

Getting Started with EC-Lab[®]: EIS: Electrochemical Impedance Spectroscopy

The aim of this presentation is to guide the user to set the appropriate parameters to perform an EIS measurement.


Only PEIS technique will be discussed hereafter but the information given in the presentation can be adapted to GEIS, SPEIS, SGEIS, PEISW techniques.

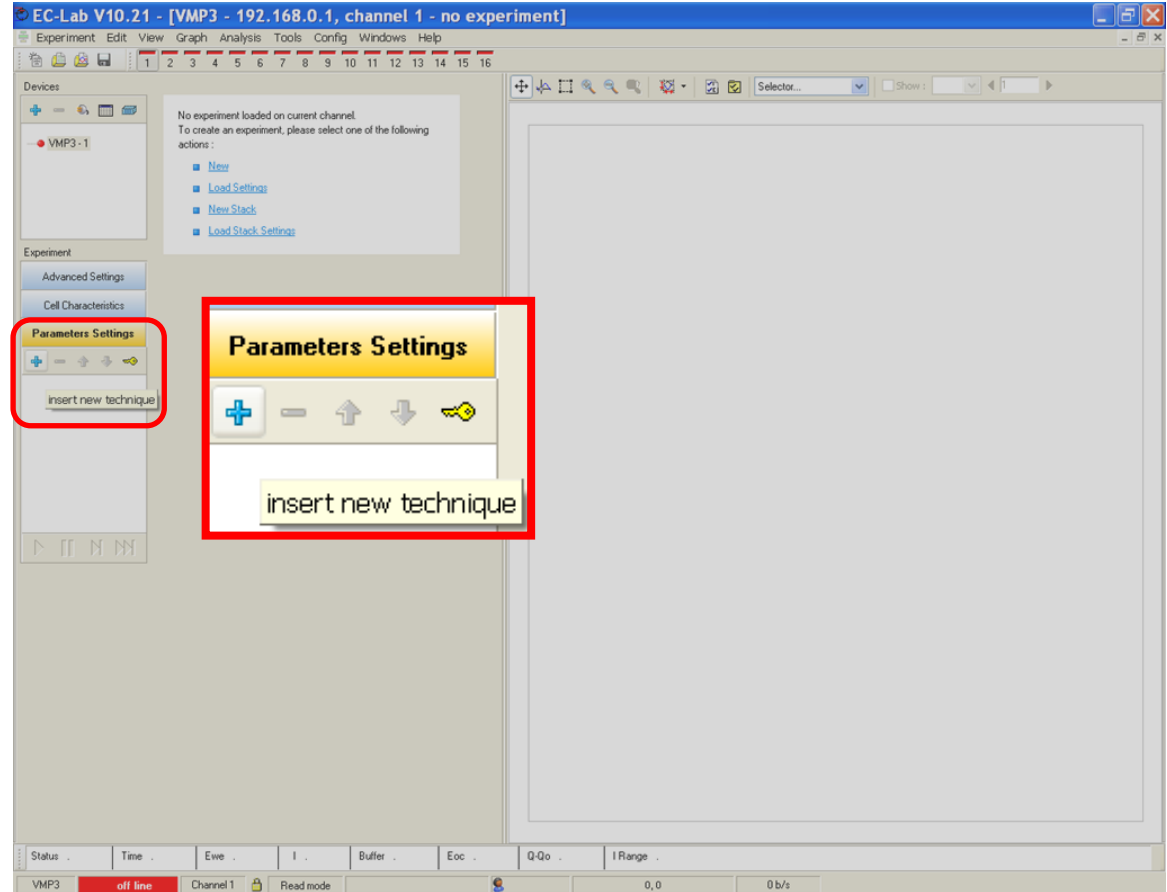
1. Insert the EIS technique
2. Insert other(s) technique(s) if needed
3. Set the « Advanced Setting » tab
4. Set the « Cell Characteristics » tab
5. Set EIS technique
6. Start the experiment

NOTE:

It is assumed that the computer and the instruments are connected. This is explained in the Getting Started named “EC-Lab®: Connection to the instrument(s) & Channel(s) selection”.

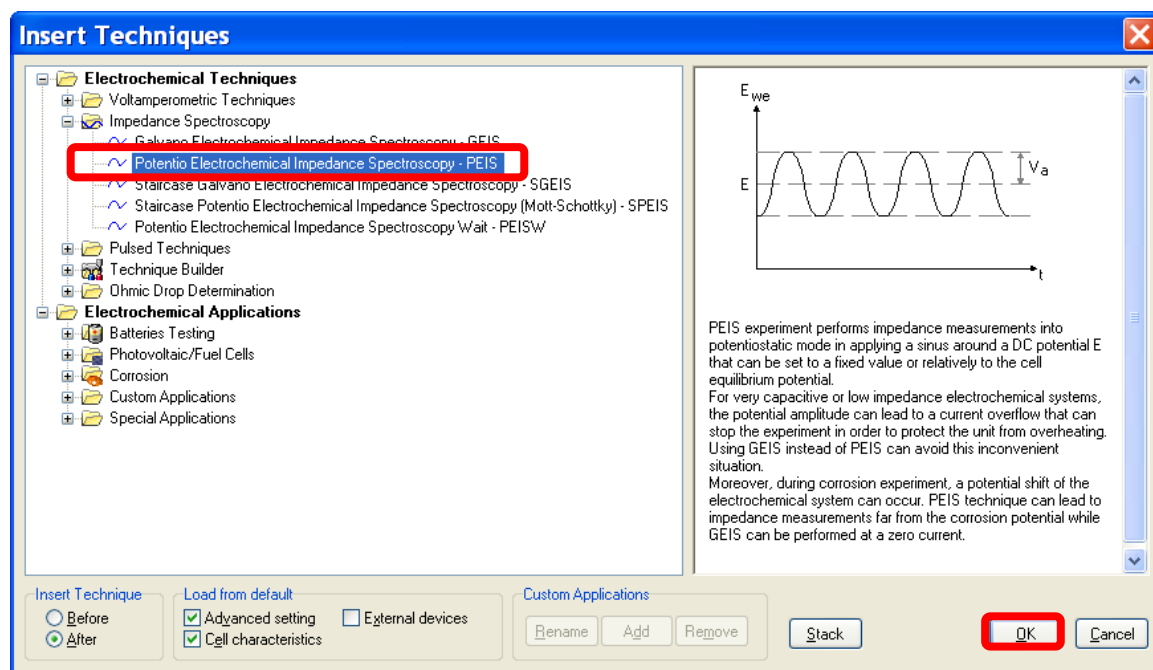
Tutorials on impedance theory are available on request. No theoretical background will be discussed in this getting started.


- In the experiment frame, click on the  button to insert the new technique







- Select “Potentio Electrochemical Impedance Spectroscopy – PEIS” technique available in the “Impedance Spectroscopy” folder. The technique is highlighted in blue when selected

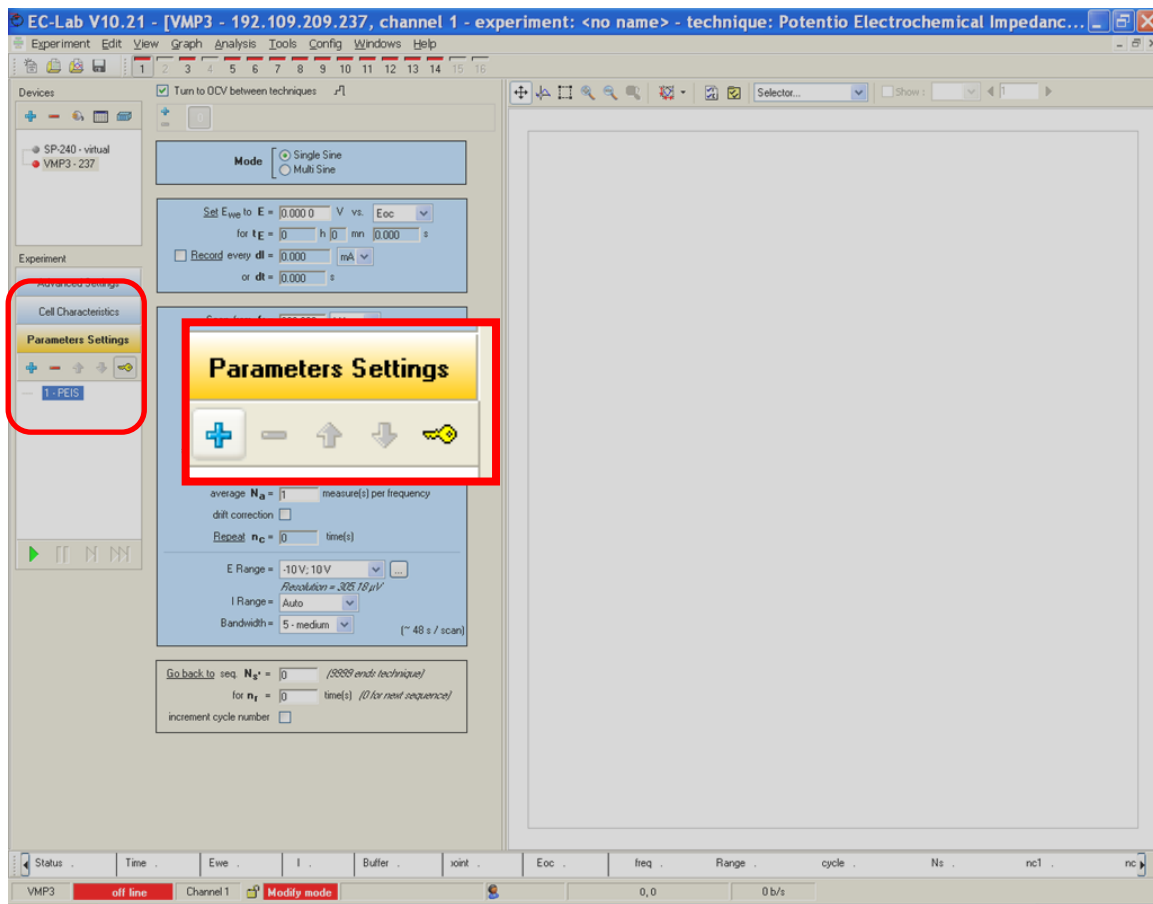
- Click on the “OK” button



• Click on the  button to insert any additional technique(s).

Note: it is possible to remove technique or to move technique before or after. First select the technique that you want to remove/move (the technique will be highlighted in blue) and then by clicking on the appropriate button.

-  To add
-  To remove
-  To move before
-  To move after



- Click on the **Advanced Settings** tab.

Then the « Advanced Settings » window is displayed.

For EIS measurements, the default parameters of the « Advanced Settings » are suitable for most of application.

NOTE:

This window is different for the VMP3 family and for the SP-300 family.

VMP3 family:

SP-50, SP-150, VSP, VMP3, CLB-500, CLB-2000, HCP-803; HCP-1005

SP-300 family:

SP-200, SP-240, SP-300, VSP-300

VMP3 family

Compliance Modify on disconnected cells only !

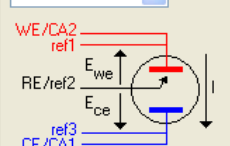
Ewe from -10 V 10 V
 Ece from -10 V 10 V

[More information >>](#)

Safety Limits

E_{we} max = V
 E_{we} min = V
 I_l = mA
 IQ-Qol = mA.h
 Analog IN 1 max V
 Analog IN 2 max V
 E stack slave max = V
 E stack slave min = V
 for t > ms

Electrodes Connection Modify on disconnected cells only !



Miscellaneous

Text export
 Filter [Edit](#)
 Smooth on points
 Create one data file per loop (linked techniques only)

SP-300 family

Filtering

Ewe, I

Safety Limits

E_{we} max = V
 E_{we} min = V
 I_l = mA
 IQ-Qol = mA.h
 Analog IN 1 max V
 Analog IN 2 max V
 for t > ms

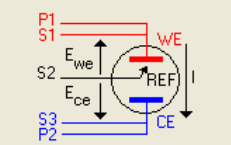
Channel

Floating
 Grounded

Ultra Low Current Option

High speed scan
Definition of high speed value depends on the current range used.

Electrodes Connection Modify on disconnected cells only !



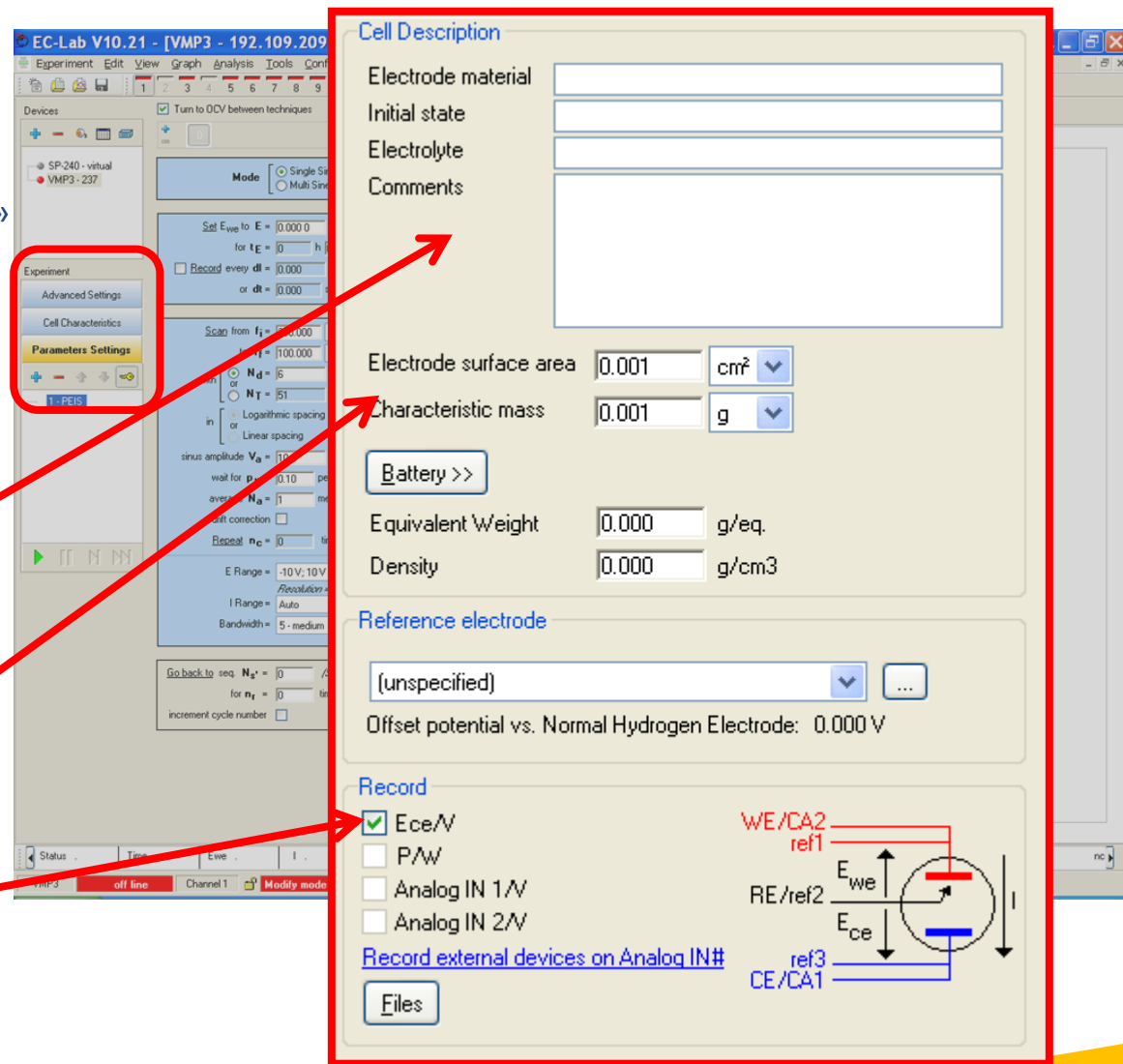
Miscellaneous

Text export
 Filter [Edit](#)
 Smooth on points
 Create one data file per loop (linked techniques only)

4- Set the « Cell Characteristics » tab

- Click on the **Cell Characteristics** tab.

then the « Cell Characteristics » window is displayed.



The screenshot shows the 'Cell Characteristics' tab in the EC-Lab V10.21 software. The 'Cell Description' section is highlighted with a red box. It contains the following fields and options:

- Electrode material: [Empty text box]
- Initial state: [Empty text box]
- Electrolyte: [Empty text box]
- Comments: [Empty text area]
- Electrode surface area: [0.001] cm² (dropdown)
- Characteristic mass: [0.001] g (dropdown)
- Battery >> [Button]
- Equivalent weight: [0.000] g/eq.
- Density: [0.000] g/cm³
- Reference electrode: [(unspecified)] (dropdown)
- Offset potential vs. Normal Hydrogen Electrode: 0.000 V
- Record section:
 - E_{ce}/V
 - P/W
 - Analog IN 1/V
 - Analog IN 2/V
- Record external devices on Analog IN# [Link]
- Files [Button]

At the bottom right of the 'Cell Description' section, there is a schematic diagram of an electrochemical cell. It shows three electrodes: WE/CA2 (top), RE/ref2 (middle), and CE/CA1 (bottom). The WE/CA2 electrode is connected to a positive terminal, and the CE/CA1 electrode is connected to a negative terminal. The RE/ref2 electrode is connected to a reference terminal. The diagram also shows the potential E_{we} and E_{ce} and the current I.

Information about the cell and some comments.

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

TIP:
Possible to record the impedance of the WE but also the **impedance of the CE**.


NOTE:
All these information are stored in the data file

5- Set the EIS technique

Parameters Settings

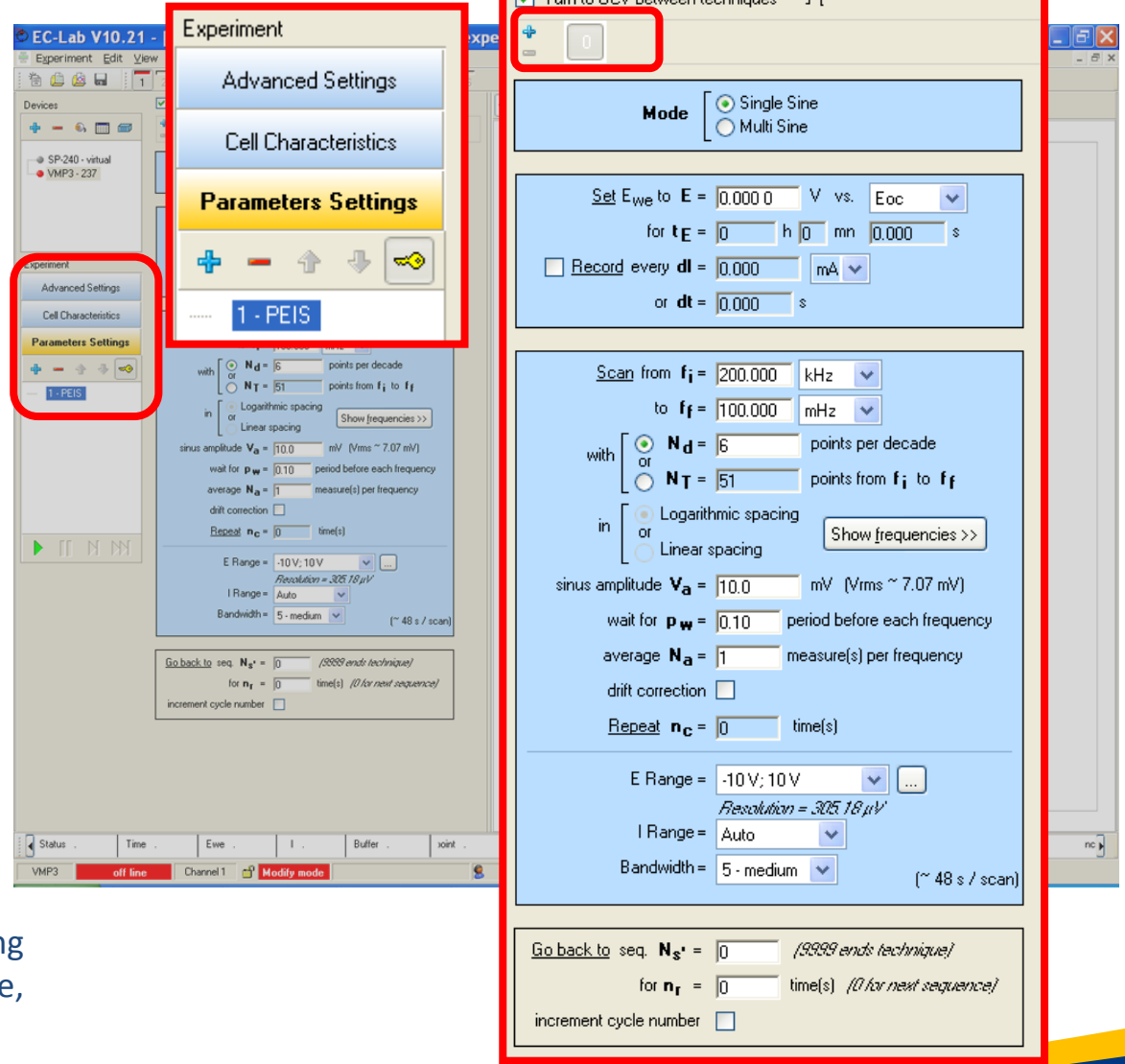
Click on the **Parameters Settings** tab or directly on the EIS technique in the list of techniques. The technique is highlighted in blue.

- Three different blocks composed the EIS technique (described in the next slide):
 - First, select single or multisine mode
 - Second, conditioning and initial period
 - Third, EIS measurement (amplitude, frequency, sampling rate)

It is possible to add or remove sequence by clicking on the  buttons

NOTE:

All the settings may be changed during the experiment (except I range, E range, bandwidth, single/multisine mode).



Turn to OCV between techniques

Mode Single Sine Multi 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

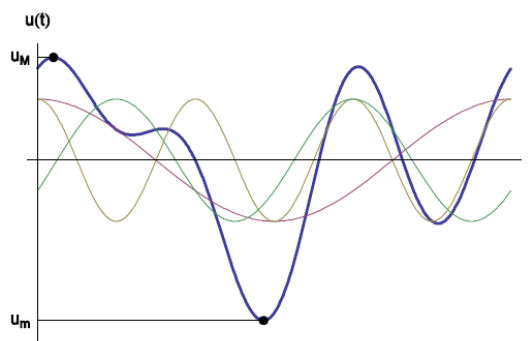
Scan from $f_i = 200.000$ kHz to $f_f = 100.000$ mHz
 with $N_d = 6$ points per decade
 or $N_T = 51$ points from f_i to f_f
 in Logarithmic spacing Linear spacing Show frequencies >>

sinus amplitude $V_a = 10.0$ mV ($V_{rms} \sim 7.07$ mV)
 wait for $p_w = 0.10$ period before each frequency
 average $N_a = 1$ measure(s) per frequency
 drift correction
 Repeat $n_c = 0$ time(s)

E Range = -10 V; 10 V
Resolution = 305.18 μ V
 I Range = Auto
 Bandwidth = 5 - medium (~ 48 s / scan)

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

To reduce the duration of the experiment, the multisine mode is available. Several frequencies are applied in the meantime. This mode is active only for frequencies below 10 Hz.



5- Set the EIS technique

Turn to OCV between techniques

Mode: Single Sine Multi Sine

Set E_{we} to $E = 0.0000$ V vs. E_{oc} 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 or $N_T = 51$ points from f_i to f_f

in Logarithmic spacing or Linear spacing Show frequencies >>

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

wait for $p_w = 0.10$ period before each frequency

average $N_a = 1$ measure(s) per frequency

drift correction

Repeat $n_c = 0$ time(s)

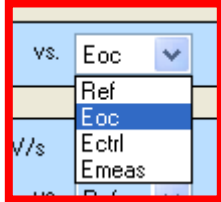
E Range = -10 V; 10 V Resolution = $305.18 \mu V$

I Range = Auto

Bandwidth = 5 - medium (~ 48 s / scan)

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

- Defines the potential at which the EIS measurement will be performed. This can be defined *versus* several voltage reference.



- Ref** (the potential of the reference electrode)
- Eoc** (Open circuit voltage)
- Ectrl** (potential of the previous controlled voltage, if a technique is set before the EIS)
- Emeas** (potential of the previous measured voltage, if a technique is set before the EIS)

It is possible to hold this potential during a certain time (t_E) before starting the experiment (conditioning period).

5- Set the EIS technique

Turn to OCV between techniques

Mode: Single Sine, Multi Sine

Set E_{We} to $E = 0.0000$ V vs. E_{oc}
 for $t_E = 0$ h 0 min 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
 or $N_T = 51$ points from f_i to f_f
 in Logarithmic spacing
 or Linear spacing **Show frequencies >>**

sinus amplitude $V_a = 10.0$ mV ($V_{rms} \sim 7.07$ mV)
 wait for $p_w = 0.10$ period before each frequency
 average $N_a = 1$ measure(s) per frequency
 drift correction
 Repeat $n_c = 0$ time(s)

E Range = -10 V; 10 V
Resolution = 305.18 μ V
 I Range = Auto
 Bandwidth = 5 - medium **(~ 48 s / scan)**

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

Defines the frequency sweep:

- min and max frequencies
- data point sampling (log or linear spacing, points per decade, or total point between min and max frequencies).

NOTE:

To check the frequencies at which the EIS are performed, click on the **Show frequencies >>** button.

The duration of the experiment is indicated at the bottom of the block in *italics*. It depends on the range of frequencies, the chosen sampling and also on the N_a parameters (shown in a next slide).

Frequencies list

Frequencies (Hz)

200 000.000 000
135 123.811 858
91 292.222 655
61 678.765 590
41 671.349 586
28 153.958 007
19 021.350 624
12 851.187 015
8 682.506 882
5 866.067 132
3 963.226 757
2 677.631 533
1 809.058 898
1 222.234 671

Number of frequencies: 38

EC-Lab calculus **Close**

Turn to OCV between techniques

Mode Single Sine Multi 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
or $N_T = 51$ points from f_i to f_f

in Logarithmic spacing Linear spacing Show frequencies >>

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

wait for $p_w = 0.10$ period before each frequency

average $N_a = 1$ measure(s) per frequency

drift correction

Repeat $n_c = 0$ time(s)

E Range = -10 V; 10 V ...
Resolution = 305.18 μ V

I Range = Auto

Bandwidth = 5 - medium (~ 48 s / scan)

Go back to seq. $N_s = 0$ (9999 ends technique)
for $n_r = 0$ time(s) (0 for next sequence)

increment cycle number

Amplitude of the perturbation. The corresponding RMS value is indicated between brackets on the right.

Turn to OCV between techniques

Mode Single Sine Multi 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
or $N_T = 51$ points from f_i to f_f

in Logarithmic spacing Linear spacing Show frequencies >>

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

wait for $p_w = 0.10$ period before each frequency

average $N_a = 1$ measure(s) per frequency

drift correction

Repeat $n_c = 0$ time(s)

E Range = -10 V; 10 V ...
Resolution = 305.18 μ V

I Range = Auto

Bandwidth = 5 - medium (~ 48 s / scan)

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

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

increment cycle number

- Period of rest before a new frequency.

TIP:

Important to activate when there is a big gap between two frequencies. For example, if one measurement is performed at 1 kHz and the following one is performed at 1 Hz

5- Set the EIS technique

Turn to OCV between techniques

Mode Single Sine Multi 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
or $N_T = 51$ points from f_i to f_f

in Logarithmic spacing Linear spacing Show frequencies >>

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

wait for $p_w = 0.10$ period before each frequency

average $N_a = 1$ measure(s) per frequency

drift correction

Repeat $n_c = 0$ time(s)

E Range = -10 V; 10 V
Resolution = 305.18 μ V

I Range = Auto

Bandwidth = 5 - medium (~ 48 s / scan)

Go back to seq. $N_s = 0$ (9999 ends technique)
for $n_r = 0$ time(s) (0 for next sequence)

increment cycle number

- Number of measurements performed at the same frequency.
- repeat the sweep of frequencies.

Turn to OCV between techniques

Mode Single Sine Multi 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
or $N_T = 51$ points from f_i to f_f

in Logarithmic spacing Linear spacing Show frequencies >>

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

wait for $p_w = 0.10$ period before each frequency

average $N_a = 1$ measure(s) per frequency

drift correction

Repeat $n_c = 0$ time(s)

E Range = -10 V; 10 V
Resolution = 305.18 μ V

I Range = Auto

Bandwidth = 5 - medium (~ 48 s / scan)

Go back to seq. $N_s = 0$ (9999 ends technique)
for $n_r = 0$ time(s) (0 for next sequence)

increment cycle number

- Patented drift correction. Must be activated for measurements on slow systems which is not yet in his steady state conditions.

Turn to OCV between techniques

Mode Single Sine Multi 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
or $N_T = 51$ points from f_i to f_f

in Logarithmic spacing Linear spacing Show frequencies >>

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

wait for $p_w = 0.10$ period before each frequency

average $N_a = 1$ measure(s) per frequency

drift correction

Repeat $n_c = 0$ time(s)

E Range = -10 V; 10 V ...
Resolution = 305.18 μ V

I Range = Auto

Bandwidth = 5 - medium (~ 48 s / scan)

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

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

increment cycle number

The Erange has to be wide enough to be in the range of the operating voltage of the battery but narrow enough to get an optimized resolution in voltage measurement/control. It can be modified by clicking on ▼ or The resolution is given in *italics* below the box.

Turn to OCV between techniques

Mode Single Sine Multi 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 or $N_T = 51$ points from f_i to f_f

in Logarithmic spacing or Linear spacing Show frequencies >>

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

wait for $p_w = 0.10$ period before each frequency

average $N_a = 1$ measure(s) per frequency

drift correction

Repeat $n_c = 0$ time(s)

E Range = -10 V; 10 V Resolution = $305.18 \mu V$

I Range = Auto

Bandwidth = 5 - medium (~ 48 s / scan)

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

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

increment cycle number

- Current range for EIS experiment.

TIP:

Select auto as the level of current at low and high frequency may be very different.

5- Set the EIS technique

Turn to OCV between techniques

Mode Single Sine Multi 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
or $N_T = 51$ points from f_i to f_f

in Logarithmic spacing Linear spacing Show frequencies >>

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

wait for $p_w = 0.10$ period before each frequency

average $N_a = 1$ measure(s) per frequency

drift correction

Repeat $n_c = 0$ time(s)

E Range = -10 V; 10 V ...
Resolution = 305.18 μ V

I Range = Auto

Bandwidth = 5 - medium (~ 48 s / scan)

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

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

increment cycle number

- This parameter defines the stability/speed of the instrument. For high frequency measurement, set fast bandwidth. For example, Bd 7 for VMP3 family and 9 for SP-300 family. (See manuals and application note for more information bandwidth).

Note:

The bandwidths of the VMP3 family and the bandwidth of SP-300 family are not identical. Bandwidth 7 of VMP3 is different from the bandwidth 7 of the SP-300.

Turn to OCV between techniques

Mode Single Sine Multi 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
or $N_T = 51$ points from f_i to f_f

in Logarithmic spacing Linear spacing Show frequencies >>

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

wait for $p_w = 0.10$ period before each frequency

average $N_a = 1$ measure(s) per frequency

drift correction

Repeat $n_c = 0$ time(s)

E Range = -10 V; 10 V
Resolution = 305.18 μ V

I Range = Auto

Bandwidth = 5 - medium (~ 48 s / scan)


Go back to seq. $N_s = 0$ (9999 ends technique)
for $n_r = 0$ time(s) (0 for next sequence)

increment cycle number

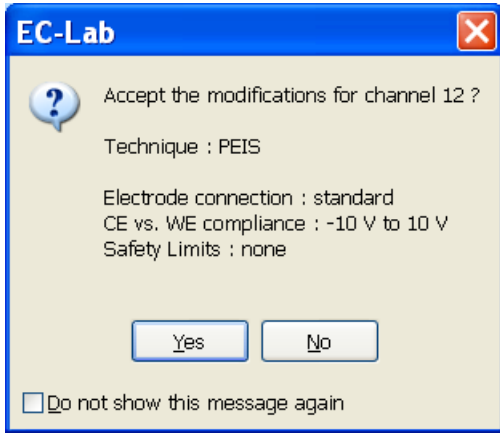
- This allows you to perform several cycles or sequences of EIS measurement.


The user defines at which sequence he/she would like to go back and for how many times.


6- Start the experiment

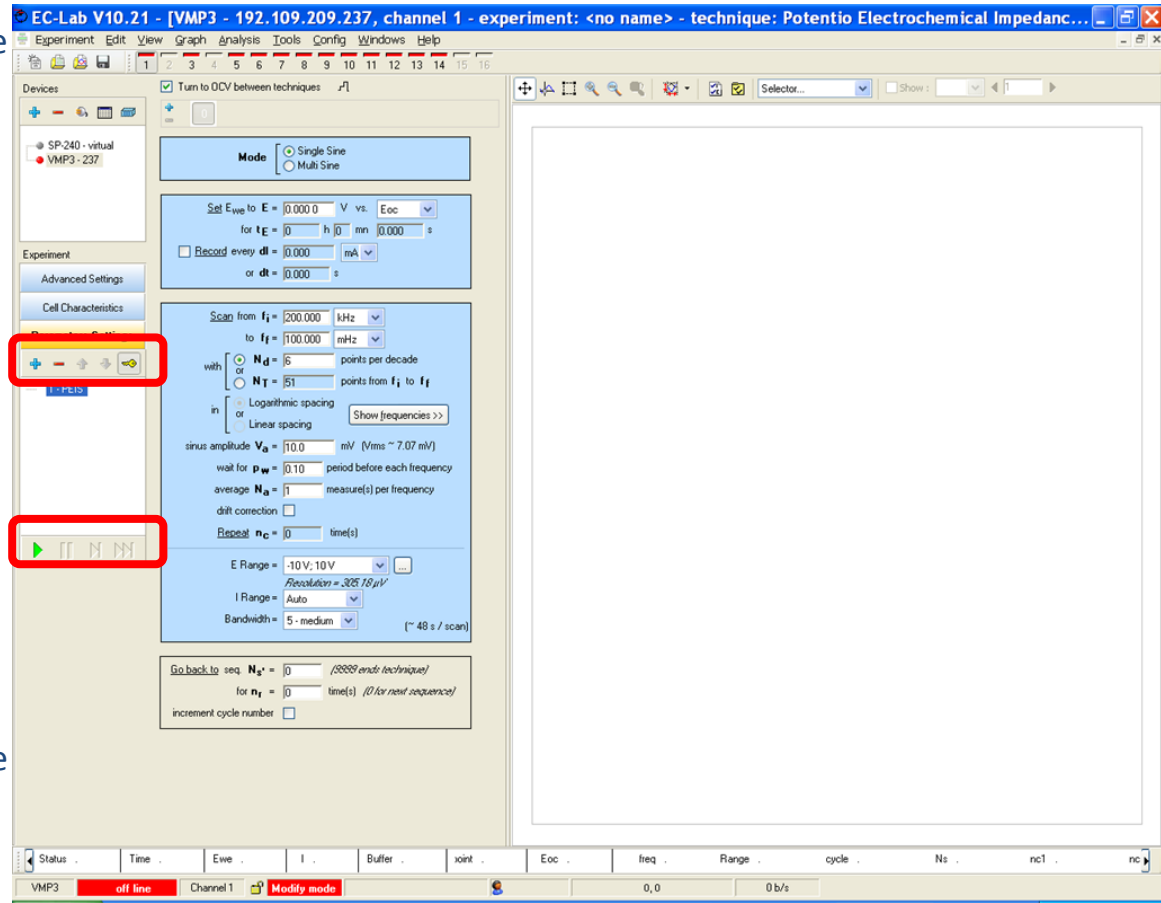
- Click on  button to check if the settings are accepted

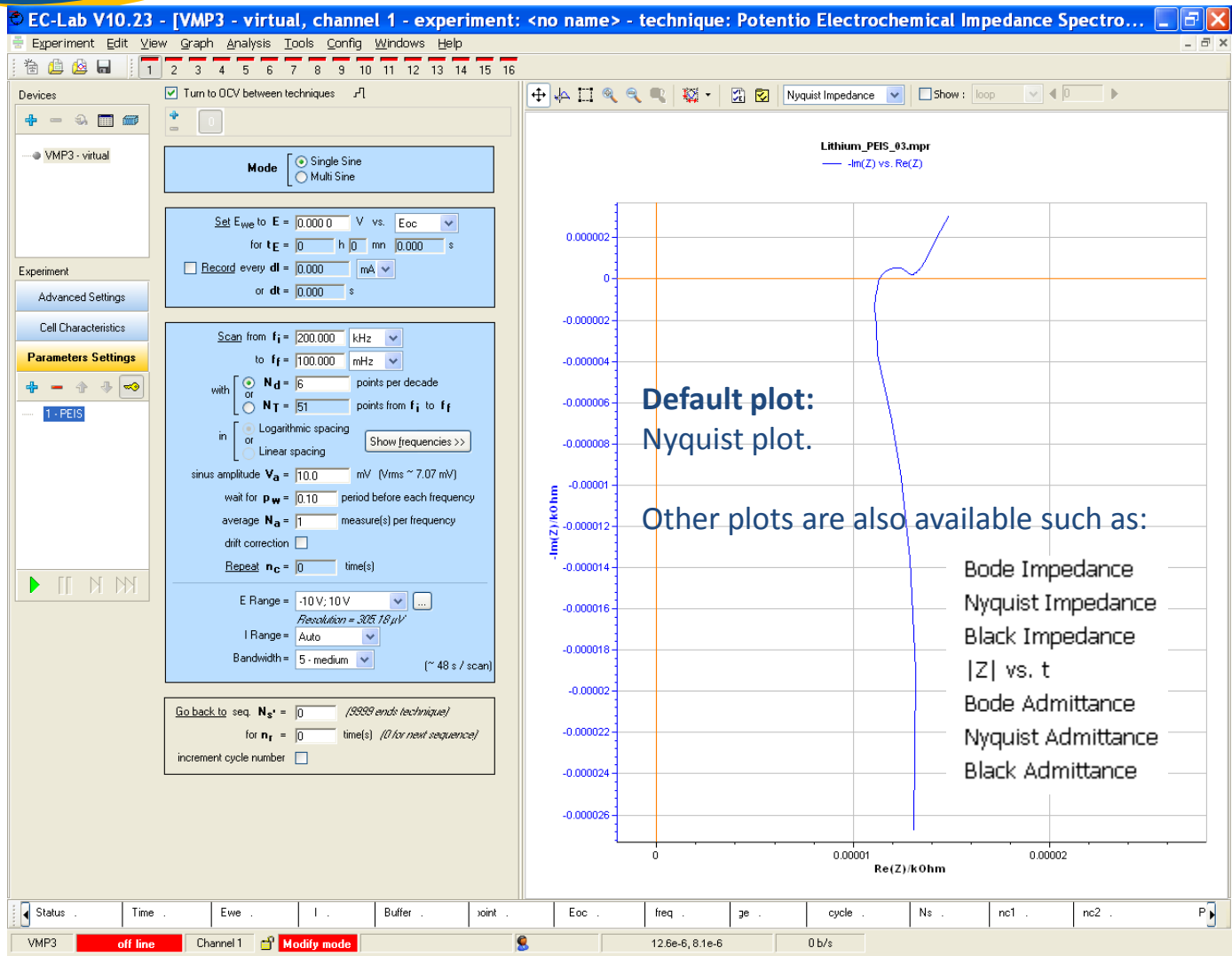
- Some warning messages may show up.



- Click on the  button to start the experiment.

- It is possible to stop, pause, go to next sequence, go to next technique by clicking on the buttons .





- Check the value of the AC and DC current and potential.

DC values are <I> and <E> for current and potential, respectively.

AC values are III and IEI for current and potential, respectively.

To get AC values, the box « Hide Additional Variables » has to be unchecked.

