



Getting Started with EC-Lab[®]:

Cyclic voltammetry

V1

Getting Started EC-Lab: CV

March 2024



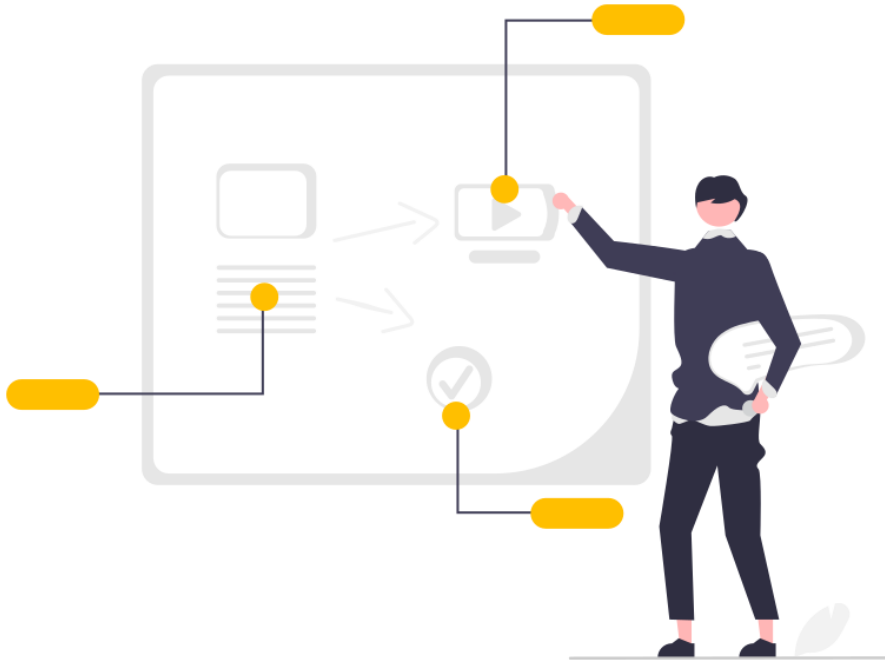
Overview and quick access

■ Procedure

- Launch the experiment
 - [Step 0](#): Connect instrument and select channel
 - [Step 1](#): Add CV technique
 - [Step 2](#): Set CV parameters
 - [Step 3](#): Optimize the measurement
 - [Step 4](#): Set general parameters
 - [Step 5](#): Launch the measurement
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- Investigate the results
 - [Step 7](#): Read the graph
 - [Step 8](#): Analyse the data

■ Find out more

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

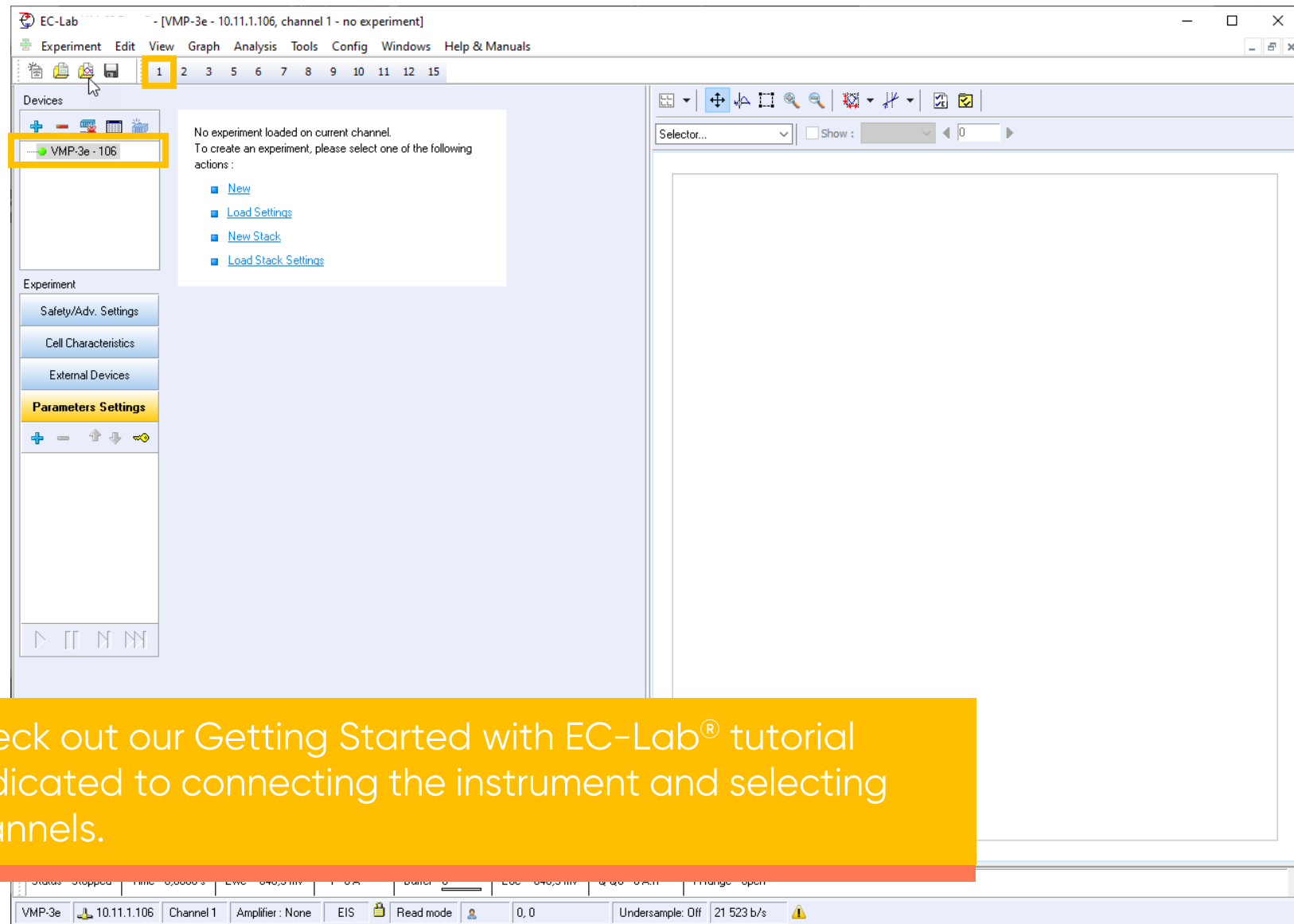


Procedure



Step 0: Connect instrument and select channel

- Connect instrument and select channel

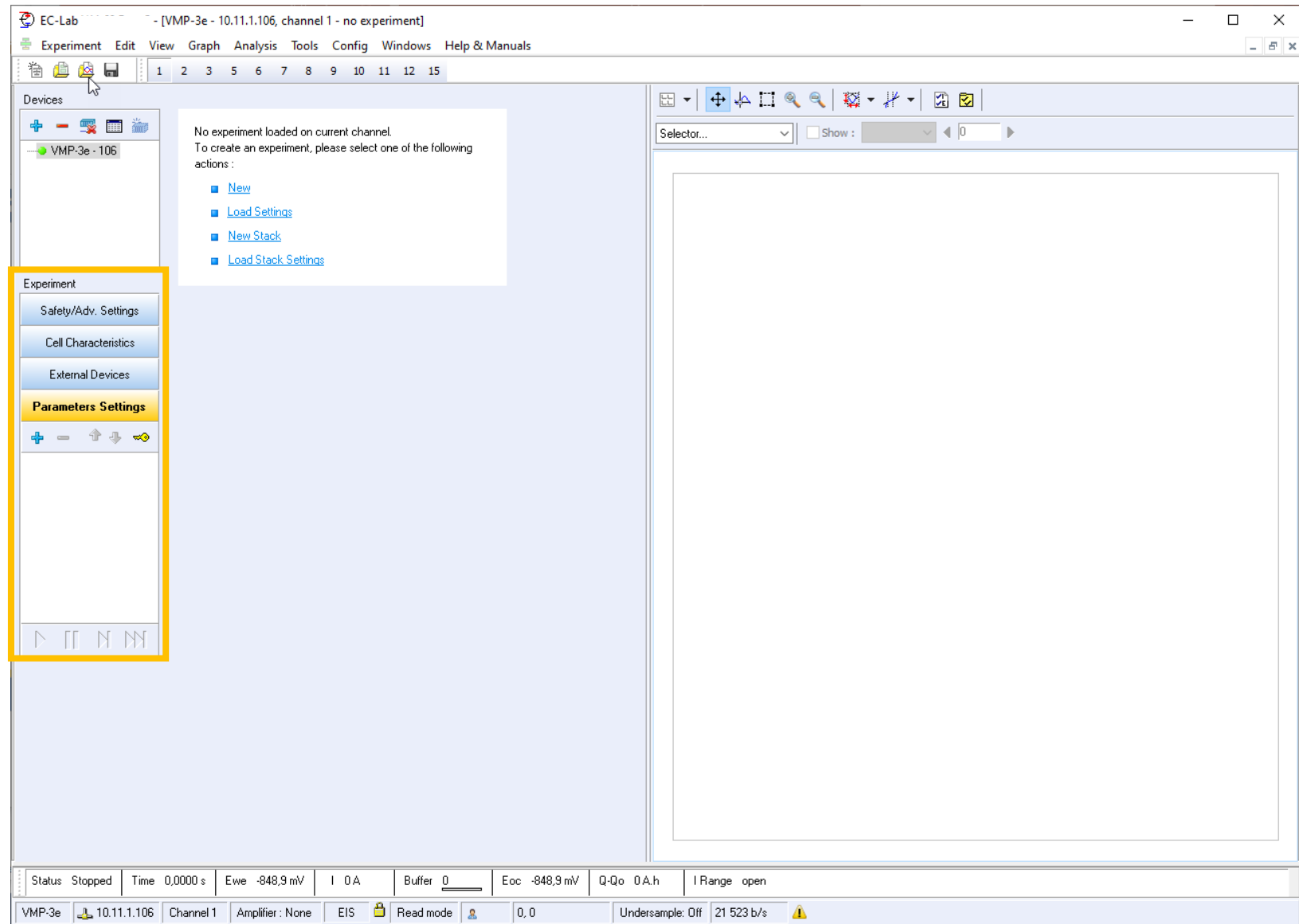


Check out our Getting Started with EC-Lab[®] tutorial dedicated to connecting the instrument and selecting channels.



Step 0: Connect instrument and select channel

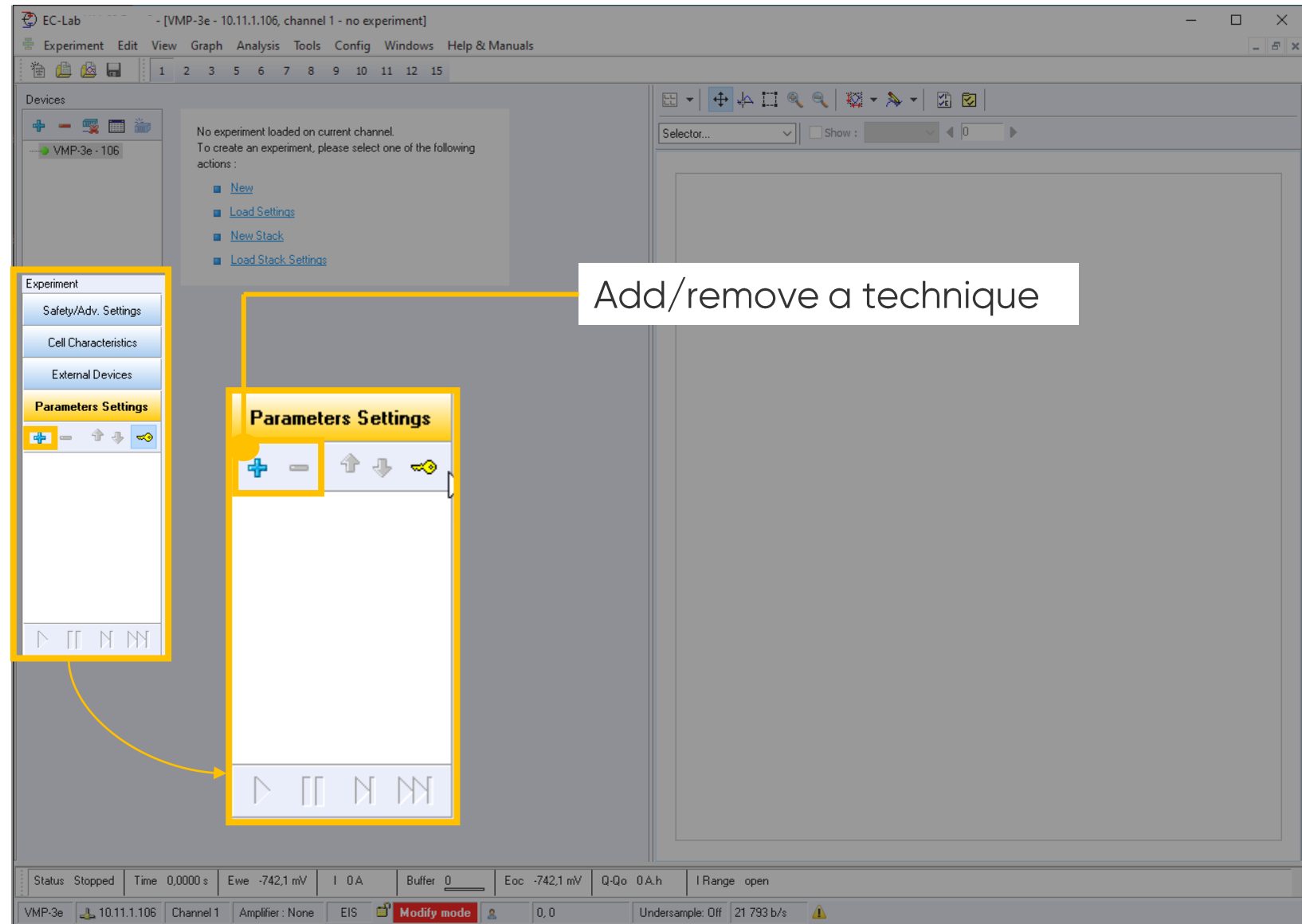
- When the instrument and channel are selected, the user can set the experiment

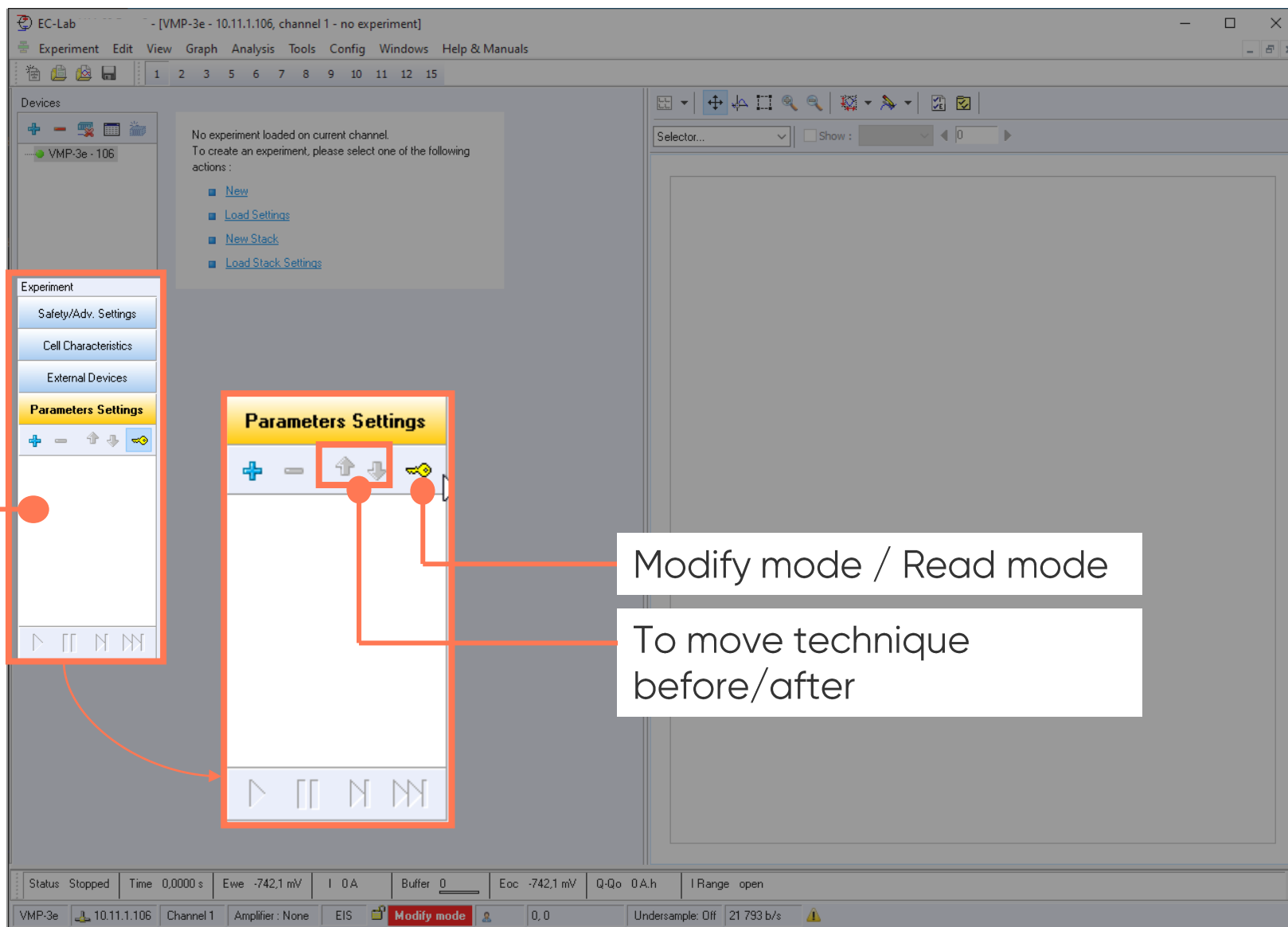




Step 1: Add CV technique

- Click on + to add a technique to the list





- To move technique before/after

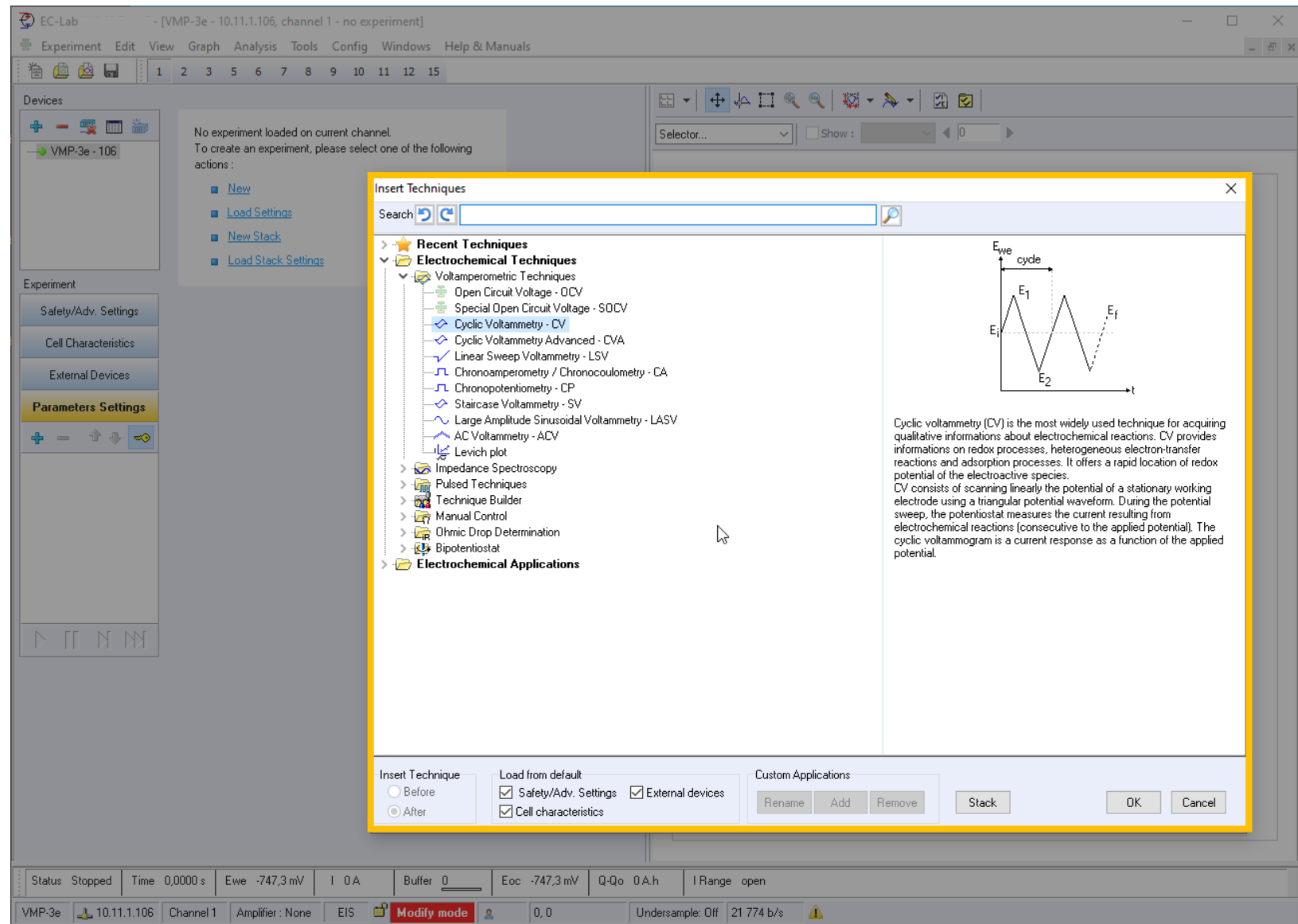


Step 1: Add CV technique

- Select Cyclic Voltammetry – CV technique

It is in the Voltamperometric techniques folder

- Click on **OK** to validate





Step 1: Add CV technique

Search bar
to quickly find the
desired technique

Description of the settings
technique and associated
graph

EC-Lab - [VMP-3e - 10.11.1.106, channel 1 - no experiment]

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

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

- New
- Load Settings
- New Stack
- Load Stack Settings

Experiment

Safety/Adv. Settings

Cell Characteristics

External Devices

Parameters Settings

Insert Techniques

Search

Recent Techniques

- Electrochemical Techniques
 - Voltamperometric Techniques
 - Open Circuit Voltage - OCv
 - Special Open Circuit Voltage - SOCv
 - Cyclic Voltammetry - CV
 - Cyclic Voltammetry Advanced - CVA
 - Linear Sweep Voltammetry - LSV
 - Chronoamperometry / Chronocoulometry - CA
 - Chronopotentiometry - CP
 - Staircase Voltammetry - SV
 - Large Amplitude Sinusoidal Voltammetry - LASV
 - AC Voltammetry - ACV
 - Levich plot
 - Impedance Spectroscopy
 - Pulsed Techniques
 - Technique Builder
 - Manual Control
 - Ohmic Drop Determination
 - Bipotentiostat
- Electrochemical Applications

Insert Technique

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 -747,3 mV I 0 A Buffer 0 Eoc -747,3 mV Q-Qo 0 A.h I Range open

VMP-3e 10.11.1.106 Channel 1 Amplifier : None EIS Modify mode 0,0 Undersample: Off 21 774 b/s

Cyclic voltammetry (CV) description and graph:

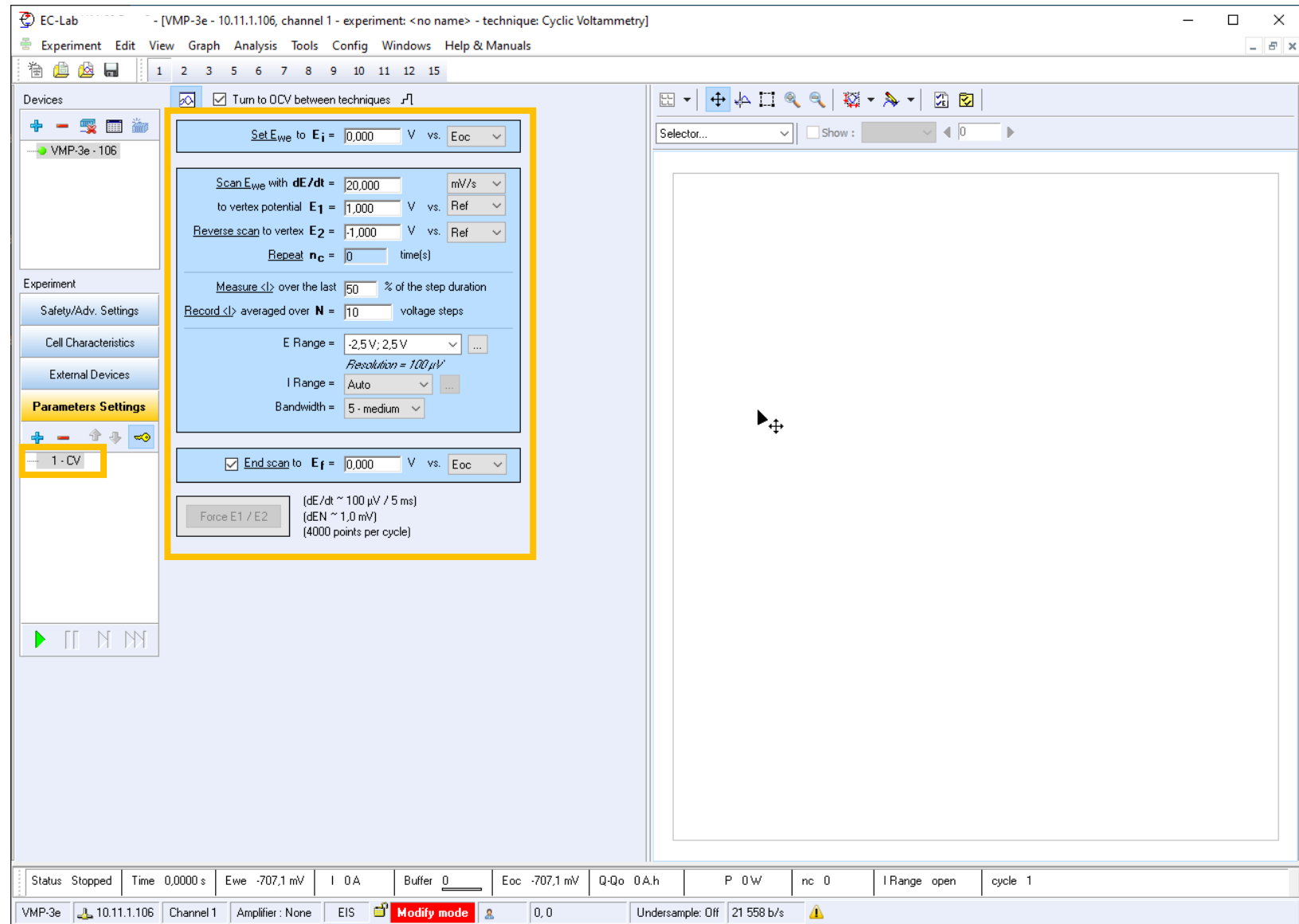
Cyclic voltammetry (CV) is the most widely used technique for acquiring qualitative informations about electrochemical reactions. CV provides informations on redox processes, heterogeneous electron-transfer reactions and adsorption processes. It offers a rapid location of redox potential of the electroactive species. CV consists of scanning linearly the potential of a stationary working electrode using a triangular potential waveform. During the potential sweep, the potentiostat measures the current resulting from electrochemical reactions (consecutive to the applied potential). The cyclic voltammogram is a current response as a function of the applied potential.

The graph shows a triangular potential waveform with potential (E) on the y-axis and time (t) on the x-axis. The waveform is labeled 'cycle' and shows the potential scanning between E₁ and E₂, with E_f indicating the final potential.



Step 1: Add CV technique

- CV technique is loaded in the technique list
- Corresponding CV parameter settings appear





Step 1: Add CV technique

General parameters

Technique parameters

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 - CV

Turn to OCV between technique 

Set E_{we} to $E_i = 0,000$ V vs. Eoc

Scan E_{we} with $dE/dt = 20,000$ mV/s

to vertex potential $E_1 = 1,000$ V vs. Ref

Reverse scan to vertex $E_2 = -1,000$ V vs. Ref

Repeat $n_c = 0$ time(s)

Measure <I> over the last 50 % of the step duration

Record <I> averaged over N = 10 voltage steps

E Range = -2,5 V; 2,5 V

Resolution = 100 μ V

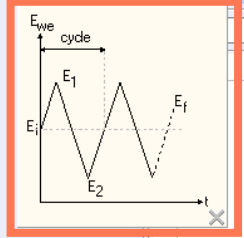
I Range = Auto

Bandwidth = 5 - medium

End scan to $E_f = 0,000$ V vs. Eoc

Force E_1 / E_2

($dE/dt \sim 100 \mu$ V / 5 ms)
($dEN \sim 1,0$ mV)
(4000 points per cycle)



Status: Stopped Time: 0,0000 s $E_{we} = -717,6$ mV $I = 0$ A Buffer: 0 $E_{oc} = -717,6$ mV $Q_{cd} = 0$ A.h Power: 0 mW $n_c = 0$ I Range: open cycle: 1

VMP-3e 10.11.1.106 Channel 1 Amplifier: None EIS **Modify mode** 0,0 Undersample: Off 21 738 b/s

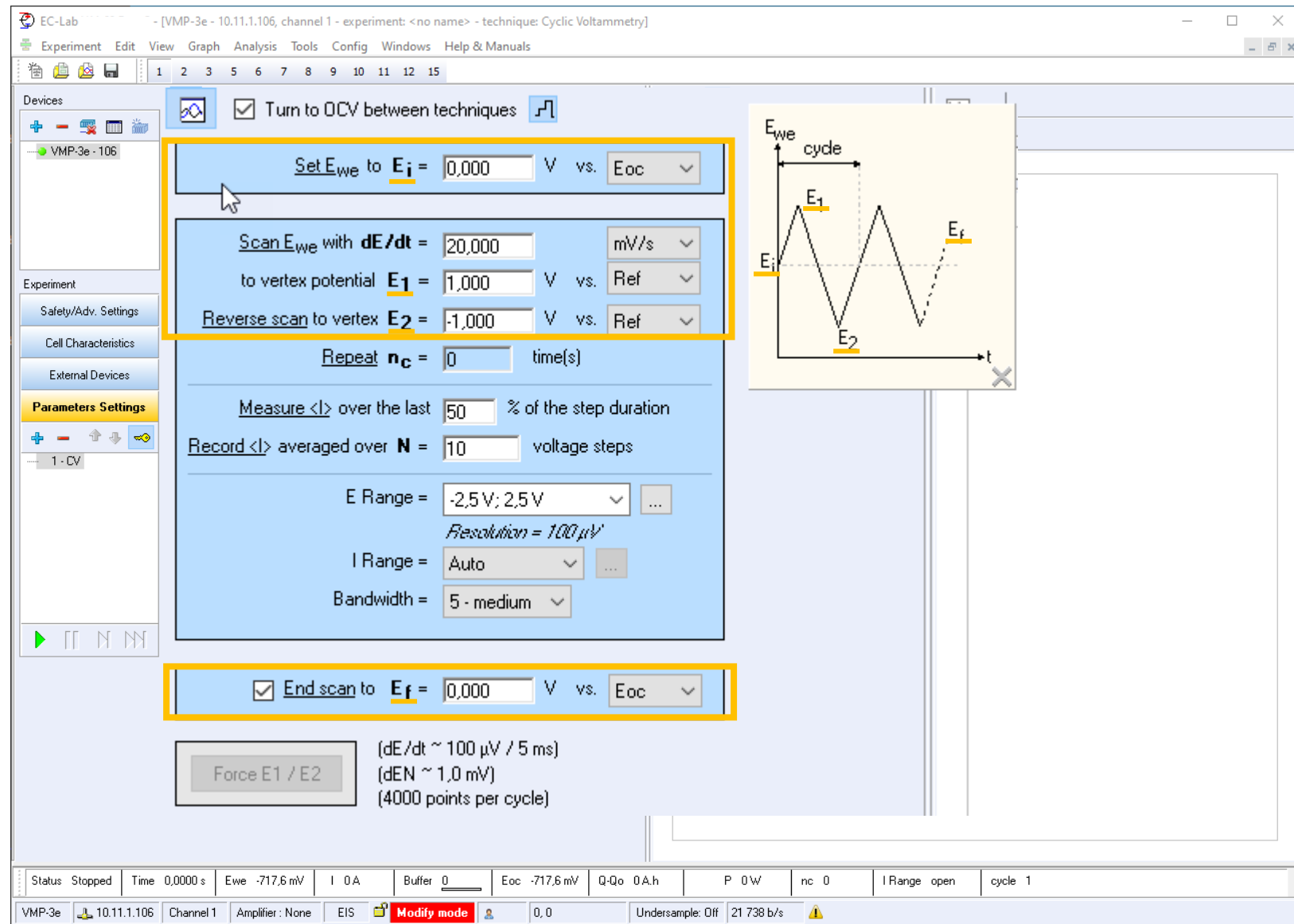


You can display the description of the settings by clicking on the  icon.



Step 2: Set CV parameters

- Set E_i , dE/dt , E_1 and E_2 to define voltage ramp and voltage sweep
- The final voltage E_f can be defined





Step 2: Set CV parameters

Define E_i , E_1 , E_2 , E_f versus the voltage of:

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

Turn to OCV between techniques ☒

Set E_{we} to E_i = 0,000 V vs. **Eoc**

Scan E_{we} with dE/dt = 20,000 mV/s

to vertex potential E_1 = 1,000 V vs. **Ref**

Reverse scan to vertex E_2 = -1,000 V vs. **Ref**

Repeat n_c = 0 time(s)

Measure <I> over the last 50 % of the step duration

Record <I> averaged over N = 10 voltage steps

E Range = -2,5 V; 2,5 V Resolution = 100 μV

I Range = Auto

Bandwidth = 5 - medium

☒ End scan to E_f = 0,000 V vs. **Eoc**

vs. **Eoc**

Ref

Eoc

Ectrl

Emeas



- Set E_i = 0 V vs. Eoc to avoid a current jump at the beginning of the CV.
- Set E_1 and E_2 vs. Ref as OCV may change. E_{Ref} is an absolute voltage value.



Step 2: Set CV parameters

- To perform several cycles, set Repeat n_c

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 - CV

Turn to OCV between techniques

Set E_{we} to E_i = 0,000 V vs. Eoc

Scan E_{we} with dE/dt = 20,000 mV/s to vertex potential E_1 = 1,000 V vs. Ref

Reverse scan to vertex E_2 = -1,000 V vs. Ref

Repeat n_c = 0 time(s)

Measure $\langle I \rangle$ over the last 50 % of the step duration

Record $\langle I \rangle$ averaged over N = 10 voltage steps

E Range = -2,5 V; 2,5 V Resolution = 100 μV

I Range = Auto

Bandwidth = 5 - medium

End scan to E_f = 0,000 V vs. Eoc

Force E_1 / E_2

($dE/dt \sim 100 \mu V / 5 ms$)
($dEN \sim 1,0 mV$)
(4000 points per cycle)

E_{we} cycle
 E_1
 E_i
 E_2
 E_f
 t

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 I Range open cycle 1

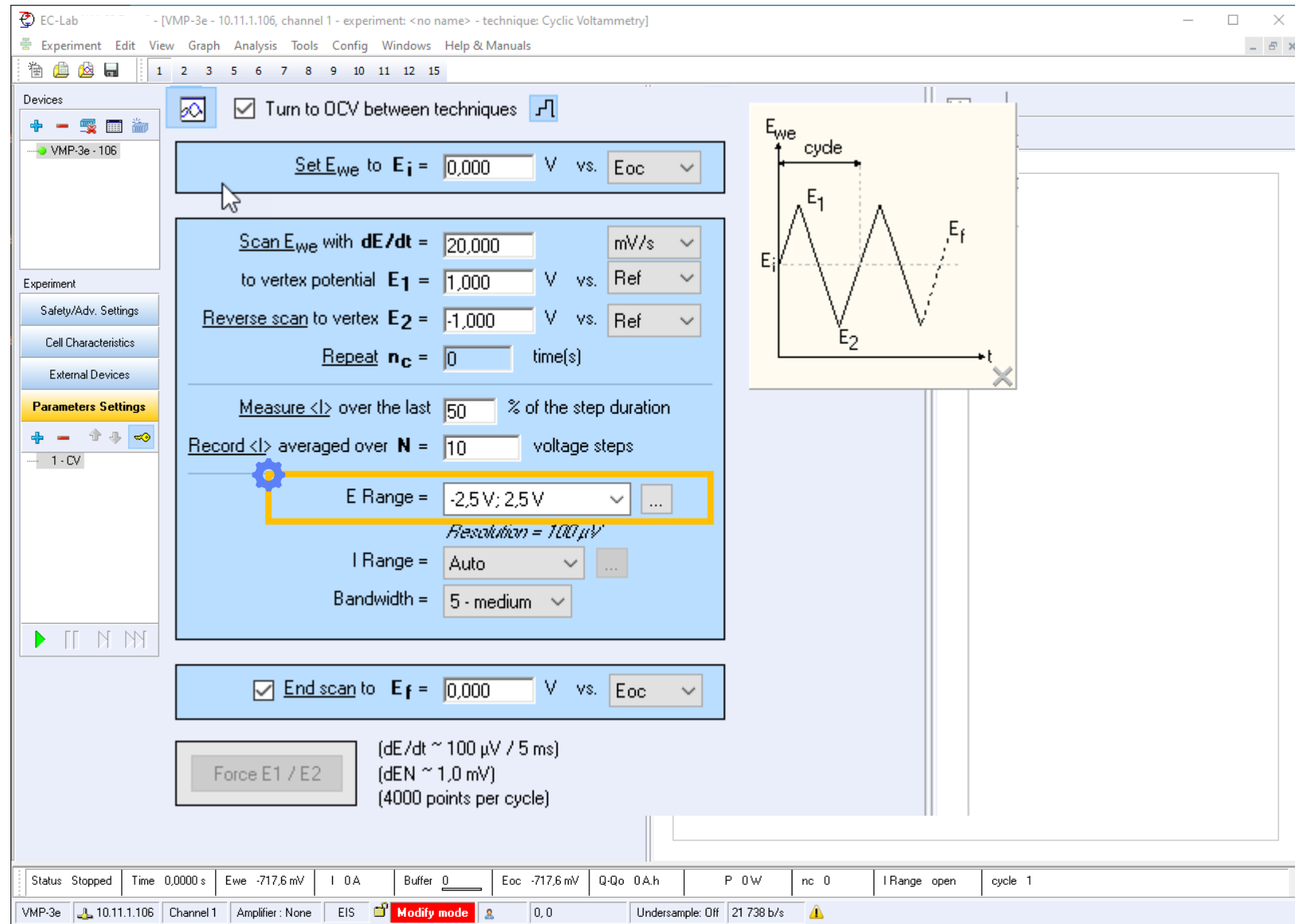
VMP-3e 10.11.1.106 Channel 1 Amplifier: None EIS Modify mode 0,0 Undersample: Off 21 738 b/s



Step 3: Optimize the measurement

- E Range is the range of expected voltage
- E_i , E_1 and E_2 must be in the E Range

⚙️ E Range has to be as narrow as possible, the resolution depends on it.

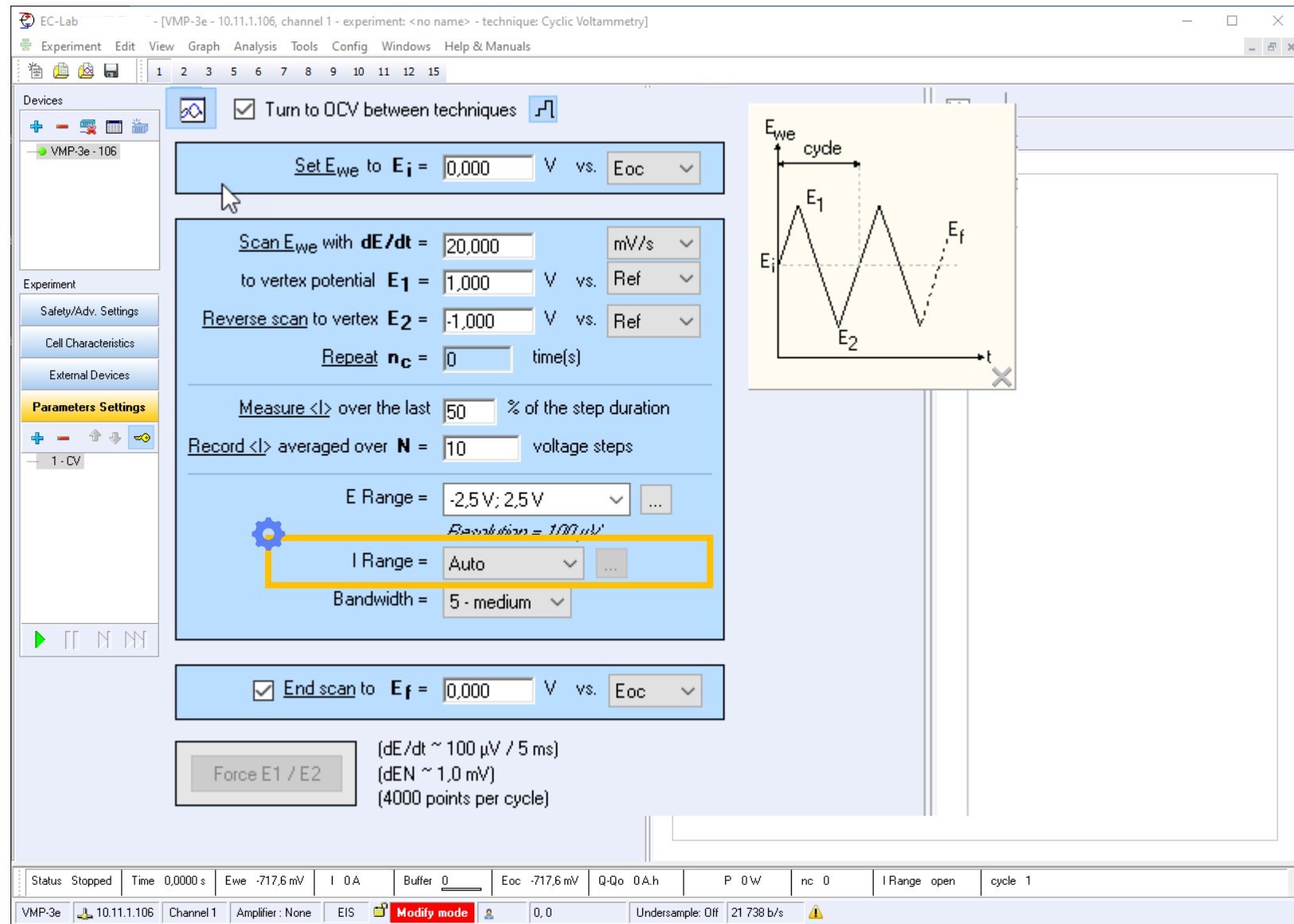




Step 3: Optimize the measurement

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

⚙ For high scan rates, it is recommended to set a fixed I Range because I Range shift duration may be no more negligible.



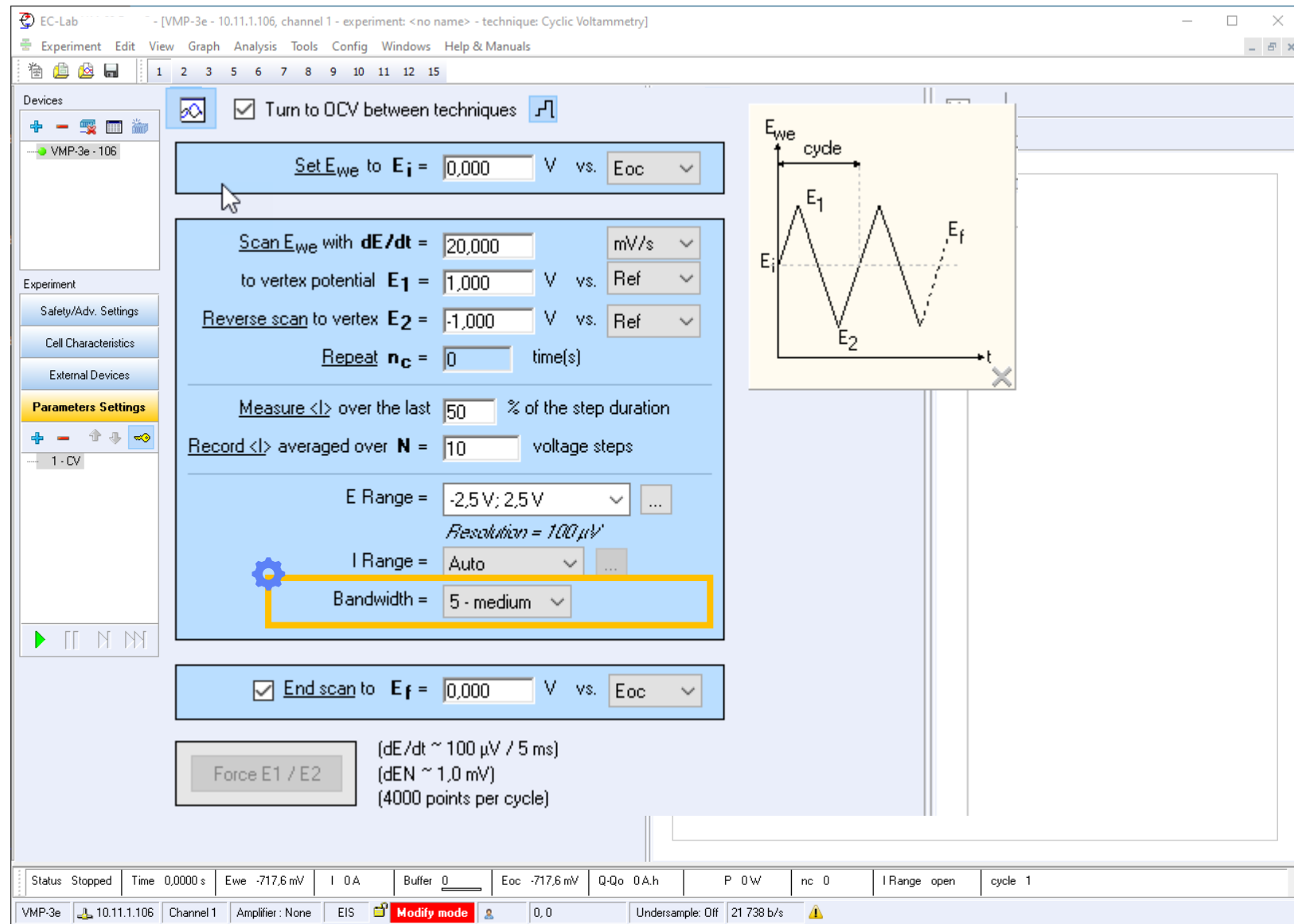


Step 3: Optimize the measurement

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

⚙️ Set fast bandwidth for high scan rate (200mV/s)

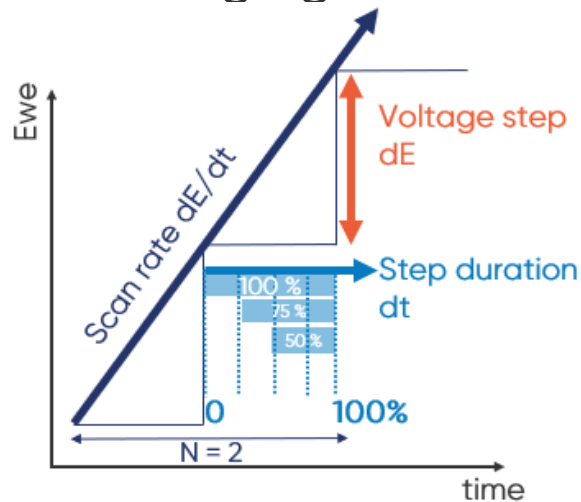
- 7-fast for essential
- 9-fast for premium





Step 3: Optimize the measurement

- Adjust current measurement and averaging



Note: dE is dependent on potential resolution

⚙️ Set to 50% to cut first current value points corresponding to undesired capacitive response of the cell

$N = 10$ voltage steps allows to get smoother data

The screenshot shows the EC-Lab software interface for a Cyclic Voltammetry experiment. The main window displays the following settings:

- Turn to OCV between techniques** (checked)
- Set E_{we} to E_i** = 0,000 V vs. E_{oc}
- Scan E_{we} with dE/dt** = 20,000 mV/s
- to vertex potential E_1** = 1,000 V vs. Ref
- Reverse scan to vertex E_2** = -1,000 V vs. Ref
- Repeat n_c** = 0 time(s)
- Measure <I> over the last** 50 % of the step duration
- Record <I> averaged over N** = 10 voltage steps
- E Range** = -2,5 V; 2,5 V
- Resolution** = 100 μV
- I Range** = Auto
- Bandwidth** = 5 - medium
- End scan to E_f** = 0,000 V vs. E_{oc}
- Force E_1 / E_2** button

Summary of calculated values:

- $dE/dt \sim 100 \mu V / 5 ms$
- $dEN \sim 1,0 mV$
- 4000 points per cycle

The status bar at the bottom shows: Status Stopped, Time 0,000 s, E_{we} -717,6 mV, I 0 A, Buffer 0, E_{oc} -717,6 mV, Q-Qo 0 A.h, P 0 W, n_c 0, I Range open, cycle 1.



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 - CV

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 are store in the data file



Step 4: Set general parameters

Electrode surface area must be set if the user want to work with current density (mA/cm²) instead of current (mA)

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

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

Experiment

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

1 - CV

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 I Range open cycle 1

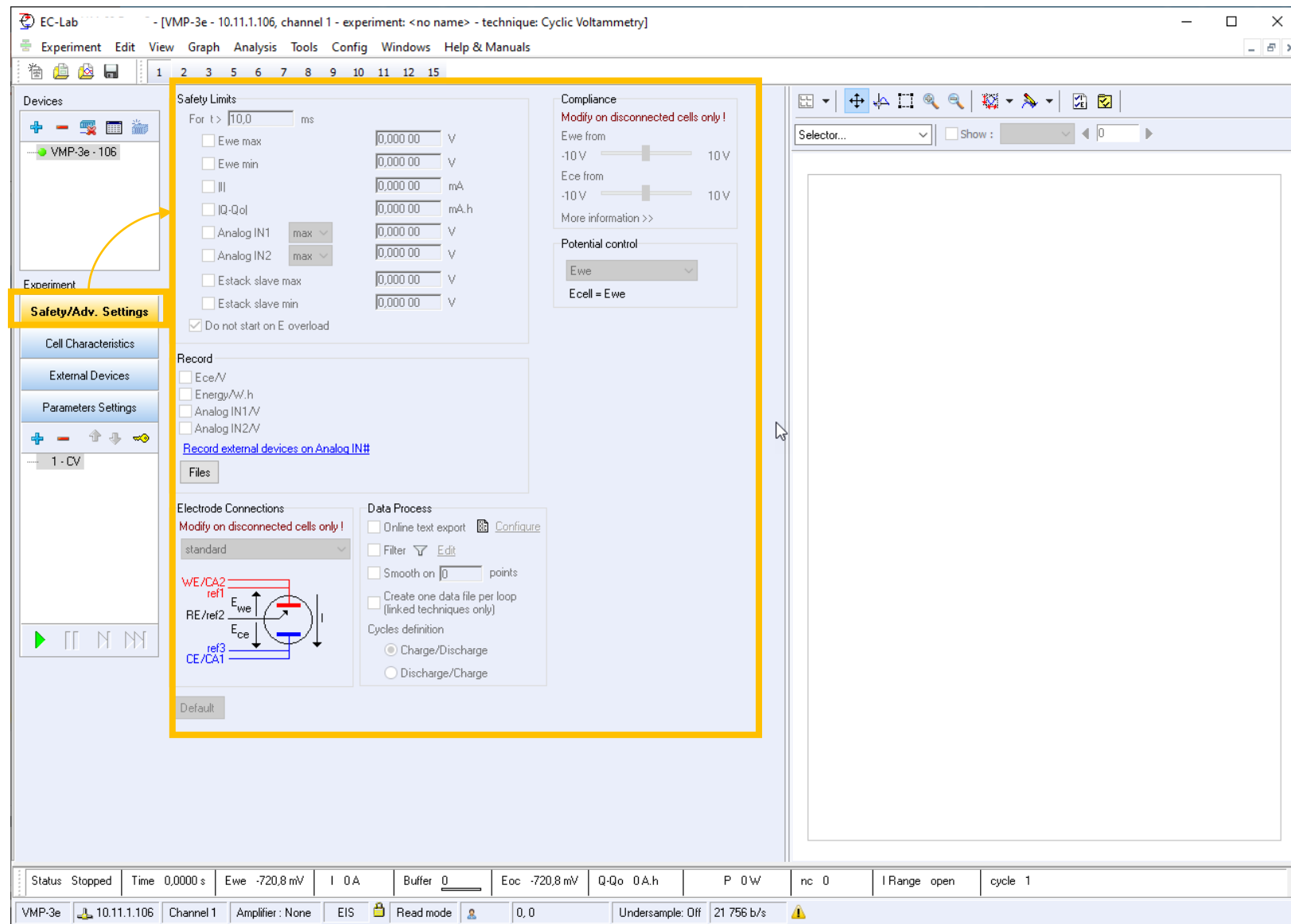
VMP-3e 10.11.1.106 Channel 1 Amplifier: None EIS Read mode 0,0 Undersample: Off 21 540 b/s



Step 4: Set general parameters

- Safety and Advanced Settings are available here

Note: This window is different for the Essential and Premium instruments

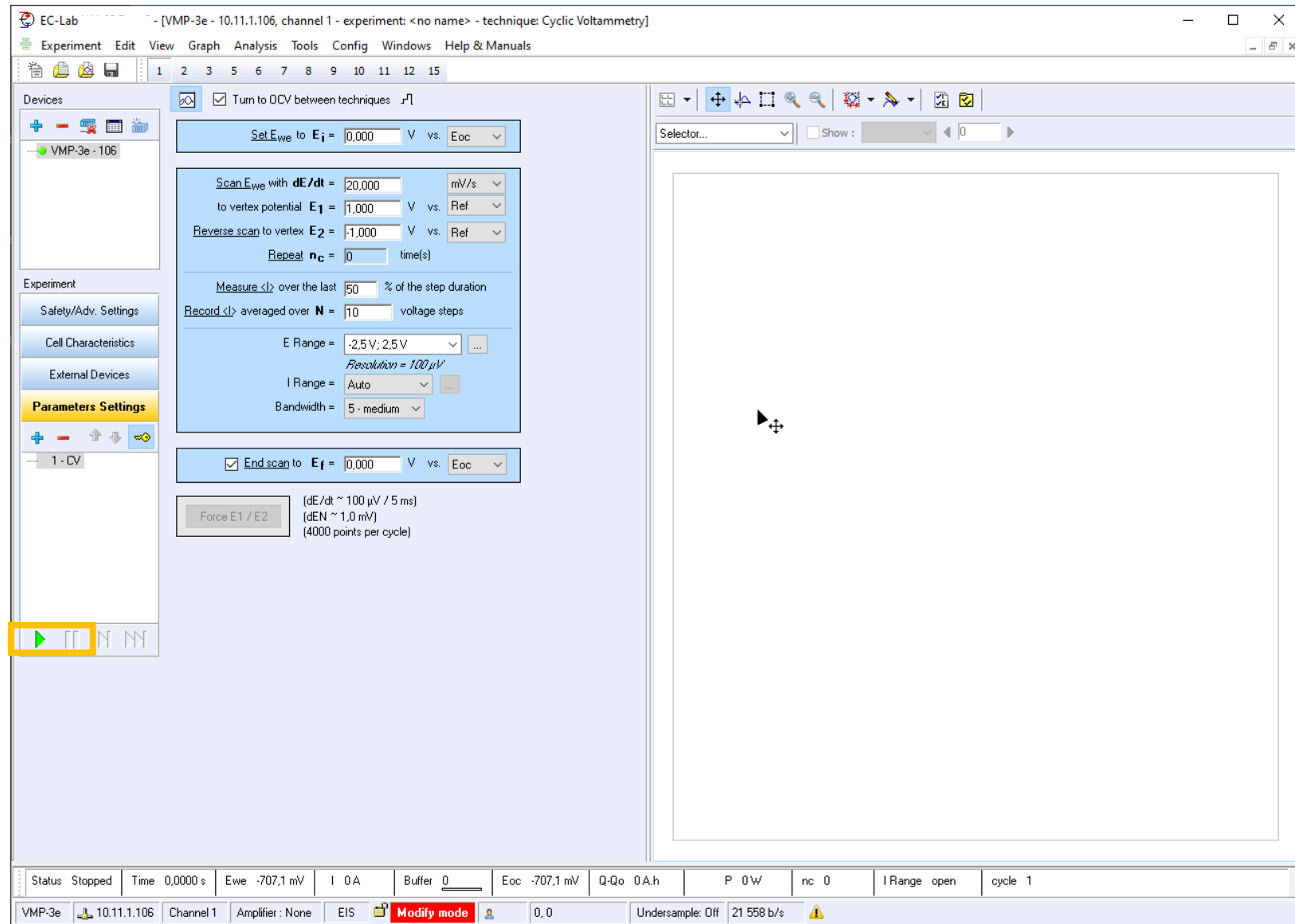




Step 5: Launch the measurement

- Click on ▶ to launch experiment

Note: All the settings may be changed during the experiment (Modify on the fly) except I Range, E Range and bandwidth





Step 5: Launch the measurement

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

Stop experiment

Pause experiment

Next technique

Next sequence

Status Stopped

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

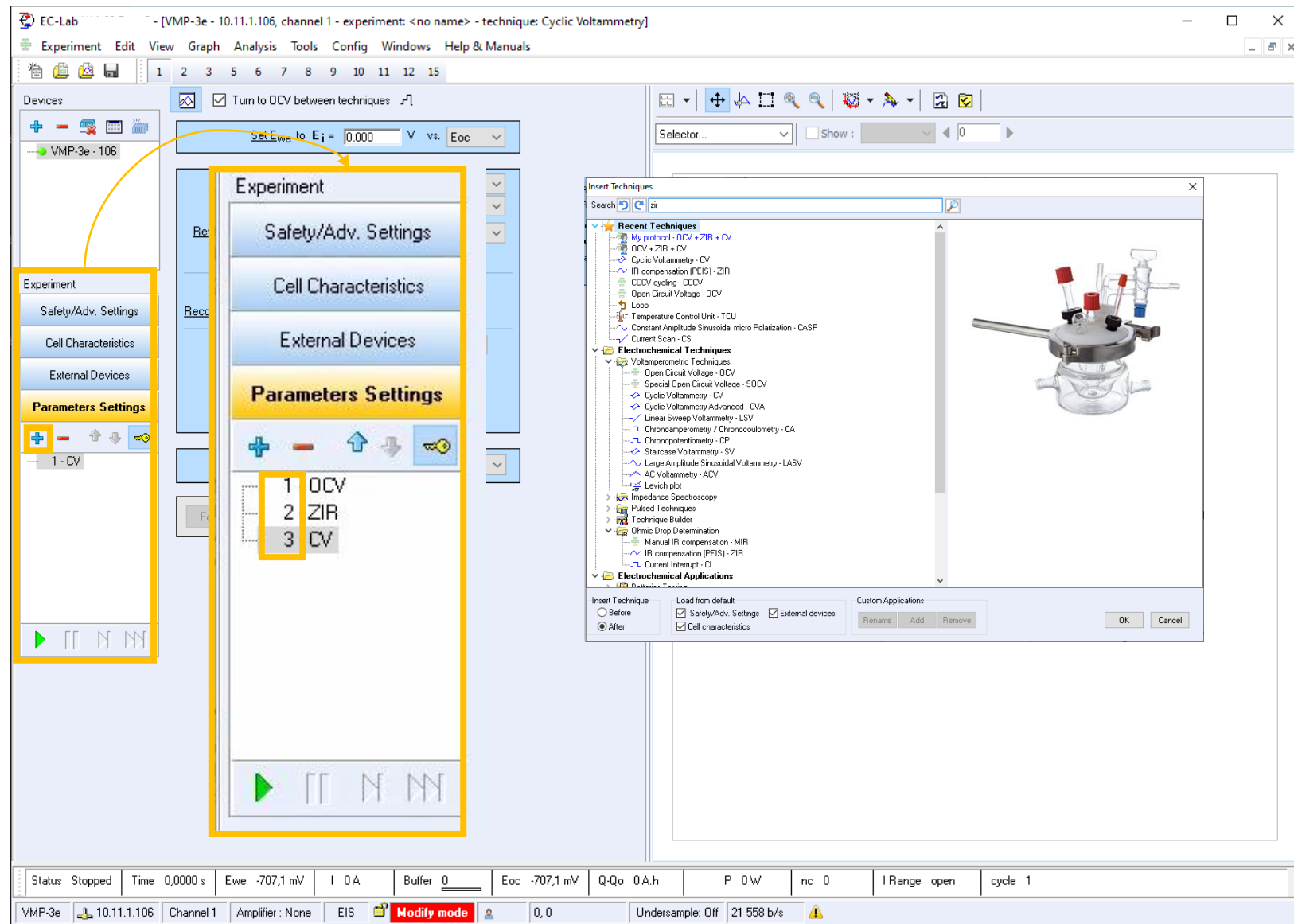
VMP-3e 10.11.1.106 Channel 1 Amplifier : None EIS Modify mode 0,0 Undersample: Off 21 558 b/s

Status of experiment is displayed (Stopped, Paused, Relax...)



Step 6: Add additional experiments

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





Step 6: Add additional experiments

Can be used as a waiting time
for equilibration of the
electrochemical cell

Note: CA or CVA technique
can be used to set a conditioning
period before starting voltage ramp

Can be used to determine
and compensate ohmic drop

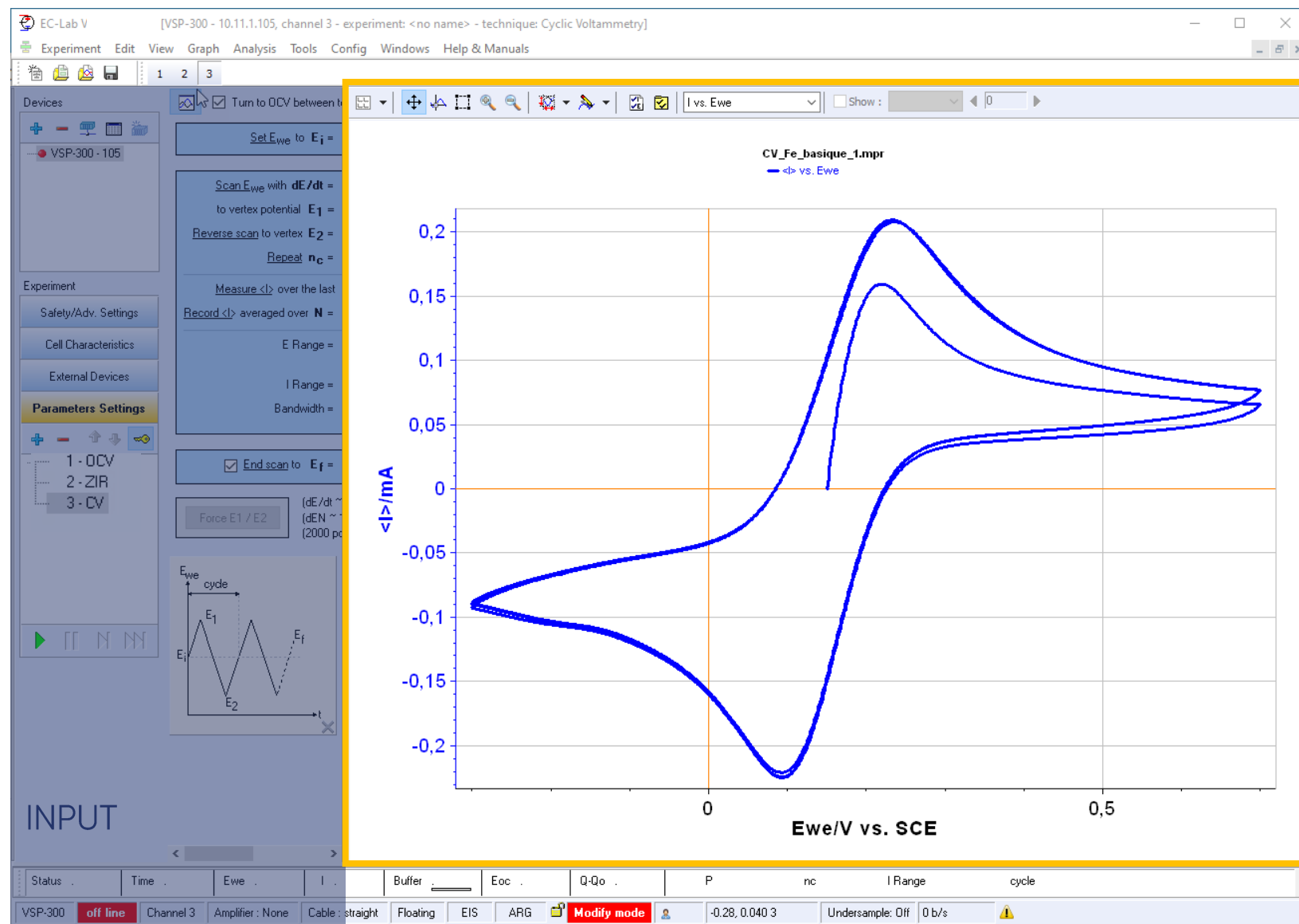
The screenshot displays the EC-Lab software interface. The main window shows the 'Parameters Settings' tab for a 'Cyclic Voltammetry' experiment. Key settings include: 'Set E_{we} to E_i = 0,000 V vs. E_{oc}', 'Scan E_{we} with dE/dt = 20,000 mV/s', 'to vertex potential E₁ = 1,000 V vs. Ref', 'Reverse scan to vertex E₂ = -1,000 V vs. Ref', 'Repeat n_c = 0 time(s)', 'Measure <I> over the last 50 % of the step duration', 'Record <I> averaged over N = 10 voltage steps', 'E Range = -2,5 V; 2,5 V', 'Resolution = 100 µV', 'I Range = Auto', 'Bandwidth = 5 - medium', and 'End scan to E_f = 0,000 V vs. E_{oc}'. A 'Force E1 / E2' button is visible. The 'Devices' list on the left includes 'VMP-3e - 106'. The 'Experiment' section shows 'Safety/Adv. Settings', 'Cell Characteristics', and 'External Devices'. The 'Parameters Settings' section has a list of techniques: '1 - OCV', '2 - ZIR', and '3 - CV'. A red arrow points from the text 'Can be used as a waiting time for equilibration of the electrochemical cell' to the '1 - OCV' technique. Another red arrow points from the text 'Can be used to determine and compensate ohmic drop' to the '2 - ZIR' technique. A third red arrow points from the text 'Note: CA or CVA technique can be used to set a conditioning period before starting voltage ramp' to the '3 - CV' technique. An inset window titled 'Insert Techniques' shows a tree view of 'Recent Techniques' and 'Electrochemical Techniques'. The 'Recent Techniques' list includes 'My protocol - OCV + ZIR + CV', 'OCV + ZIR + CV', 'Cyclic Voltammetry - CV', 'IR compensation (FEIS) - ZIR', 'CCCV cycling - CCCV', 'Open Circuit Voltage - OCV', 'Loop', 'Temperature Control Unit - TCU', 'Constant Amplitude Sinusoidal micro Polarization - CASP', and 'Current Scan - CS'. The 'Electrochemical Techniques' list includes 'Voltamperometric Techniques', 'Open Circuit Voltage - OCV', 'Special Open Circuit Voltage - SOCV', 'Cyclic Voltammetry - CV', 'Cyclic Voltammetry Advanced - CVA', 'Linear Sweep Voltammetry - LSV', 'Chronoamperometry / Chronocoulometry - CA', 'Chronopotentiometry - CP', 'Staircase Voltammetry - SV', 'Large Amplitude Sinusoidal Voltammetry - LASV', 'AC Voltammetry - ADV', 'Levich plot', 'Impedance Spectroscopy', 'Pulsed Techniques', 'Technique Builder', 'Ohmic Drop Determination', 'Manual IR compensation - MIR', 'IR compensation (FEIS) - ZIR', and 'Current Interrupt - CI'. The 'Electrochemical Applications' section has buttons for 'Insert Technique', 'Load from default', 'Safety/Adv. Settings', 'External devices', 'Cell characteristics', 'Rename', 'Add', and 'Remove'. The status bar at the bottom 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', 'nc 0', 'I Range open', 'cycle 1', 'VMP-3e', '10.11.1.106', 'Channel 1', 'Amplifier: None', 'EIS', 'Modify mode', '0,0', 'Undersample: Off', and '21 558 b/s'.

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 - OCV + ZIR + CV**



Step 7: Read the graph

- Graphic is 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)

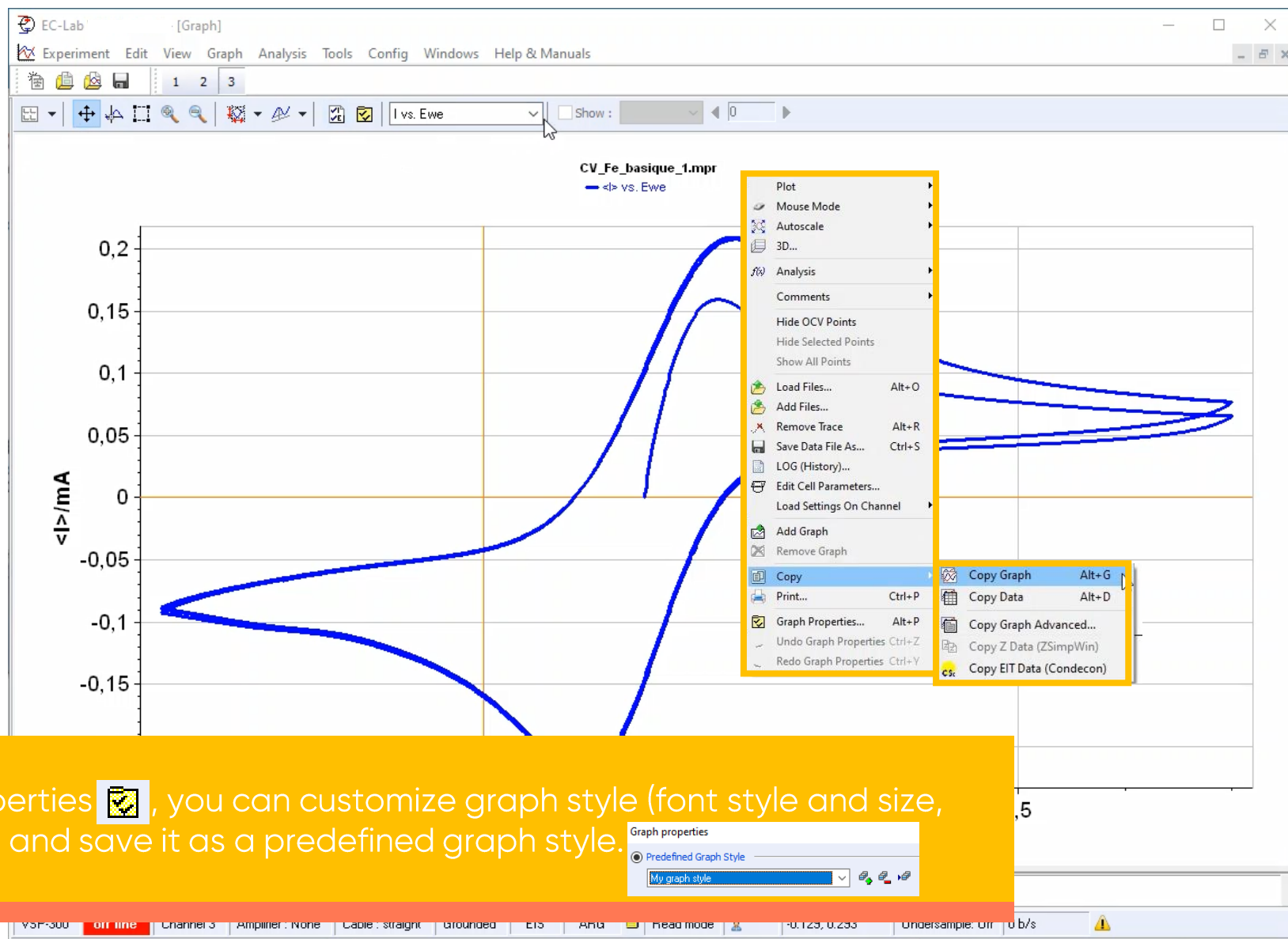
Show only selected
cycle





Step 7: Read the graph

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



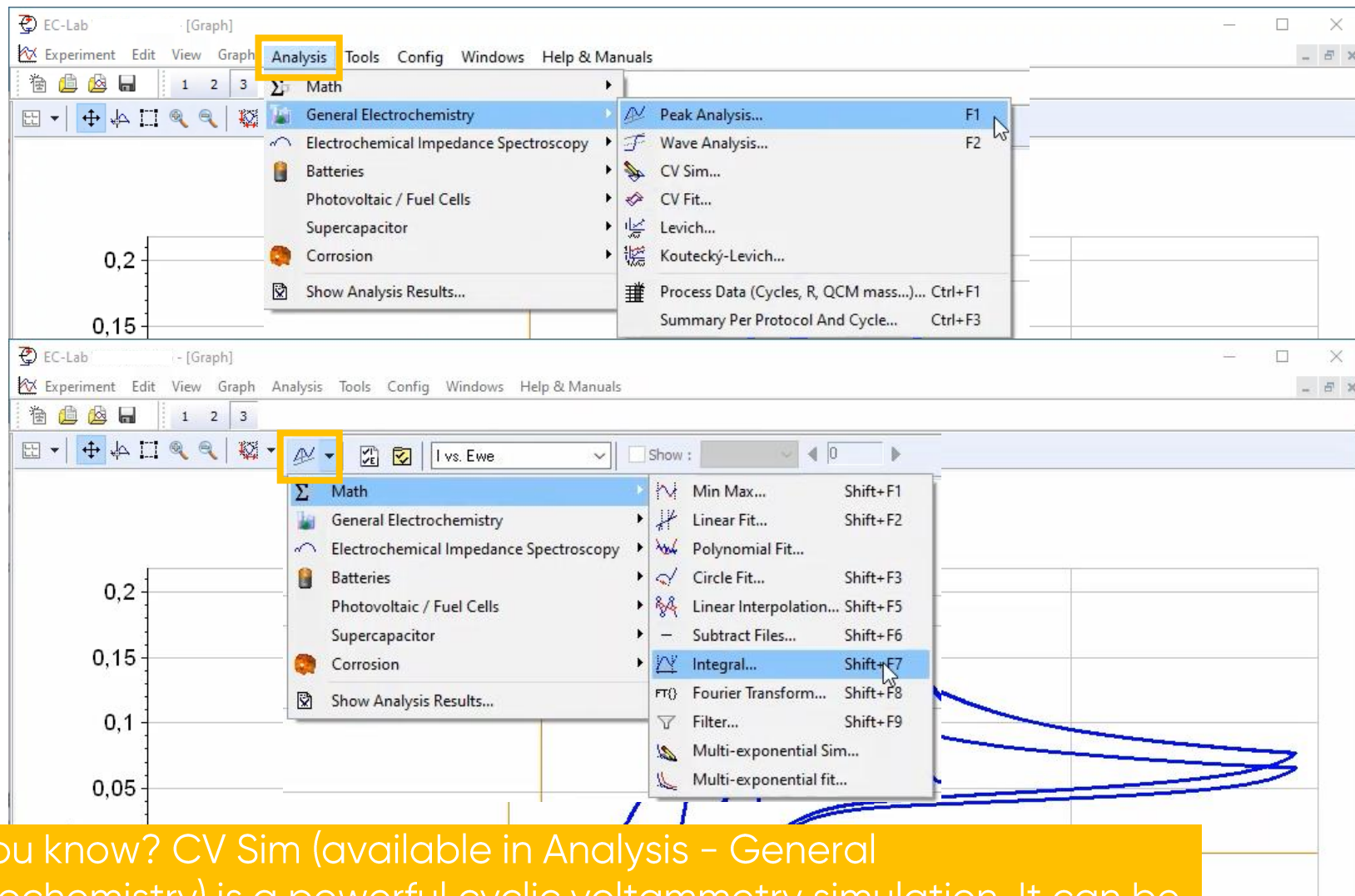
In graph properties , you can customize graph style (font style and size, traces, grid...) and save it as a predefined graph style.



Step 8: Analyse the data

- Analyse the CV
 - Math
 - General Electrochemistry

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



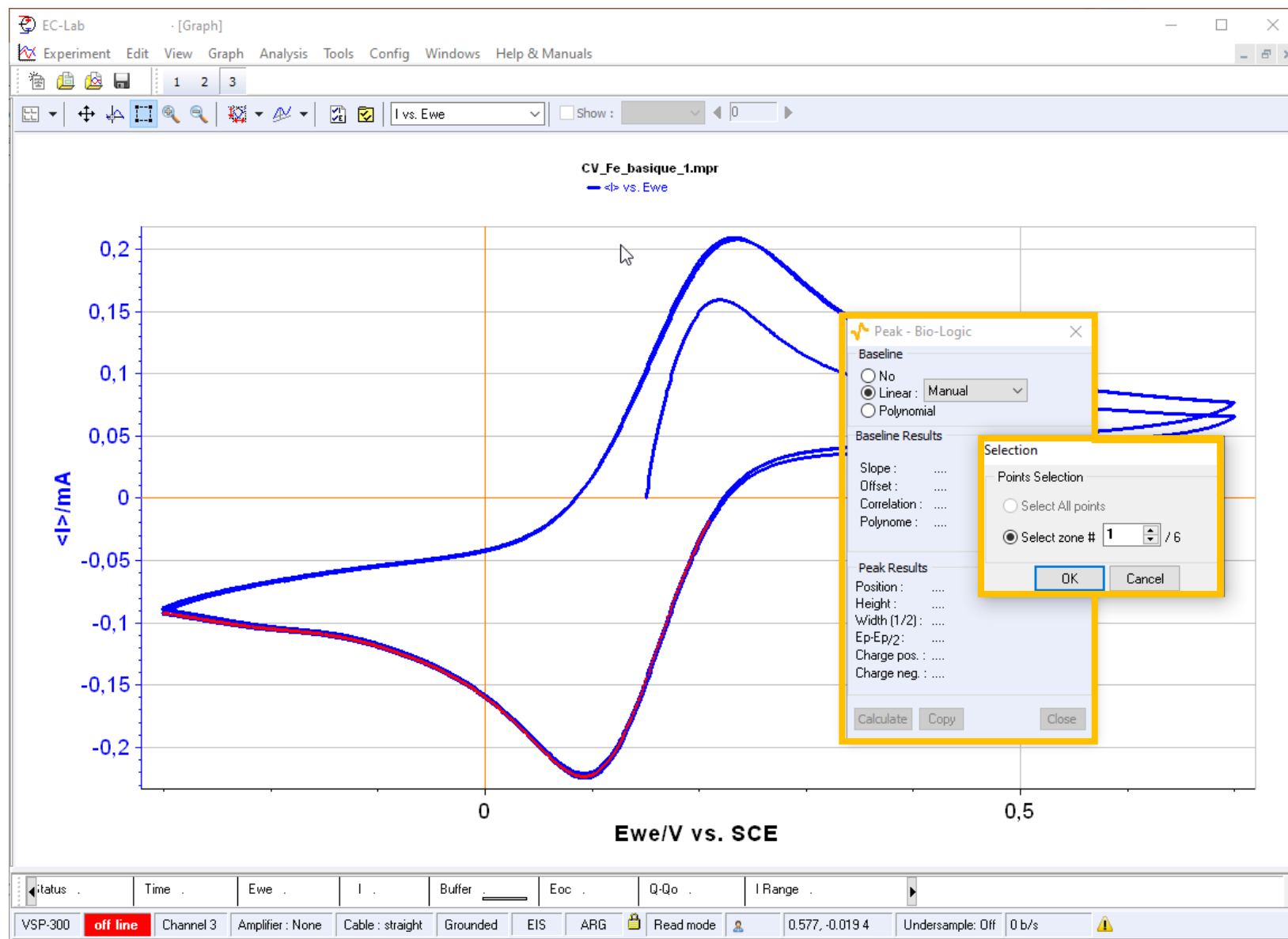
Did you know? CV Sim (available in Analysis – General Electrochemistry) is a powerful cyclic voltammetry simulation. It can be used as a learning tool.



Step 8: Analyse the data

- Peak analysis
 - Select the peak on the graph
 - Click on calculate
 - Select zone (if needed) and click on ok

Note: For details on baseline options, refer to EC-Lab Analysis and Data Process manual

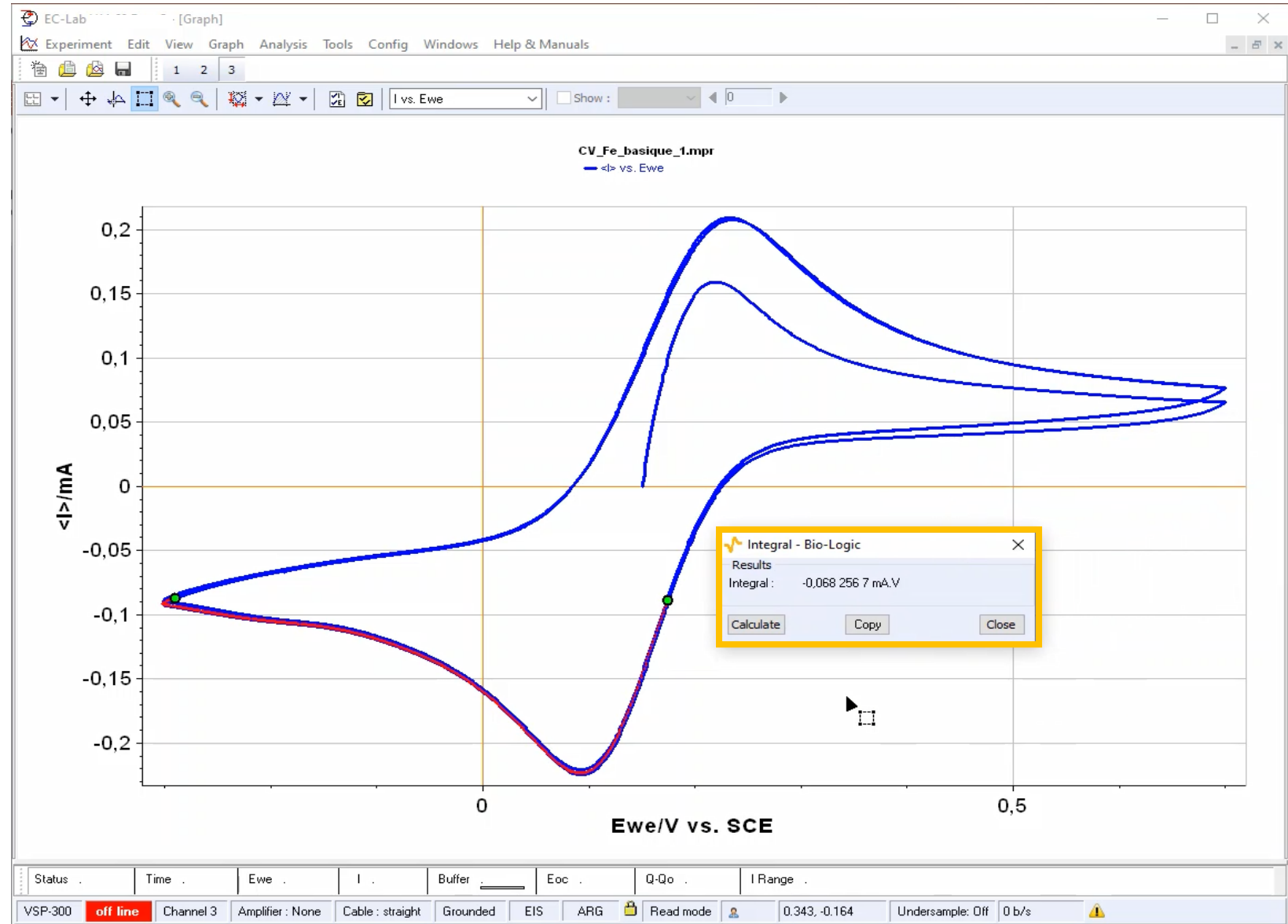




Step 8: Analyse the data

■ Integral

- Select the area of interest on the graph
- Click on calculate
- Select zone (if needed)



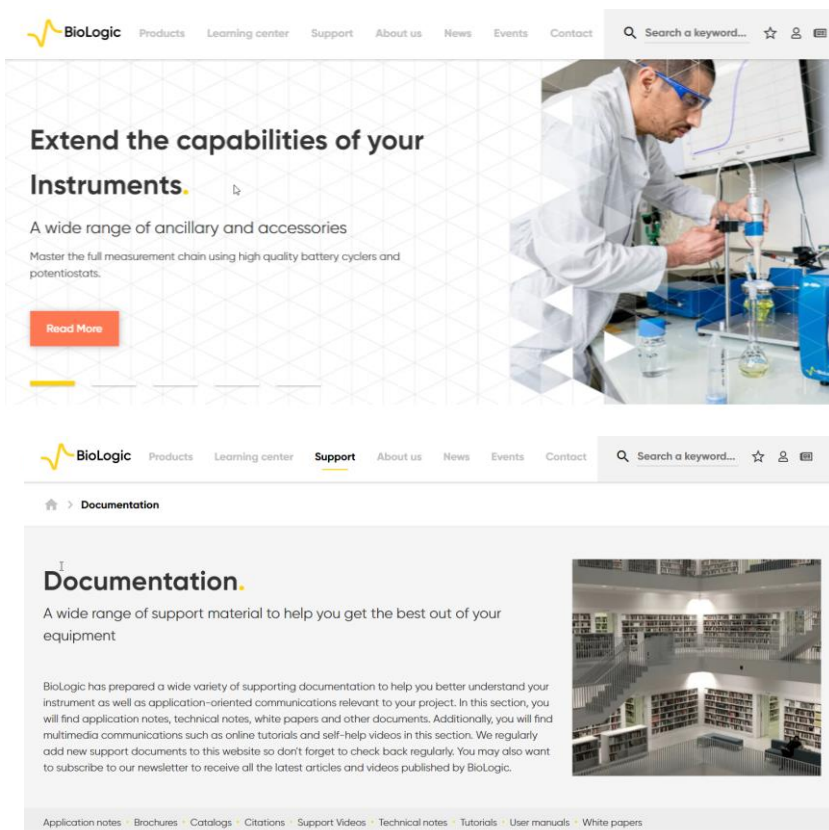


Find out more



For supplementary information

Visit our website!



■ Documentation list

- What is CV? A comprehensive guide to Cyclic Voltammetry (article)
- 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 provide 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

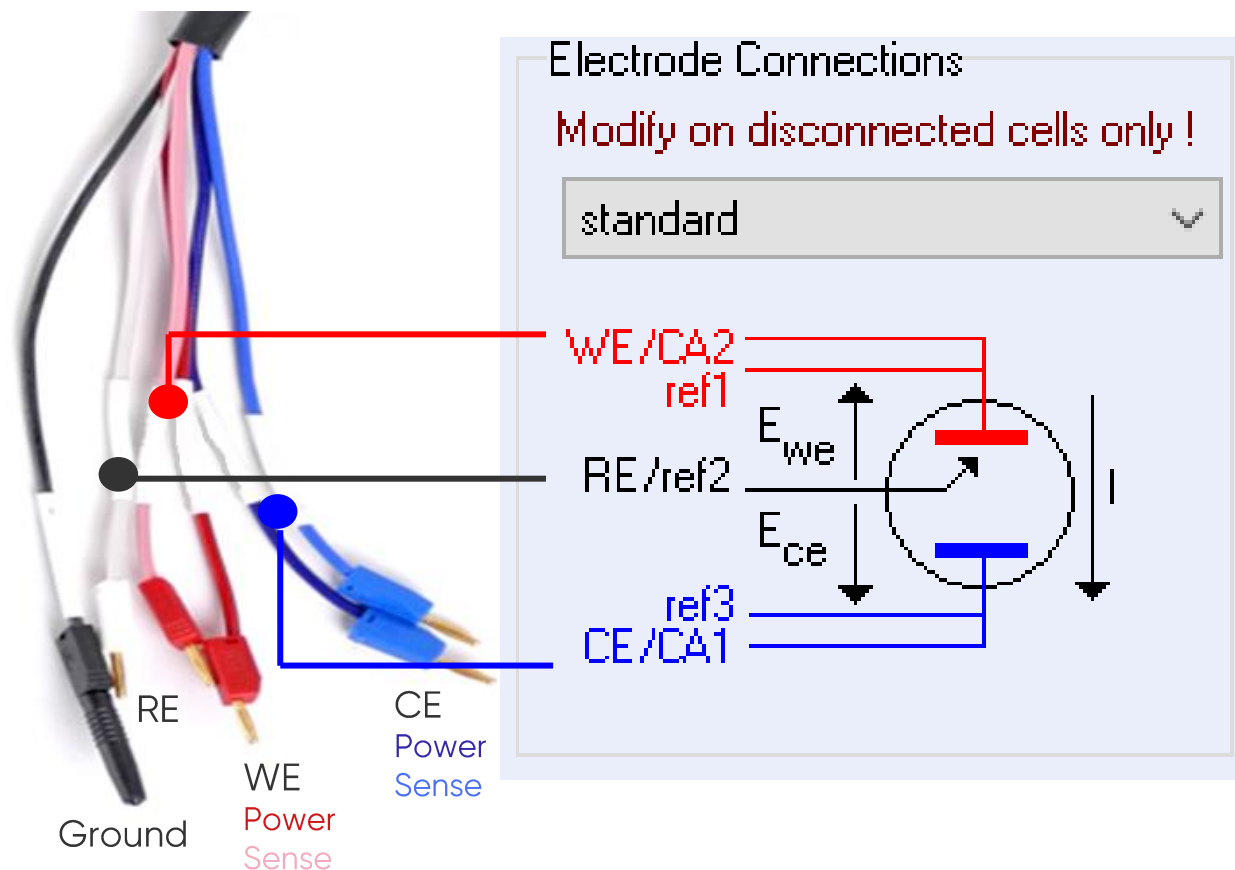


FAQ

- How do I connect potentiostat to the cell?
- How do I select correct bandwidth?
- What is the difference between compliance and control voltage?
- If I do some modifications on the fly on the experiment parameters, how can I remember what I have done?



How do I connect potentiostat to the cell?



- In standard electrode connections mode:
 - Working Electrode (WE)
Connect power and sense
 - Reference Electrode (RE)
 - Counter Electrode (CE)
Connect power and sense

Note: For other connection modes, refer to Connection to the cell (article) or Technical Note #09 and #11, or the Installation and Configuration Manual.



How do I select correct bandwidth?

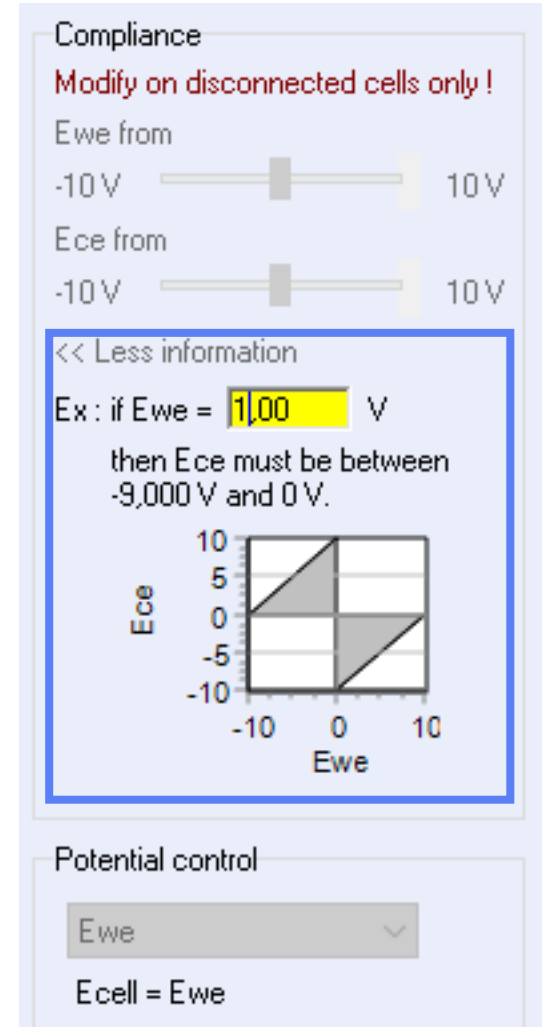
- To quickly verify if the correct bandwidth is selected (no oscillation and stable measurement), you can follow these steps:
 - Change the Bandwidth factor. Start with a lower value. If decreasing the bandwidth factor does not work, try to increase it. The faster, the better.
 - For potentio-dynamic measurements carried out at high scan rates, fast bandwidths must be set.
 - The hardware ohmic drop compensation slows down the regulation loop, so in some cases, you may need to decrease the bandwidth.
 - For Premium range potentiostats, adjust bandwidths 7, 8, 9 first. Then, if the measurement still shows signs of oscillation try the advanced bandwidths 1 to 6.

Note: To go further, refer to Get more from your potentiostat, Understanding bandwidth & its effect on measurements (articles), Application Note #04, Technical Notes #35

What is the difference between compliance and control voltage?

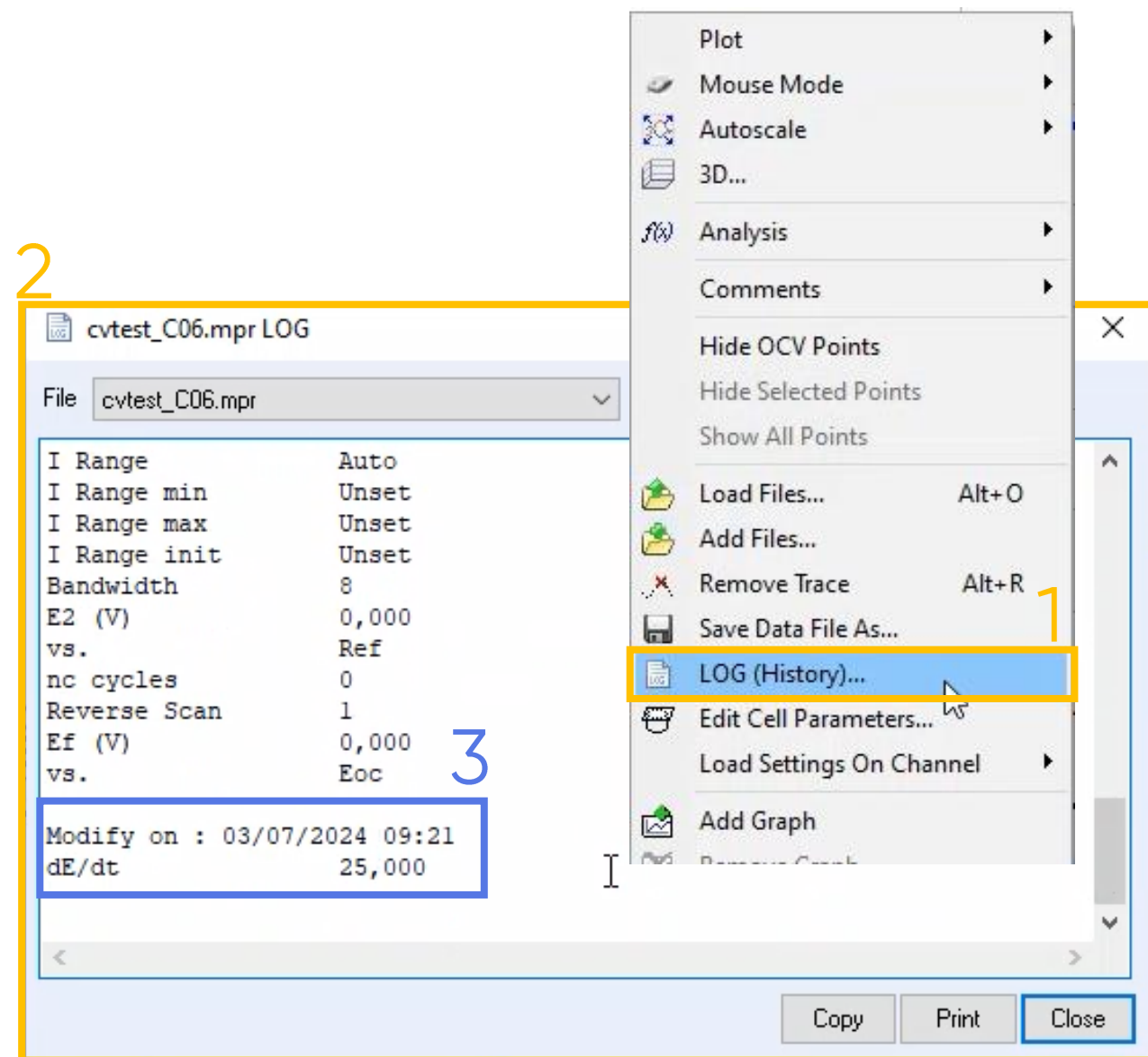
- Compliance is the voltage between WE and CE
- Control voltage is the voltage between WE and RE
- Verify the desired voltage to apply matches with the compliance.
 - For Premium: compliance = ± 12 V
 - For Essential: compliance = 20 V adjustable from ± 10 V, between $[-20 ; 20]$ V

Note: Compliance is adjustable only on essential instrument in Safety/Adv Settings.



If I modify-on-the-fly the experiment parameters, how can I remember what I have done?

- Each experiment is associated with a LOG file (right click on the graph), which is the memory of an experiment
- This file contains the mark of all the change parameters happening during the experiment





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