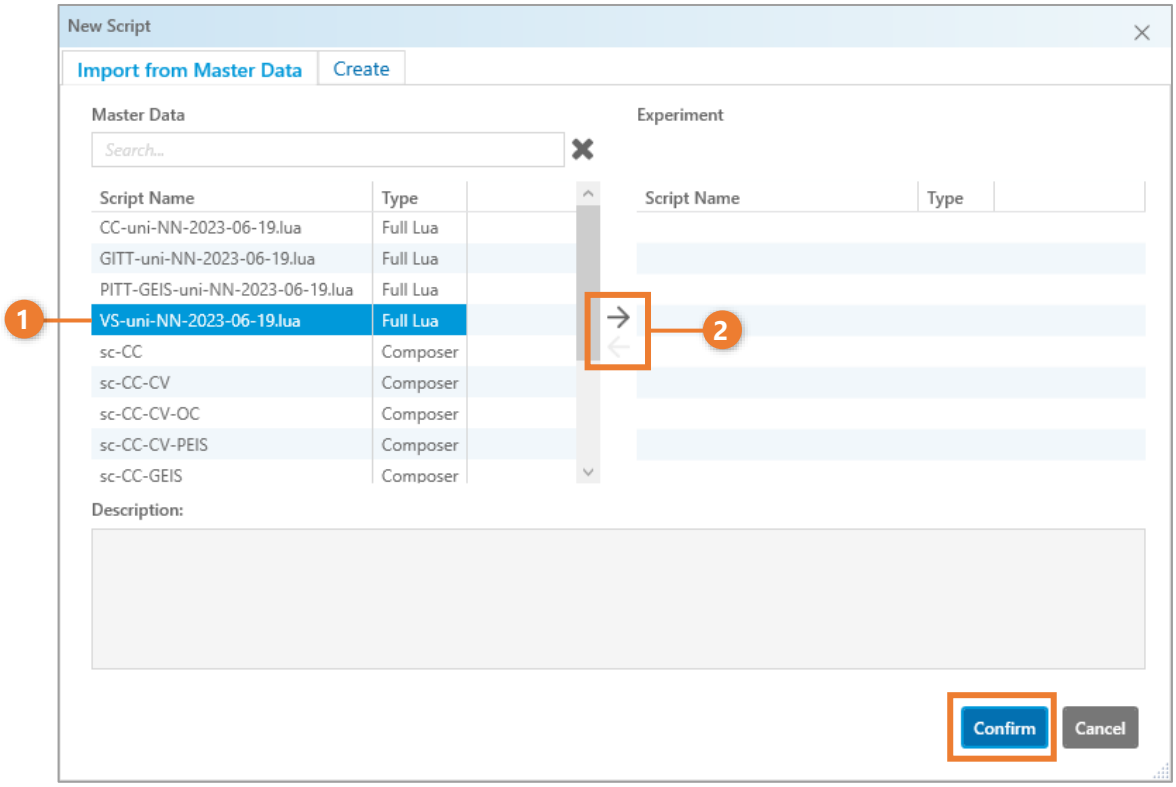
As soon as a cell group has been created, the "Script Editor" button in the menu bar is enabled. An experiment can only be started once at least one test script has been assigned to each cell group.

1. Open the list view of the cell groups. Then select a cell group from the list (1) and click "Script Editor" in the menu bar (2).



2. A dialog window opens. The tab navigation at the top offers you the possibility to import or to create a new script.

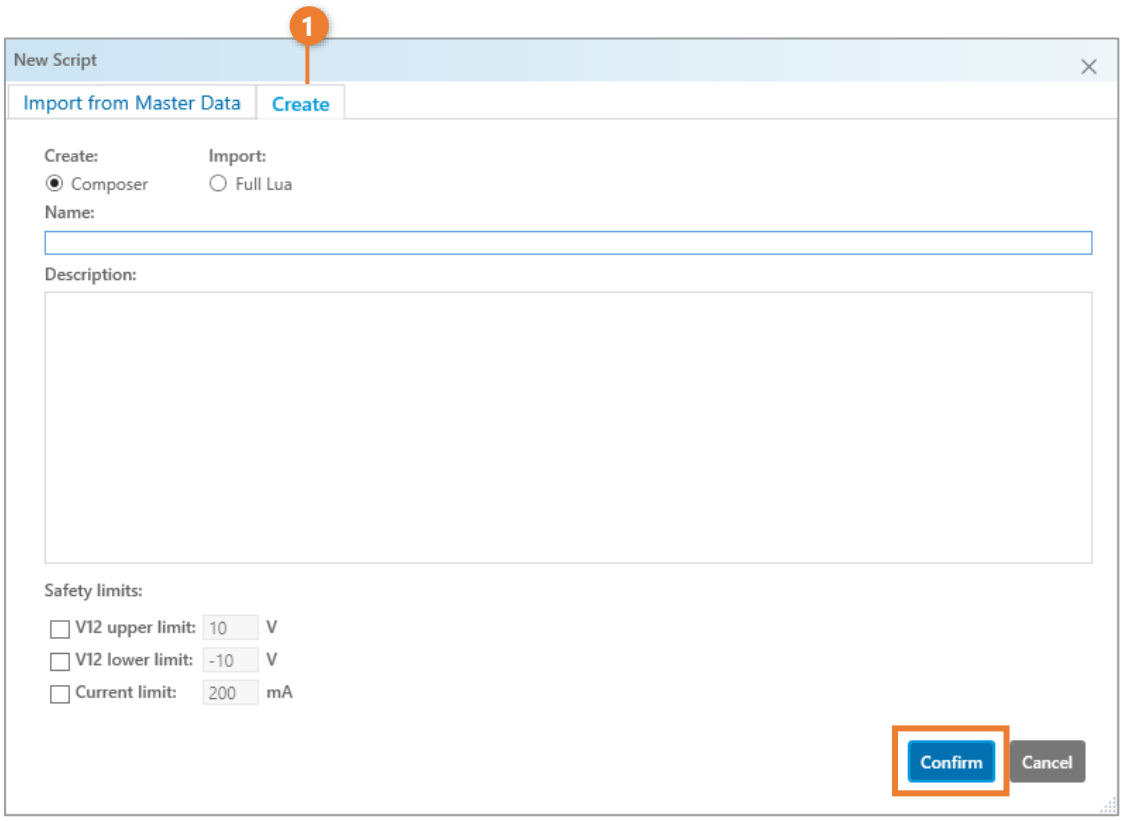
   a. **Assign an imported script from the database**
   To import from the Master Data database, select a script in the list (1). Double-click on the list entry or use the arrow icons to assign the script to the cell group or to remove it. You can assign as many scripts to a cell group as you like. Then click on "Confirm".



b. Create and assign a new script or import an external file

Change the view to the "Create" tab (1). Here you can create a new script in the composer editor or import externally created Lua scripts.

Click on "Confirm" to assign the imported script or to open the script editor where you can create the new script. For more information about script types and script creation, please refer to the corresponding chapters.



PLEASE NOTE

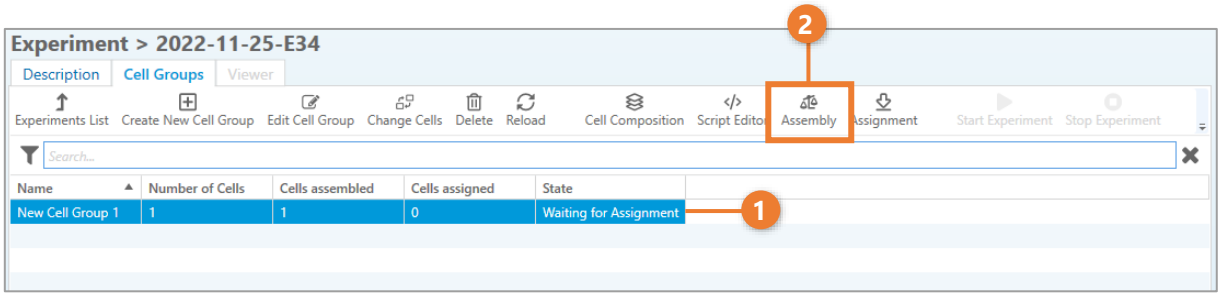
As soon as you have assigned a script to the cell group, the behavior of the "Script Editor" button changes, and the next time you press the button, you are taken directly to the Script Editor

If you want to open the dialog again to assign or create another script, click on "New Script" in the menu bar of the Script Editor.

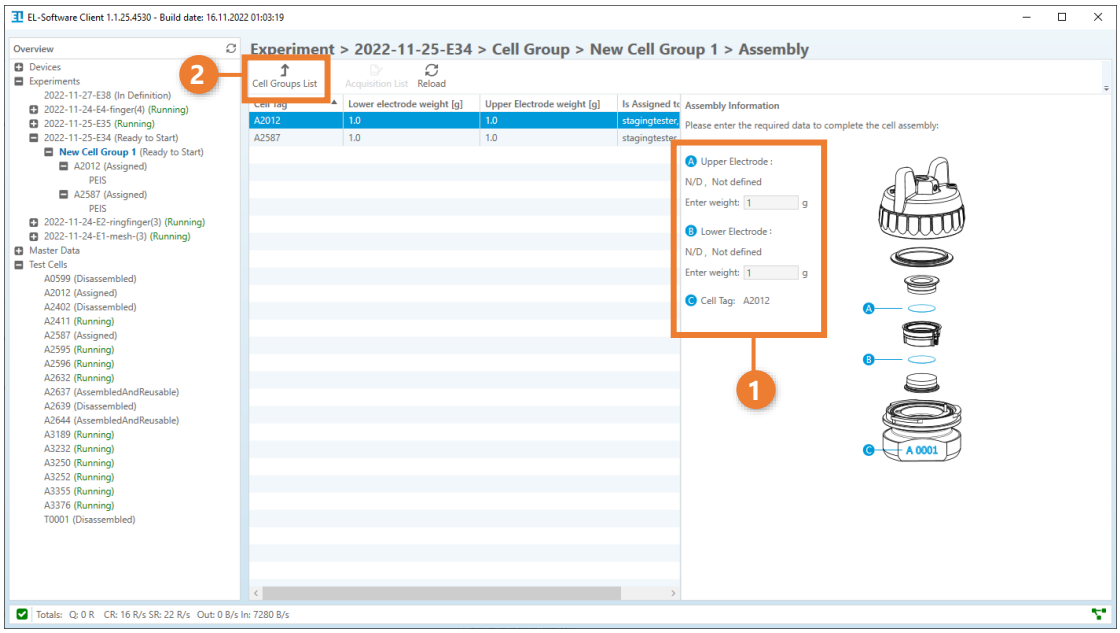
7.2.6 Recording the electrode weights of the test cells

You can record the electrode weights of the test cells of a cell group via the "Assembly" button in the menu bar, provided that a script has already been assigned to the cell group. These weights are used by EL-Software for calculations. This is an optional step, and a weight of 1g will be used in case you skip it.

1. Open the list view of the cell groups. Then select a cell group from the list (1) and click on "Assembly" in the menu bar (2). The menu item is selectable as soon as a script has been assigned to the cell group.



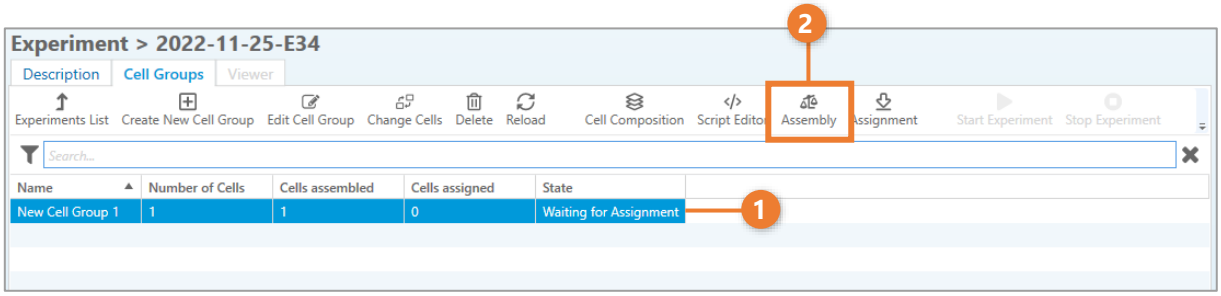
2. You can now enter the electrode weights for each cell of the cell group (1). After that click on the "Cell Groups List" button to return to the cell group view (2).



7.2.7 Assigning test cells to test channels

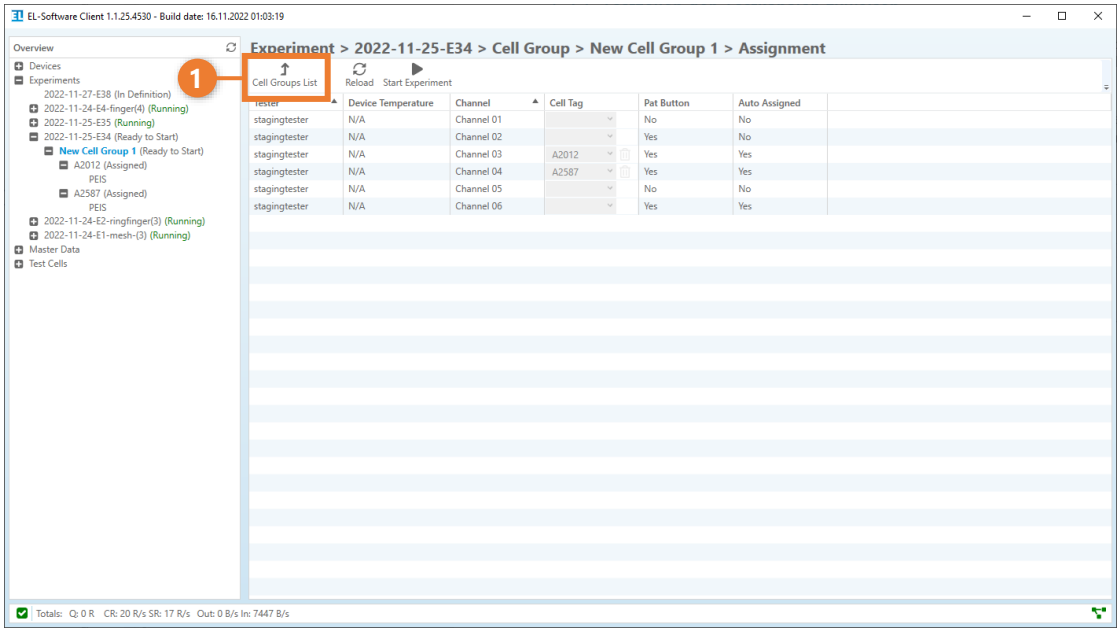
PAT series test cells are usually equipped with a PAT-Button. This is an electronic chip in the bottom of the cell that transmits information about the serial number and the cell type to the PAT-Tester when it is inserted into a test channel. It also enables automatic assignment of the test channel in the PAT-Tester. For cells without a PAT-Button, you must assign the test channel manually.

1. Open the list view of the cell groups. Then select a cell group from the list (1) and click on "Assignment" in the menu bar (2). The menu option is selectable as soon as a script has been assigned to the cell group.



2. A list of available test channels appears. Here you can add cells manually. Grayed-out test channels mean that no measurement has been started here yet, but a test cell with PAT-Button has already been inserted and automatically detected.

Click on the "Cell Groups List" button in the menu bar (1) to return to the cell group view.

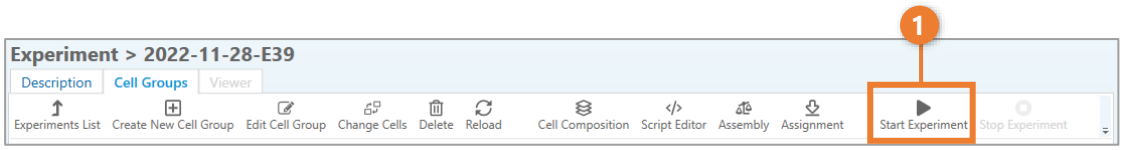


7.2.8 Starting the experiment

You can start a new experiment as soon as the following conditions are met:

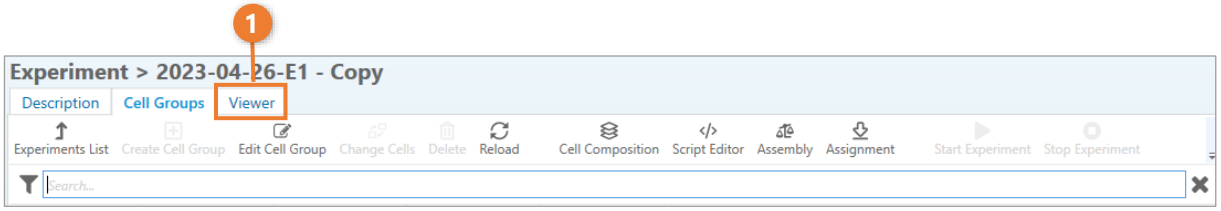
- At least one cell group exists within the experiment.
- At least one test cell has been assigned to each cell group.
- At least one script has been assigned to each cell group.
- All test cells in the experiment have been assigned to test channels. (This assignment is done automatically for test cells with integrated PAT-Button).

As soon as these conditions are met, the "Start Experiment" button in the menu bar of the experiment view is unlocked (1). Click the button to start the experiment.



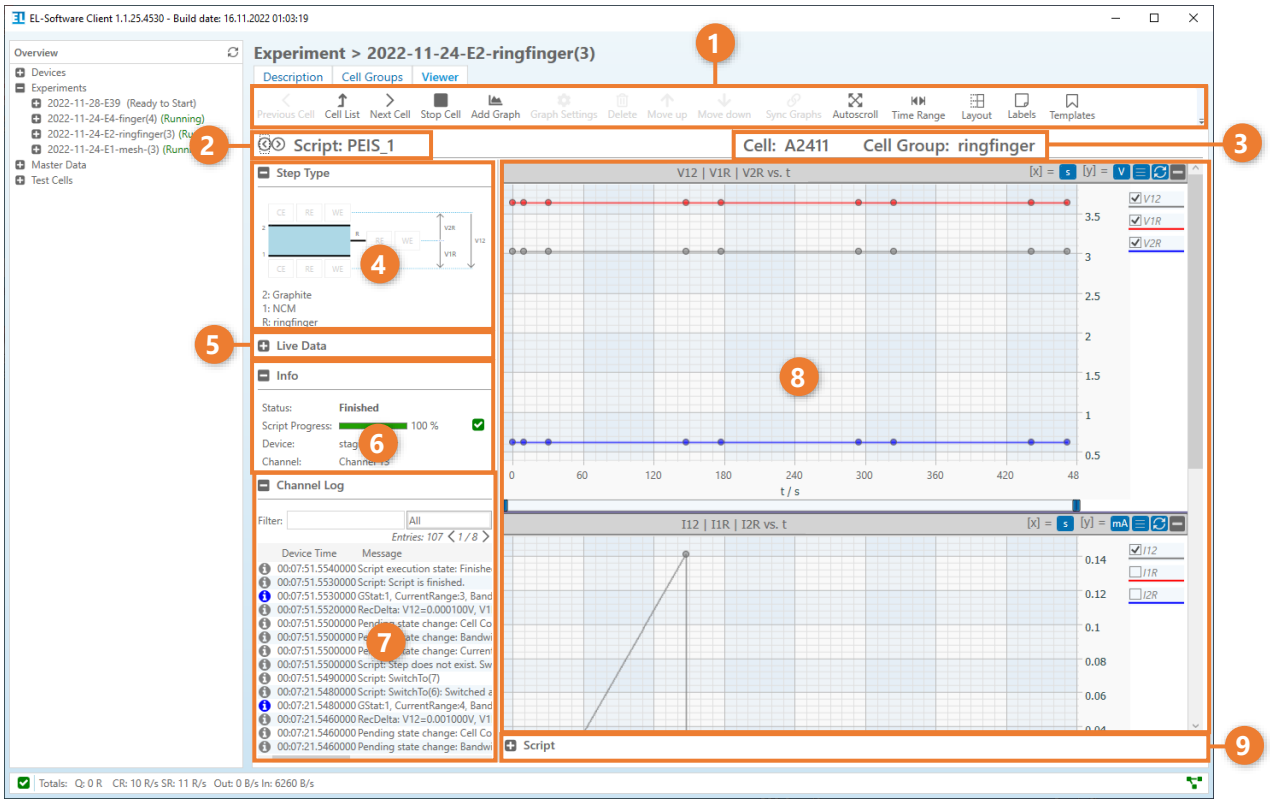
7.3 Monitoring a running experiment by using the Cell Viewer

The Cell Viewer displays the received measurement data of each test cell within a running experiment. It can be accessed by using the tab navigation found at the "Experiments" view as soon as the experiment has been started (1).



7.3.1 Cell Viewer overview

The Cell Viewer is divided into several sections.



1. Menu bar: All functions for operating and configuring the Cell Viewer are located here.

2. Script navigation: Use the arrow icons to switch between the displayed measurement data of the individual scripts that have been assigned to the selected test cell.

3. Info field: The names of the currently selected cell group and test cell are displayed here.

4. Step Type and Connection Matrix: This displays the current step in the test script and the actual current flow.

5. Live Data: This area displays real-time data of the main electrical parameters of the test cell.

6. Info: The following general information is displayed here:

   a. Status of the displayed script

   b. Progress of the script in percent

   c. The name of the PAT-Tester to which the displayed test cell is connected.

   d. The test channel of the PAT-Tester to which the displayed test cell is connected.

7. Channel Log: All events are displayed here in a filterable list.

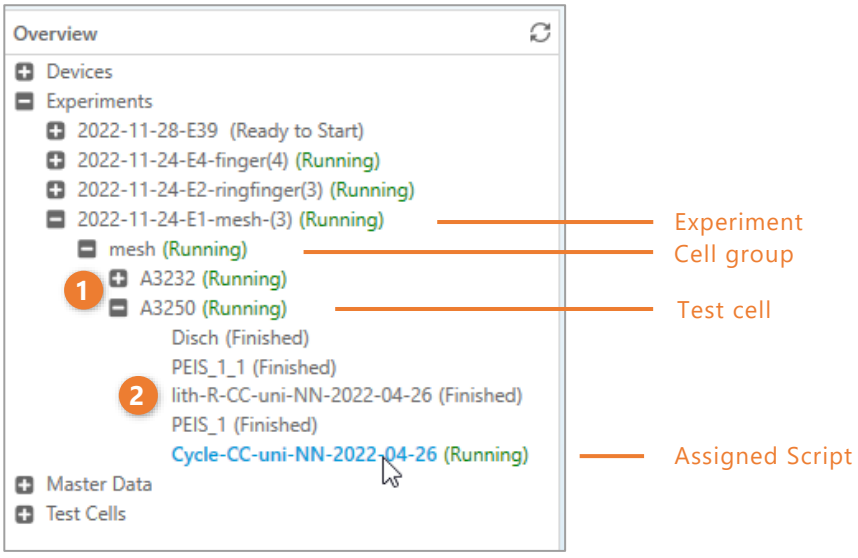
8. Graphs: The measurement data is displayed in this area. The display and number of graphs can be freely configured.

9. Script: The currently running script can be displayed and edited here.

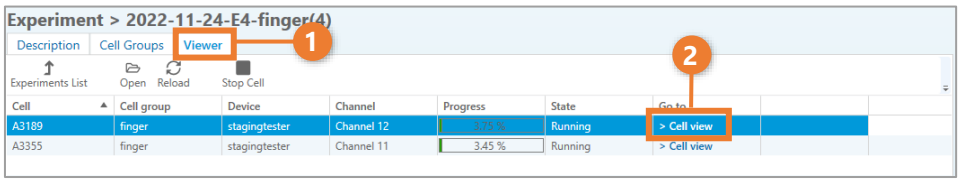
7.3.2 Open the Cell Viewer

1. There are several ways to open the Cell Viewer:

   a. In the tree view, expand the running experiment until you see the entries of the test cells (1). Now click on such an entry to view the test cell in the Cell Viewer. The measurement data of the running script will be displayed. You can view the data of other scripts by clicking on their entries (2).



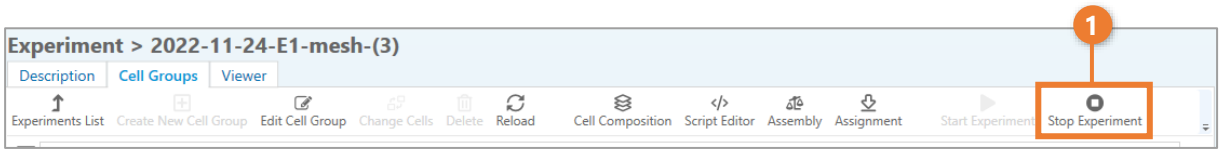
b. The Cell Viewer can also be accessed via the tab navigation of the "Experiments" view. Click on the "Viewer" tab to display the list of all running cells of the experiment (1). To view the measurement data of a test cell, click on the "Cell view" link at the end of the respective entry (2).



7.3.3 Working with the Cell Viewer

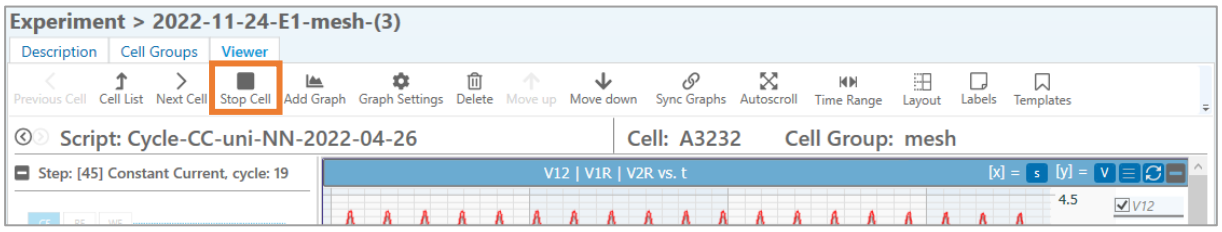
7.3.3.1 Stopping a running experiment

Once an experiment has been started, the "Stop Experiment" button (1) in the menu bar of the cell group view will be unlocked. Click it to stop the execution of the entire experiment.

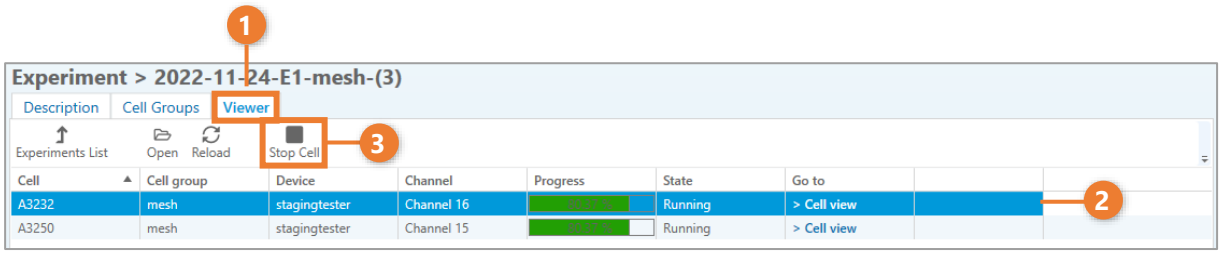


7.3.3.2 Stopping individual test cells of a running experiment

You can stop the execution of the script on individual test cells of a running experiment at any time. To do this, you can click on the "Stop Cell" button in the menu bar of the Cell Viewer. This stops the script (and possibly all subsequent scripts) on the currently displayed test cell.



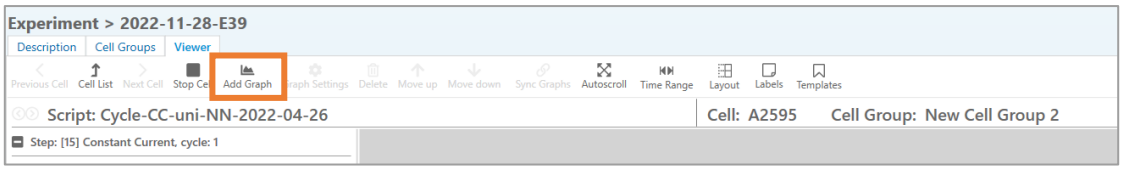
Alternatively, you can stop individual test cells in the list view of the Cell Viewer. To do this, switch to the "Viewer" tab in the experiment view (1). Now select the test cell from the list (2) and click on "Stop Cell" in the menu bar (3).



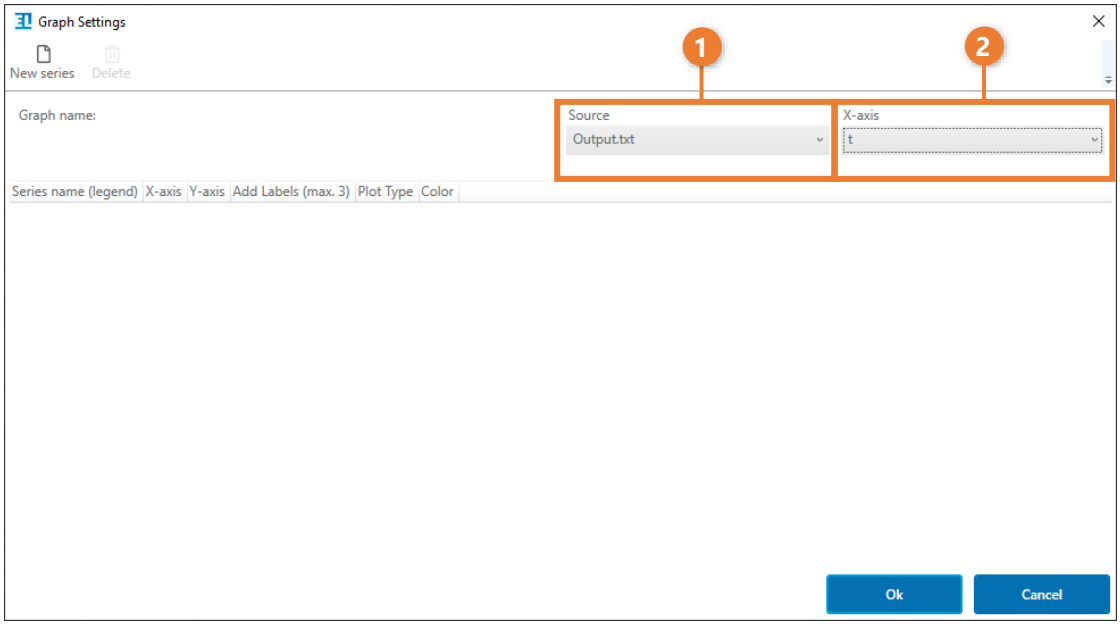
7.3.3.3 Creating a new graph

You can create new graphs in the Cell Viewer. To do this, perform the following steps:

1. Open a test cell in the Cell Viewer and click on the "Add Graph" button in the menu bar.



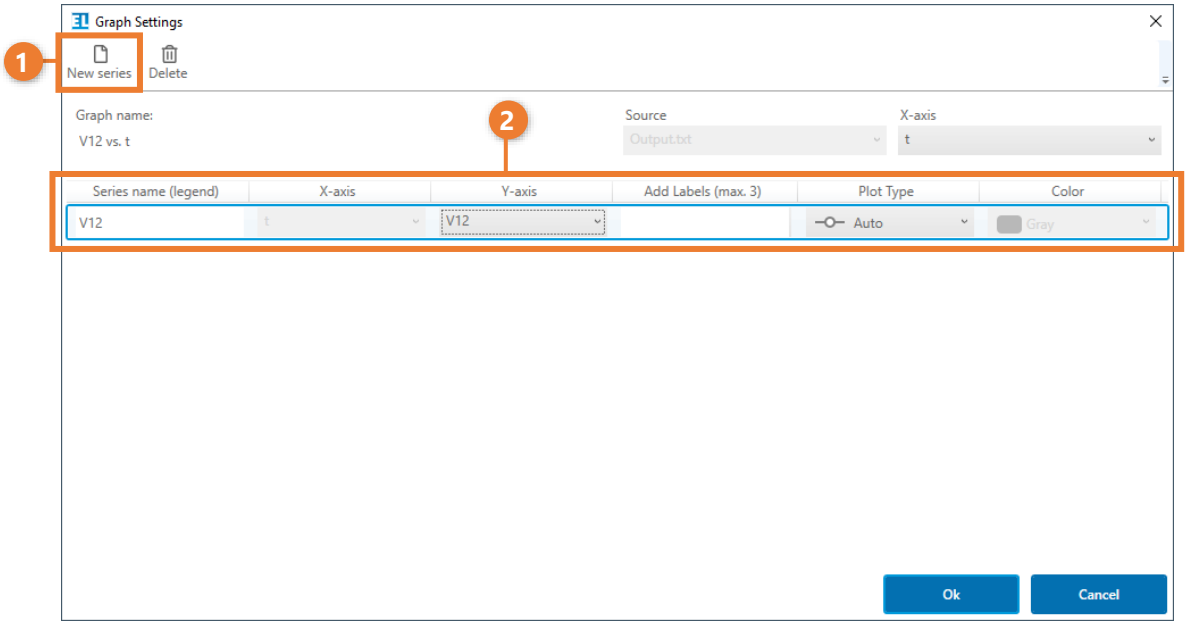
2. A dialog window appears. Select the source file of the data series in the "Source" drop-down menu (1) and the unit of the x-axis in the "X-axis" drop-down menu (2).



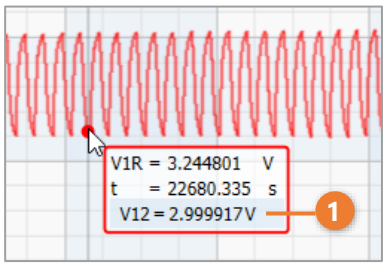
PLEASE NOTE

All acquired measurement data are automatically saved to text files in the "Exports" folder and can be used as data sources.

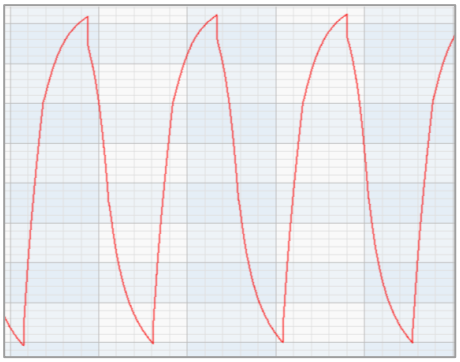
3. Now add one or more data series to be displayed in the graph by clicking on "New series"(1). A new entry (2) appears, in which you can define various parameters, that are explained below.



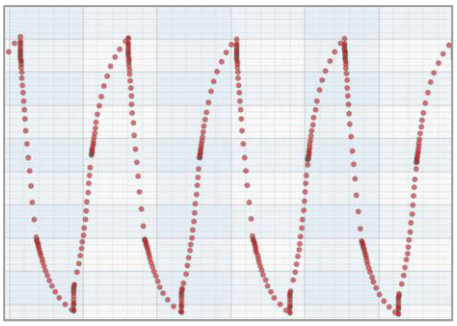
- **Series name (legend**): The displayed name in the legend.
- **Y-axis:** The measurement data to be displayed on the Y-axis.
- **Add Labels:** Here you can specify up to three additional variables, that are displayed in the detailed info of the measuring points. In the example image, V12 has been defined as an additional label (1).



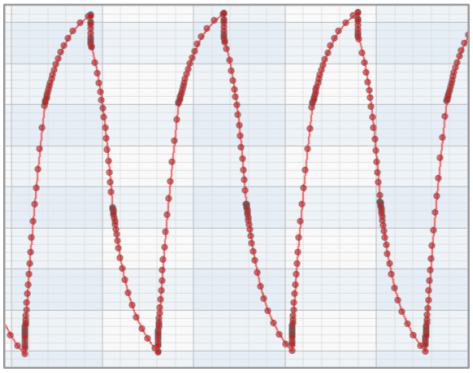
- **Plot Type:** The representation of the measurement data in the graph:
  - **Line:** The measurement data are displayed as an interconnected line.



- **Point:** The measurement data are displayed as individual points.



- **Point and Line:** The measured data appear as points and are additionally connected by a line.

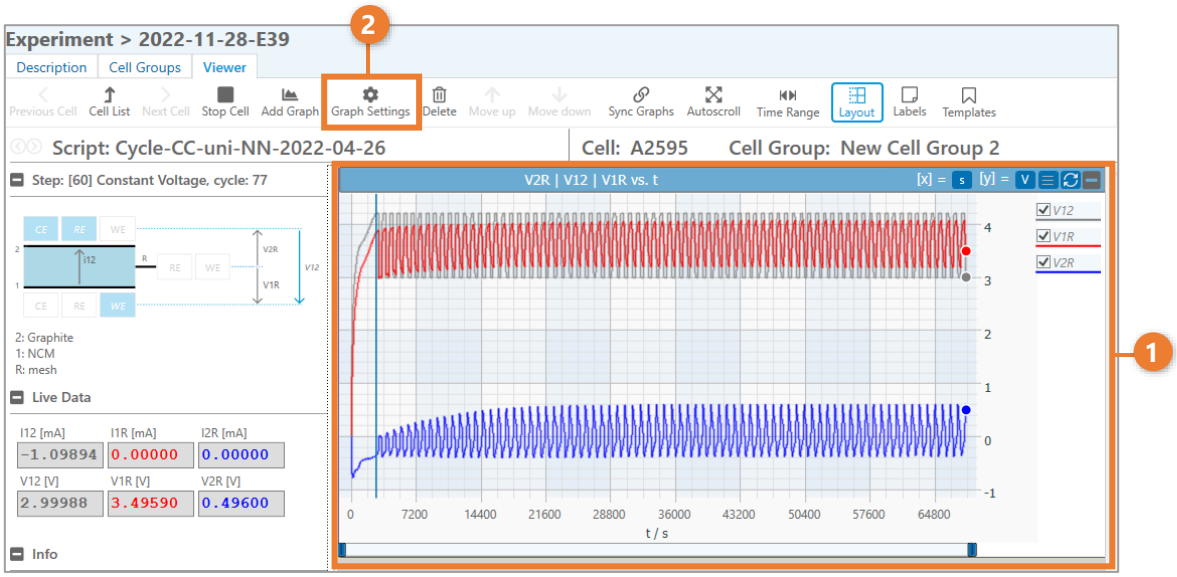


- **Auto:** The default setting in which EL-Software automatically selects the optimal display depending on the zoom level.

PLEASE NOTE

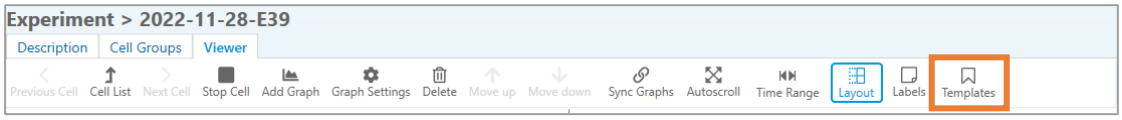
EL-Software supports you with recurring actions. For measurement data such as current voltage or current intensity, which usually contain several data series for full and half cells, it is sufficient to specify the first series (e.g. V12). After that, when adding new series, the other data series such as V1R and V2R are automatically suggested as selection for the Y-axis.

4. Click on "Ok" to complete the creation. The new graph will appear in the Cell Viewer (1). You can make further changes at any time by selecting the graph and clicking on "Graph Settings" (2).

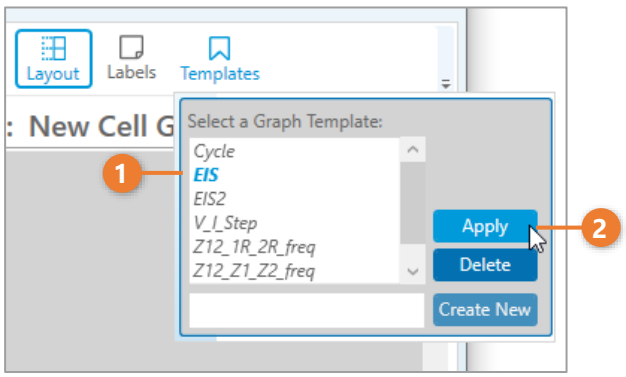


7.3.3.4 Creating new graphs via templates

In addition to setting up the individual graphs manually, you can also access predefined graphs, which you can reach via the "Templates" button. A selection of frequently used graphs is available here.



To use the graphs from a template, select the template in the list (1). You can also select multiple templates by holding down the Shift key and then clicking on additional entries. Then click on "Apply" (2) to display the graphs in your experiment.

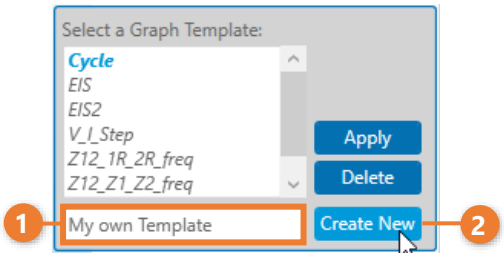


7.3.3.5 Saving your own graphs as a reusable template

You can save your own graph layouts as templates and reuse them in other experiments:

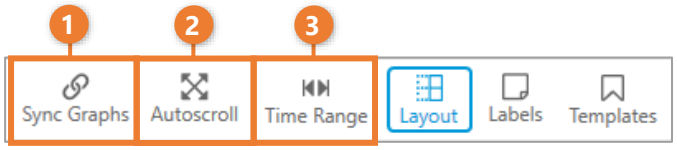
1. Set up one or more graphs in the Cell Viewer.

2. Click on “Template” in the menu bar of the Cell Viewer. Now enter a name for your new template (1) and click on "Create" (2). Your template now appears in the list and can be used. It contains all graphs that are currently set up.



7.3.3.6 Adjusting the display of the measuring points in the graphs

You can visually configure the display of the measuring points during running experiments. The following options are available:



1. **Sync Graphs:** Activate this function to synchronize the display of the measurement points of all time-based graphs on the Y-axis. As soon as you move or zoom the view, the result is displayed in all synchronized graphs in the same way.

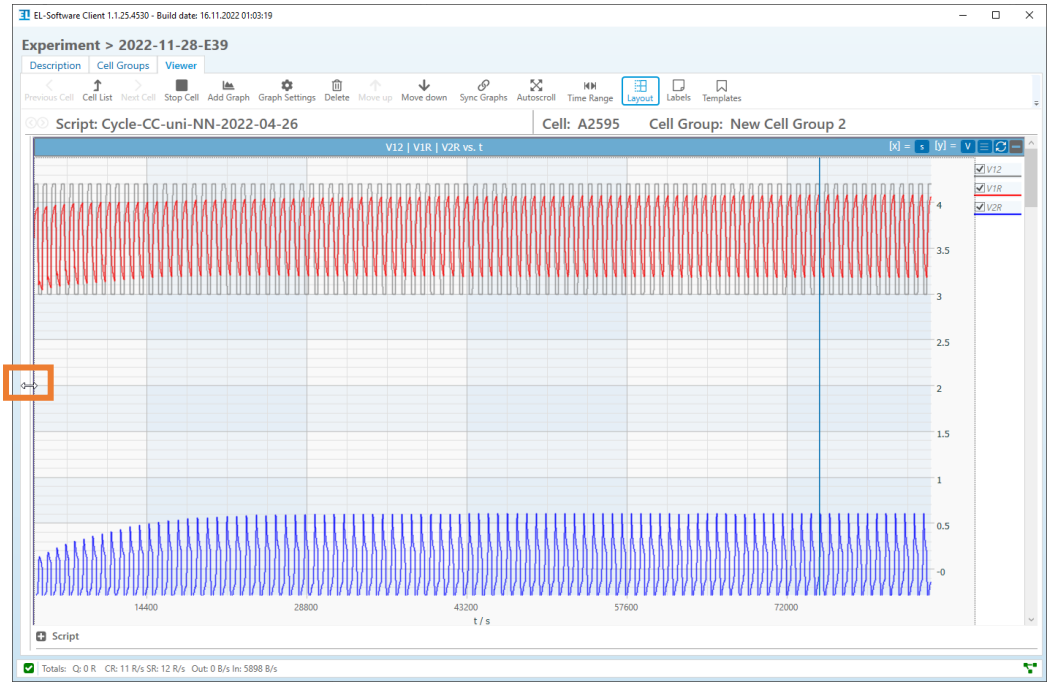
2. **Autoscroll:** Activate “Autoscroll” to let the view follow the newly acquired measuring points.

3. **Time Range:** This function allows you to limit the time range displayed in the graphs.

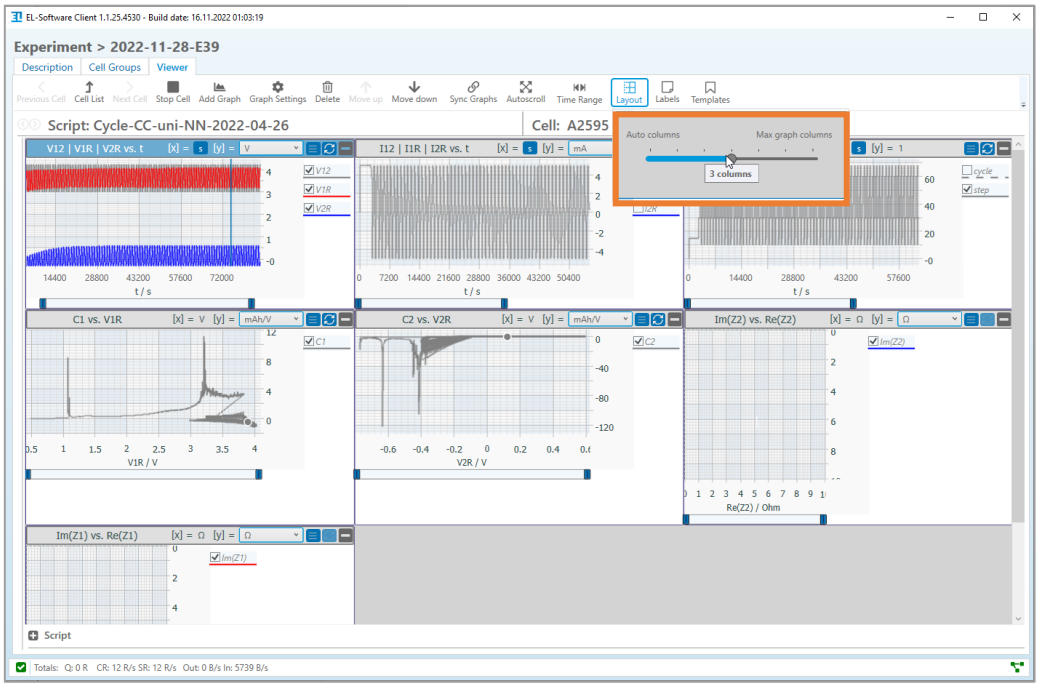
7.3.3.7 Customizing the display of graphs in the Cell Viewer

There are several ways to influence the display of the graphs.

1. **Show graphs in full screen view:** To display a graph in full screen view, move the mouse pointer to the separators between graph and info area, or between tree view and info area. Now hold down the left mouse button and drag the window to the desired size.



2. **Change column view of graphs:** You can use the "Layout" button in the Cell Viewer menu bar to set the number of columns in which the graphs are displayed next to each other by moving the slider.



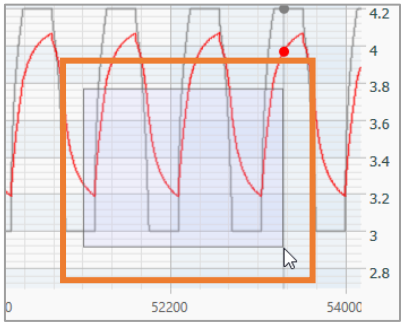
7.3.3.8 Changing the view within a graph

You can change the view of a graph as follows:

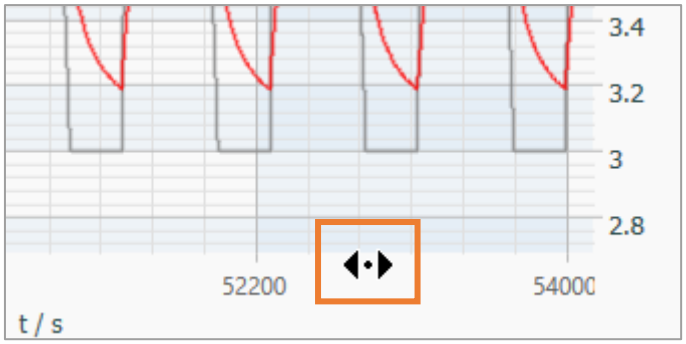
1. Enlarge or reduce the view area

a. Move the mouse pointer into a graph. Use the mouse wheel to zoom in or out on both axes simultaneously.

b. You can draw a frame of the area you want to view by dragging and holding the left mouse button at the same time.



c. Move the mouse pointer near the axis legend until it changes to an arrow symbol. Press and drag the left mouse button to change the display range of the respective axis.

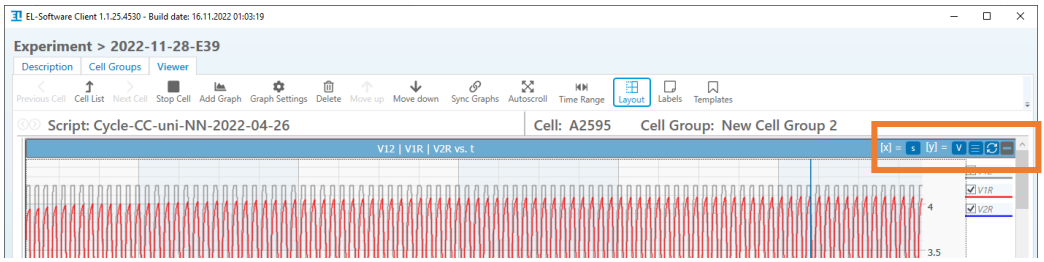


2. Reset view area

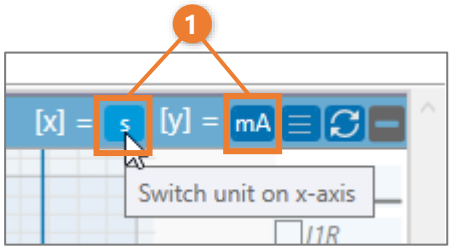
A double-click in a diagram resets the view.

7.3.3.9 Change the unit and axis display

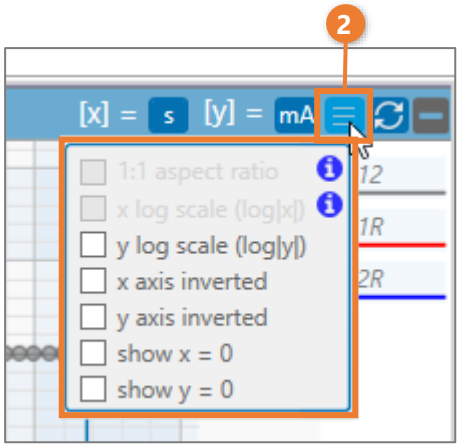
On the right side of each graph you can find controls to change the display.



You can change the displayed units for both axes of the respective graph by clicking on the buttons (1).



In addition, you also find a menu here (2) where you can make further changes to the graph's display mode.



7.4 Working with the Master Data database

7.4.1 Manage materials

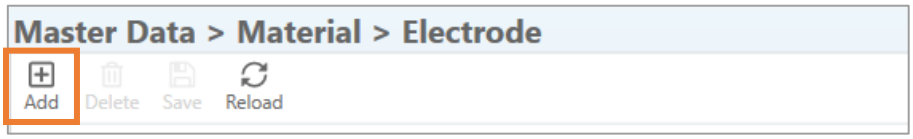
The individual components and materials used in the test cells for experiments are displayed in the Master Data. In addition, test scripts are stored here for use in new experiments.

7.4.2 Adding a material

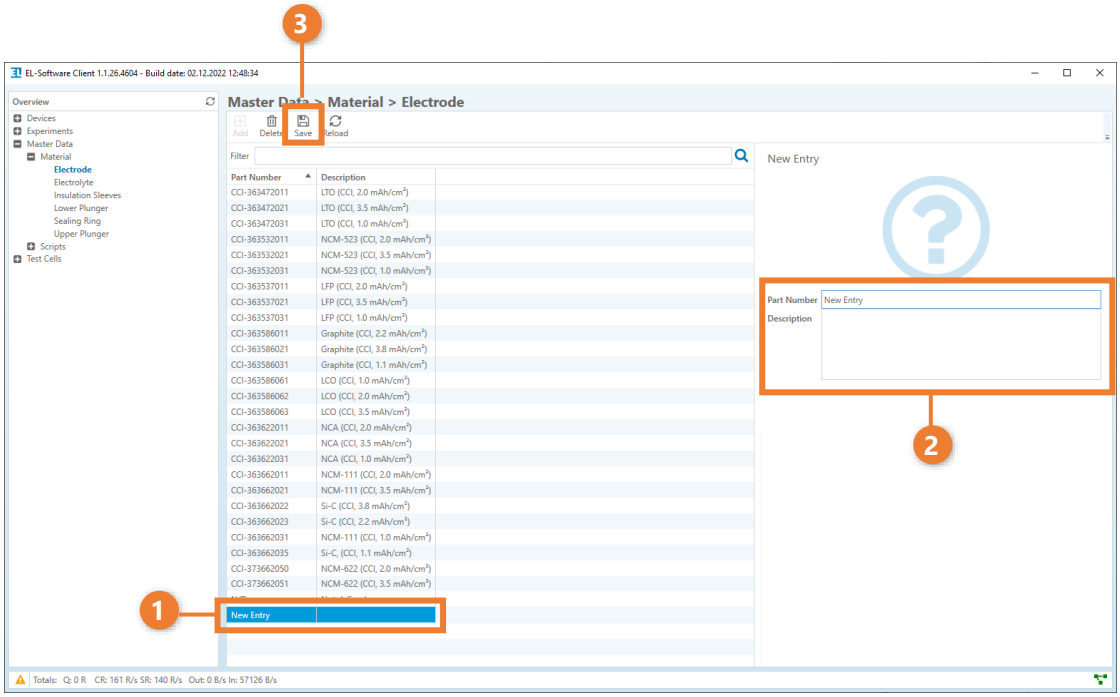
You can add new elements in the Master Data, such as cell components.

1. In the tree view, select the area where you want to add a material.

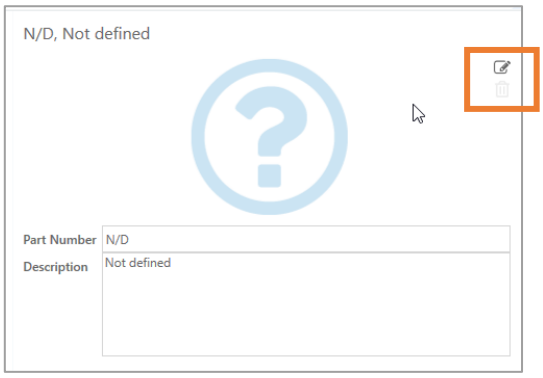
2. To add click on the "Add" button in the menu bar.



3. A new entry named "New Entry" (1) appears in the list. Enter the necessary data in the right content area (2).



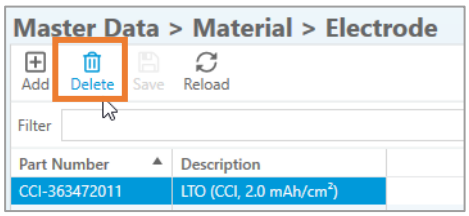
4. You can also add a custom image for the material. To do this, move the mouse pointer over the placeholder image until an icon appears. Click the icon to select a new image.



5. Click on "Save" (3) in the menu bar to save the changes. The new material is now created.

7.4.3 Deleting a material

Select the material in the list that you want to delete. Then click on "Delete" in the menu bar and confirm the action.



7.5 Manage test cells and cell builds

EL-Software enables the management and logging of the test cells used. Each test cell equipped with a PAT-Button is recognized by the EL-Software when inserted into a PAT-Tester and recorded in the database. Other cells can be entered manually. As soon as the cell has been assembled within an experiment, a so-called *Cell Build* is created for it. A Cell Build records the time of assembly, as well as all information about the cell composition and cell chemistry used, which was entered by the user when creating the experiment. The Cell Build remains active for EL-Software until the cell is disassembled. It is thus possible to continue to use a test cell in a new experiment without changing the composition. EL-Software will recognize the cell and its composition when reinserting it into a PAT-Tester, or will suggest it as a compatible test cell for the new experiment during cell assignment. If a test cell is to be used for a new experiment with a changed configuration, it must first be marked as disassembled. After that it will be shown as available. After assignment, a new cell build is created for it that includes the new configuration.

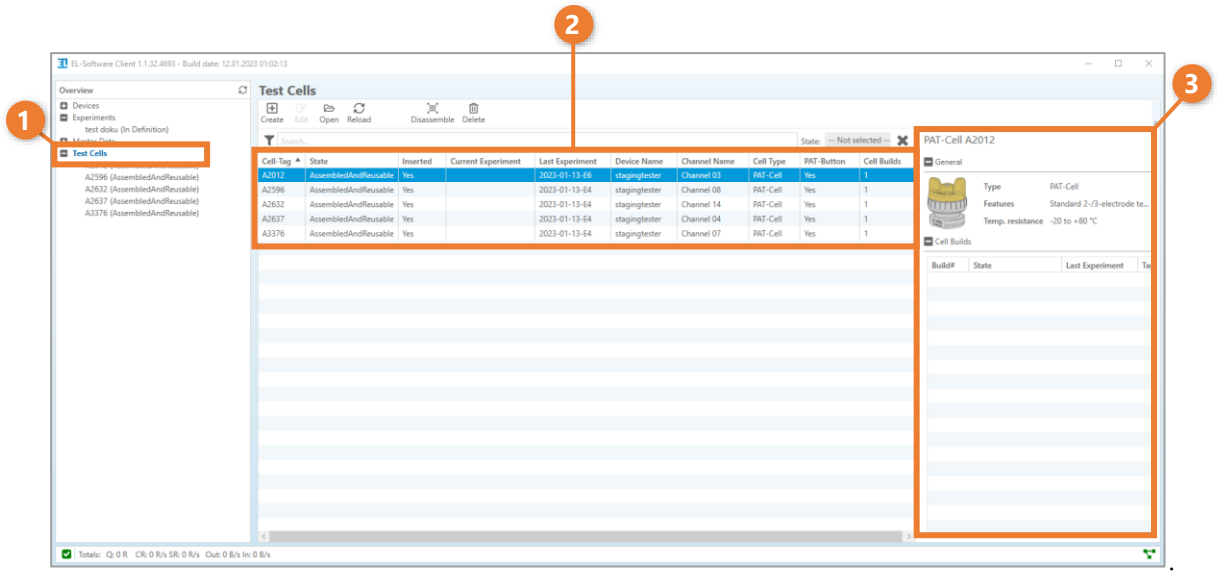
The individual cell builds of a test cell are logged and can be viewed at any time. There are several possible states for a test cell:

Status	Meaning
Unknown	The status of the test cell is unknown and no PAT-Button can be detected.
Disassembled	The test cell has been disassembled and is available for a new experiment with a new configuration. It currently has no active Cell Build
Assembled	The test cell was assembled and a new cell build was created. This Cell Build has not yet been used in an experiment.
Assigned	The test cell is assembled and assigned to an experiment that has not yet been started.
Running	The test cell is currently being used in an ongoing experiment.
Inserted	The test cell was registered in EL-Software when it was inserted into the PAT-Tester
AssembledAndReusable	The test cell has been assembled and has already run in an experiment. It can be reused in the current configuration.
Assembling	The test cell has been assigned to an experiment and is currently being assembled.

PLEASE NOTE
EL-Software assigns the state automatically. Only the “disassembled” state can be set by the user.

7.5.1 Test Cells overview

Click on "Test Cells" in the tree view to open the view (1). The content area will display a table with all test cells that have been detected by EL-Software or added manually (2). When you select a list entry, additional information about this test cell, such as cell properties and existing cell builds, appears in the detail area on the right (3).

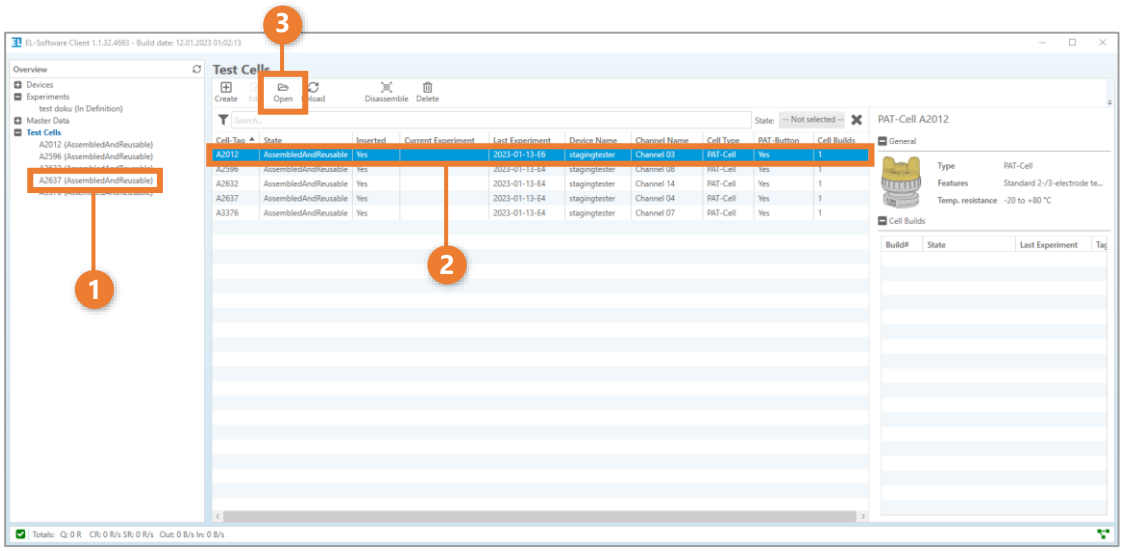


PLEASE NOTE

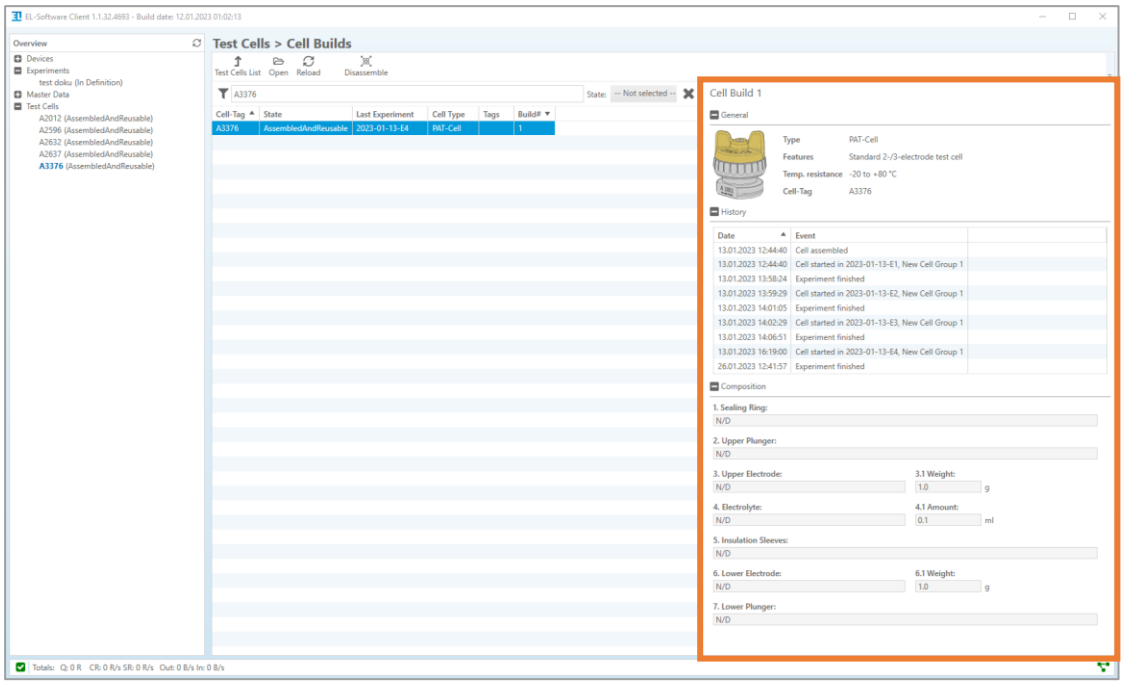
EL-Software automatically records all test cells as soon as they are inserted into a connected PAT-Tester and have a PAT-Button. Test cells without a PAT-Button must be created manually in the system.

7.5.1.1 Open the detail view of a test cell

To view the cell builds of an individual test cell, you can click on the entry in the tree view (1). Alternatively, you can open the respective entry in the list by double-clicking on it (2), or click on it and call it up via the "Open" button in the menu bar (3).

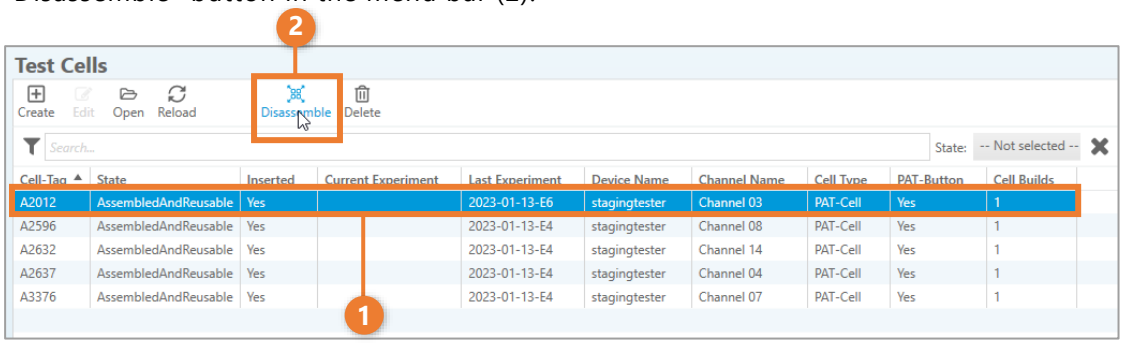


The overview of the cell builds created with this test cell is now displayed. Further details on the selected cell build are displayed on the right. This includes the history of all experiments performed with it, as well as the cell composition.



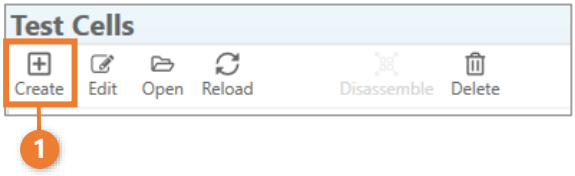
7.5.1.2 Marking a test cell as “disassembled”

After a test cell has been disassembled, it must be assigned the "disassembled" status in EL-Software. To do this, select the cell in the list in the “Test Cells” view (1) and click on the "Disassemble" button in the menu bar (2).

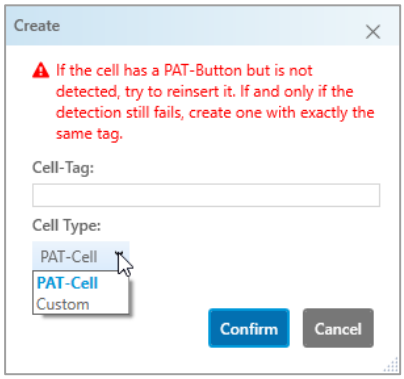


7.5.1.3 Manually creating a test cell without a PAT-Button

Test cells without a built-in PAT-Button are not automatically recognized when inserted into a PAT-Tester, but must be created manually. To do this, click on the "Create" button in the menu bar in the “Test Cells” view (1).



A window opens in which you can specify the cell tag or any name and the type of the cell. Then click on "Confirm" to create the test cell.



PLEASE NOTE

Manually created cells are not automatically recognized when they are inserted into a PAT-Tester. They must therefore be manually assigned to a test channel as described in **chapter 7.2.7**

8 Working with scripts in EL-Software

A script in EL-Software defines the commands and conditions required by the battery tester to charge and discharge a battery test cell. Scripts are created in the Lua programming language. Lua scripts can either be created in EL-Software using the Composer, a visual editor, or imported as Lua scripts.

The general structure of Lua scripts in EL-Software

The Lua script can be considered as consisting of two components: the base script and the embedded configuration section. The configuration section contains a list of test steps with all required parameters. The base script contains the Lua code that processes the steps in the configuration section. Normally, only the configuration section should be edited by the user. Editing the base script requires a profound knowledge of the Lua language and the machine and is only recommended in special cases.

Composer scripts can be saved (and reloaded) with the file extension *elc*, for example `testscript.elc`. Within EL-Software, the composer script can be translated (exported) to Lua format, for example as `testscript.lua`.

Lua scripts can be saved (and reloaded), but there is no way back to the Composer format.

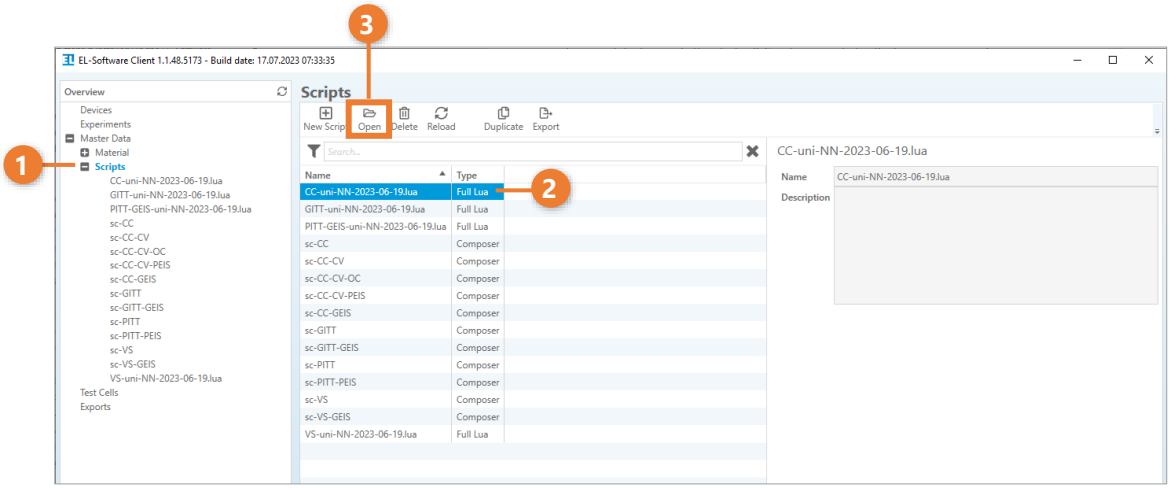
At the time of writing, only the Lua format supports edit-on-the-fly, that means the ability to change the test script during the runtime of the experiment.

8.1 The Script Editor

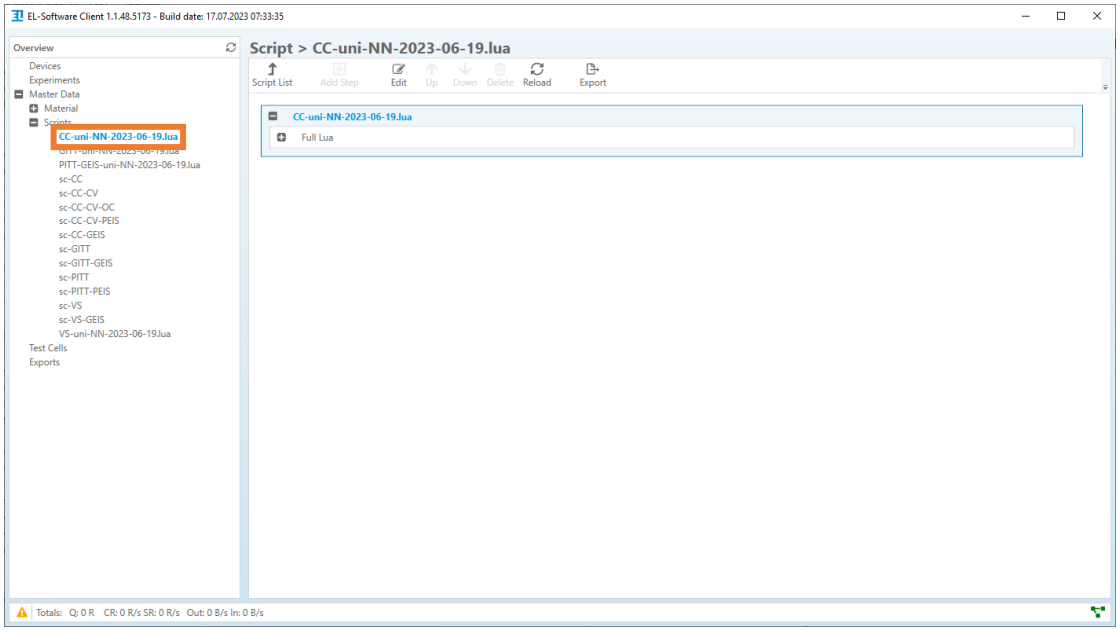
The Script Editor allows you to create and modify scripts. It can be called up via the menu options “Master Data” and “Experiments”.

8.1.1 Opening a script in Master Data

You can modify scripts stored in the Master Data database in the Script Editor, or create new ones for later use. To do this, select the "Scripts" area in the tree view (1). Now select a script from the list (2) and open it via the "Open" button in the menu bar (3), or by double-clicking on the list entry.



Alternatively, you can expand the “Script” entry in the tree view and open a script directly from there.



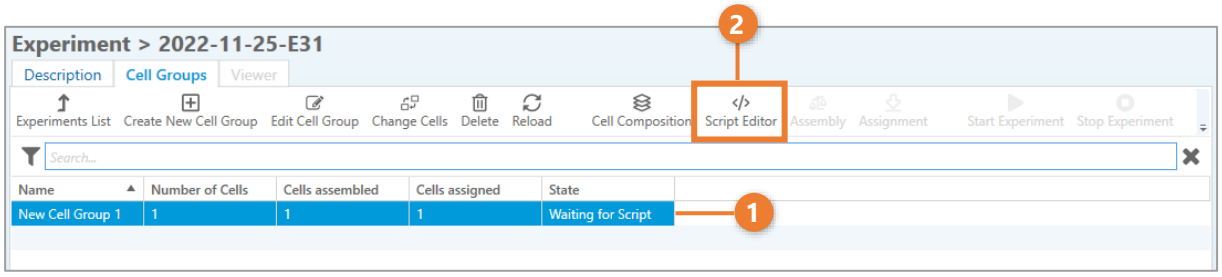
PLEASE NOTE

Only individual scripts can be created and edited in Master Data.

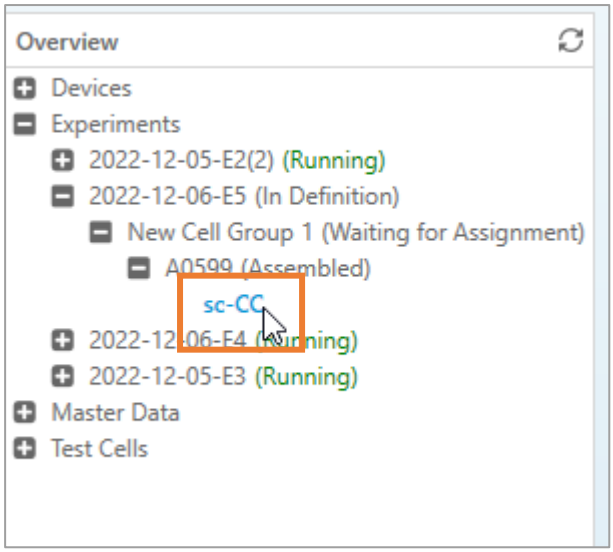
8.1.2 Opening a script in an experiment

An experiment can only be started if at least one script has been assigned to each cell group, as described in chapter 7.2.7.

To open an assigned script, open the list view of the cell groups in the "Experiments" view. Then select a cell group from the list (1) and click on "Script Editor"(2) in the menu bar.



Alternatively, you can open the script directly via the tree view.



8.2 Composer Scripts

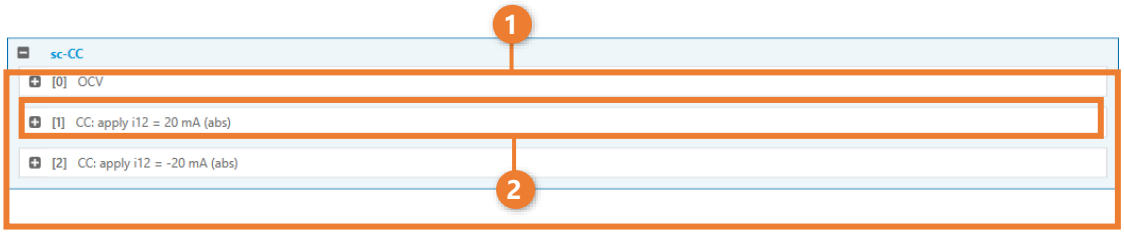
The Composer offers a comfortable, visual representation of the underlying Lua script and thus enables fast and efficient working with scripts. Its possibilities cover all common scenarios for battery tests.

8.2.1 Differences between Composer and Lua scripts

Direct editing of the source code is more powerful and flexible, as the user can take full advantage of the Lua programming language. In contrast, the Composer is easier to use and less prone to syntax errors. To get the most out of both methods, the user can first write the basic test flow using Composer, then have the software translate the Composer script into Lua source code, and finally, modify and refine the Lua source code as needed.

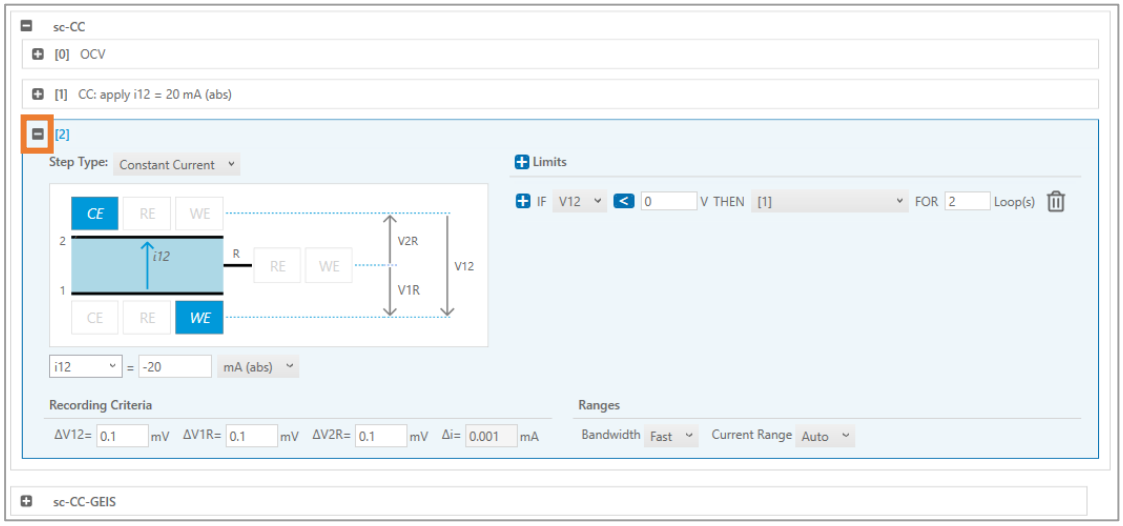
8.2.2 Elements of a Composer script

Scripts are represented in the Composer as visual building blocks, each consisting of a container for the script (1) and one or more containers for the contained process steps (2).



8.2.3 Displaying the contents of the Composer script

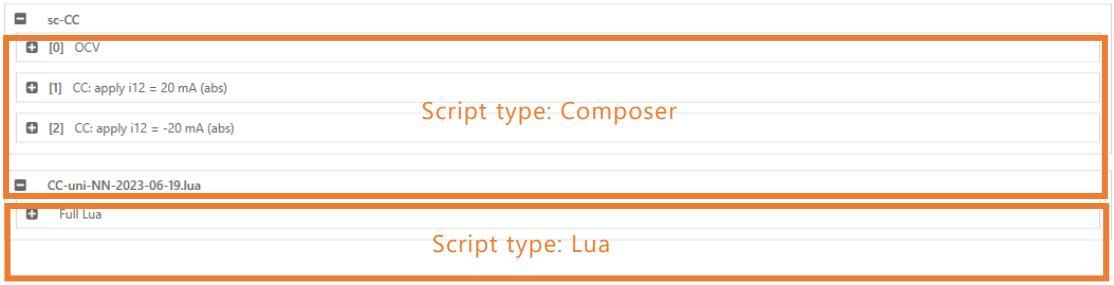
Within the scope of an experiment, several scripts can be added, each consisting of one or more steps. For a better overview, the contents of the scripts and steps can be expanded and collapsed using the plus or minus symbol.



8.2.4 Mixed view of different script types

It is possible to display scripts of different type in the composer.

Lua scripts are represented as script containers with only a single step container, even though the scripts may contain multiple steps. The container is named after the respective script type.



8.2.5 Creating a new Composer script

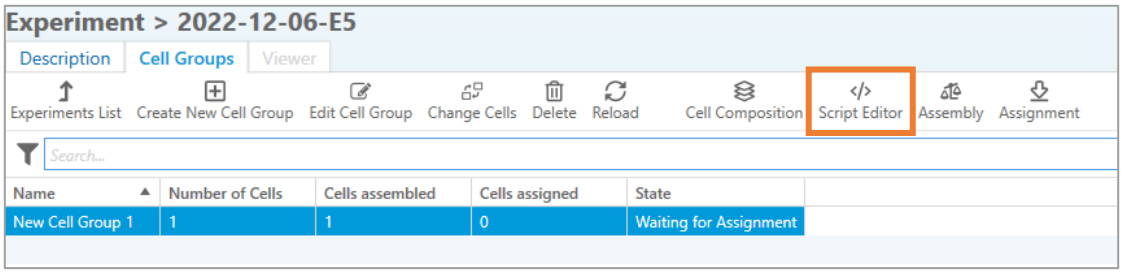
You can create scripts directly in a new experiment or in the Master Data database. Of course, you can also export scripts created in an experiment to Master Data for later use.

In EL-Software itself, only scripts of the Composer type can be created. Other types of scripts must be created in an external editor and then imported for use in EL-Software.

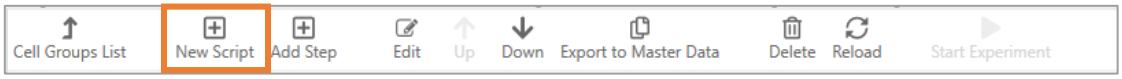
Create a script in an experiment

1. Create an experiment with a cell group as described in **chapter 7.2** and assign at least one test cell to the cell group.

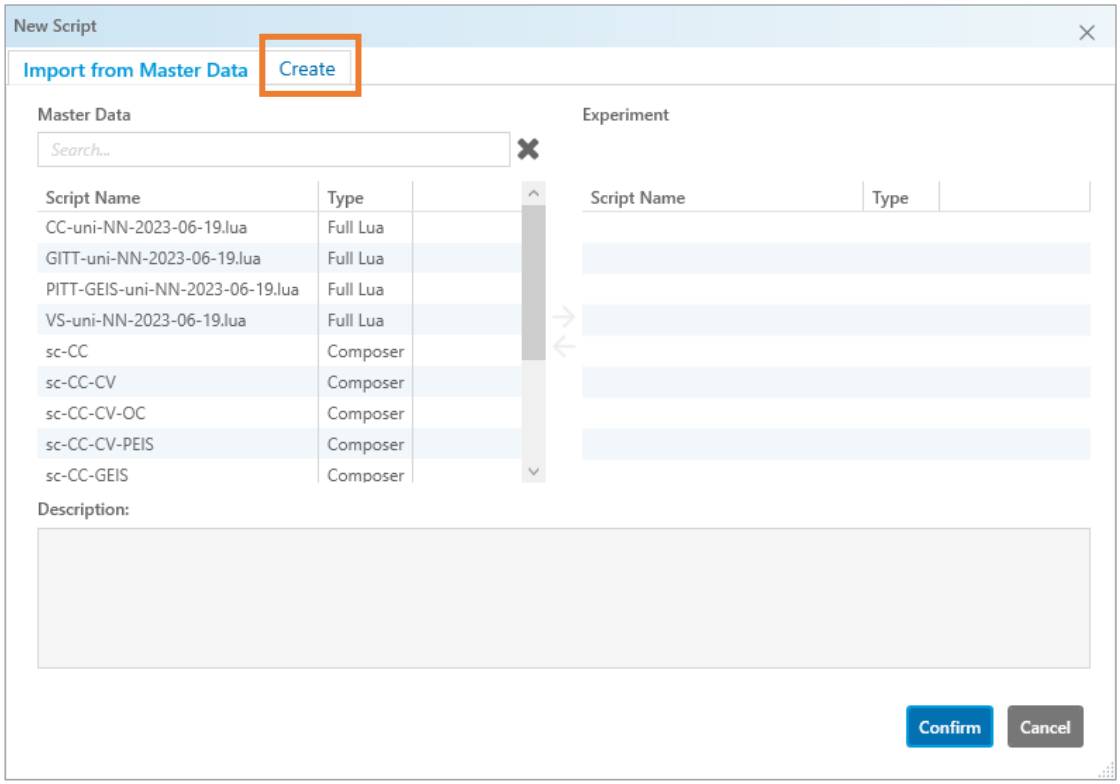
2. Select the cell group in the list and click the "Script Editor" button in the menu bar.



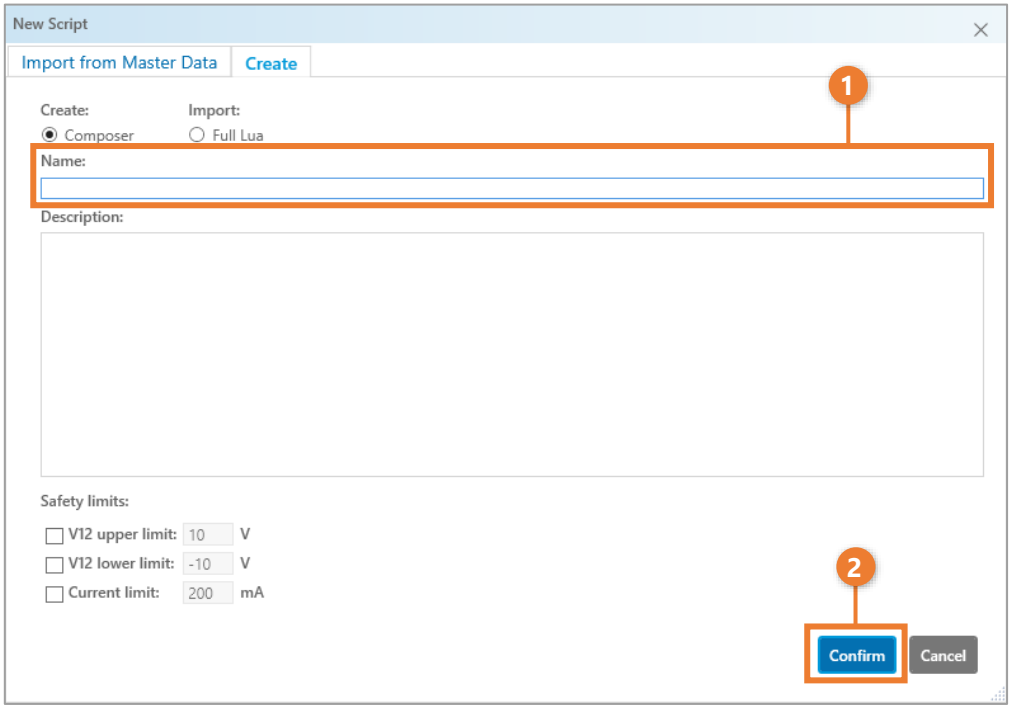
If you have already assigned a script, the Script Editor opens. In this case, click on "New Script" in the menu bar of the Script Editor.



3. The dialog for creating a script opens. By default, you will be offered the option to import a script from the Master Data database. Click on the "Create" tab.

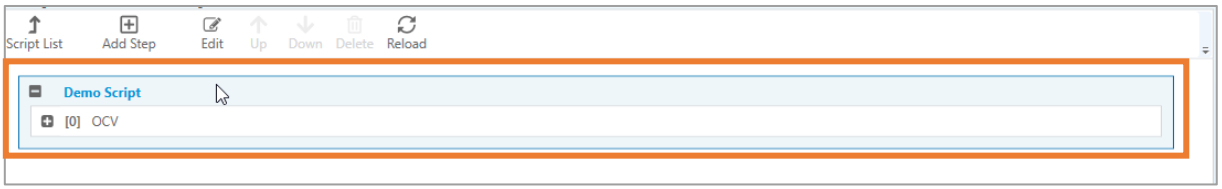


4. Assign a name (1) for the new script and click "Confirm" (2).

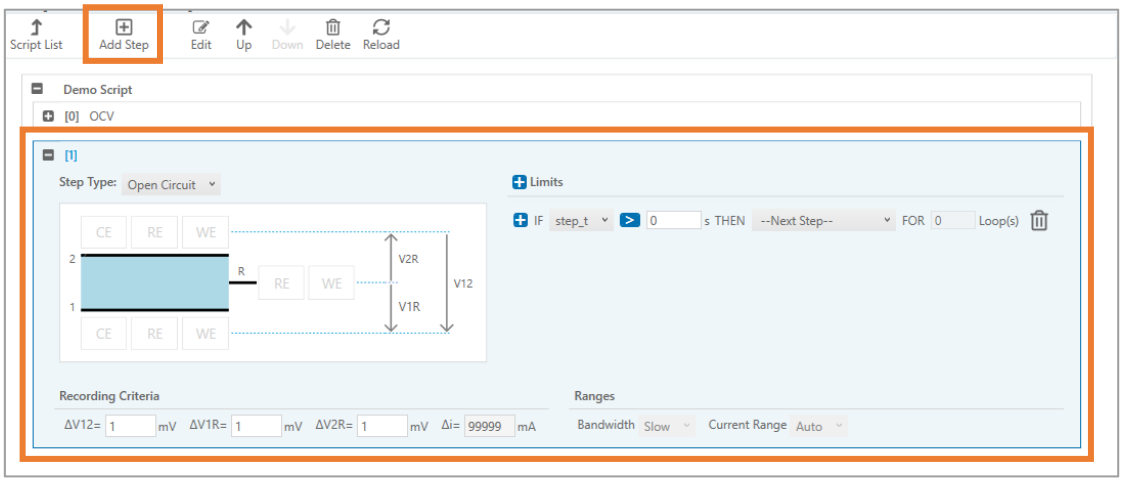


8.2.6 Add a new composer step

1. Select the script container to which you want to add a new step by clicking on it. The container is now displayed in blue.



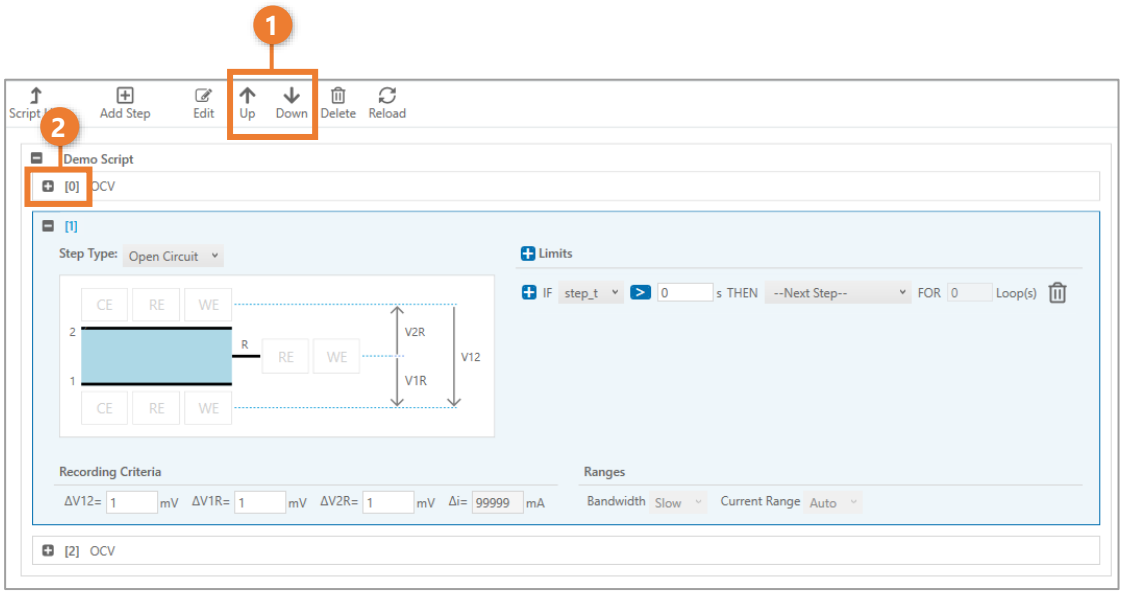
2. Click “Add Step” to add a new step. It will be created after the last step.



8.2.7 Editing a composer step

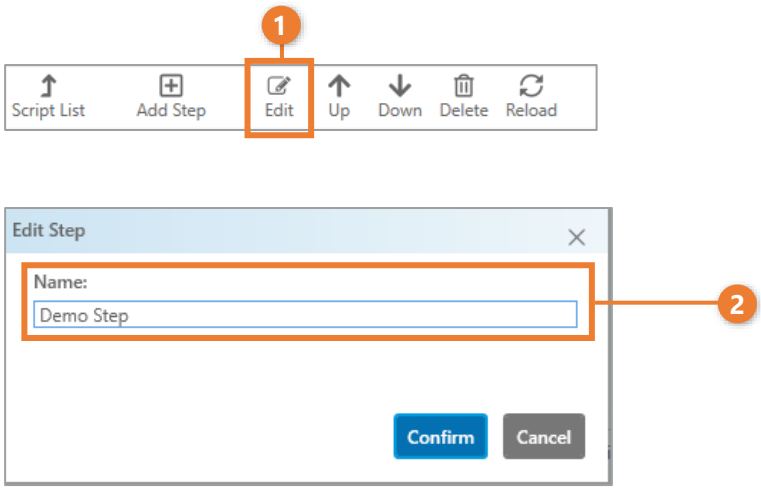
8.2.7.1 Move a step in the sequence

Select the step and move it in front of or behind other steps using the "Up" and "Down" buttons (1). You can see the position of a step by the number in the step container (2).



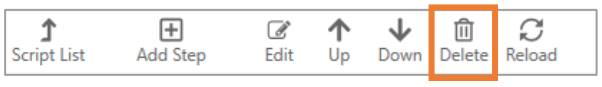
8.2.7.2 Adding/editing the name of a step

Select the step and then click on the "Edit" button (1). A dialog box opens in which you can now assign a name for this step (2). This name is subsequently displayed in the header of the container (3).

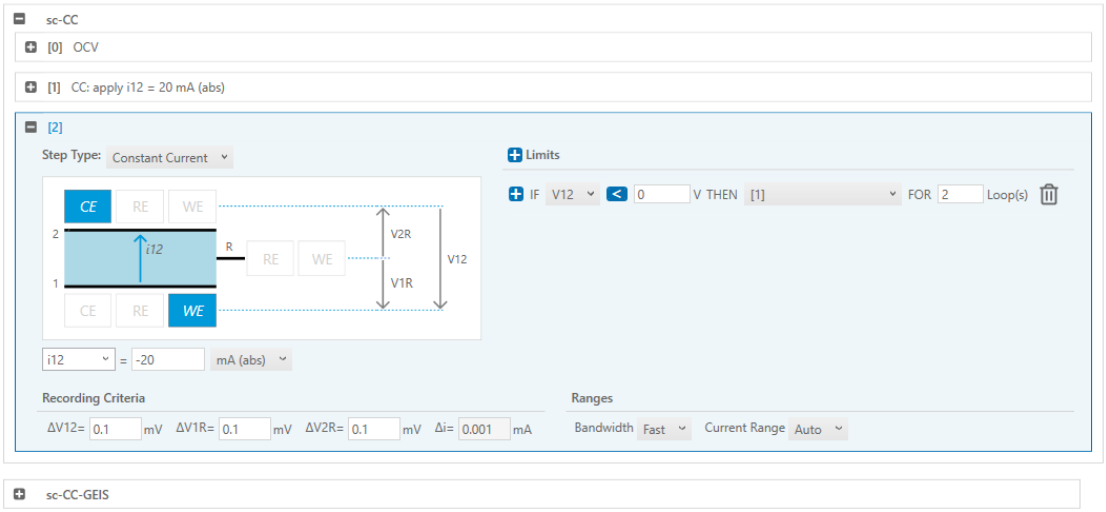


8.2.7.3 Deleting a step

To remove a step, select it and click the "Delete" button in the menu bar.



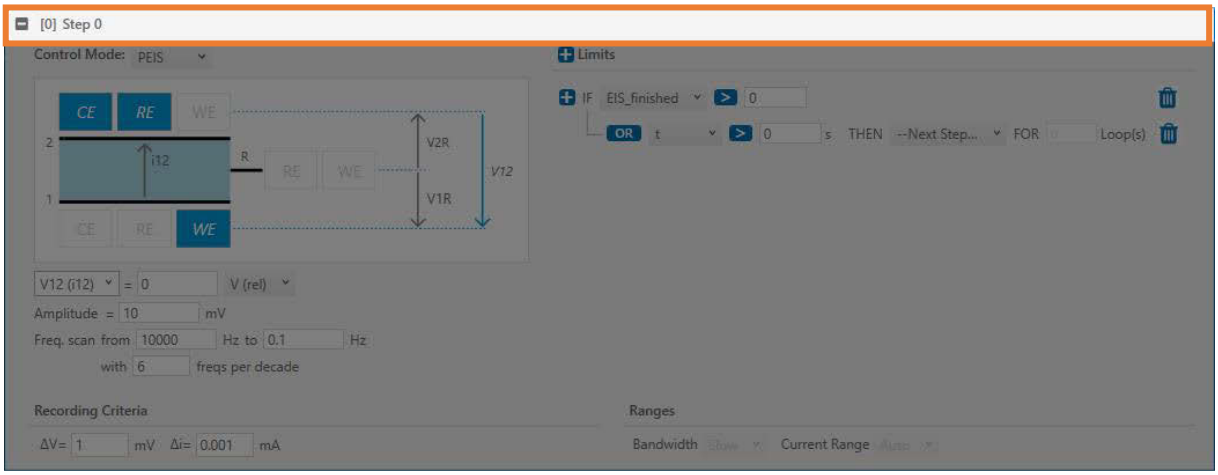
8.2.8 Composer Step overview and options



Each test script inside EL-Software contains one or multiple steps. They are processed in a user-defined order during the experiment.

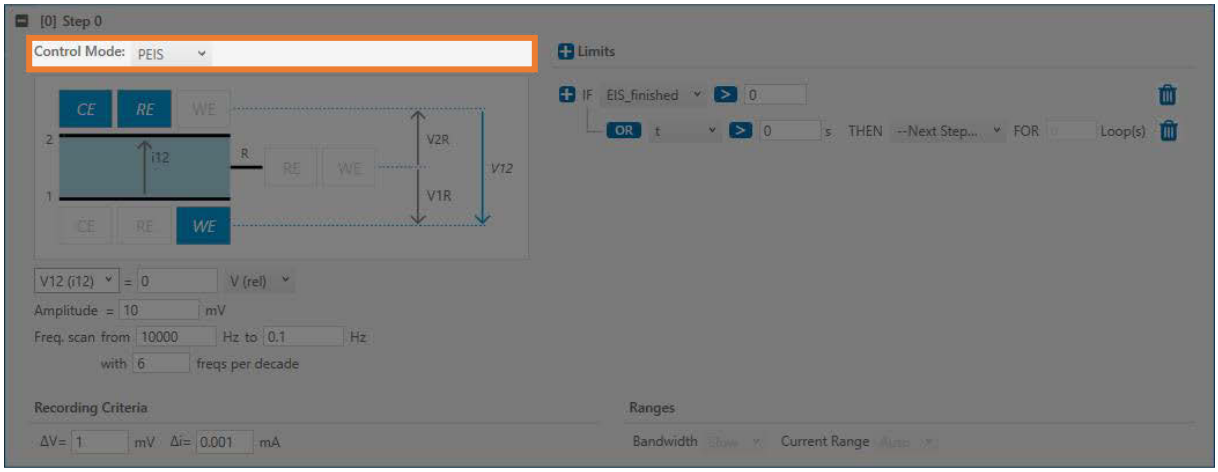
Each step is defined by a measurement mode such as CC (constant current) or CV (constant voltage) and one or more limits. After reaching this limit, the script will perform a loop through the same step again or jump to another step.

8.2.8.1 Step label



The position of each step in the script is shown in square brackets. In addition, an extract of the set parameters appears in the collapsed state. A label text can also be defined for each step. This is done via the “Edit” button in the menu bar.

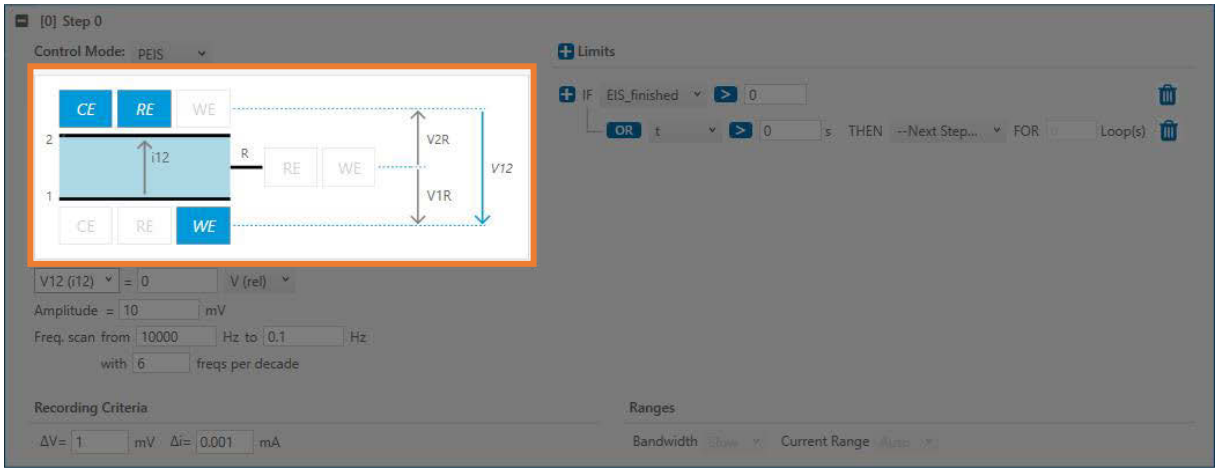
8.2.8.2 Control modes



The working mode of the PGStat (potentiostat/ galvanostat). The following modes are available:

- Off
- Open Circuit (OC)
- Constant Voltage (CV)
- Constant Current (CC)
- Voltage Scan (VS)
- PEIS
- GEIS
- See **chapter 8.6** for further details.

8.2.8.3 Connection matrix



The connection matrix is an interactive graphical representation of the electrical connection between the three electrodes of the test cell (1, 2, R) and the three terminals of the PGStat (WE, CE, RE). Depending on the step type, various connections are available, from which the user can select by clicking on the elements WE, CE, and RE in the connection matrix, or by direct entry into the corresponding field.

Note: The individual electrodes cannot be active in several places at the same time. Therefore, you must first deactivate them by clicking on them to make them available elsewhere. Then you can activate them at the new position.

During a galvanostatic step, the current between two (of the three) electrodes is controlled. The following galvanostatic control modes are available:

	WE	CE	Current control
i12	1	2	1 to 2
i1R	R	1	R to 1
i2R	R	2	R to 2

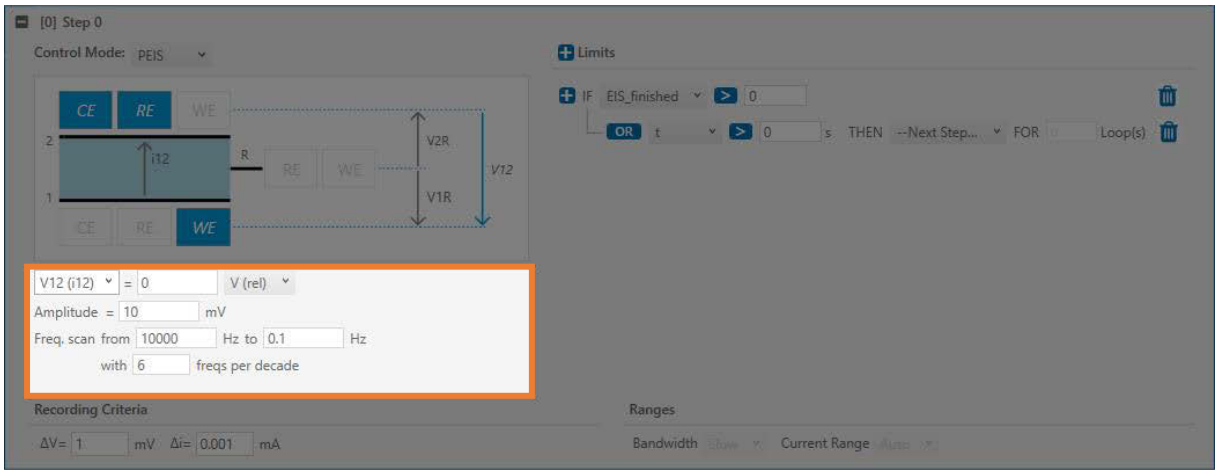
Most common is to apply a current i12 between electrodes 1 and 2 and so to leave electrode R unaffected. However, sometimes a current should also flow over electrode R, for instance to check its state of health or to plate it galvanically. The above settings, i1R and i2R serve this purpose.

During a potentiostatic step, the voltage between two (of the three) electrodes is controlled. The corresponding current can flow between the same two electrodes between which the voltage is controlled, or between two other electrodes. The user can select between the following potentiostatic control modes:

	WE	CE	RE	Voltage control
V12 (i12)	1	2	2	full cell 1 vs 2
V1R (i12)	1	2	R	half cell 1 vs R
V2R (i12)	2	1	R	half cell 2 vs R
V1R (i1R)	R	1	1	R vs 1
V2R (i2R)	R	2	2	R vs 2

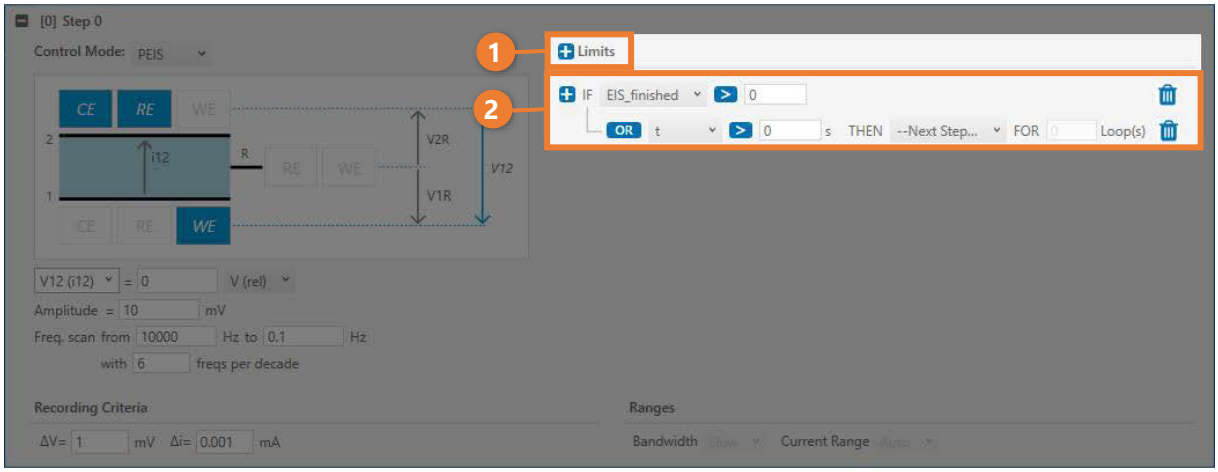
Again, it is most common to apply the current between electrodes 1 and 2, while electrode R is left uncharged. This can be done in three different potentiostatic modes: Either the voltage V12 of the full cell is controlled, or the voltage V1R or V2R of one of the two half cells. Sometimes the current should also flow over the R electrode during potentiostatic control, e.g., to check the impedance of the R electrode by a PEIS measurement. The above potentiostatic settings V1R(i1R) and V2R(i2R) serve this purpose.

8.2.8.4 Control mode parameters

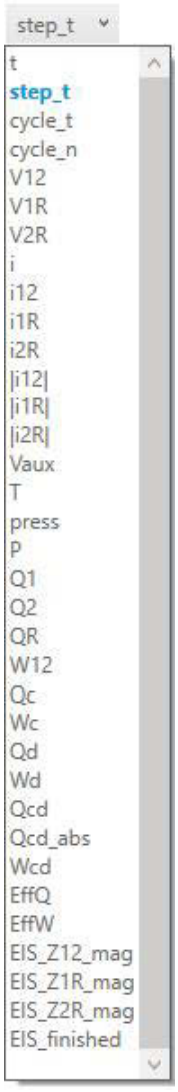


Depending on the control mode, additional parameters can be set here. See **chapter 8.6** for further details.

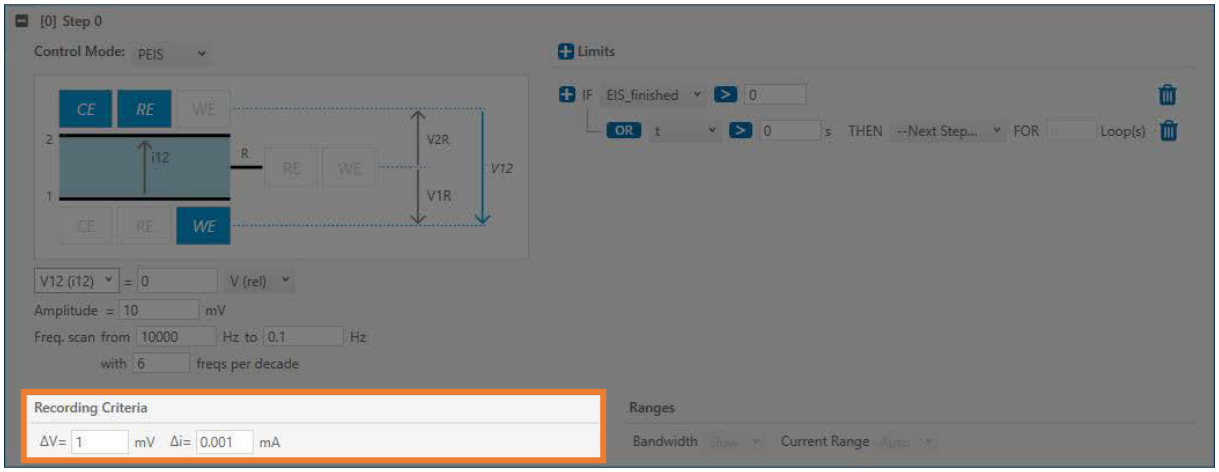
8.2.8.5 Limits



A step ends once a step limit is reached. Multiple limits can be defined (1). In addition, each limit can contain further conditions (2) that can be linked with AND or OR. IF..THEN.. clauses can be formed using the operators > and < and a variable from the list below.

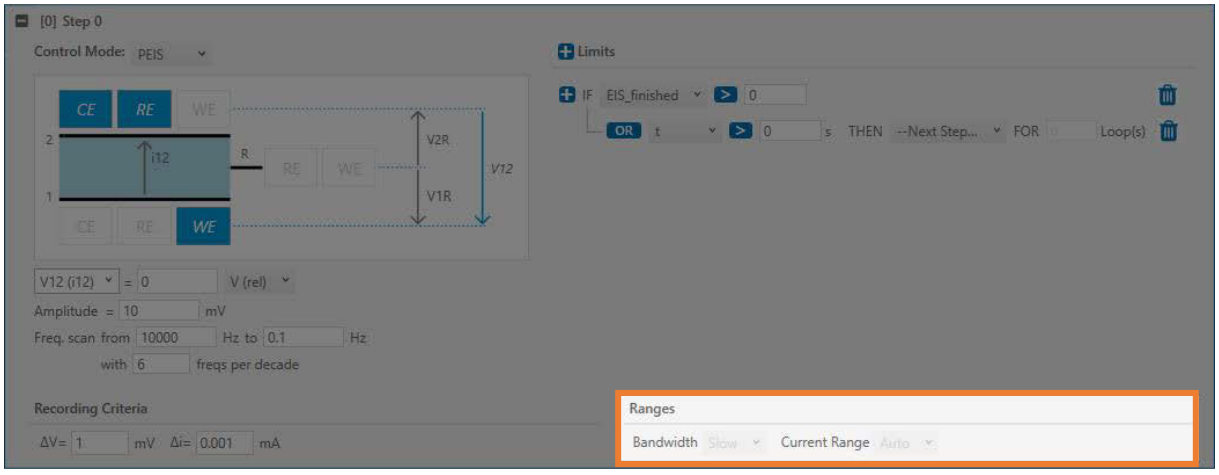


8.2.8.6 Recording Criteria



The recording criteria ΔV and Δi aim to minimize the amount of stored data without losing much information. The special algorithm used in EL-Software is much more effective and provides much better data compression than conventional methods. In short, drawing lines between adjacent data points of the reduced data results in a curve that is always close to the original curve, with the maximum difference between the two curves defined by the recording criteria ΔV and Δi. Depending on the step type, the reduction can be applied on V(t) or i(t), or on both. For best accuracy, all continuous calculations (e.g. of capacity and energy) are performed directly on the raw data rather than the reduced data.

8.2.8.7 Ranges



"Autorange" and 4 fixed current ranges (100 µA, 1 mA, 10 mA, 100 mA) are available. "Autorange" is the default setting for all step types.

8.3 Exporting a script from the Script Editor

Scripts that you create as part of an experiment can be saved to the Master Data for later reuse or to the hard drive for use in an external editor.

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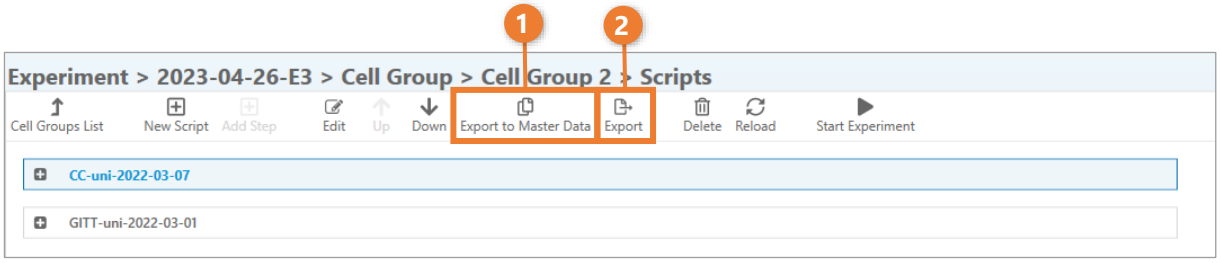
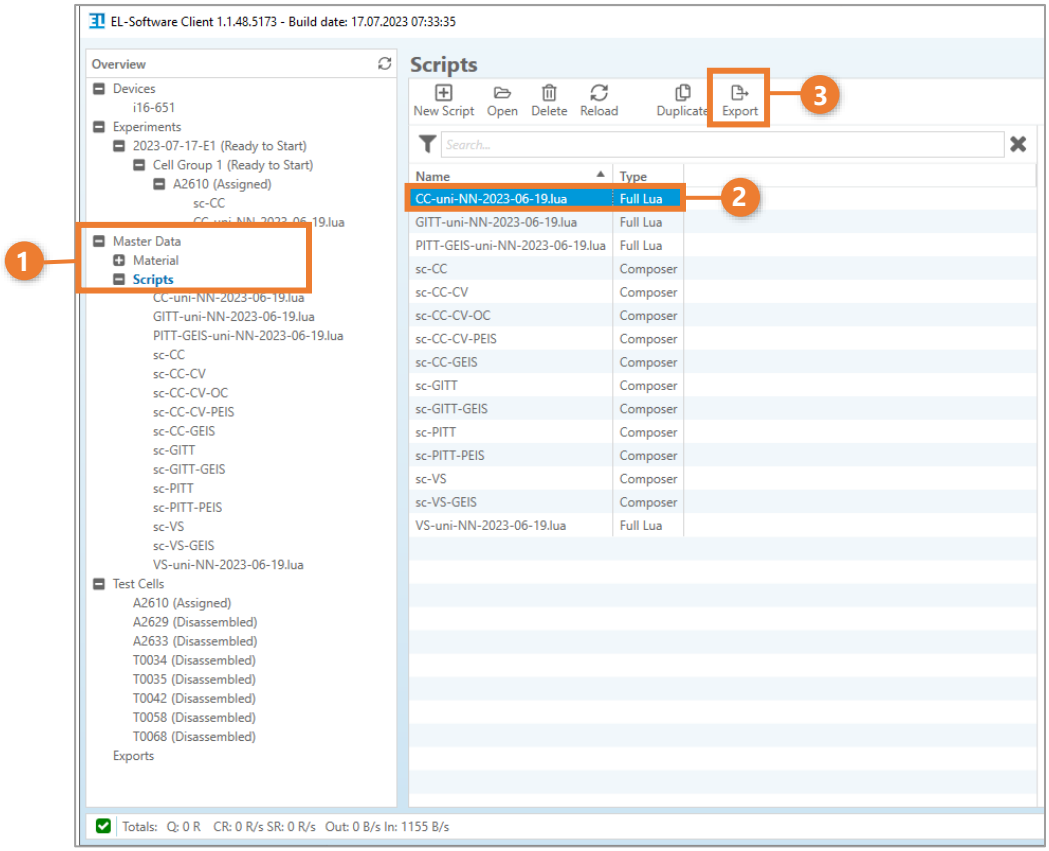
To save a duplicate of the currently selected script in Master Data, open the Script Editor in your experiment and then click the "Export to Master Data" button (1). To save the script to your hard drive, simply click on the “Export” button (2).



8.4 Exporting a script from Master Data

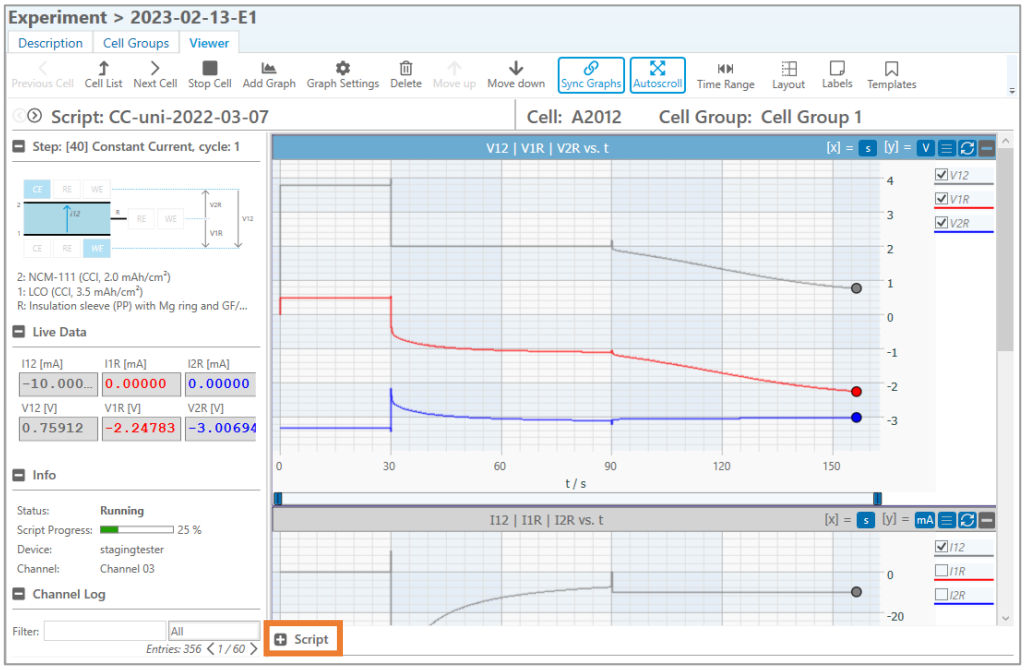
You can export any script stored in the database to your hard drive. To do this, click on the "Master Data" entry in the tree view and then on "Scripts"(1). Select a script from the list (2) and click on the "Export" button in the menu bar (3).



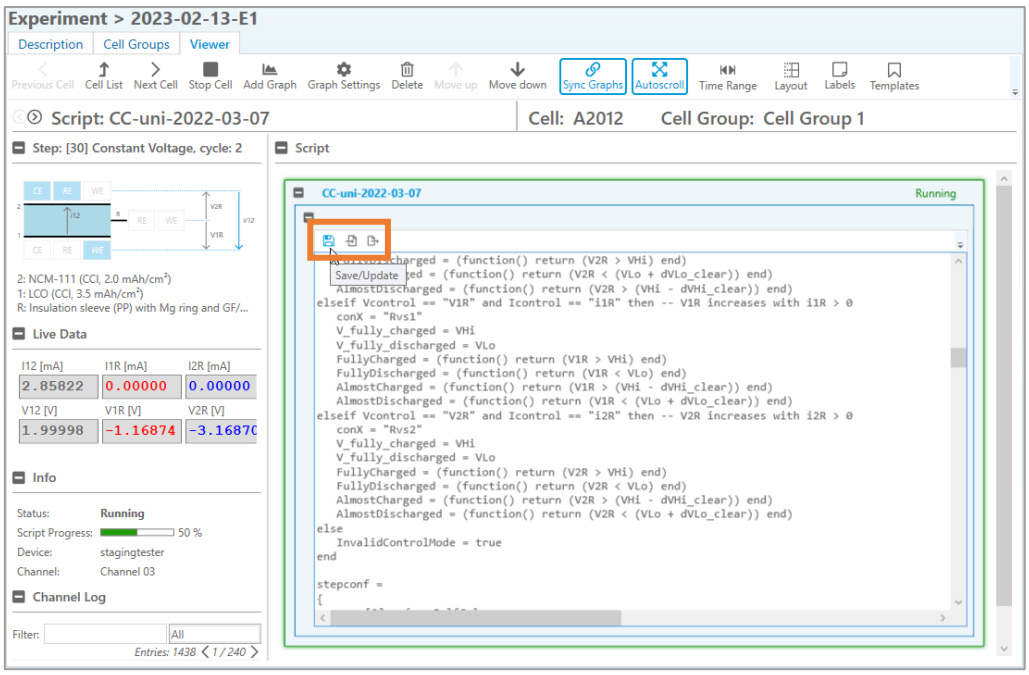
8.5 Changing scripts at runtime (Edit-on-the-fly)

At the time of writing, only scripts of type Lua can be modified at experiment runtime.

1. Open the Cell Viewer and expand the script view by clicking on "Script".



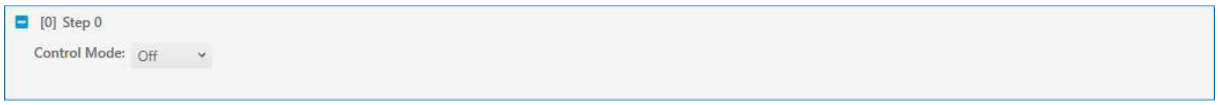
2. Modify the script as desired and then save the changes by clicking on the floppy disk icon. The script is retransmitted to the PAT-Tester and the changes are applied. You can also use the "Import" and "Export" icons to save the script to your hard drive or replace it by another script.



8.6 Available control types

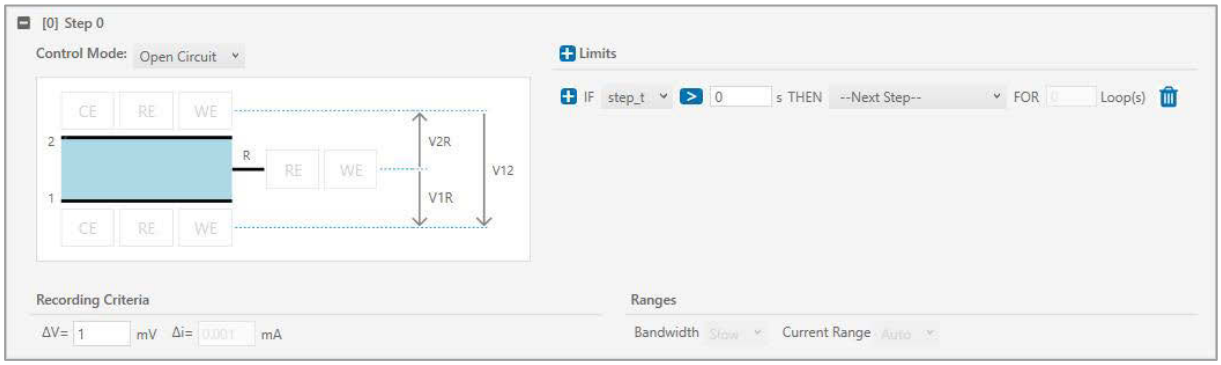
In the following, we explain the different control modes available to you in EL-Software test scripts. In addition to the representation in the Composer, we also show the corresponding source code in Lua.

Off



When OFF, the PGStat is disconnected from the test cell, and no data are recorded. Note that any script is ending with an OFF step, even if not explicitly set in the composer.

Open Circuit (OC)

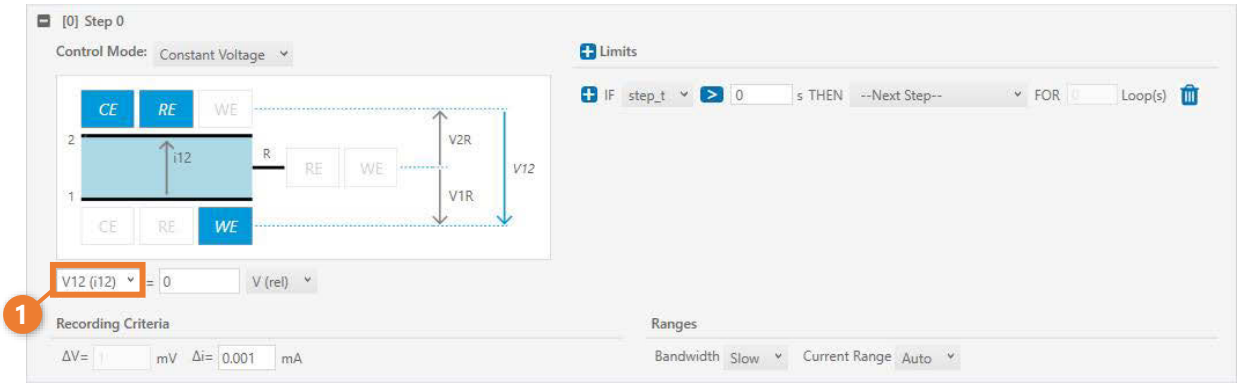


Open Circuit (OC) is the default for new steps. As a good practice, any script should begin with an OC step. In open circuit, the PGStat is disconnected from the test cell. Still, data are recorded as defined by the recording criterion ΔV.

Corresponding Lua Code:

```
[1] = {      --
    step_type = "OCV", -- or "Rest"
    record = {V12 = 0.001, V1R = 0.001, V2R = 0.001, i = 99.999},
    limits = {
       [0] = function(limit) if step_t > 10 then SwitchNext() end end
    }
},
```

Constant Voltage (CV)



During a CV step, the voltage between two electrodes is held constant by applying a current between the same two or different two electrodes. The desired potentiostatic control mode can be selected by clicking on the elements WE, CE and RE in the connection matrix or by direct selection from a drop-down list (1). The setpoint of the control voltage is either given as an absolute value, V(abs), or relative to the last voltage measured in the previous step, V(rel). During a CV step, data are recorded as defined by the recording criterion Δi.

Corresponding Lua Code:

```
[2] = {--
      step_type = "CV",
      v = V12_last_step + 0,
      con = "1vs2",
      range = "auto",
      bw = "fast",
      record = {V12 = 0.001, V1R = 0.001, V2R = 0.001, i = 0.00001},
      limits = {
            [0] = function(limit) if step_t > 10 then SwitchNext() end end
      }
},
```

By default, the voltage is set to 0 V(**rel**). The unit V(rel) means that this setpoint refers to the last voltage reading of the previous step.

Constant Current (CC)

During a CC step, the current between two electrodes is held constant. The desired galvanostatic control mode can be selected by clicking on the elements WE, CE and RE in the connection matrix or by direct selection from the drop-down list (1).

The setpoint of the current is given either as an absolute value (mA(abs)) or relative to the last measured current value of the previous step (mA(rel)), or relative to the weight of electrode 1 (mA/g(1)), or relative to the weight of electrode 2 (mA/g(2)).

During a CC step, data are recorded as defined by the recording criterion ΔV.

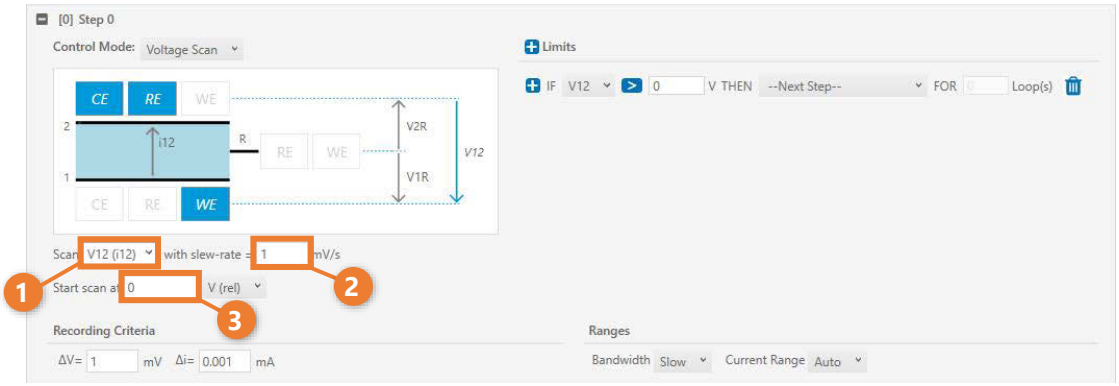
Corresponding Lua Code:

```
[3] = {--
        step_type = "CC",
        i = 0.001,
        con = "1vs2",
        range = "auto",
        diffcap_dV = 0.001,
        diffcap_startdelayR = 5,
        bw = "fast",
        cd = "auto",
        record = {V12 = 0.001, V1R = 0.001, V2R = 0.001, i = 0.00001},
        limits = {
                [0] = function(limit) if step_t > 10 then SwitchNext() end end
        }
},
```

Recording of the differential capacities C = dQ/dV during a CC step is controlled by two parameters:

- diffcap_dV is the voltage interval dV used for calculating C = dQ/dV (same dV used for C12, C1 and C2)
- diffcap_startdelay**R** defines the delay at the beginning of a CC step before the dQ/dV calculation starts

Voltage Scan (VS)



During a VS step, the selected voltage (1) is increased or decreased linearly with time. The slew rate (2) defines the slope ΔV/Δt in units of mV/s. The slew rate can be positive or negative. The start point of the scan (3) can either be given as an absolute value, V(abs), or relative to the last voltage measured in the previous step, V(rel). By default, the scan starts at 0 V(rel). During a VS scan, data are recorded as defined by the recording criteria ΔV and Δi.

Corresponding Lua Code:

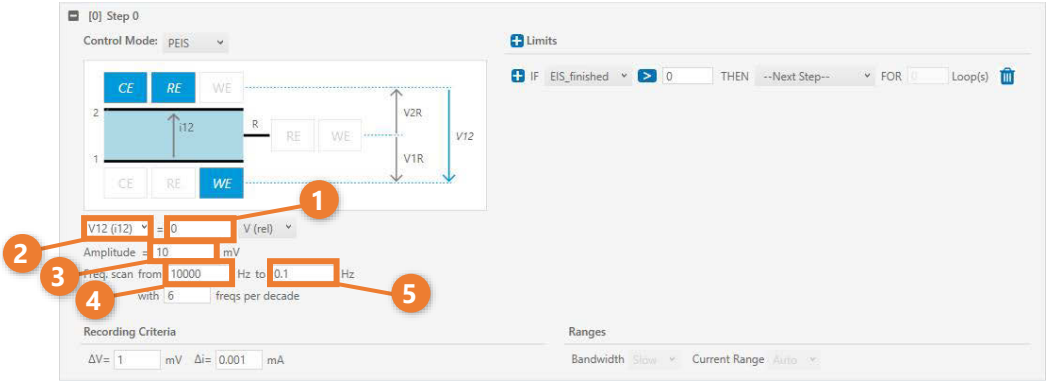
```
[4] = {--
        step_type = "VS",
        v = V12_last_step + 0,
        slope = 0.001,
        con = "1vs2",
        range = "auto",
        diffcap_dV = 0.001,
        diffcap_startdelayR = 5,
        bw = "fast",
        cd = "c",
        record = {V12 = 0.001, V1R = 0.001, V2R = 0.001, i = 0.00001},
        limits = {
                [0] = function(limit) if V12 > 0 then SwitchNext() end end
        }
},
```

Parameters:

v	start point of the voltage scan
slope	slope of V(t) in V/s
con	connection between PGStat and test cell
range	current range

diffcap_dV	the interval dV for which the differential capacity dQ/dV is calculated
bw	bandwidth
cd	step belongs to charge (cd = c) or discharge (cd = d)

Potentiostatic Electrochemical Impedance Spectroscopy (PEIS)



During a PEIS step, the setpoint (1) of the voltage (2) is modulated with a sinoidal voltage perturbation of amplitude (3). The frequency of the sinoidal voltage can be swept between two frequency limits (4 and 5), starting from either high or low values, and with logarithmic spacing between the frequency values.

The calculated impedance data is always stored in the Output-Impedance table. In contrast, the sine waves are only stored in the Output table at frequencies above 1 Hz and only if the recording criteria ΔV and Δi are set accordingly. This prevents too much data from being recorded.

Corresponding Lua Code:

```
[5] = {--
        step_type = "PEIS",
        v = V12_last_step + 0,
        con = "1vs2",
        range = "auto",
        bw = "fast",
        eis_amplitude = 0.01,
        -- peis_limit_i_amplitude = 0,
        eis_fstart = 100000,
        eis_fend = 0.1,
        eis_fcount_per_ordermagnitude = 6,
        eis_ordermagnitude = 10,
        eis_averages = 1,
        eis_precycles = 1,
        eis_record_waveform_up_to_frequency = 1,
        eis_apply_drift_correction = 1,
        record = {V12 = 99.999, V1R = 99.999, V2R = 99.999, i = 99.999},
        limits = {
```

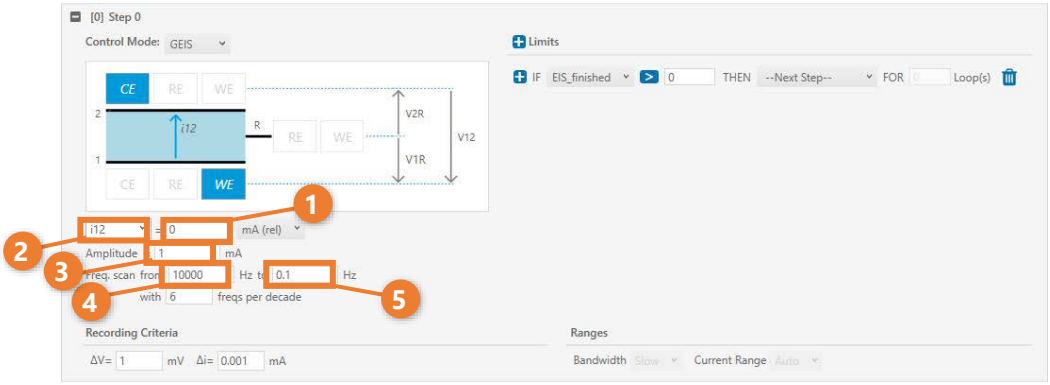
```
            [0] = function(limit) if EIS_finished > 0 then SwitchNext() end
end
      }
},
```

Optional parameters:

peis_limit_i_amplitude

During the frequency sweep, the amplitude of the ac voltage is corrected, so as to ensure that the resulting current amplitude doesn't exceed peis_limit_i_amplitude. Note that the algorithm only works with f0 > fe.

Galvanostatic Electrochemical Impedance Spectroscopy (GEIS)



During a GEIS step, the setpoint (1) of the current (2) is modulated with a sinoidal current perturbation of amplitude (3). The frequency of the sinoidal current can be swept between two frequency limits (4 and 5), starting from either high or low values, and with logarithmic spacing between the frequency values.

The resulting impedance data is always stored in the Output-Impedance table. In contrast, the sine waves are only stored in the Output table at frequencies above 1 Hz and only if the recording criteria ΔV and Δi are set accordingly. This prevents too much data from being recorded.

Corresponding Lua Code:

```
[6] = {--
        step_type = "GEIS",
        i = i12_last_step + 0,
        con = "1vs2",
        range = "auto",
        bw = "fast",
        eis_amplitude = 0.001,
        -- geis_limit_V12_amplitude = 0,
        -- geis_limit_V1R_amplitude = 0,
        -- geis_limit_V2R_amplitude = 0,
        eis_fstart = 100000,
        eis_fend = 0.1,
        eis_fcount_per_ordermagnitude = 6,
        eis_ordermagnitude = 10,
        eis_averages = 1,
        eis_precycles = 1,
        eis_record_waveform_up_to_frequency = 1,
        eis_apply_drift_correction = 1,
        record = {V12 = 99.999, V1R = 99.999, V2R = 99.999, i = 99.999},
```

```
	limits = {
		[0] = function(limit) if EIS_finished > 0 then SwitchNext() end end
	}
}
```

Optional parameters:

geis_limit_V12_amplitude

geis_limit_V1R_amplitude

geis_limit_V2R_amplitude

During a frequency sweep, the amplitude of the ac current is corrected, so as to ensure that the resulting voltage amplitude doesn't exceed geis_limit_Vxx_amplitude. If multiple amplitude limits are defined, then none of the respective limits will be exceeded. Note that the algorithm only works with f0 > fe.

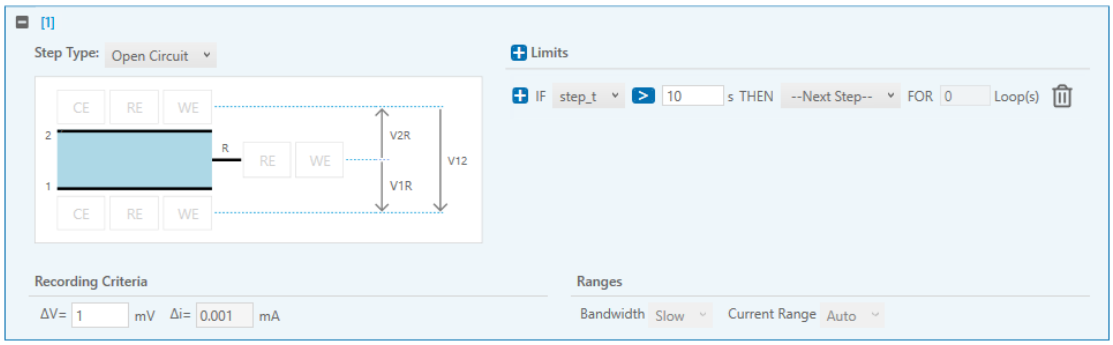
8.7 Script example in Composer and Lua format

In this chapter, we describe both types of scripting. For a given step type, we first explain the Composer form, then we show the resulting Lua source code and explain optional parameters that are only accessible in the Lua source code.

8.7.1 A simple example script

The test script "Test" given below includes a single step "Open circuit" of 10 seconds duration.

Composer format:



Lua format:

```lua
--------------------------------------------------------------------------------
--                            PAT-Tester-Script                               --
--                     using script-base version 2021-06-24                   --
--                     requires channel-firmware V60 or higher                --
--------------------------------------------------------------------------------



--##############################################################################--
--##                                                                          ##--
--##            P A R T  1 :     S T A T E   M A C H I N E                  ##--
--##                                                                          ##--
--##############################################################################--

-------------------- Generate Step Configuration -------------------------------
-- This function contains the defintion of the script steps.
-- It is called before every step transition, to re-calculate any math expressions.
-- The user can overwrite and call this function at _any_ time during measurement:
--   * Changes to limits will become effective immediately.
--   * All other changes will become effective after the next step transition.
--   * It is possible to force a step transition by calling SwitchTo().
--------------------------------------------------------------------------------
function Generate_StepConfiguration()

    -- weight section --
    -- m1 = ...
    -- m2 = ...
    -- end of weight section --

    -- configuration section --
    safetylimits = {V12_min = -10, V12_max = 10, i = 0.1, delay_count = 10}
    stepconf =
    {
        [0] = { -- Stepname: , Id: 6ee7c50e-be7e-4fde-a7dc-77f8f654ef73
            step_type = "OCV",
            record = {V12 = 0.001, V1R = 0.001, V2R = 0.001, i = 0.000001},
            limits = {
                [0] = function(limit) if step_t > 10 then
                    AddProgress(100)
                    SwitchNext() end end
            }
        }
    }
    -- end of configuration section --

end
```

The script starts with a comment block (1) specifying the base version of the script, here 2021-06-24, and the minimum required channel firmware, here V60.

The configuration section (2), lines 30 to 44, is always framed by the comments *-- configuration section --* and *-- end of configuration section --.*

This is the only part of the Lua source code that should be edited by the user. Therefore, only the configuration section is shown below. Note that the version number of the base script will change over time. However, the configuration section will remain compatible with all future versions of the base script.

In the above example, after 10 seconds (step_t > 10), the progress counter is incremented by 100% (AddProgress (100)) and the next step is called with SwitchNext(). Since there is no next step, the test is finished.

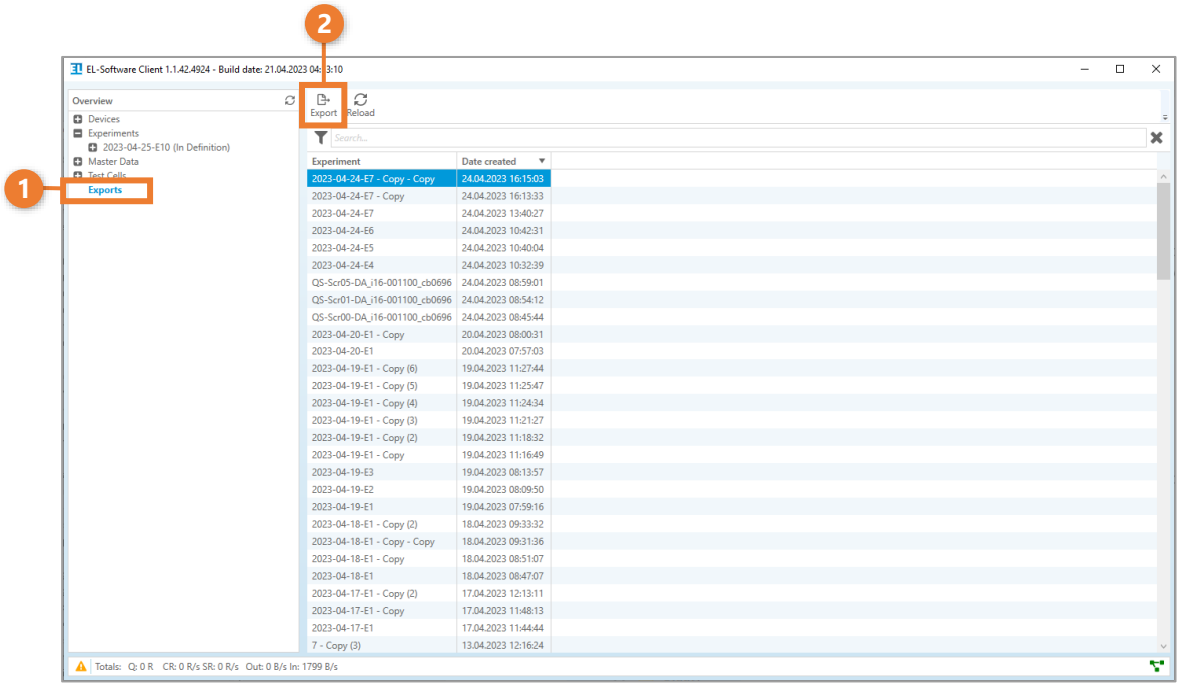
Corresponding Lua code

```
[1] = {      --
    step_type = "OCV", -- or "Rest"
    record = {V12 = 0.001, V1R = 0.001, V2R = 0.001, i = 99.999},
    limits = {
       [0] = function(limit) if step_t > 10 then SwitchNext() end end
    }
},
```

9 Data export

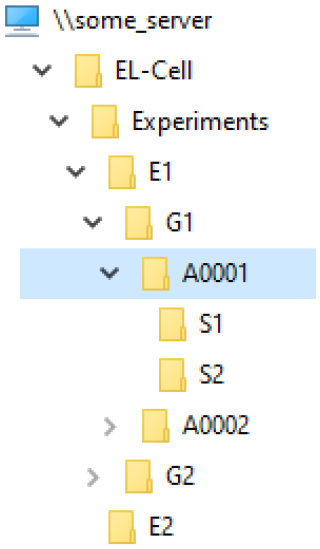
For a given test cell and script, the recorded data ends up in the database of EL-Software and is simultaneously exported to text files for further processing with third-party software such as Excel, Origin or Matlab. The export files can already be accessed during the runtime of the experiment.

To access the export files, simply navigate to “Exports” in the tree view (1). Select an experiment in the list and click on the “Export” button (2) to download a zipped file containing all output files related to this experiment.

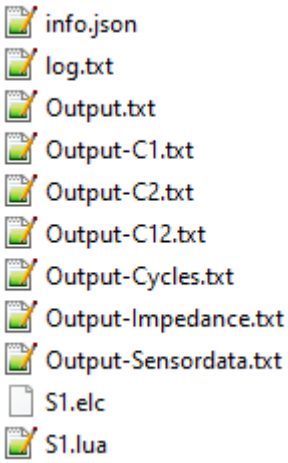


9.1 Log files

During an experiment, data is continuously written to the database and simultaneously to export files. The export folder is organized as follows:



In this example. Experiment E1 contains 2 groups, G1 and G2. Group G1 contains two cells, A0001 and A0002. Two scripts, S1 and S2, were successively run on these two cells. The export data of E1\G1\A0001\S1 are shown below.



- Info.json contains cell information such as composition, electrode weights etc.
- log.txt contains the channel log data and may be used for debugging.
- Output.txt contains the "time data". The file size is mainly controlled by the step parameter 'record'.
- Output-C1.txt contains the differential capacity of electrode 1. Only recorded during CC and VS steps. The file size is mainly controlled by the step parameter 'diffcap_dV'.

- Output-C2.txt contains the differential capacity of electrode 2. Only recorded during CC and VS steps. The file size is mainly controlled by the step parameter 'diffcap_dV'.
- Output-C12.txt contains the differential capacity of the full cell. Only recorded during CC and VS steps. The file size is mainly controlled by the step parameter 'diffcap_dV'.
- Output-Cycles.txt contains the cumulative "cycle" data.
- Output-Impedance.txt contains the impedance data calculated during PEIS and GEIS steps.
- Output-Sensordata.txt contains the sensor data. The file size is mainly controlled by the parameter record_sensor_dt.
- S1.elc is the applied test script in composer format.
- S1.lua is the applied test script in Lua format.
- Note that more or less Output.txt files may exist depending on the applied script.

9.1.1 Output.txt

The Output.txt file contains the so-called time data:

Variable	Description
Id	Sequential number
t	Time (s) since measurement start
t_cycle	Time (s) since cycle start
t_step	Time (s) since step start
over	Overflow flag
cycle	Cycle number
step	Step number
type	Step type
p/g	Potentiostatic or galvanostatic control
c/d	Data belongs to charging or discharging
con	Connection between test cell and PGStat
I-Range	Current range (100µA, 1mA, 10mA, 100mA, auto)
V12	Voltage (V) between electrodes 1 and 2
V1R	Voltage (V) between electrodes 1 and R
V2R	Voltage (V) between electrodes 2 and R
I12	Current (mA) between electrodes 1 and 2
I1R	Current (mA) between electrodes 1 and R
I2R	Current (mA) between electrodes 2 and R
Qcd	Charge (mAh), reset at start of half cycle, positive for i > 0, negative for i < 0
|Qcd|	Absolute value of Qcd (mAh)
Qc	Charge (mAh) for i > 0, reset at start of cycle, always positive
Qd	Charge (mAh) for i < 0, reset at start of cycle, always positive
Q1	Charge (mAh) on electrode 1
Q2	Charge (mAh) on electrode 2
QR	Charge (mAh) on electrode R
P	Power (mW), always positive
W12	Energy (mWh), reset at start of half cycle, always positive
Vaux	Auxiliary voltage (V)
T_cell	Cell temperature (option) (°C)
Pressure	Gas pressure inside PAT-Cell (option) (mbar)
Dilation	Dimensional change (ECD only) (µm)
Force	Force on cell stack (PAT-Cell-Force only) (N)

9.1.2 Output-Impedance.txt

Output-Impedance.txt contains all impedance data generated during PEIS and GEIS steps.

Variable	Description
Id	Sequential number
freq	Frequency
t	Time (s) since measurement start
t_cycle	Time (s) since step start
cycle	Cycle number
step	Step number
type	Step type
p/g	Potentiostatic or galvanostatic control
c/d	Data belongs to charging or discharging
con	Connection between test cell and PGStat
I-Range	Current range (100µA, 1mA, 10mA, 100mA, auto)
V12	Voltage (V) between electrodes 1 and 2
V1R	Voltage (V) between electrodes 1 and R
V2R	Voltage (V) between electrodes 2 and R
I12	Current (mA) between electrodes 1 and 2
I1R	Current (mA) between electrodes 1 and R
I2R	Current (mA) between electrodes 2 and R
Q1	Charge (mAh) on electrode 1
Q2	Charge (mAh) on electrode 2
QR	Charge (mAh) on electrode R
Qcd	Charge (mAh), reset at start of half cycle, positive for i > 0, negative for i < 0
|Qcd|	Absolute value of Qcd (mAh)
Qc	Charge (mAh) for i > 0, reset at start of cycle, always positive
Qd	Charge (mAh) for i < 0, reset at start of cycle, always positive
Re(Z12)	Real part of Z12 (Ohm)
Im(Z12)	Imaginary part of Z12 (Ohm)
|Z12|	Magnitude of Z12 (Ohm)
phi(Z12)	Phase shift of Z12 (deg)
dV12	Voltage amplitude of V12 (mV)
dI12	Current amplitude of i12 (mA)
SFDR(Z12)	Spurious free dynamic range of Z12 (dB)
Re(Z1)	Real part of Z1 (Ohm)
Im(Z1)	Imaginary part of Z1 (Ohm)
|Z1|	Magnitude of Z1 (Ohm)
phi(Z1)	Phase shift of Z1 (deg)
dV1R	Voltage amplitude of V1R (mV)
SFDR(Z1)	Spurious free dynamic range of Z1 (dB)
Re(Z2)	Real part of Z2 (Ohm)
Im(Z2)	Imaginary part of Z2 (Ohm)
|Z2|	Magnitude of Z2 (Ohm)

phi(Z2)	Phase shift of Z2 (deg)
dV2R	Voltage amplitude of V2R (mV)
SFDR(Z2)	Spurious free dynamic range of Z2 (dB)
Re(Z1R)	Real part of Z1R (Ohm)
Im(Z1R)	Imaginary part of Z1R (Ohm)
|Z1R|	Magnitude of Z1R (Ohm)
phi(Z1R)	Phase shift of Z1R (deg)
dI1R	Current amplitude of i1R (mA)
SFDR(Z1R)	Spurious free dynamic range of Z1R (dB)
Re(Z2R)	Real part of Z2R (Ohm)
Im(Z2R)	Imaginary part of Z2R (Ohm)
|Z2R|	Magnitude of Z2R (Ohm)
phi(Z2R)	Phase shift of Z2R (deg)
dI2R	Current amplitude of i2R (mA)
SFDR(Z2R)	Spurious free dynamic range of Z2R (dB)
Cs	Capacitance (µF) calculated for an R+C series equivalent circuit
Cp	Capacitance (µF) calculated for an R|C parallel equivalent circuit
pre	number of sine-cycles before the start of each EIS single-frequency measurement
avg	number of sine-cycles averaged during each EIS single-frequency-measurement

9.1.3 Output-Cycles.txt

The Output-Cycles.txt contains the so-called cumulative (cycle-by-cycle) data

Variable	Description
Id	Sequential number
t	Time (s) since measurement start
t_cycle	Time (s) since step start
cycle	Cycle number
Qc_cyc	Charge (mAh) during the charging half cycle (i > 0), always positive
Qd_cyc	Charge (mAh) during the discharging half cycle (i < 0) , always positive
Wc_cyc	Energy (mWh) during the charging half cycle (i > 0) , always positive
Wd_cyc	Energy (mWh) during the discharging half cycle (i < 0) , always positive
Eff_Q	Coulomb efficiency. Eff_Q = Qd_cyc / Qc_cyc if cycle starts with i > 0
Eff_W	Energy efficiency. Eff_W = Wd_cyc / Wc_cyc if cycle starts with i > 0

9.1.4 Output-C12.txt

The Output-C12.txt contains the differential capacity data of the full cell when a current i12 is applied. This data is calculated only during CC and VS steps.

Variable	Description
Id	Sequential number
t	Time (s) since measurement start
cycle	Cycle number
step	Step number
V12	Voltage (V) between electrodes 1 and 2
dQ12	Charge increment (mAh)
C12	Differential capacity C12 = dQ12/|dV12| (mAh/V)

9.1.5 Output-C1.txt

The Output-C1.txt contains the differential capacity data of electrode 1 when a current i12 is applied. This data is calculated only during CC and VS steps.

Variable	Description
Id	Sequential number
t	Time (s) since measurement start
cycle	Cycle number
step	Step number
V12	Voltage (V) between electrodes 1 and 2
V1R	Voltage (V) between electrodes 1 and R
dQ1	Charge increment (mAh)
C1	Differential capacity C1 = dQ1/|dV1R| (mAh/V)

9.1.6 Output-C2.txt

The Output-C2.txt contains the differential capacity data of electrode 2 when a current i12 is applied. This data is calculated only during CC and VS steps.

Variable	Description
Id	Sequential number
t	Time (s) since measurement start
cycle	Cycle number
step	Step number
V12	Voltage (V) between electrodes 1 and 2
V2R	Voltage (V) between electrodes 2 and R
dQ2	Charge increment (mAh)
C2	Differential capacity C2 = dQ2/|dV2R| (mAh/V)

9.1.7 Output-CR.txt

The Output-CR.txt contains the differential capacity data of electrode R when a current i1R or i2R is applied. This data is calculated only during CC and VS steps.

Variable	Description
Id	Sequential number
t	Time (s) since measurement start
cycle	Cycle number
step	Step number
V1R	Voltage (V) between electrodes 1 and 2
V2R	Voltage (V) between electrodes 2 and R
dQR	Charge increment (mAh)
CR	Differential capacity CR = dQR/|dVxR| (mAh/V)

9.1.8 Output-C1R.txt

The Output-C1R.txt contains the differential capacity data of electrode 1 when a current i1R is applied. This data is calculated only during CC and VS steps.

Variable	Description
Id	Sequential number
t	Time (s) since measurement start
cycle	Cycle number
step	Step number
V1R	Voltage (V) between electrodes 1 and R
dQ1R	Charge increment (mAh)
C1R	Differential capacity C1R = dQ1R/|dV1R| (mAh/V)

9.1.9 Output-C2R.txt

The Output-C2R.txt contains the differential capacity data of electrode 2 when a current i2R is applied. This data is calculated only during CC and VS steps.

Variable	Description
Id	Sequential number
t	Time (s) since measurement start
cycle	Cycle number
step	Step number
V2R	Voltage (V) between electrodes 2 and R
dQ2R	Charge increment (mAh)
C2R	Differential capacity C2R = dQ2R/|dV2R| (mAh/V)

9.1.10 Output-Sensordata.txt

The Output-Sensordata.txt contains.

Variable	Description
Id	Sequential number
t	Time (s) since measurement start
t_cycle	Time (s) since cycle start
t_step	Time (s) since step start
T_set	Temperature set point of the PAT-Tester (only i-16) (°C)
T_chamber	Temperature of the test chamber (only i-16) (°C)
T_cell	Temperature of the individual PAT-Cell (option) (°C)
T_board	Temperature of the individual channel board (°C)
T_ambient	Ambient temperature (only i-16) (°C)
Pressure	Gas pressure inside PAT-Cell (option) (mbar)
Dilation	Dimensional change (ECD only) (µm)
Force	Force on cell stack (PAT-Cell-Force only) (N)