



Getting Started with EC-Lab[®]:

Electrochemical Impedance Spectroscopy

V1

Getting Started EC-Lab: EIS

March 2024



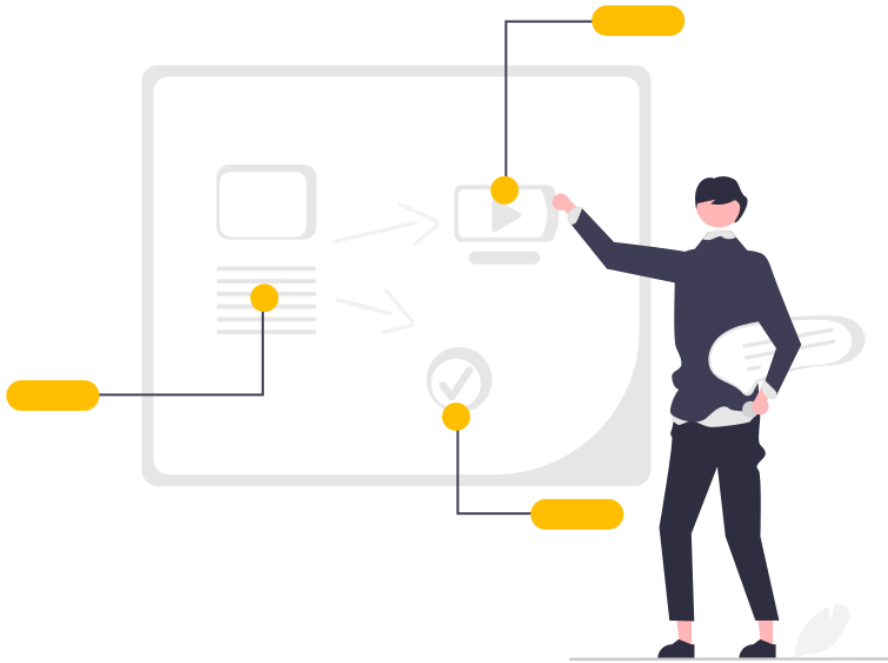
Overview and quick access

■ Procedure

- Launch the experiment
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- Investigate the result
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■ Find out more

- [For supplementary information](#)
- [Need help?](#)
- [FAQ](#)

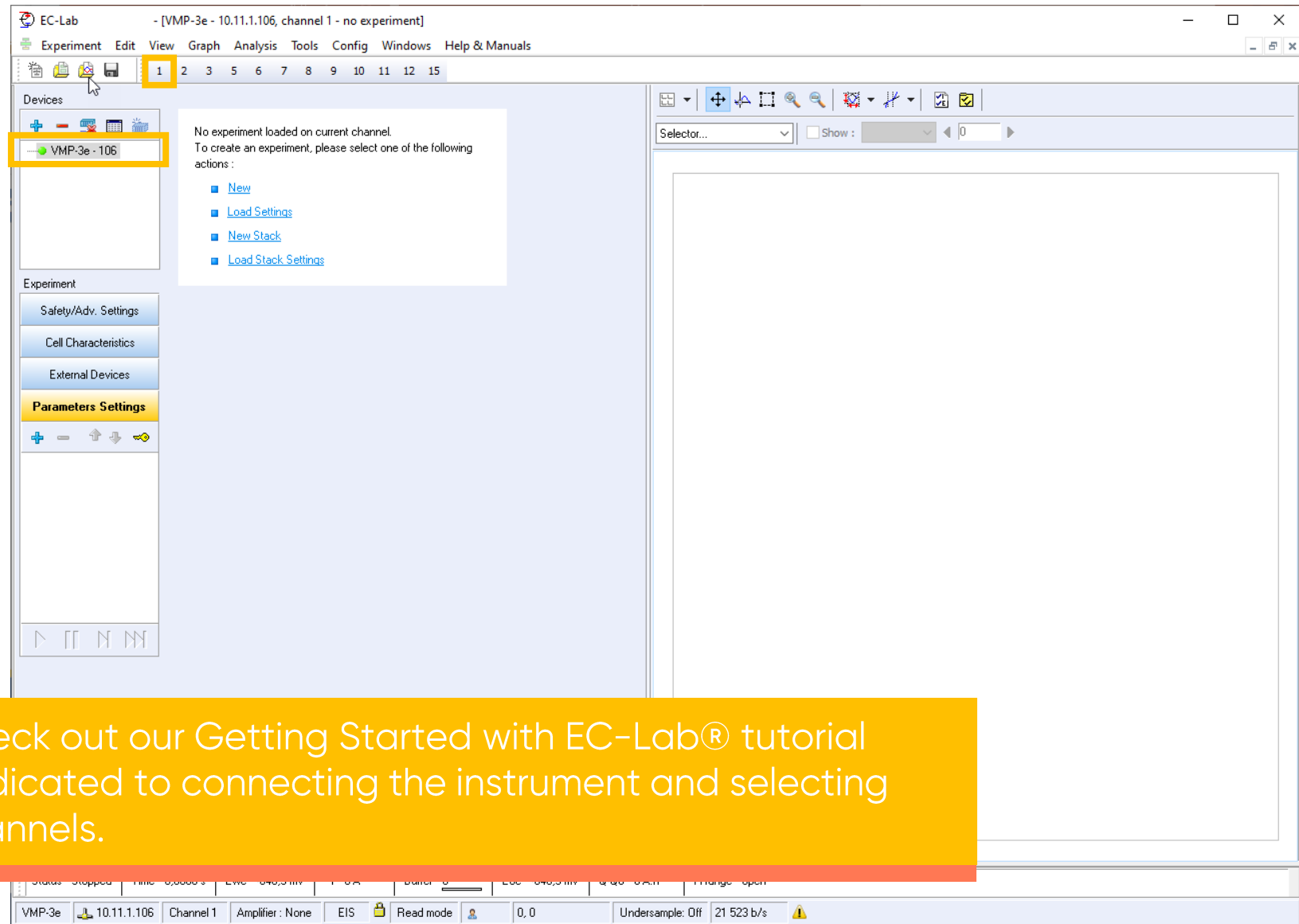


Procedure



Step 0: Connect instrument and select channel

- Connect instrument and select channel

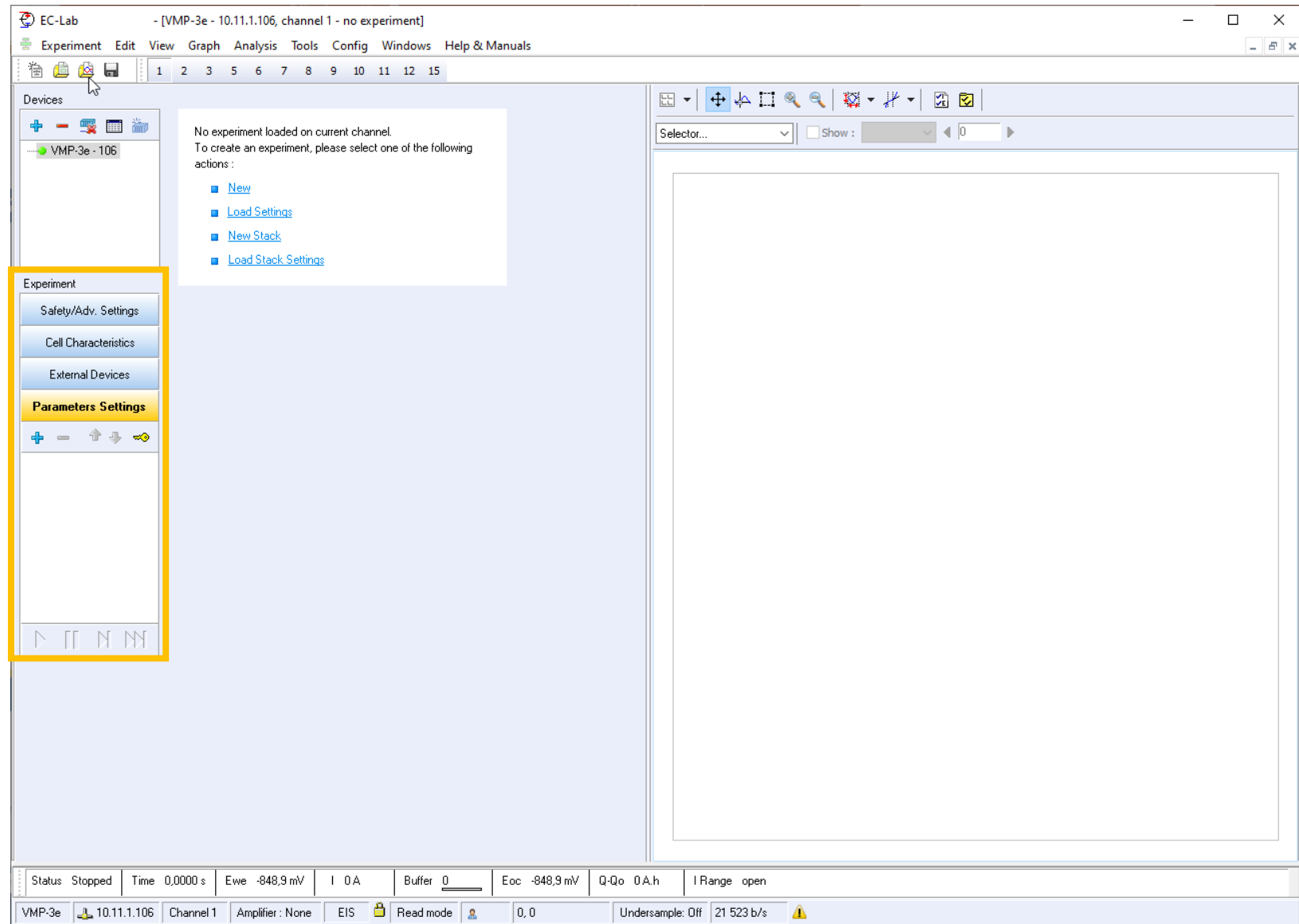


Check out our Getting Started with EC-Lab® tutorial dedicated to connecting the instrument and selecting channels.



Step 0: Connect instrument and select channel

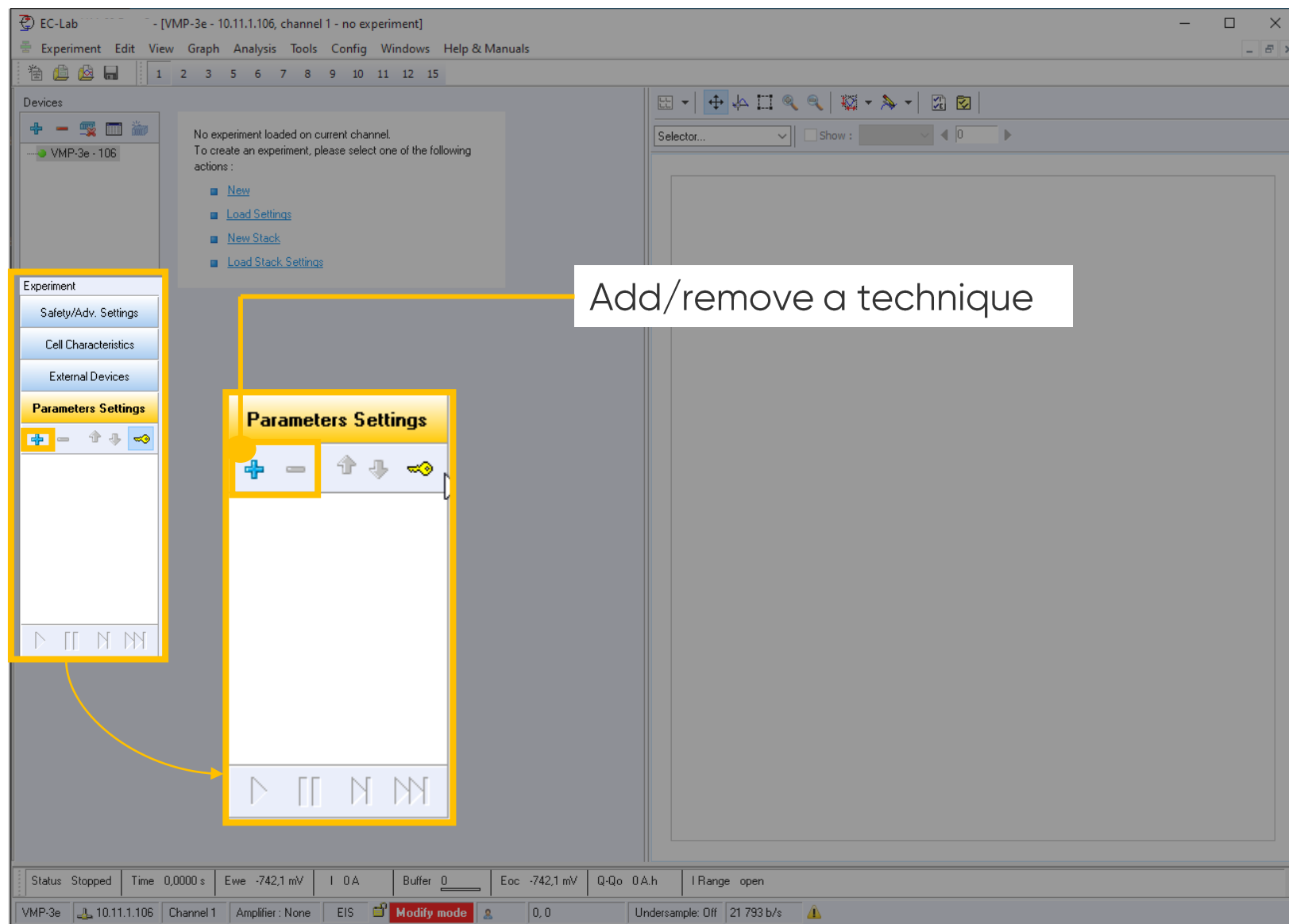
- When the instrument and channel are selected, the user can set-up the experiment





Step 1: Add EIS technique

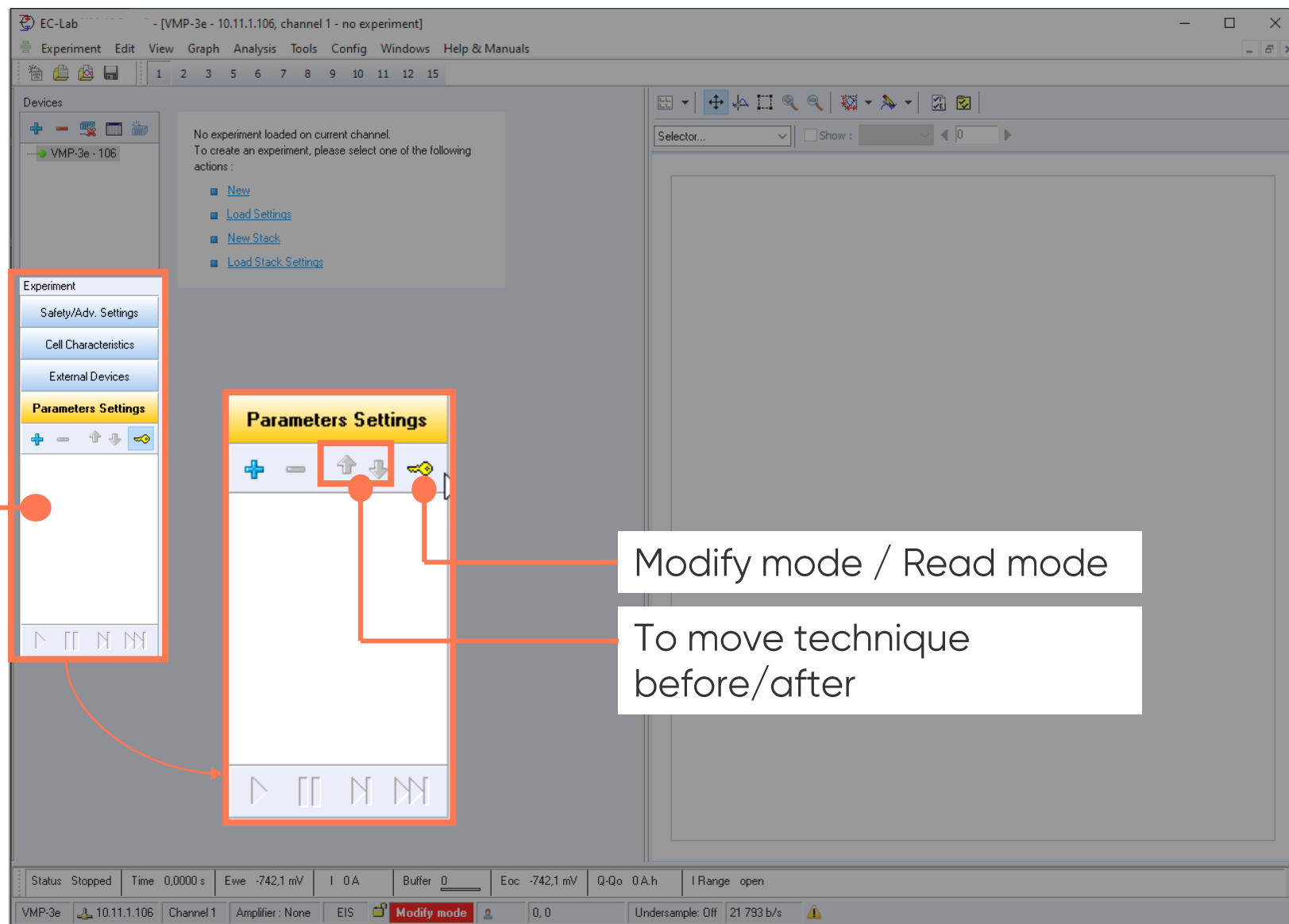
- Click on + to add a technique in the list





Step 1: Add EIS technique

Empty window:
no loaded technique



Modify mode / Read mode

To move technique
before/after



Step 1: Add EIS technique

- Select PEIS technique

It is in the Impedance Spectroscopy folder

- Click on OK to validate

EC-Lab [VSP - 10.11.1.102, channel 5 - no experiment]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

Devices: VSP - 102

No experiment loaded on current channel. To create an experiment, please select one of the following actions:

- New
- Load Settings
- New Stack
- Load Stack

Experiment: Safety/Adv. Settings, Cell Characteristics, External Devices, Parameters Settings

Insert Techniques

Search: PEIS

Recent Techniques

- Electrochemical Techniques
 - Voltamperometric Techniques
 - Impedance Spectroscopy
 - Galvano Electrochemical Impedance Spectroscopy - GEIS
 - Potentio Electrochemical Impedance Spectroscopy - PEIS
 - Staircase Galvano Electrochemical Impedance Spectroscopy - SGEIS
 - Staircase Potentio Electrochemical Impedance Spectroscopy (Mott-Schottky) - SPEIS
 - Potentio Electrochemical Impedance Spectroscopy Wait - PEISW
 - Pulsed Techniques
 - Technique Builder
 - Manual Control
 - Ohmic Drop Determination
 - Bipotentostat
- Electrochemical Applications

Graph: E_{we} vs t . The waveform is a sinusoid around a DC potential E with amplitude V_a .

PEIS experiment performs impedance measurements into potentiostatic mode in applying a sinus around a DC potential E that can be set to a fixed value or relatively to the cell equilibrium potential. For very capacitive or low impedance electrochemical systems, the potential amplitude can lead to a current overflow that can stop the experiment in order to protect the unit from overheating. Using GEIS instead of PEIS can avoid this inconvenient situation. Moreover, during corrosion experiment, a potential shift of the electrochemical system can occur. PEIS technique can lead to impedance measurements far from the corrosion potential while GEIS can be performed at a zero current.

Stack OK Cancel

Status: Stopped Time: 0.0000 s Ewe: -17.71 mV I: 0.0 A Buffer: 0 Eoc: -17.71 mV Q-Qo: 0.0 A.h I Range: open

VSP 10.11.1.102 Channel 5 Amplifier: None EIS Modify mode 0.0 Undersample: Off 21 738 b/s



Only PEIS technique is described hereafter but information given can be adapted to [GEIS](#), [SPEIS](#), [SGEIS](#), [PEISW](#) techniques.



Step 1: Add EIS technique

Search bar
to quickly find the
desired technique

Description of the settings
technique and associated
graph

EC-Lab [VSP - 10.11.1.102, channel 5 - no experiment]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

Devices: VSP - 102

No experiment loaded on current channel. To create an experiment, please select one of the following actions:

- New
- Load Settings
- New Stack
- Load Stack

Experiment: Safety/Adv. Settings, Cell Characteristics, External Devices, Parameters Settings

Insert Techniques

Search: PEIS

Recent Techniques

- Electrochemical Techniques
 - Voltamperometric Techniques
 - Impedance Spectroscopy
 - Galvano Electrochemical Impedance Spectroscopy - GEIS
 - Potentio Electrochemical Impedance Spectroscopy - PEIS
 - Staircase Galvano Electrochemical Impedance Spectroscopy - SGEIS
 - Staircase Potentio Electrochemical Impedance Spectroscopy (Mott-Schottky) - SPEIS
 - Potentio Electrochemical Impedance Spectroscopy Wait - PEISW
 - Pulsed Techniques
 - Technique Builder
 - Manual Control
 - Ohmic Drop Determination
 - Bipotentiostat
- Electrochemical Applications

Graph: A plot of potential E_{we} versus time t showing a sinusoidal waveform with amplitude V_a and average potential E .

PEIS experiment performs impedance measurements into potentiostatic mode in applying a sinus around a DC potential E that can be set to a fixed value or relatively to the cell equilibrium potential.

For very capacitive or low impedance electrochemical systems, the potential amplitude can lead to a current overflow that can stop the experiment in order to protect the unit from overheating. Using GEIS instead of PEIS can avoid this inconvenient situation.

Moreover, during corrosion experiment, a potential shift of the electrochemical system can occur. PEIS technique can lead to impedance measurements far from the corrosion potential while GEIS can be performed at a zero current.

Insert Technique: Before (radio button), After (radio button)

Load from default: ☒ Safety/Adv. Settings, ☒ External devices, ☒ Cell characteristics

Custom Applications: Rename, Add, Remove, Stack, OK, Cancel

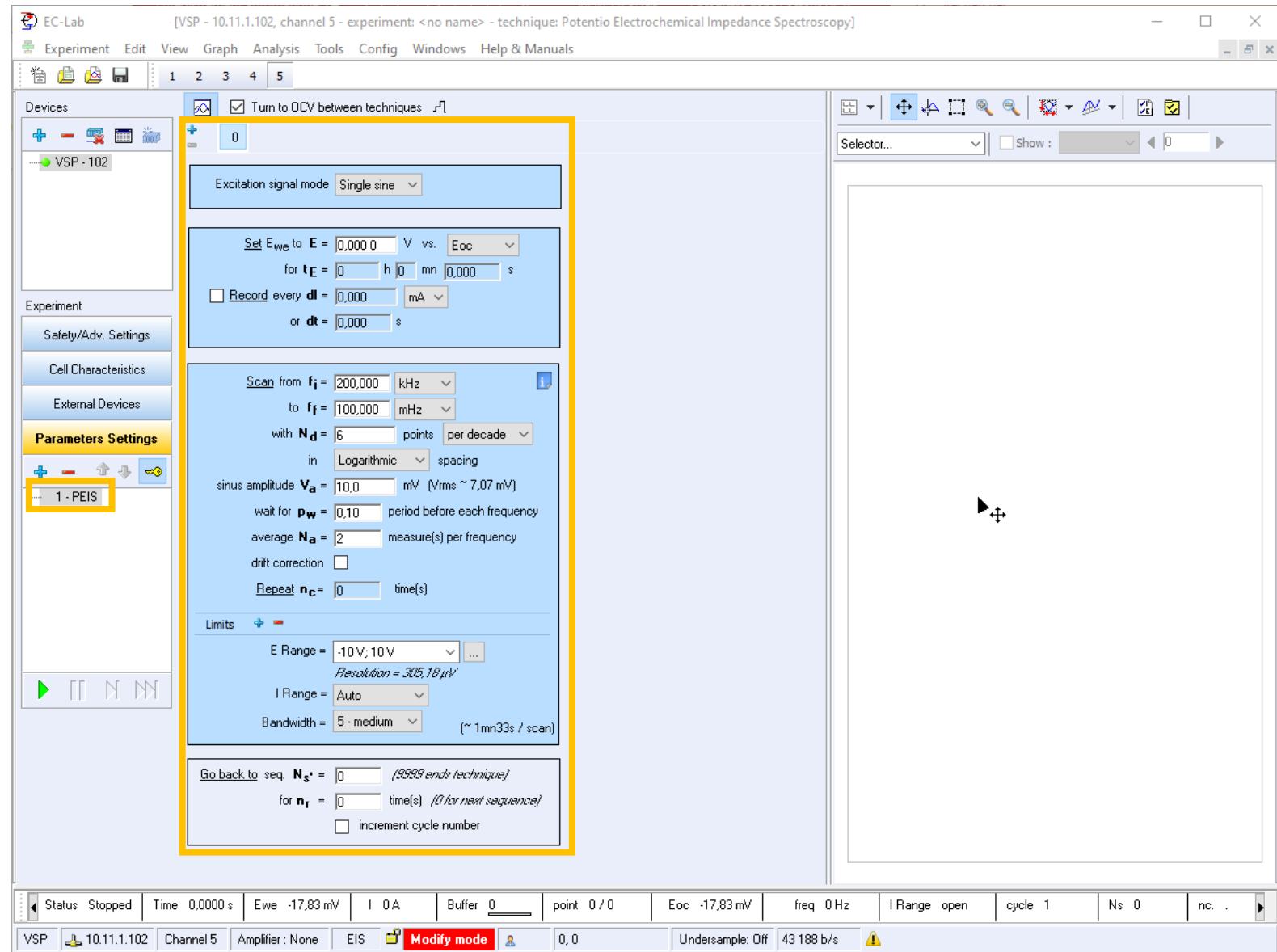
Status: Stopped, Time: 0,0000 s, Ewe: -17,71 mV, I: 0 A, Buffer: 0, Eoc: -17,71 mV, Q-Qo: 0 A.h, I Range: open

VSP 10.11.1.102 Channel 5 Amplifier: None EIS Modify mode 0,0 Undersample: Off 21 738 b/s



Step 1: Add EIS technique

- PEIS technique is loaded in the technique list
- Corresponding PEIS parameters settings appear






Step 1: Add EIS technique

General parameters

Technique parameters

You can display the description of the settings by clicking on the  icon.

EC-Lab [VSP - 10.11.1.102, channel 5 - experiment: <no name> - technique: Potentio Electrochemical Impedance Spectroscopy]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

1 2 3 4 5

Devices

VSP-102

Experiment


Safety/Adv. Settings

Cell Characteristics

External Devices

Parameters Settings

1-PEIS

Turn to OCV between techniques 

Excitation signal mode Single sine

Set E_{we} to $E = 0,000\ 0$ V vs. E_{oc}

for $t_E = 0$ h 0 mn $0,000$ s

☐ Record every $dI = 0,000$ mA

or $dt = 0,000$ s

Scan from $f_i = 200,000$ kHz

to $f_f = 100,000$ mHz

with $N_d = 6$ points per decade

in Logarithmic spacing

sinus amplitude $V_a = 10,0$ mV ($V_{rms} \sim 7,07$ mV)

wait for $p_w = 0,10$ period before each frequency

average $N_a = 2$ measure(s) per frequency

drift correction ☐

Repeat $n_c = 0$ time(s)

Limits

E Range = $-10\text{ V}; 10\text{ V}$

Resolution = $305,18\ \mu\text{V}$

I Range = Auto

E_{we}

E

V_a

t

Status Stopped Time 0,0000 s Ewe -17,75 mV I 0 A Buffer 0 point 0 / 0 Eoc -17,75 mV freq 0 Hz I Range open cycle 1 Ns 0 nc .

VSP 10.11.1.102 Channel 5 Amplifier : None EIS Modify mode 0, 0 Undersample: Off 21 523 b/s



Step 2: Set EIS parameters

- Select Single sine

Note: [Multisine](#) can be performed (it is the sum of sinus)

The screenshot displays the EC-Lab software interface for Potentiostatic Electrochemical Impedance Spectroscopy (PEIS). The window title is "[VSP - 10.11.1.102, channel 5 - experiment: <no name> - technique: Potentiostatic Electrochemical Impedance Spectroscopy]". The interface includes a menu bar (Experiment, Edit, View, Graph, Analysis, Tools, Config, Windows, Help & Manuals) and a toolbar. The left sidebar shows the "Parameters Settings" tab selected. The main panel is divided into several sections:

- Excitation signal mode:** A dropdown menu set to "Single sine".
- Set E_{we} to E :** A field set to "0,000 0 V vs. E_{oc} ".
- for t_E :** Fields for "0 h 0 mn 0,000 s".
- Record every dI :** A field set to "0,000 mA".
- or dt :** A field set to "0,000 s".
- Scan from f_i :** A field set to "200,000 kHz".
- to f_f :** A field set to "100,000 mHz".
- with N_d :** A field set to "6 points per decade".
- in:** A dropdown menu set to "Logarithmic".
- spacing:** A dropdown menu set to "Logarithmic".
- sinus amplitude V_a :** A field set to "10,0 mV ($V_{rms} \sim 7,07$ mV)".
- wait for p_w :** A field set to "0,10 period before each frequency".
- average N_a :** A field set to "2 measure(s) per frequency".
- drift correction:** A checkbox that is unchecked.
- Repeat n_c :** A field set to "0 time(s)".
- Limits:** A section with a plus icon and a minus icon.
- E Range:** A dropdown menu set to "-10 V; 10 V".
- Resolution:** A field set to "305,18 μV ".
- I Range:** A dropdown menu set to "Auto".
- Bandwidth:** A dropdown menu set to "5 - medium".
- Go back to seq. N_s :** A field set to "0 (/9999 ends technique)".
- for n_f :** A field set to "0 time(s) (/0 for next sequence)".
- increment cycle number:** A checkbox that is unchecked.

A graph on the right shows a sine wave with amplitude V_a and frequency f . The y-axis is labeled E and the x-axis is labeled t . An arrow points from the "Excitation signal mode" dropdown to the graph.

The status bar at the bottom shows: Status Stopped, Time 0,0000 s, E_{we} -17,75 mV, I 0 A, Buffer 0, point 0 / 0, E_{oc} -17,75 mV, freq 0 Hz, I Range open, cycle 1, N_s 0, n_c .



Step 2: Set EIS parameters

- Set E_{we} to E to define the bias voltage level
- E can be held during a time t_E before starting

EC-Lab [VSP - 10.11.1.102, channel 5 - experiment: <no name> - technique: Potentio Electrochemical Impedance Spectroscopy]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

1 2 3 4 5

Devices

- VSP - 102

Experiment

- Safety/Adv. Settings
- Cell Characteristics
- External Devices
- Parameters Settings

1 - PEIS

Turn on OCV between techniques

Excitation signal mode: Single sine

Set E_{we} to $E = 0,000\ 0$ V vs. E_{oc}

for $t_E = 0$ h 0 mn $0,000$ s

☐ Record every $dI = 0,000$ mA

or $dt = 0,000$ s

Scan from $f_i = 200,000$ kHz to $f_f = 100,000$ mHz

with $N_d = 6$ points per decade in Logarithmic spacing

sinus amplitude $V_a = 10,0$ mV ($V_{rms} \sim 7,07$ mV)

wait for $p_w = 0,10$ period before each frequency

average $N_a = 2$ measure(s) per frequency

drift correction ☐

Repeat $n_c = 0$ time(s)

Limits

E Range = -10 V; 10 V Resolution = $305,18\ \mu V$

I Range = Auto

Bandwidth = 5 - medium (~ 1mn33s / scan)

Go back to seq. $N_s = 0$ (9999 ends technique)

for $n_f = 0$ time(s) (0 for next sequence)

☐ increment cycle number

Graph: E_{we} vs t

Set E_{we} to $E = 0,000\ 0$ V vs. E_{oc}

for $t_E = 0$ h 0 mn $0,000$ s

☐ Record every $dI = 0,000$ mA

or $dt = 0,000$ s

Status Stopped Time 0,0000 s Ewe -17,75 mV I 0 A Buffer 0 point 0 / 0 Eoc -17,75 mV freq 0 Hz I Range open cycle 1 Ns 0 nc .

VSP 10.11.1.102 Channel 5 Amplifier : None EIS Modify mode 0, 0 Undersample: Off 21 523 b/s



Step 2: Set EIS parameters

Define E versus voltage of:

- **Ref**: the reference electrode
- **Eoc**: open circuit voltage
- **Ectrl**: the previous controlled voltage, if a technique is set before the PEIS
- **Emeas**: the previous measured voltage, if a technique is set before the PEIS

The screenshot shows the EIS software interface with the following settings:

- ☒ Turn to OCV between techniques
- Excitation signal mode: Single sine
- Set E_{we} to $E = 0,000\ 0$ V vs. **Eoc**
- for $t_E = 0$ h 0 mn $0,000$ s
- ☐ Record every $dI = 0,000$ mA or $dt = 0,000$ s
- Scan from $f_i = 200,000$ kHz to $f_f = 100,000$ mHz
- with $N_d = 6$ points per decade in Logarithmic spacing
- sinus amplitude $V_a = 10,0$ mV ($V_{rms} \sim 7,07$ mV)
- wait for $p_w = 0,10$ period before each frequency
- average $N_a = 2$ measure(s) per frequency

A graph on the right shows E_{we} versus time t with a sinusoidal wave. A red arrow points from the 'Eoc' selection in the 'vs.' dropdown to the graph. The dropdown menu is open, showing the following options: **Ref**, Eoc, Ectrl, and Emeas.



Be aware that Eoc is a relative voltage value as OCV may change. E_{Ref} is an absolute voltage value.



Step 2: Set EIS parameters

- Set f_i and f_f to define the frequencies range
- Set V_a to define amplitude of perturbation

The screenshot displays the EC-Lab software interface for Potentiostatic Electrochemical Impedance Spectroscopy (PEIS). The main window is titled "[VSP - 10.11.1.102, channel 5 - experiment: <no name> - technique: Potentiostatic Electrochemical Impedance Spectroscopy]". The interface includes a menu bar (Experiment, Edit, View, Graph, Analysis, Tools, Config, Windows, Help & Manuals) and a toolbar with various icons. On the left, a sidebar shows the "Devices" list with "VSP - 102" selected, and the "Experiment" section with "Parameters Settings" highlighted. The main panel is divided into several sections: "Excitation signal mode" set to "Single sine", "Set E_{we} to $E = 0,000\ 0$ V vs. E_{oc} ", "Record every $dt = 0,000$ mA" or $dt = 0,000$ s, "Scan from $f_i = 200,000$ kHz to $f_f = 100,000$ mHz with $N_d = 6$ points per decade in Logarithmic spacing", "sinus amplitude $V_a = 10,0$ mV ($V_{rms} \sim 7,07$ mV)", "wait for $p_w = 0,10$ period before each frequency", "average $N_a = 2$ measure(s) per frequency", "drift correction" checkbox, "Repeat $n_c = 0$ time(s)", "Limits" section with "E Range = -10 V; 10 V", "Resolution = 305,18 μV ", "I Range = Auto", "Bandwidth = 5 - medium (~ 1mn33s / scan)", and "Go back to seq. $N_s = 0$ (9999 ends technique)" for $n_f = 0$ time(s) (0 for next sequence) with an "increment cycle number" checkbox. A graph on the right shows a sinusoidal waveform E_{we} with amplitude V_a . A yellow box highlights the "Scan from $f_i = 200,000$ kHz to $f_f = 100,000$ mHz with $N_d = 6$ points per decade in Logarithmic spacing sinus amplitude $V_a = 10,0$ mV ($V_{rms} \sim 7,07$ mV)" section. The status bar at the bottom shows "Status Stopped", "Time 0,0000 s", "Ewe -17,75 mV", "I 0 A", "Buffer 0", "point 0 / 0", "Eoc -17,75 mV", "freq 0 Hz", "I Range open", "cycle 1", "Ns 0", "nc .", and "VSP 10.11.1.102 Channel 5 Amplifier : None EIS Modify mode 0, 0 Undersample: Off 21 523 b/s".



Step 2: Set EIS parameters

- Define data point sampling
 - Points per decade N_d
 - in log or linear spacing

EC-Lab [VSP - 10.11.1.102, channel 5 - experiment: <no name> - technique: Potentio Electrochemical Impedance Spectroscopy]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

1 2 3 4 5

Devices

- VSP - 102

Experiment

- Safety/Adv. Settings
- Cell Characteristics
- External Devices
- Parameters Settings**

1 - PEIS

Turn to OCV between techniques ☒

Excitation signal mode: Single sine

Set E_{we} to $E = 0,000\ 0$ V vs. E_{oc}

for $t_E = 0$ h 0 mn $0,000$ s

☐ Record every $dI = 0,000$ mA

or $dt = 0,000$ s

Scan from $f_i = 200,000$ kHz to $f_f = 100,000$ mHz

with $N_d = 6$ points per decade

in Logarithmic spacing

sinus amplitude $V_a = 10,0$ mV ($V_{rms} \sim 7,07$ mV)

wait for $p_w = 0,10$ period before each frequency

average $N_a = 2$ measure(s) per frequency

drift correction ☐

Repeat $n_c = 0$ time(s)

Limits

E Range = $-10\text{ V}; 10\text{ V}$

Resolution = $305,18\ \mu\text{V}$

I Range = Auto

Bandwidth = 5 - medium (~ 1mn33s / scan)

Go back to seq. $N_s = 0$ (9999 ends technique)

for $n_f = 0$ time(s) (0 for next sequence)

☐ increment cycle number

Graph: E_{we} vs. t showing a sine wave with amplitude V_a .

Status: Stopped Time: 0,0000 s $E_{we} -17,75\text{ mV}$ $I 0\text{ A}$ Buffer: 0 point: 0 / 0 $E_{oc} -17,75\text{ mV}$ freq: 0 Hz I Range: open cycle: 1 $N_s 0$ nc: .

VSP 10.11.1.102 Channel 5 Amplifier: None EIS Modify mode 0, 0 Undersample: Off 21 523 b/s



Step 2: Set EIS parameters

Frequencies list at which
the EIS are performed

The corresponding RMS
value is indicated

The screenshot shows the EC-Lab software interface for Potentiostatic Electrochemical Impedance Spectroscopy (EIS). The main window displays various settings for the experiment, including the excitation signal mode (Single sine), the set potential E_{we} (0.0000 V vs. E_{oc}), and the scan range (from $f_i = 200,000$ kHz to $f_f = 100,000$ mHz). The sinus amplitude V_a is set to 10.0 mV, with a note indicating $V_{rms} \sim 7.07$ mV. The dialog box titled "Frequencies list" is open, showing a list of 39 frequencies in Hz, ranging from 200,000,921.875 to 1,397,734.009. The number of frequencies is 39, and the VSP calculation is indicated. The status bar at the bottom shows the current status as "Stopped", time as 0.0000 s, and various other parameters.

EC-Lab [VSP - 10.11.1.102, channel 5 - experiment: <no name> - technique: Potentiostatic Electrochemical Impedance Spectroscopy]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

Devices: VSP - 102

Experiment: Safety/Adv. Settings, Cell Characteristics, External Devices, Parameters Settings, 1 - PEIS

Excitation signal mode: Single sine

Set E_{we} to $E = 0.0000$ V vs. E_{oc}

for $t_E = 0$ h 0 mn 0.000 s

☐ Record every $dI = 0.000$ mA or $dt = 0.000$ s

Scan from $f_i = 200,000$ kHz to $f_f = 100,000$ mHz

with $N_d = 6$ points per decade in Logarithmic spacing

sinus amplitude $V_a = 10.0$ mV ($V_{rms} \sim 7.07$ mV)

wait for $p_w = 0.10$ period before each frequency

average $N_a = 2$ measure(s) per frequency

drift correction ☐

Repeat $n_c = 0$ time(s)

Limits: E Range = -10 V; 10 V Resolution = 305.18 μ V I Range = Auto Bandwidth = 5 - medium (~ 1mn33s / scan)

Go back to seq. $N_s = 0$ (9999 ends technique) for $n_f = 0$ time(s) (0 for next sequence) ☐ increment cycle number

Frequencies list

Frequencies (Hz)

200 000,921 875
136 515,109 375
93 185,351 563
63 606,156 250
43 417,691 406
29 634,736 328
20 230,115 234
13 806,090 820
9 423,130 859
6 433,278 809
4 392,217 285
2 999,111 328
2 045,690 063
1 397,734 009

Number of frequencies: 39

VSP calculation

Close

Status: Stopped Time: 0.0000 s E_{we} : -17.75 mV I: 0.0 A Buffer: 0 point: 0 / 0 E_{oc} : -17.75 mV freq: 0 Hz I Range: open cycle: 1 N_s : 0 n_c : .

VSP 10.11.1.102 Channel 5 Amplifier: None EIS Modify mode 0.0 Undersample: Off 21 523 b/s



Step 2: Set EIS parameters

- Set n_c to repeat the sweep of frequencies

The screenshot shows the EC-Lab software interface for Potentiostatic Electrochemical Impedance Spectroscopy (PEIS). The window title is "[VSP - 10.11.1.102, channel 5 - experiment: <no name> - technique: Potentiostatic Electrochemical Impedance Spectroscopy]". The left sidebar shows the "Parameters Settings" tab selected. The main panel displays various configuration options:

- Excitation signal mode:** Single sine
- Set E_{we} to E :** 0,000 0 V vs. E_{oc}
- for t_E :** 0 h 0 mn 0,000 s
- Record every dI :** 0,000 mA or dt : 0,000 s
- Scan from f_i :** 200,000 kHz to f_f : 100,000 mHz
- with N_d :** 6 points per decade in Logarithmic spacing
- sinus amplitude V_a :** 10,0 mV ($V_{rms} \sim 7,07$ mV)
- wait for p_w :** 0,10 period before each frequency
- average N_a :** 2 measure(s) per frequency
- drift correction:** ☐
- Repeat n_c :** 0 time(s) (highlighted with a yellow box)
- Limits:** E Range = -10 V; 10 V, Resolution = 305,18 μV , I Range = Auto, Bandwidth = 5 - medium (~ 1mn33s / scan)
- Go back to seq. N_s :** 0 (9999 ends technique)
- for n_f :** 0 time(s) (0 for next sequence)
- increment cycle number:** ☐

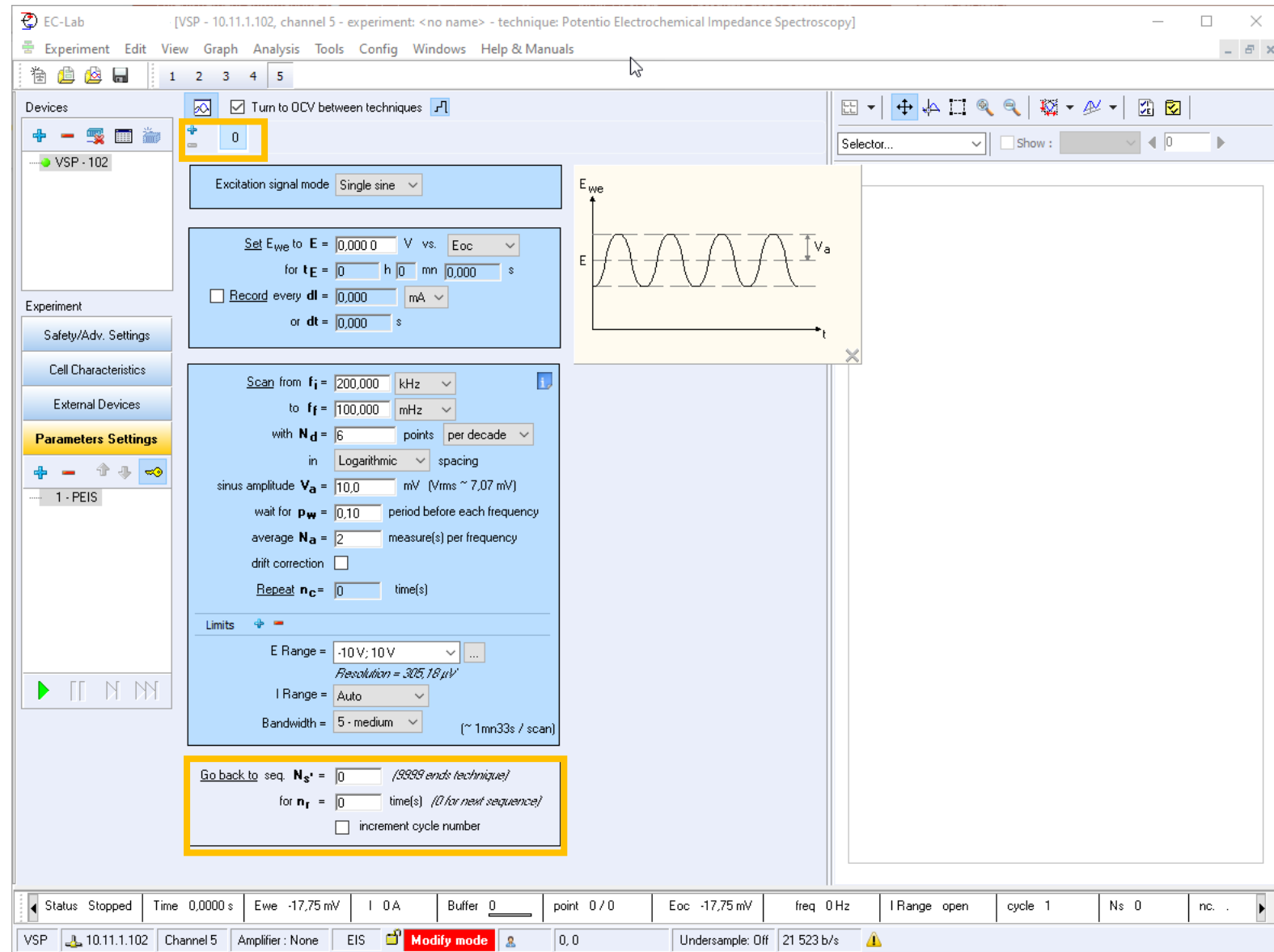
A small inset graph shows a sinusoidal waveform with amplitude V_a and equilibrium potential E on the y-axis and time t on the x-axis.

The status bar at the bottom shows: Status Stopped, Time 0,0000 s, E_{we} -17,75 mV, I 0 A, Buffer 0, point 0 / 0, E_{oc} -17,75 mV, freq 0 Hz, I Range open, cycle 1, N_s 0, n_c .



Step 2: Set EIS parameters

- Sequences can be added
- Go back to a desired cycle or sequence





Step 3: Optimize the measurement

- A delay p_w can be added before the measurement for each frequency

wait for $p_w = 0.10$ period before each frequency
average $N_a = 2$ measure(s) per frequency
drift correction ☐

It is important to activate when there is a big gap between two frequencies. Delay is longer for low frequencies.



Step 3: Optimize the measurement

- Set N_a to repeat measurements at each frequency and average the values

wait for $p_w = 0.10$ period before each frequency
average $N_a = 2$ measure(s) per frequency
drift correction ☐

Status Stopped Time 0.0000 s Ewe -17.75 mV I 0.0 A Buffer 0 point 0 / 0 Eoc -17.75 mV freq 0 Hz I Range open cycle 1 Ns 0 nc .

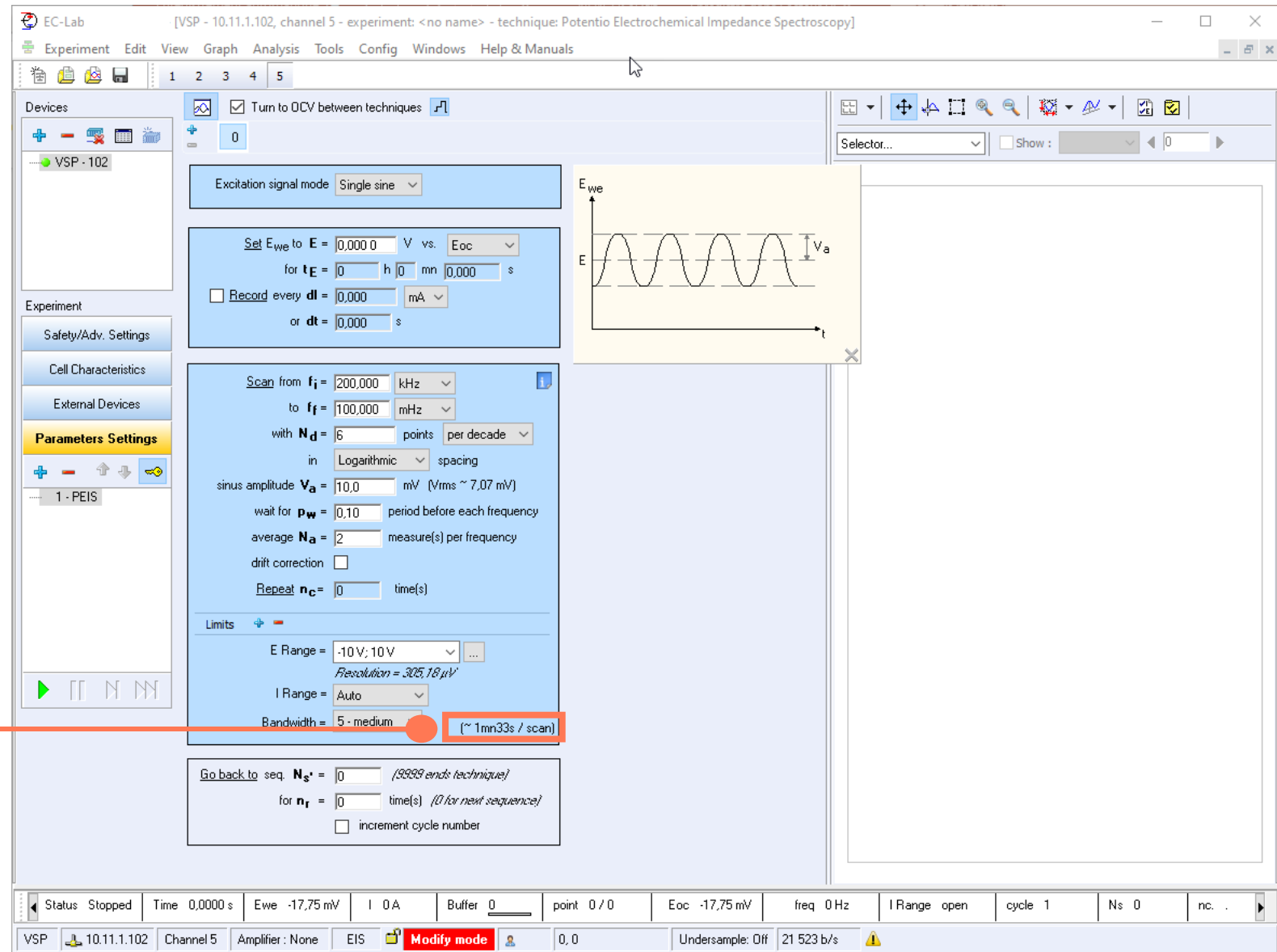
VSP 10.11.1.102 Channel 5 Amplifier : None EIS Modify mode 0.0 Undersample: Off 21 523 b/s



This average process smooths the random error of the measurement, but the experiment lasts longer.



Step 3: Optimize the measurement



The duration of the experiment is indicated. It depends on frequency range, sampling and averaging N_a



Step 3: Optimize the measurement

- Drift correction corrects non stationarity

⚙️ This has to be activated for measurements on slow systems which has not reached steady state conditions

EC-Lab [VSP - 10.11.1.102, channel 5 - experiment: <no name> - technique: Potentio Electrochemical Impedance Spectroscopy]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

Devices: VSP - 102

Experiment: Safety/Adv. Settings, Cell Characteristics, External Devices, Parameters Settings, 1 - PEIS

Excitation signal mode: Single sine

Set E_{we} to $E = 0,000\ 0$ V vs. E_{oc}

for $t_E = 0$ h 0 mn $0,000$ s

☐ Record every $dI = 0,000$ mA or $dt = 0,000$ s

Scan from $f_i = 200,000$ kHz to $f_f = 100,000$ mHz

with $N_d = 6$ points per decade in Logarithmic spacing

sinus amplitude $V_a = 10,0$ mV ($V_{rms} \sim 7,07$ mV)

wait for $p_w = 0,10$ period before each frequency

average $N_a = 2$ measure(s) per frequency

drift correction ☐

Repeat $n_c = 0$ time(s)

Limits: E Range = -10 V; 10 V Resolution = $305,18\ \mu V$

I Range = Auto Bandwidth = 5 - medium ($\sim 1mn33s$ / scan)

Go back to seq. $N_s = 0$ (9999 ends technique)

for $n_f = 0$ time(s) (0 for next sequence)

☐ increment cycle number

Status Stopped Time 0,0000 s Ewe -17,75 mV I 0 A Buffer 0 point 0 / 0 Eoc -17,75 mV freq 0 Hz I Range open cycle 1 Ns 0 nc .

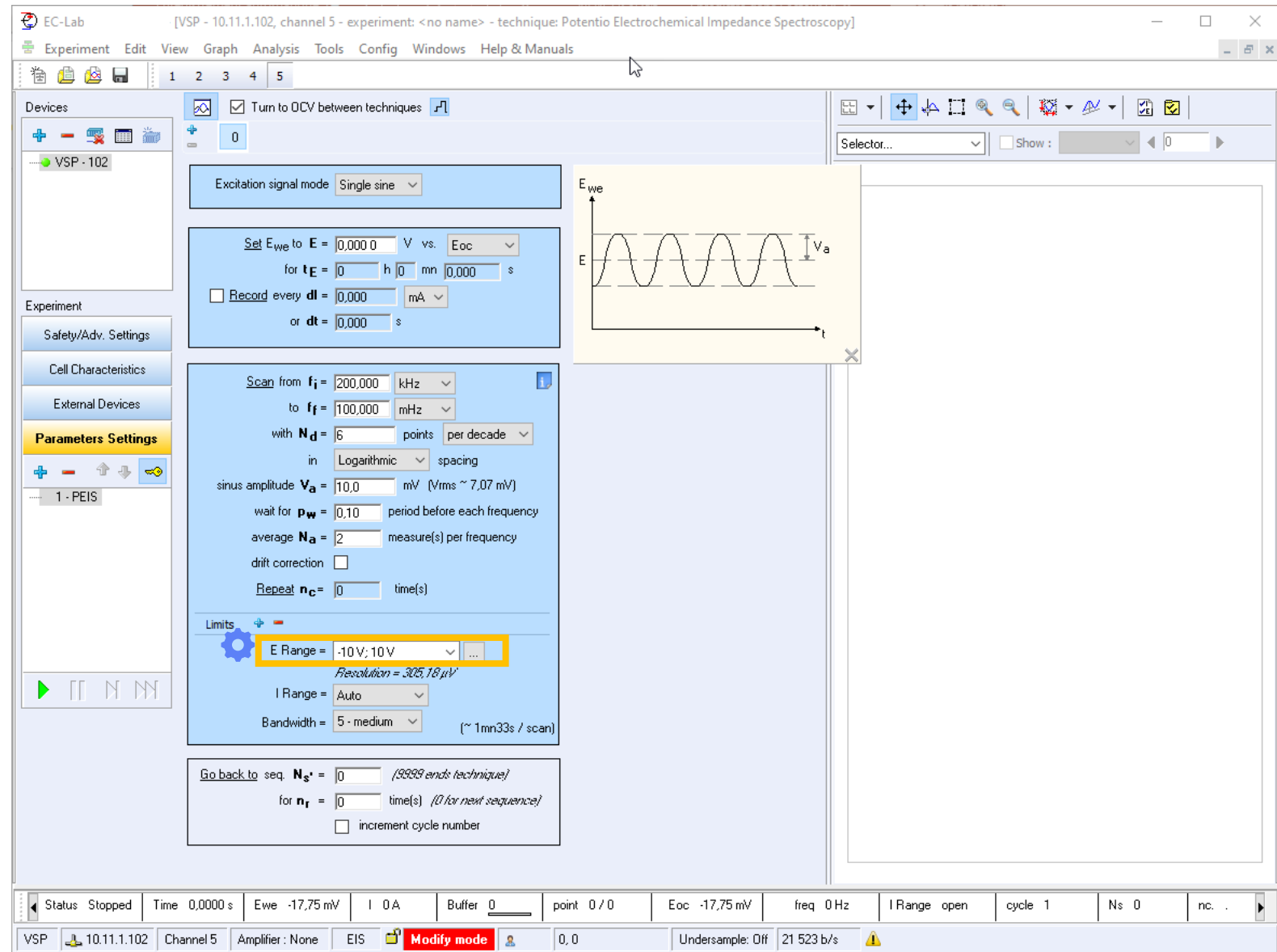
VSP 10.11.1.102 Channel 5 Amplifier : None EIS Modify mode 0, 0 Undersample: Off 21 523 b/s



Step 3: Optimize the measurement

- E Range is the range of expected voltage

⚙️ E Range has to be wide enough to be in the range of the operating voltage but narrow enough to get an optimized resolution in voltage measurement / control

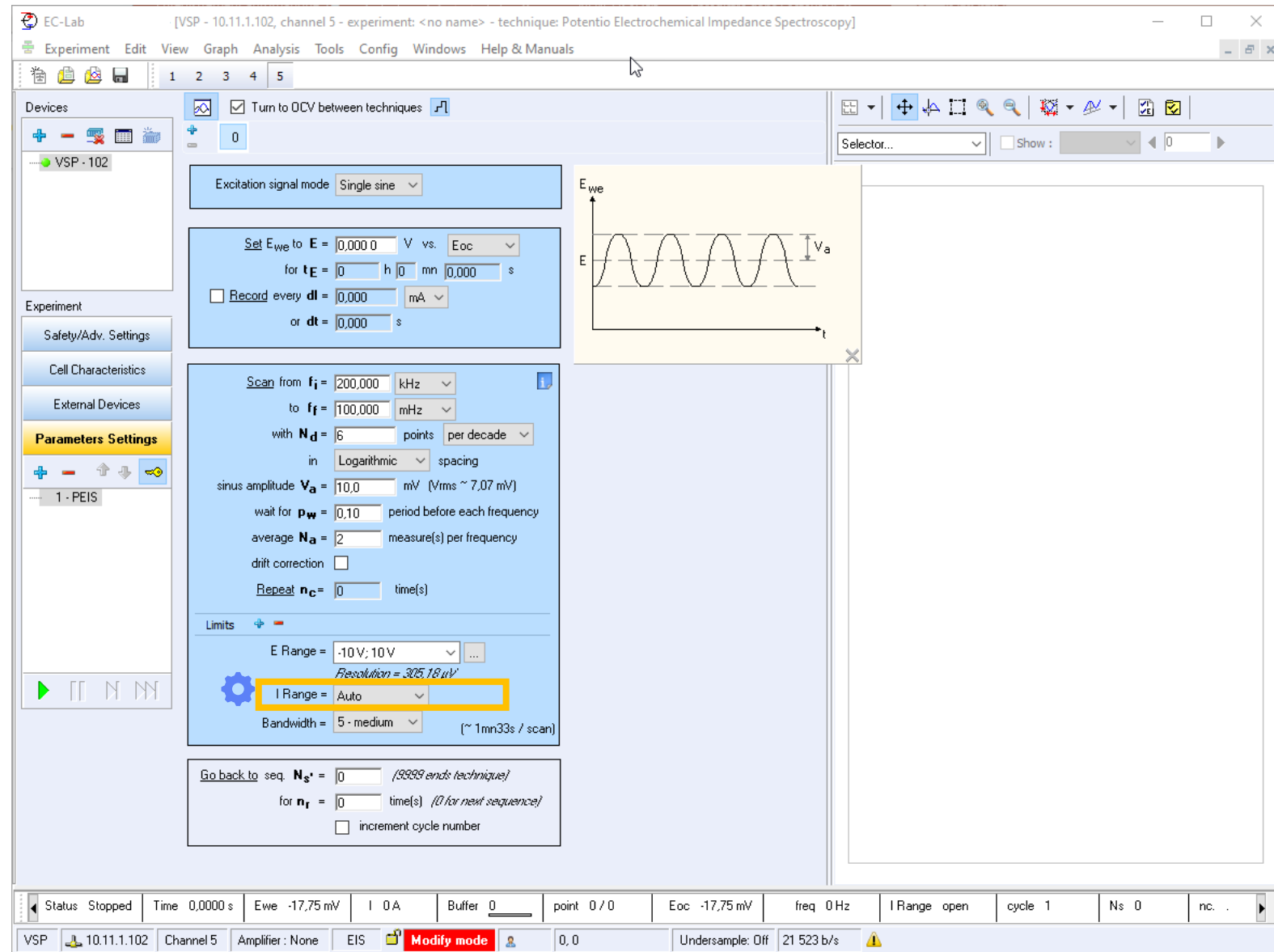




Step 3: Optimize the measurement

- I Range is the range of expected current
- Autorange is available

⚙️ Select autorange as the level of current at low and high frequency may be very different



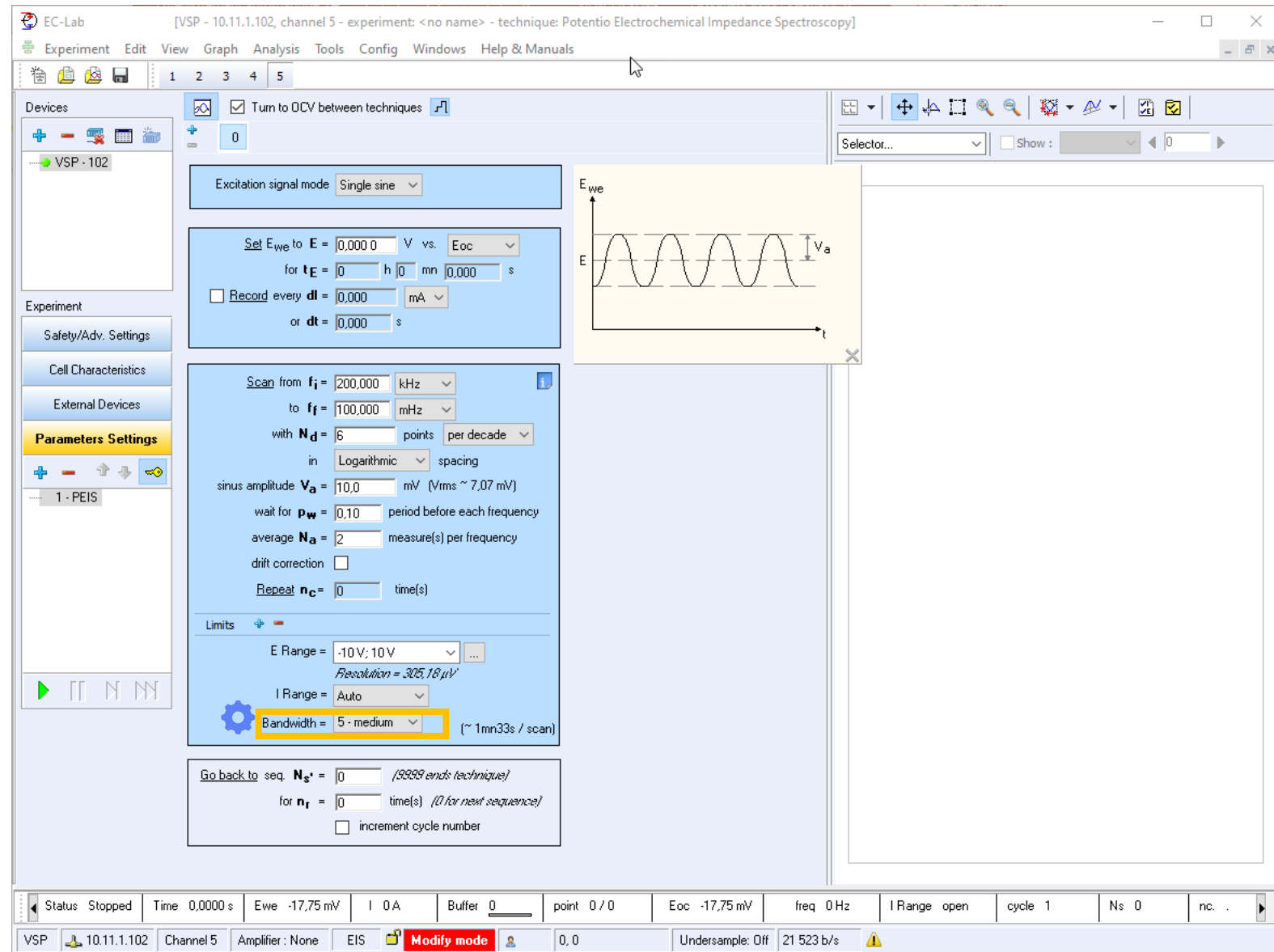


Step 3: Optimize the measurement

- Adjust bandwidth to make sure potentiostat control the cell in stable and fast way

⚙ For EIS measurements at high frequencies, the regulation loop has to be fast, so a fast bandwidth is required

- 7-fast for Essential
- 9-fast for Premium





Step 4: Set general parameters

- Add information and comments about the cell

EC-Lab - [VMP-3e - 10.11.1.106, channel 1 - experiment: <no name> - technique: Cyclic Voltammetry]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Devices

- VMP-3e - 106

Experiment

- Safety/Adv. Settings
- Cell Characteristics**
- External Devices
- Parameters Settings

1 - PEIS

Cell Description

Electrode material

Initial state

Electrolyte

Comments

Electrode surface area (A) 0,001 cm²

Characteristic mass 0,001 g

Volume (V) 0,001 cm³

Battery Corrosion Materials

Mass of active material 0,001 mg at x = 0,000

Molecular weight of active material (at x = 0): 0,001 g

Atomic weight of intercalated ion: 0,001 g

Acquisition started at: x0 = 0,000

Number of e- transferred per intercalated ions: 1

for Δx = 1, theoretical capacity ΔQ = 26,802 mA.h

Battery capacity C = 0,000 A.h

Reference Electrode

SCE Saturated Calomel Electrode

Offset potential vs. Normal Hydrogen Electrode: 0.241 V

Status Stopped Time 0,0000 s Ewe -717,6 mV I 0 A Buffer 0 Eoc -717,6 mV Q-Qo 0 A.h P 0 W nc 0 IRange open cycle 1

VMP-3e 10.11.1.106 Channel 1 Amplifier: None EIS Read mode 0,0 Undersample: Off 21 540 b/s

Note: All this information is store in the data file



Step 4: Set general parameters

Electrode surface area has to be set if the user wants to work with volumic/surfacic resistance (Ω/cm^3 or cm^2) instead of resistance (Ω)

EC-Lab - [VMP-3e - 10.11.1.106, channel 1 - experiment: <no name> - technique: Cyclic Voltammetry]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

1 2 3 5 6 7 8 9 10 11 12 15

Cell Description

Electrode material
Initial state
Electrolyte
Comments

Electrode surface area (A) 0,001 cm²

Characteristic mass 0,001 g
Volume (V) 0,001 cm³

Battery Corrosion Materials

Mass of active material 0,001 mg at x = 0,000
Molecular weight of active material (at x = 0): 0,001 g
Atomic weight of intercalated ion: 0,001 g
Acquisition started at: x₀ = 0,000
Number of e⁻ transferred per intercalated ions: 1
for Δx = 1, theoretical capacity ΔQ = 26,802 mA.h
Battery capacity C = 0,000 A.h

Reference Electrode
SCE Saturated Calomel Electrode
Offset potential vs. Normal Hydrogen Electrode: 0.241 V

Status Stopped Time 0,0000 s Ewe -717,6 mV I 0 A Buffer 0 Eoc -717,6 mV Q-Qo 0 A.h P 0 W nc 0 IRange open cycle 1

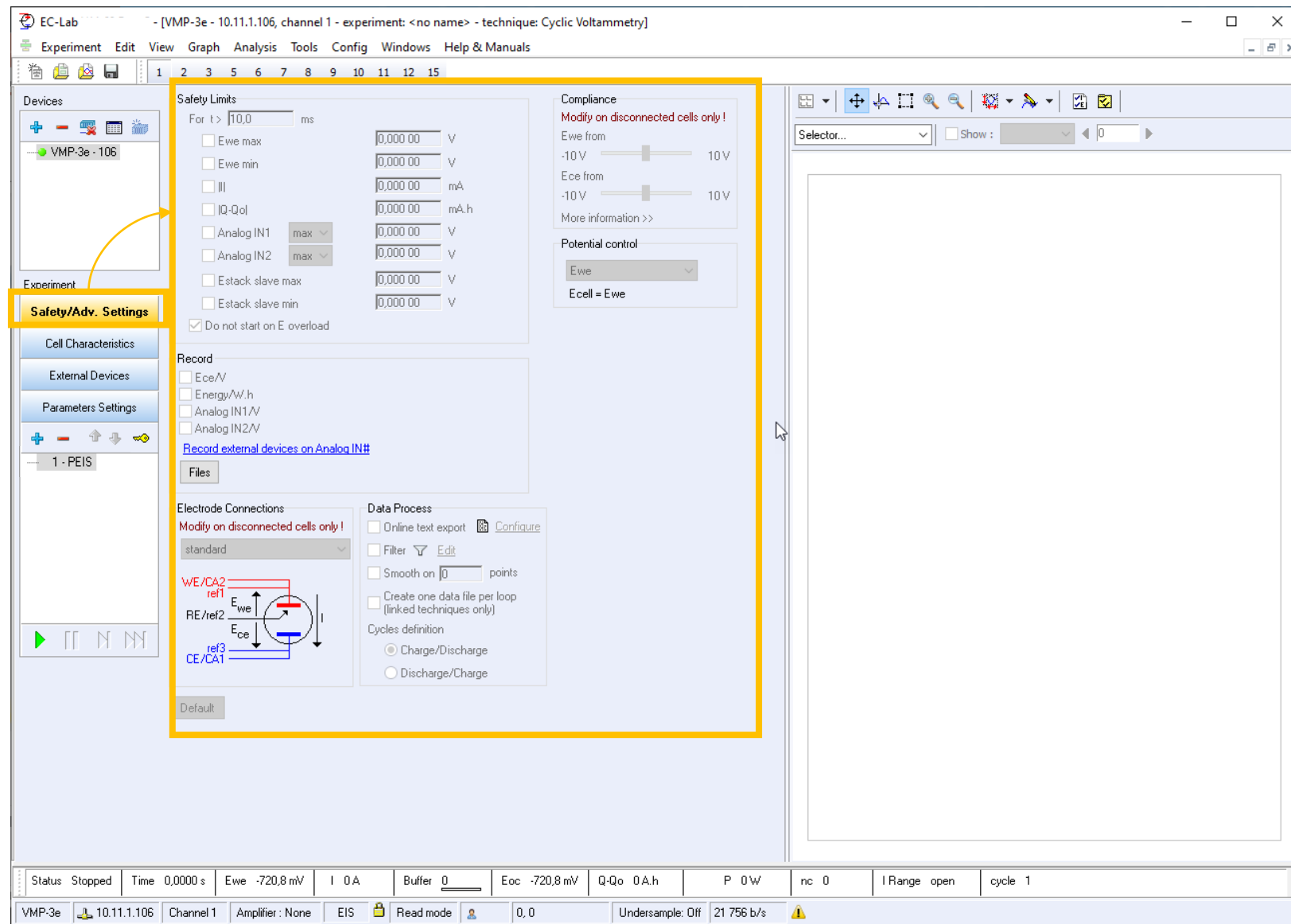
VMP-3e 10.11.1.106 Channel 1 Amplifier: None EIS Read mode 0, 0 Undersample: Off 21 540 b/s



Step 4: Set general parameters

- Safety and Advanced Settings are available here

Note: This windows is different for the Essential and Premium instruments.

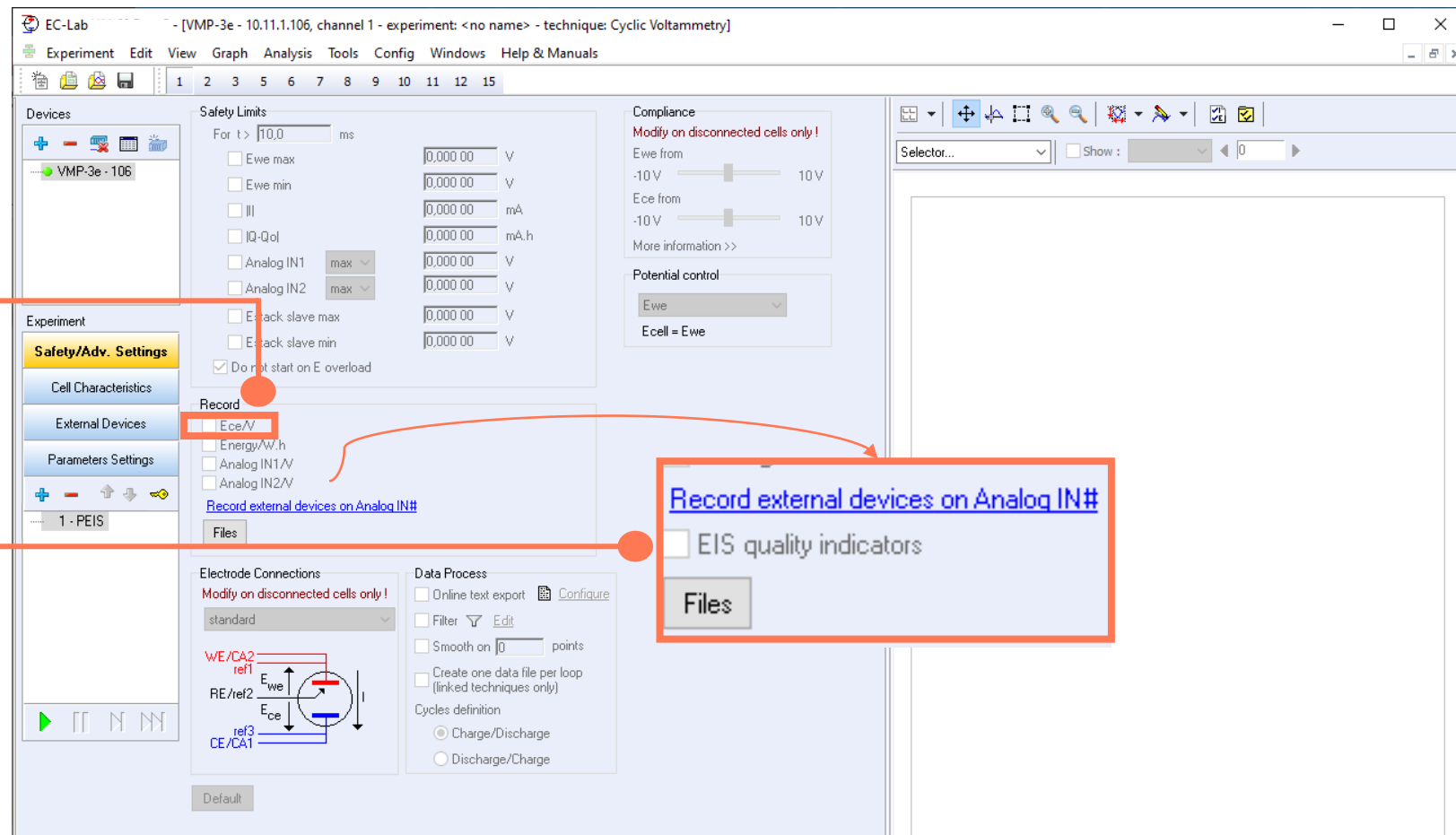




Step 4: Set general parameters

Record the impedance of the CE in addition to the impedance of the WE

Activate EIS quality indicators
(available on Premium or e-board potentiostats)



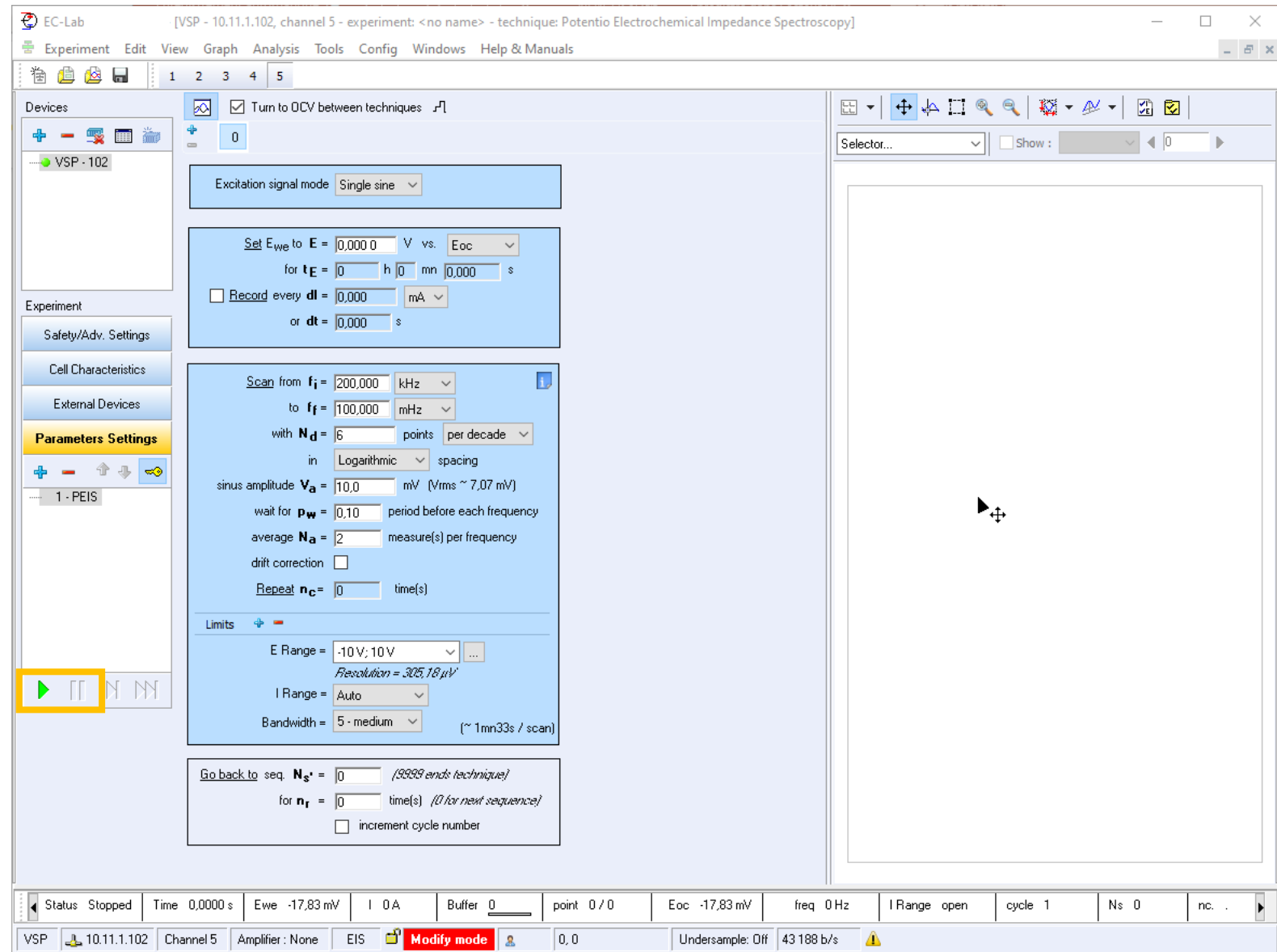
We recommend the use of EIS quality indicators (THD, NSD, NSR) to help to quickly assess the validity of the impedance measurement.



Step 5: Launch the measurement

- Click on ▶ to launch experiment

Note: All the settings may be changed during the experiment (Modify on the fly) except I range, E range, bandwidth and single sine / multisine





Step 5: Launch the measurement

Load techniques with same settings using a .mps file created when launching the experiment

The screenshot displays the EChemLab software interface. The top menu bar includes File, Experiment, Edit, View, Graph, Analysis, Tools, Config, Windows, and Help & Manuals. The left sidebar shows a tree view with 'VMP-3e - 106' selected under 'Devices', and 'Parameters Settings' selected under 'Experiment'. The main window shows various settings for a 'Cyclic Voltammetry' experiment, including 'Excitation signal mode' set to 'Single sine', 'Set E_{we} to E = 0,000 0 V vs. E_{oc}', and 'Scan from f_i = 200,000 kHz to f_f = 100,000 mHz'. A control panel at the bottom left contains a green play button, a red stop button, and a blue pause button. A status box at the bottom center displays 'Status Stopped'. A control panel at the bottom right contains a red square, a blue double bar, and two white double arrows. The bottom status bar shows 'Status Stopped', 'Time 0,0000 s', 'Ewe -707,1 mV', 'I 0 A', 'Buffer 0', 'Eoc -707,1 mV', 'Q-Qo 0 A.h', 'P 0 W', 'VMP-3e', '10.11.1.106', 'Channel 1', 'Amplifier : None', 'EIS', 'Modify mode', '0,0', 'Undersample: Off', and '21 558 b/s'.

Stop experiment

Pause experiment

Status Stopped

Next technique

Next sequence



Step 6: Add additional experiments

- Click on + button to add more techniques
- Order of execution appears in the technique list

EC-Lab - [VMP-3e - 10.11.1.106, channel 1 - experiment: <no name> - technique: Cyclic Voltammetry]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

1 2 3 5 6 7 8 9 10 11 12 15

Devices

VMP-3e - 106

Experiment

Safety/Adv. Settings

Cell Characteristics

External Devices

Parameters Settings

1 - PEIS

Insert Techniques

Search: peis

Recent Techniques

Electrochemical Applications

Batteries Testing

Supercapacitor

Photovoltaic/Fuel Cells

Corrosion

Custom Applications

Polarization Resistance - PR

Stepwise Potential Fast Chronoamperometry - SPFC

Anodic stripping voltammetry - ASV

RDE rotating speed effect

Insert Technique: Before (selected), After

Load from default: Safety/Adv. Settings, External devices, Cell characteristics

Custom Applications: Rename, Add, Remove, Stack

OK, Cancel

You can save personalized protocol to technique list with **Save As Custom Application...** (in the main bar menu Experiment) and find it under Electrochemical Application - Custom Applications **My protocol**

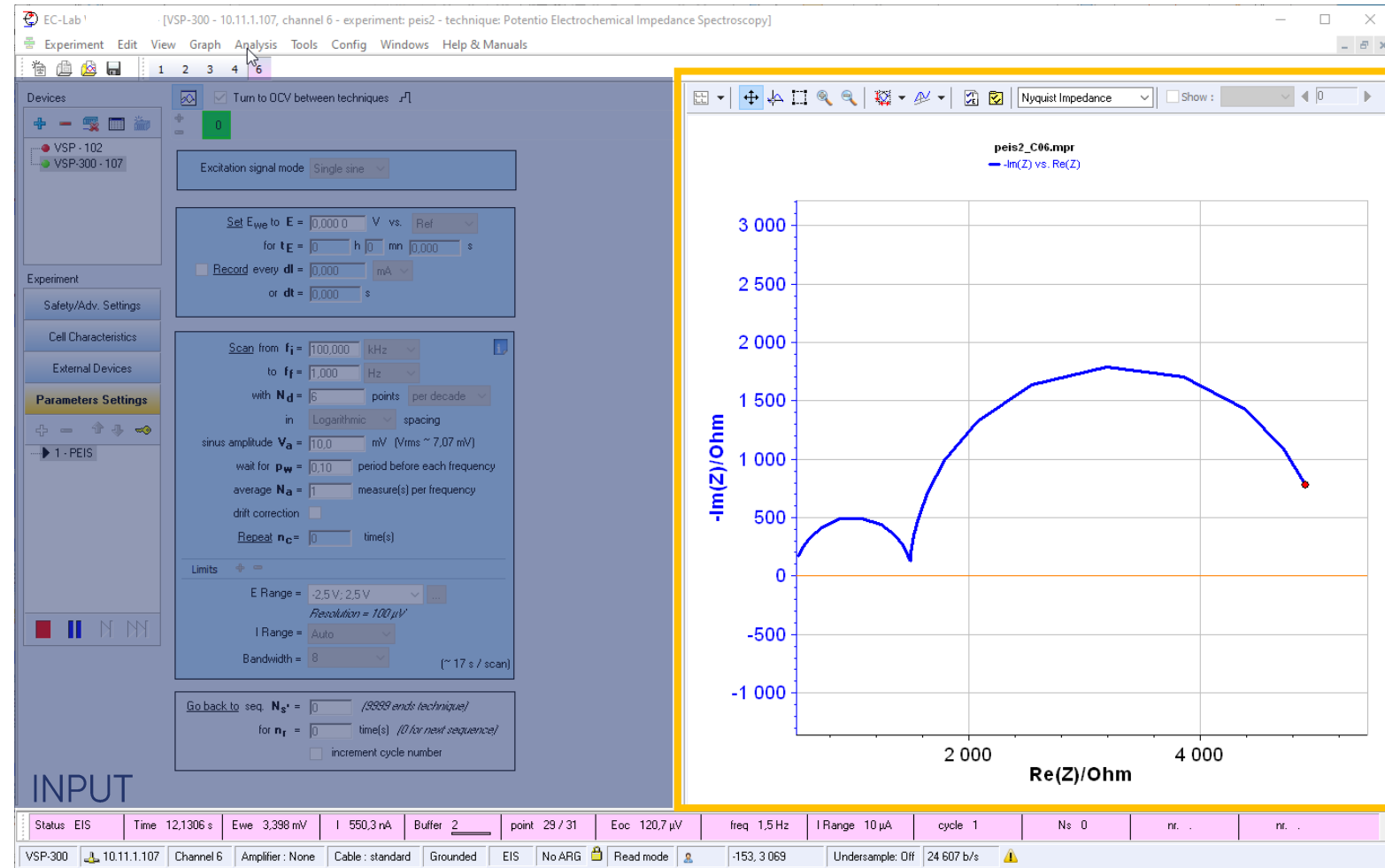
Status: Stopped | Time: 0,0000 s | Ewe: -707,1 mV | I: 0 A | Buffer: 0 | Eoc: -707,1 mV | Q-Qo: 0 A.h | P: 0 W | nc: 0 | IRange: open | cycle: 1

VMP-3e | 10.11.1.106 | Channel 1 | Amplifier: None | EIS | Modify mode | 0,0 | Undersample: Off | 21 558 b/s



Step 7: Read the graph

- Graphics are displayed in real time
- Data are saved in .mpr file



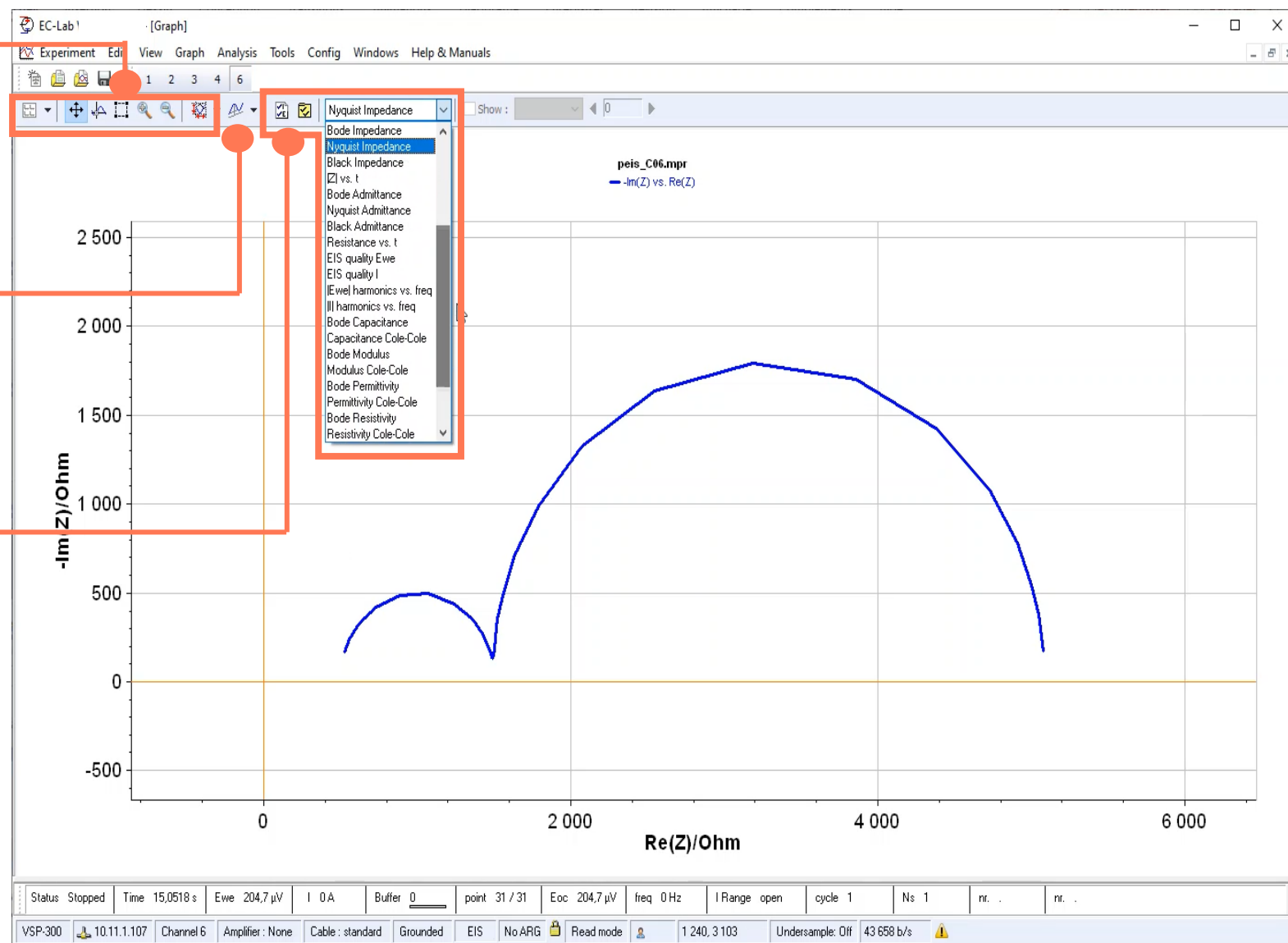


Step 7: Read the graph

Browse through the graph
(Filter, Scroll, Cursor, Selection, Zoom +, Zoom -, Autoscale)

Modify the graph
(Selector, graphic properties, representations)

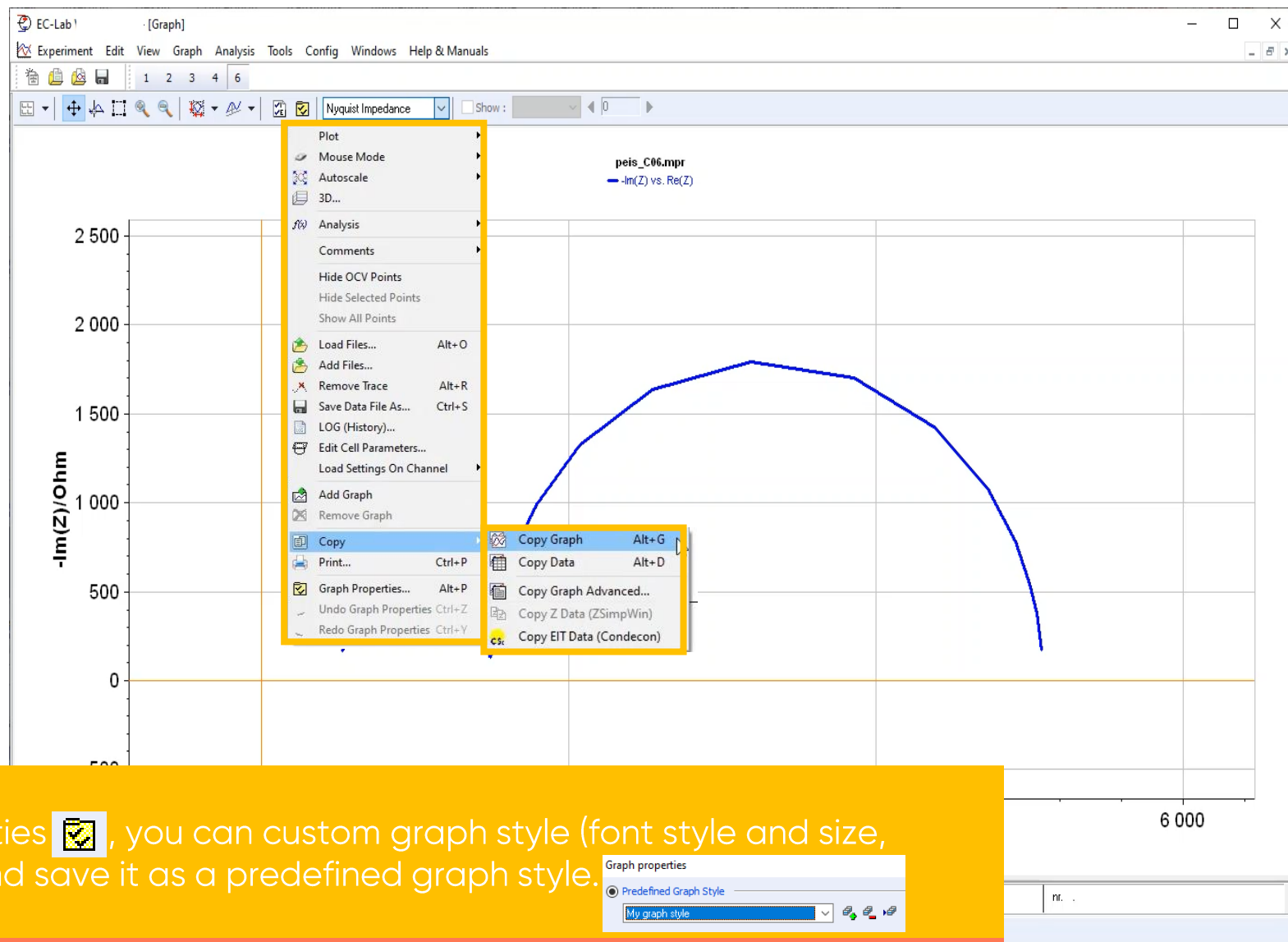
Show only selected cycle





Step 7: Read the graph

- Copy graph as a picture with a right click on the graph



In graph properties , you can custom graph style (font style and size, traces, grid...) and save it as a predefined graph style.



Step 8: Analyse the data with Z Fit

■ Analyse with Z Fit

Note: Analysis is available either in the main tool bar or as a shortcut in the graph bar or with F6

The screenshot displays the EC-Lab software interface. The top window shows the 'Analysis' menu with 'Z Fit...' highlighted. The bottom window shows the 'Analysis' menu with 'Z Fit...' highlighted. The 'ZFit - Bio-Logic' dialog box is open, showing the 'Inputs' section with 'Multi files' checked. The 'Equivalent circuit selection' is set to 'R1'. The 'Results' section shows a table with columns: param., sel., sign, value, unit, and std. err. The table contains one row for 'R1' with values: +, 1e3, Ohm, and xxx. The 'PseudoC' section shows 'χ²' as xxx, 'χ²/|Z|²' as xxx, and 'Iterations' as xxx. The 'Calculate' button is highlighted.

param.	sel.	sign	value	unit	std. err.
R1	<input checked="" type="checkbox"/>	+	1e3	Ohm	xxxx

χ²: xxx
χ²/|Z|²: xxx
Iterations: xxx



Did you know? Z Sim (available in Analysis) is a powerful impedance simulation tool. It can be helpful to learn more about equivalent circuits.



Step 8: Analyse the data with Z Fit

- Click on Edit to select the equivalent circuit

EC-Lab - [Graph]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

Nyquist Impedance

peis_C06.mpr

Equivalent Circuit Edition

Search

Display Circuits With : 28 circuits

☒ 5 Element(s)

☐ Element(s)

☐ All Application

☐ All Circuits

R1+C1/(R2+C3/R3)
R1+C1/(R2+Q3/R3)
R1+C1/(R2+R3/W3)
R1+C1/R2/(C3+R3)
R1+C1/R2/(C3+W3)
R1+C1/R2/(L3+R3)
R1+C1/R2/(Q3+R3)
R1+C1/R2/(R3+W3)
R1+C1+C2/(R2+W2)
R1+C2/(R3+W3+C3)
R1+C2/R2+C3/R3
R1+C2/R2+Q3/R3
R1+Q1/(R2+C3/R3)

Description

Impedance

$$Z(f) = R_1 + \frac{R_2}{1 + j2\pi f R_2 C_2} + \frac{R_3}{1 + j2\pi f R_3 C_3}$$

Nyquist Diagram (-Im(Z) vs. Re(Z))

order C2 < C3

Equivalent circuit(s)

R1+C1/R2+C3/R3
R1+C1/R2/(C3+R3)
R1+R2/C2+C3/R3

Graphic editor

Elements :

R1 C2 R3

Linkers :

ZFit - Bio-Logic

Inputs

☐ Multi files

Select all cycle

Equivalent circuit selection

R1

Edit Load Save

Fit

Results

param.	sel.	sign	value	unit	std err.
R1	<input checked="" type="checkbox"/>	+	1e3	Ohm	xxxx
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				

PseudoC

χ^2 xxxx χ/\sqrt{N} xxxx

$\chi^2/|Z|^2$ xxxx Cycle xxxx

Iterations xxxx

Calculate Minimize Stop Copy Close

OK Cancel



Step 8: Analyse the data with Z Fit

Sort the circuit
in the list

Build the circuit

Write the circuit

+ : elements in series
/: elements in parallel
(): several elements in series
or in parallel with each other

EC-Lab - [Graph]

Experiment Edit View Graph Analysis Tools Config Windows Help & Manuals

peis_C06.mpr

Equivalent Circuit Editor

Search

Display Circuits With :

☒ 5 Element(s)

☐ Element(s)

Application

☐ All Circuits

28 circuits

R1+C1/(R2+C3/R3)
R1+C1/(R2+Q3/R3)
R1+C1/(R2+R3/W3)
R1+C1/R2/(C3+R3)
R1+C1/R2/(C3+W3)
R1+C1/R2/(L3+R3)
R1+C1/R2/(Q3+R3)
R1+C1/R2/(R3+W3)
R1+C1+C2/(R2+W2)
R1+C2/(R3+W3+C3)
R1+C2/R2+C3/R3
R1+C2/R2+Q3/R3
R1+Q1/(R2+C3/R3)

Description

Impedance

$$Z(f) = R_1 + \frac{R_2}{1 + j2\pi f R_2 C_2} + \frac{R_3}{1 + j2\pi f R_3 C_3}$$

Nyquist Diagram (-Im(Z) vs. Re(Z))

Equivalent circuit(s)

R1+C1/(R2+C3/R3)
R1+C1/R2/(C3+R3)
R1+R2/(C2+C3/R3)

Graphic editor

Elements :

Linkers :

ZFit - Bio-Logic

Inputs

☐ Multi files

Select all cycle

Equivalent circuit selection

R1

Edit Load Save

Fit

Results

param.	sel.	sign	value	unit	std. err.
R1	<input checked="" type="checkbox"/>	+	1e3	Ohm	xxxx
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				
	<input type="checkbox"/>				

PseudoC

χ^2 xxxx χ/\sqrt{N} xxxx

$\chi^2/|z|^2$ xxxx Cycle xxxx

Iterations xxxx

Calculate Minimize Stop Copy Close

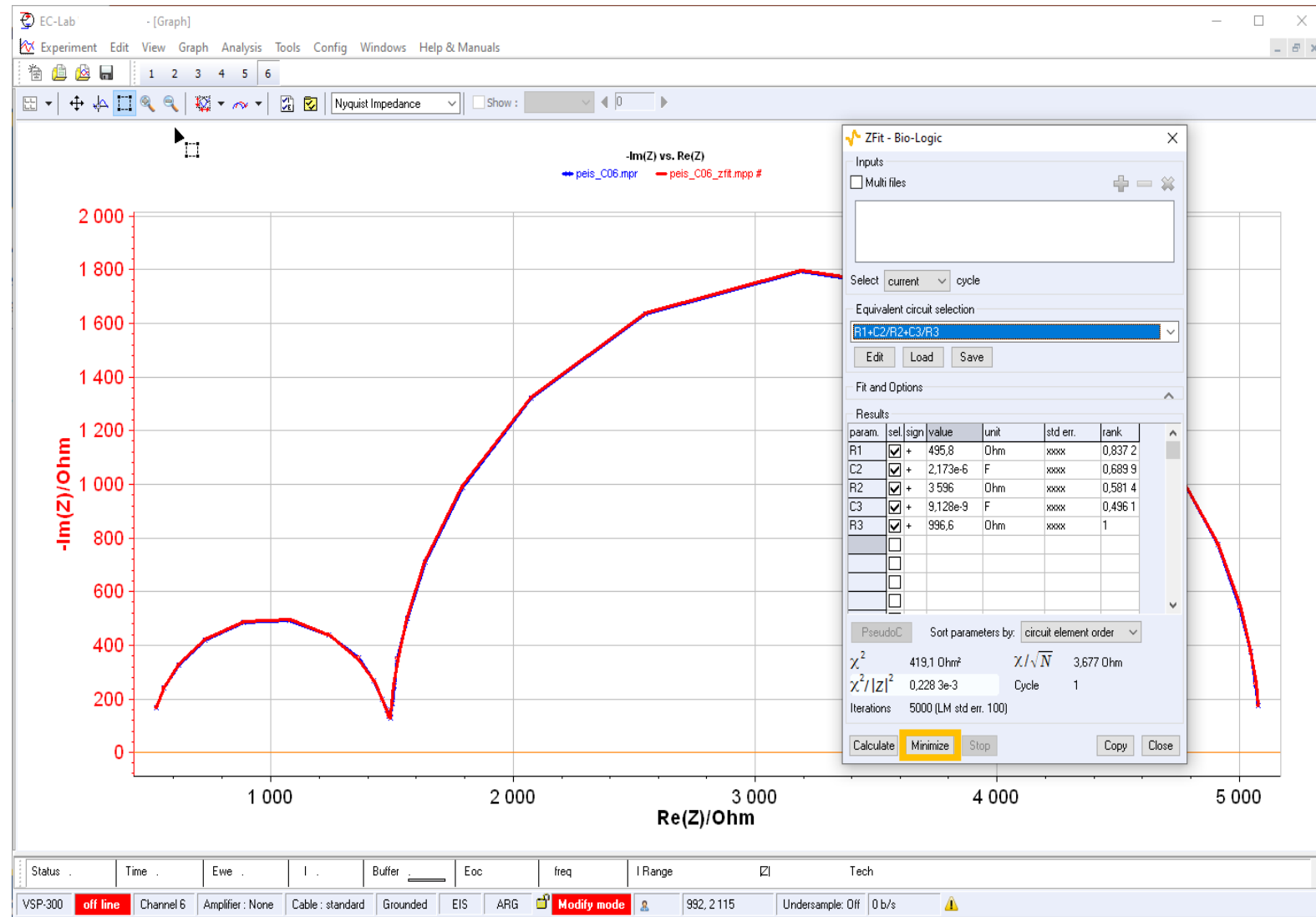
OK Cancel



Step 8: Analyse the data with Z Fit

- Click on minimize to fit the data

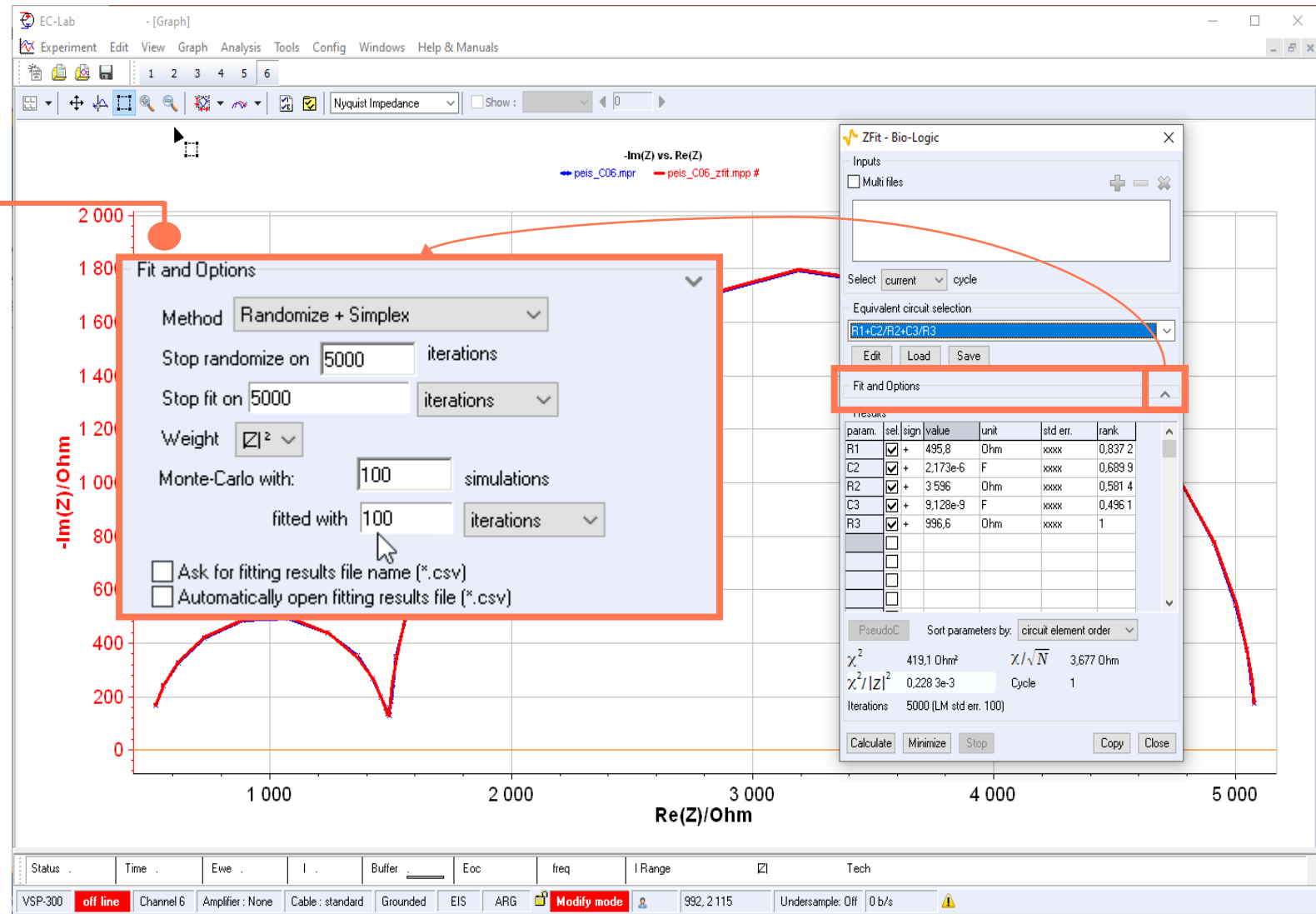
Note: xx_zfit.mpp temporary file is generated. It can be saved as .mpr file





Step 8: Analyse the data with Z Fit

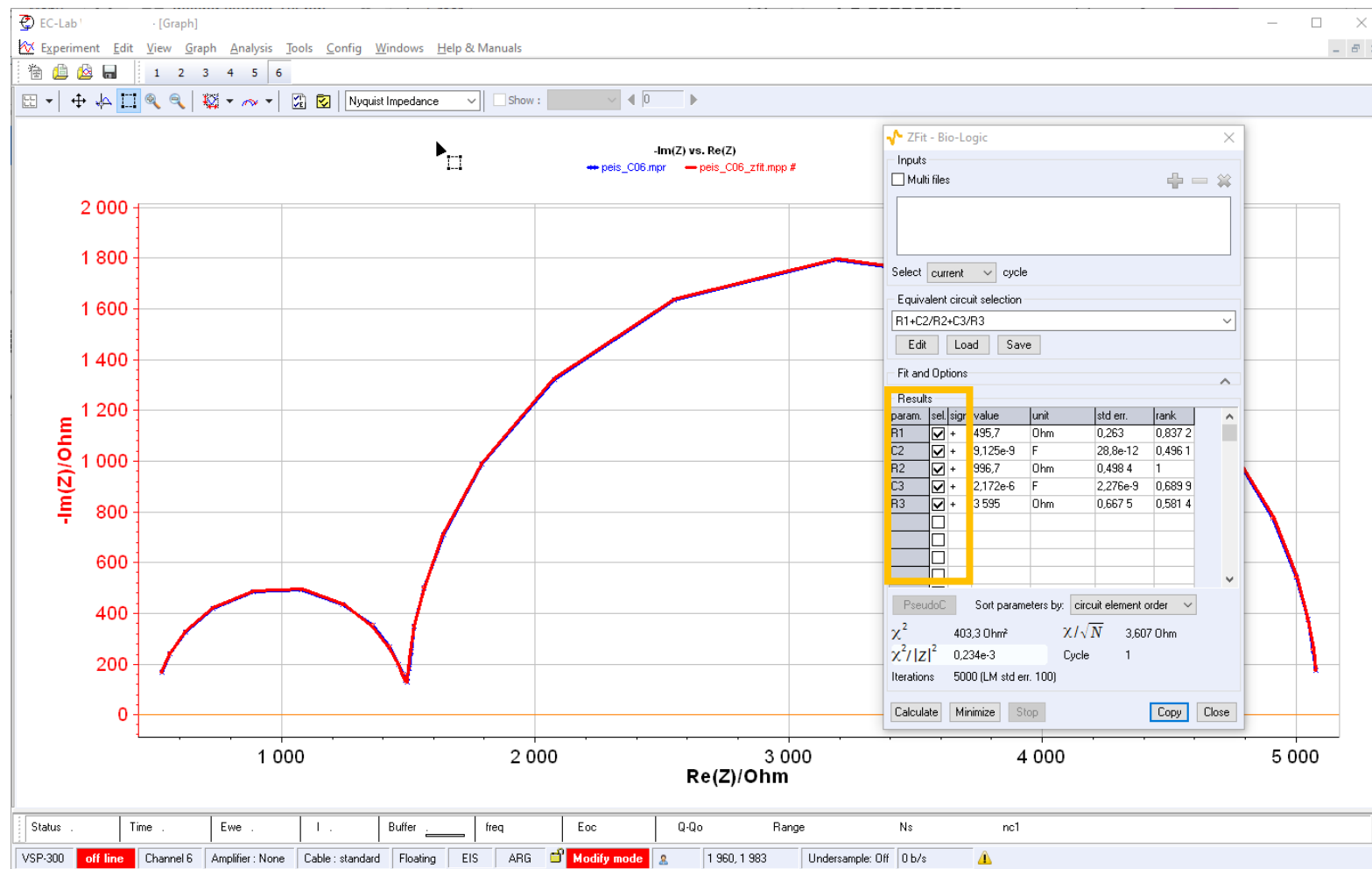
3 kinds of method to fit and
a randomize to find initial
values of the fit





Step 8: Analyse the data with Z Fit

- Take over the results during fitting process
 - Unchecked "Sel" to keep a value in the table
 - Choose +/- to force sign of a value

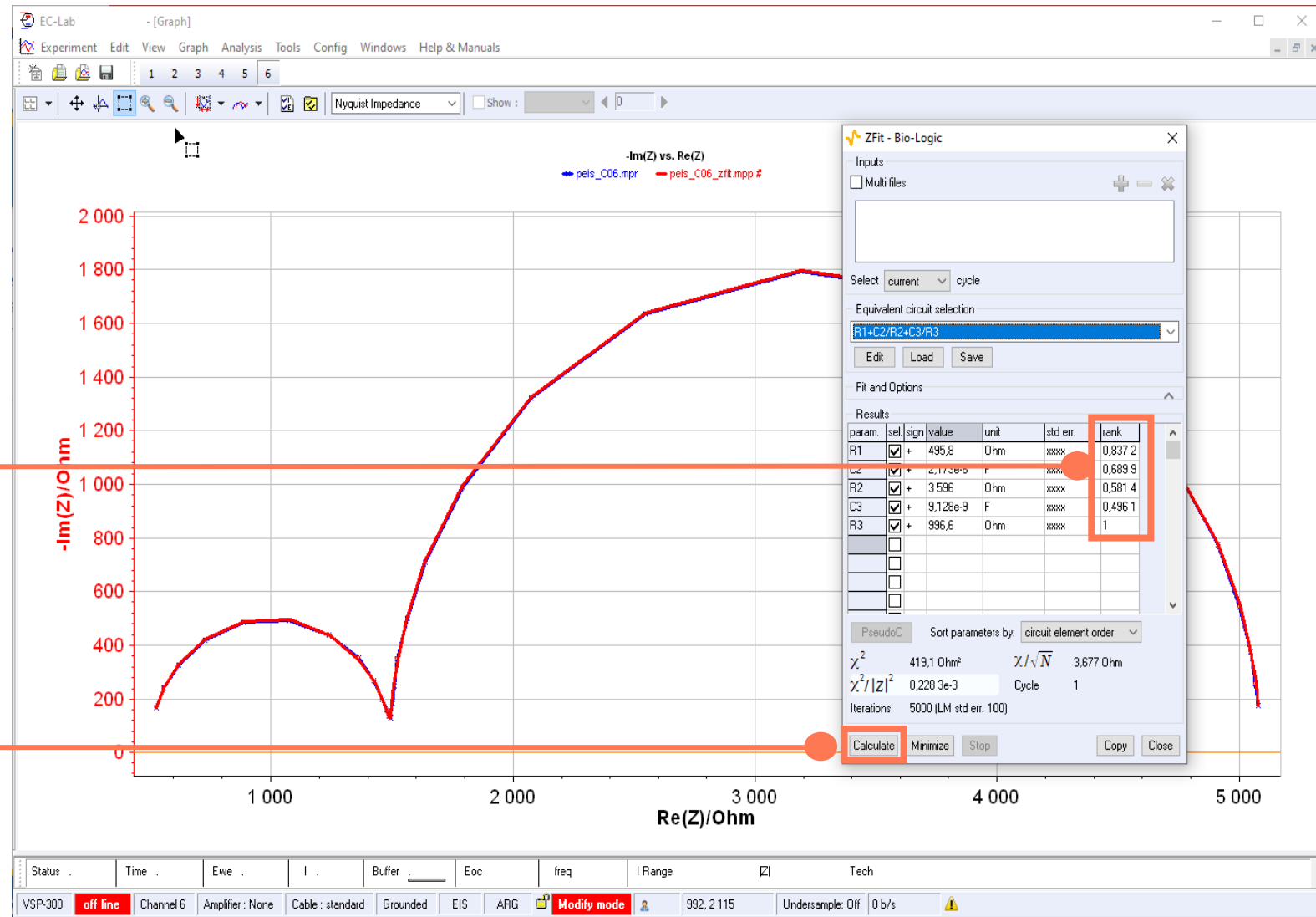




Step 8: Analyse the data with Z Fit

Rank the importance of the element in the fit

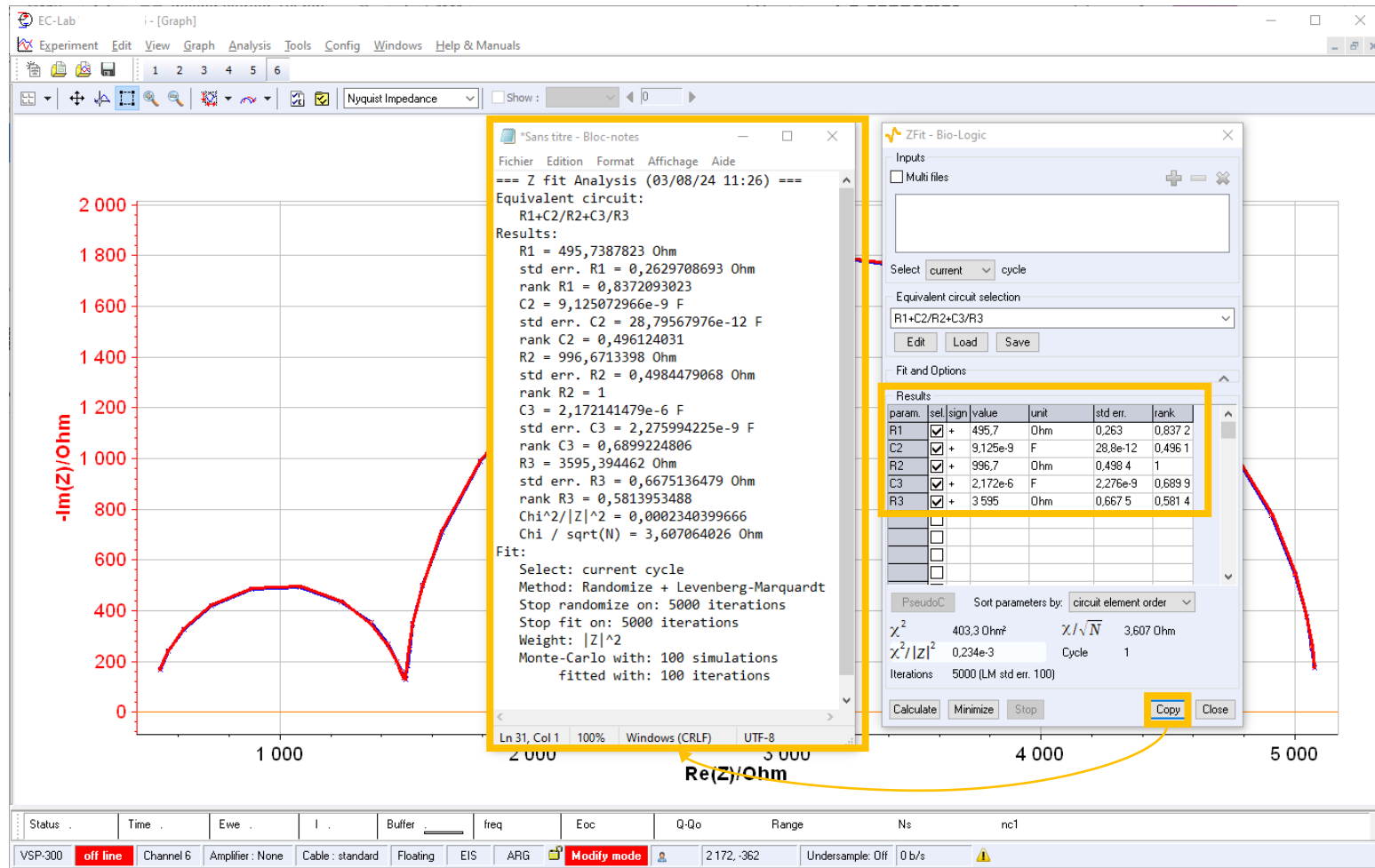
Calculate (no fitting) using parameters entered in table





Step 8: Analyse the data with Z Fit

- Save the results with copy/paste



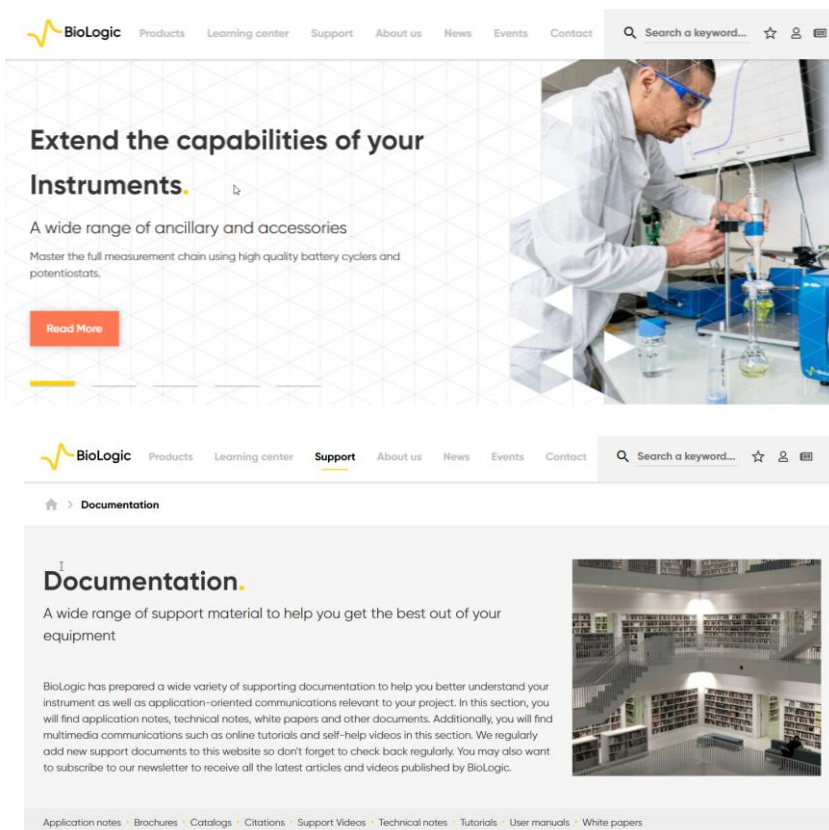


Find out more



For supplementary information

Visit our website!



- Documentation list
 - What is EIS? (article)
 - How to make reliable EIS measurements? (article)
 - Application Notes
 - EC-Lab Techniques and Applications (manual)
 - EC-Lab Analysis and Data Process (manual)



Did you know? Free update of EC-Lab® are available on our website.



Need help?

Contact us!



- Helpful information to get when contacting support center:
 - Serial number of the instrument (located on the rear panel of the device)
 - Software and hardware version you are currently using (on the Help menu, About on EC-Lab)
 - Operating system on the connected computer
 - Connection mode (Ethernet, LAN, USB) between computer and instrument

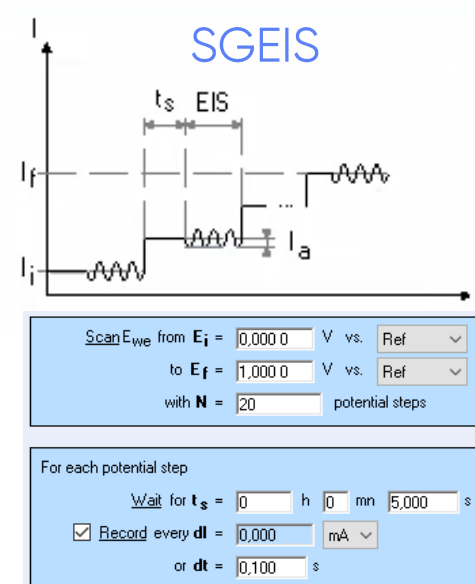
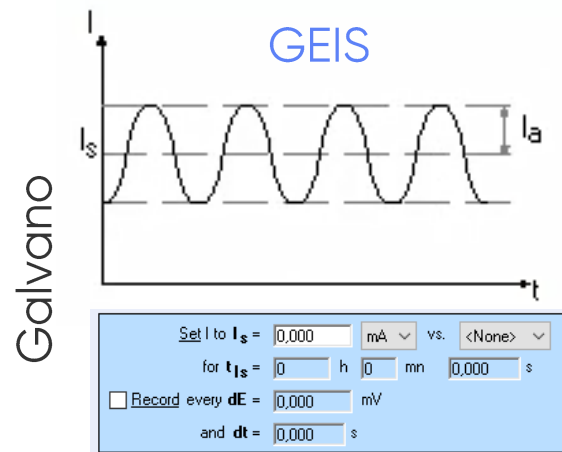
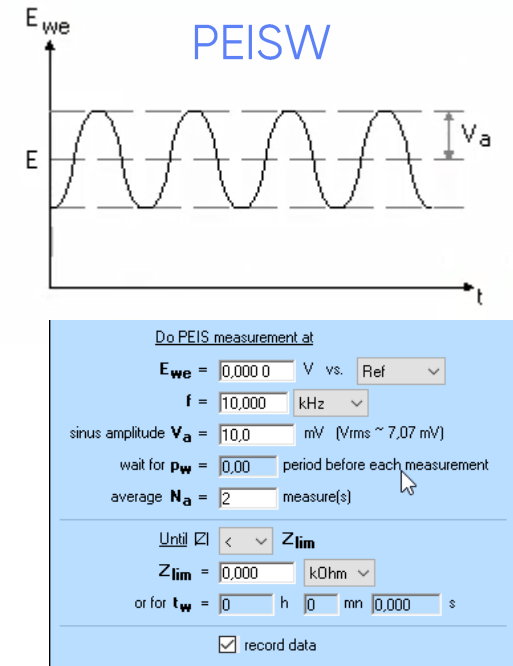
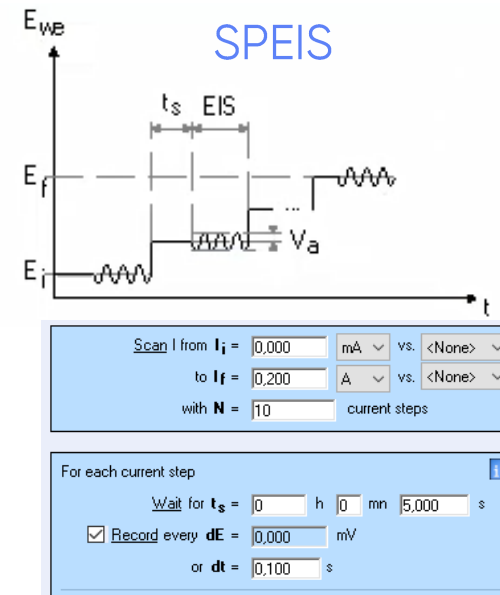
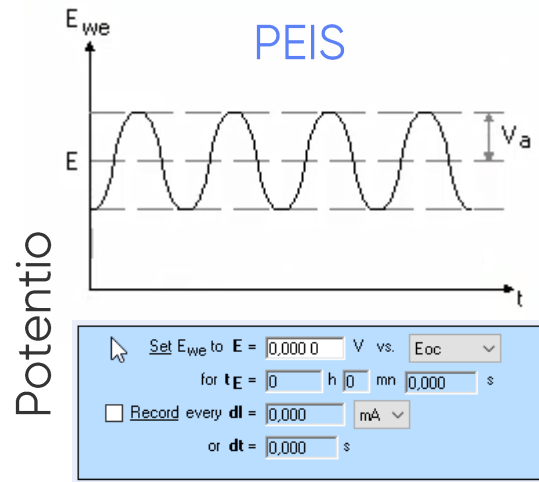


- How to adapt presented PEIS parameters on other EIS techniques?
- What is the difference between PEIS, GEIS and GEIS AA?
- What are the advantages of using multisine ?
- How to optimize the setup?
- How to ensure the reliability of the measurements?
- How to select an equivalent circuit?
- How to measure impedance on stack cell?



How to adapt presented PEIS parameters on other EIS techniques?

- EIS techniques are design in a similar way
- As control modes differ (potentio or galvano), related parameters have to be adapted





What is the difference between PEIS, GEIS and GEIS-AA?

- In most cases, performing measurements in potentiostatic or galvanostatic control are equivalent. One of the difficulties comes from finding the right sine amplitude:
 - High enough to induce a significant amplitude of the response
 - Small enough to keep the linear behavior of the cell

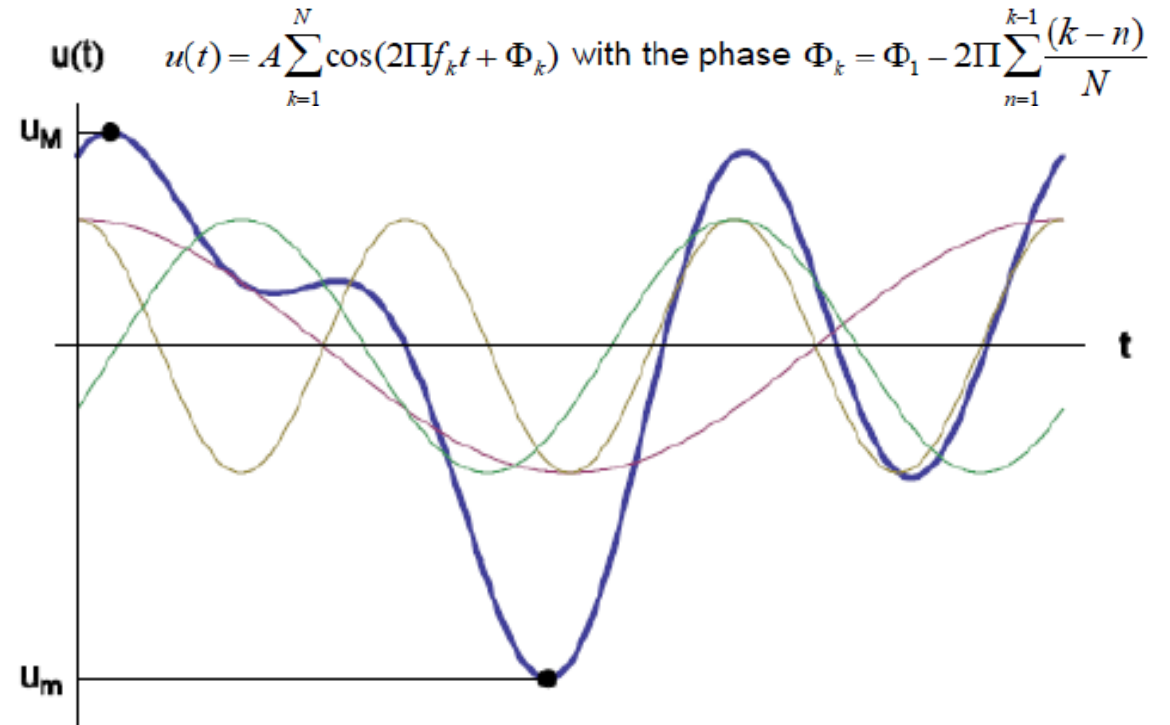
	PEIS	GEIS	GEIS-AA
Control mode	Potentiostatic	Galvanostatic	Galvanostatic (with amplitude adaptation)
Sinus amplitude to set	Input V_a (mV)	Input I_a (mA)	Output V_a (mV)
Sinus amplitude value	5-20 mV (small amplitude)	<i>Small</i> current amplitude (depends on the system). Rule of thumb 10% of the discharge/charge current for batteries	5-20 mV (small amplitude). Automatic modulation of input current amplitude to output voltage amplitude.
Use	Most applications	Low impedance system, system that change with time (battery, corrosion...)	Avoid non-linear behavior

Note: To go further, refer to PEIS or GEIS or GEIS-AA? (article), AN#49, AN#09



What are the advantages of using multisine ?

- Multisine is a sum of sinus. The advantages are:
 - Reduce time of the measurement
 - Avoid drifts for non-steady state system on measurement at low frequency



Note: To go further, refer to AN#19



How to optimize the setup?

- **Verify the impedance measurement accuracy** of the setup
(To go further, refer to AN#54)
- **Add booster** (for system with low impedance) or **low current option** (for system with high impedance) if needed
- **Use a Faraday cage** (connected to the ground of the potentiostat) to protect the cell from any external disturbance (especially for low current measurements)
- **Avoid extended cable** (capacity of the extra cable is added and affect impedance measurement at high frequencies, bandwidth is affected too)
- **Use 4-point measurements** (contact resistance not negligible for low impedance system)

Note: To go further, refer to AN#05

How to ensure the reliability of the measurements?

Criteria to respect	System is stationary	System is linear	Limited Noise
Explanation Actual signal Time record Assumed response Amplitude spectrum	<p>Steady-state NON Steady-state</p> <p>Time invariant Time variant</p> <p>Linear NON-linear</p> <p>Without noise With noise</p>		
Quality Indicators to check	NSD (Non-Stationary Distortion) has to be low	THD (Total Harmonic Distortion) has to be low	NSR (Noise to Signal Ration) has to be low
Possible actions to take	$\nearrow P_w$ Use multisine Use drift correction	$\searrow V_a$	$\nearrow V_a$ $\nearrow N_a$

Note: To go further, refer to AN#64, AN#65, AN#69 and AN#17



Check the value of the AC ($|I|$ and $|E|$) and DC ($\langle I \rangle$ and $\langle E \rangle$) current and potential in the graph selector (unchecked "hide additional variables").



How to select an equivalent circuit?

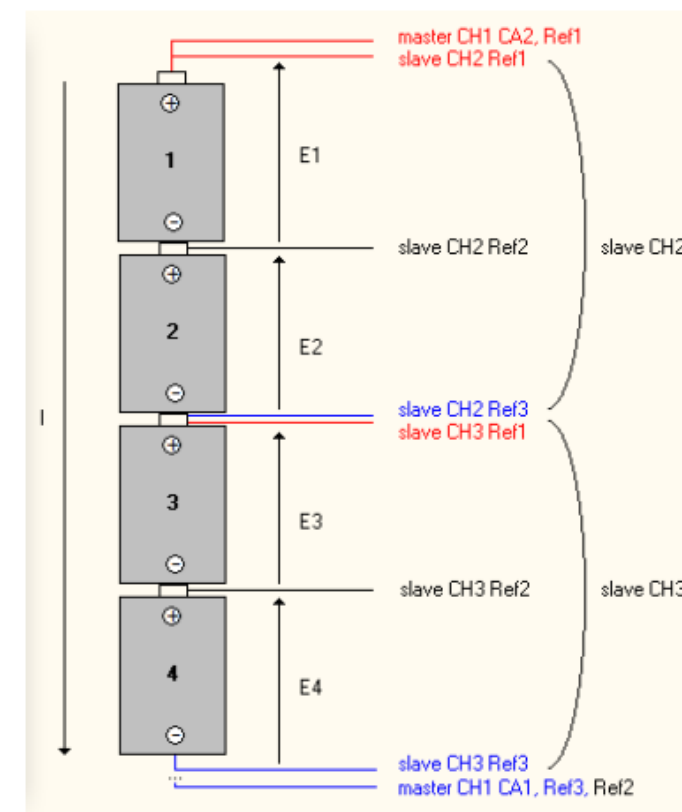
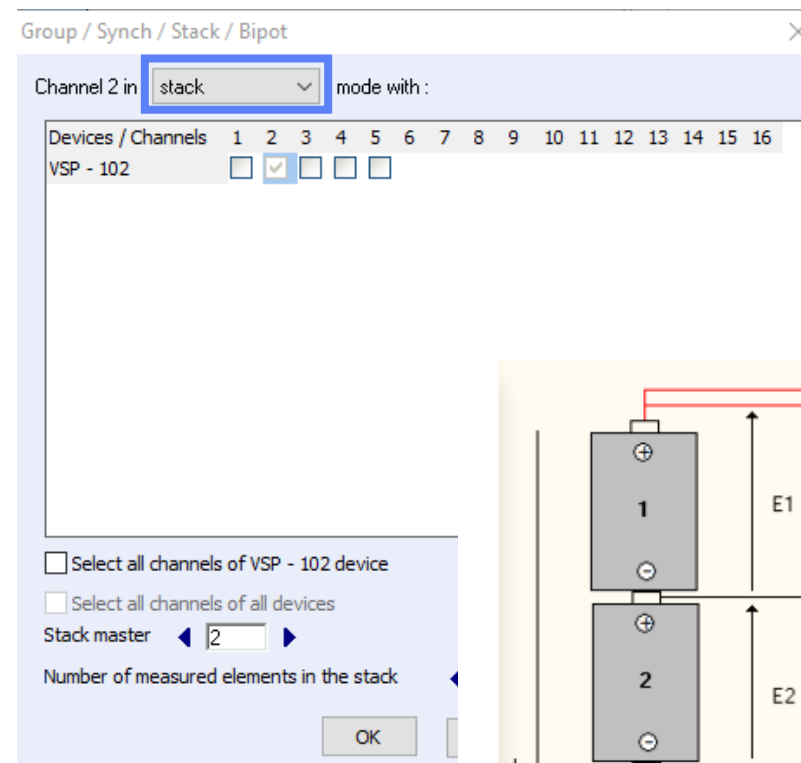
- There are many different electrical equivalent circuits which correspond one impedance diagram
- The effectiveness of the process is dependent on the ability to choose the best **circuit representing the physical reality** of the system being studied
- A sensitivity feature, « **Rank** » in the results of Z Fit, was developed to help to assess the importance of each element in the fit.
Generally the less elements in the circuit, the better it is.

Note: To go further, refer to Z Fit tutorials (videos), How to choose the proper equivalent circuit (articles), AN#14, AN#45



How to measure impedance on stack cell?

- Simultaneously assess a whole stack and each cell behavior with **stack mode** (in Edit menu)
- Connect leads to **master** (stack) and **slave channels** (each elements)
- Impedance of the stack is the sum of the impedance of each element



Note: To go further, refer to AN#59 and TN#27



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for choosing us!**