

# Getting Started with EC-Lab<sup>®</sup>: GCPL: Galvanostatic Cycling with Potential Limitation

The aim of this presentation is to guide the user to set the appropriate parameters to perform a GCPL technique

**NOTE:**


The GCPL technique is dedicated to battery/supercapacitor testing. It is the so-called GITT (Galvanostatic Intermittent Titration Technique). It is a CC-CV technique (CC: Constant current; CV: Constant Voltage).

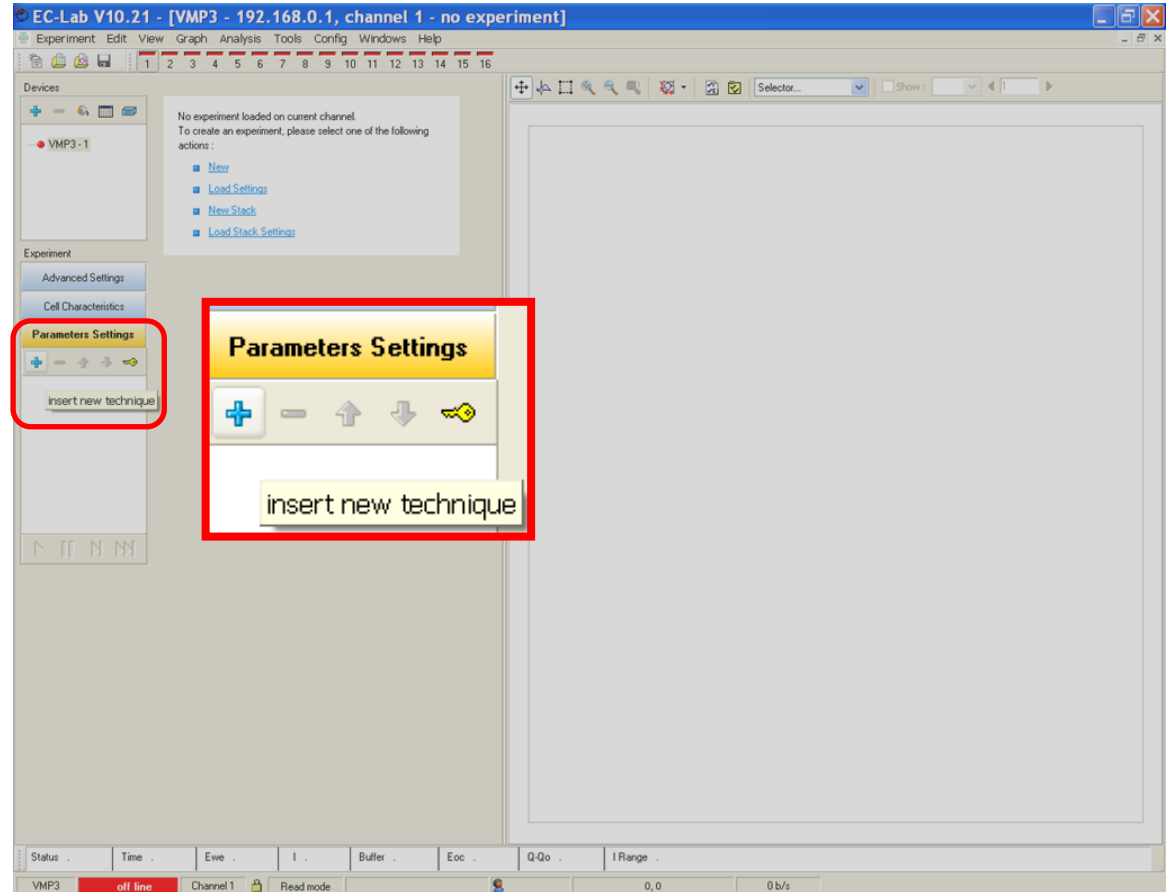
Only GCPL technique will be discussed hereafter but the information given in the presentation can be adapted to GCPL-like techniques (GCPL2 to GCPL7).

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

**NOTE:**

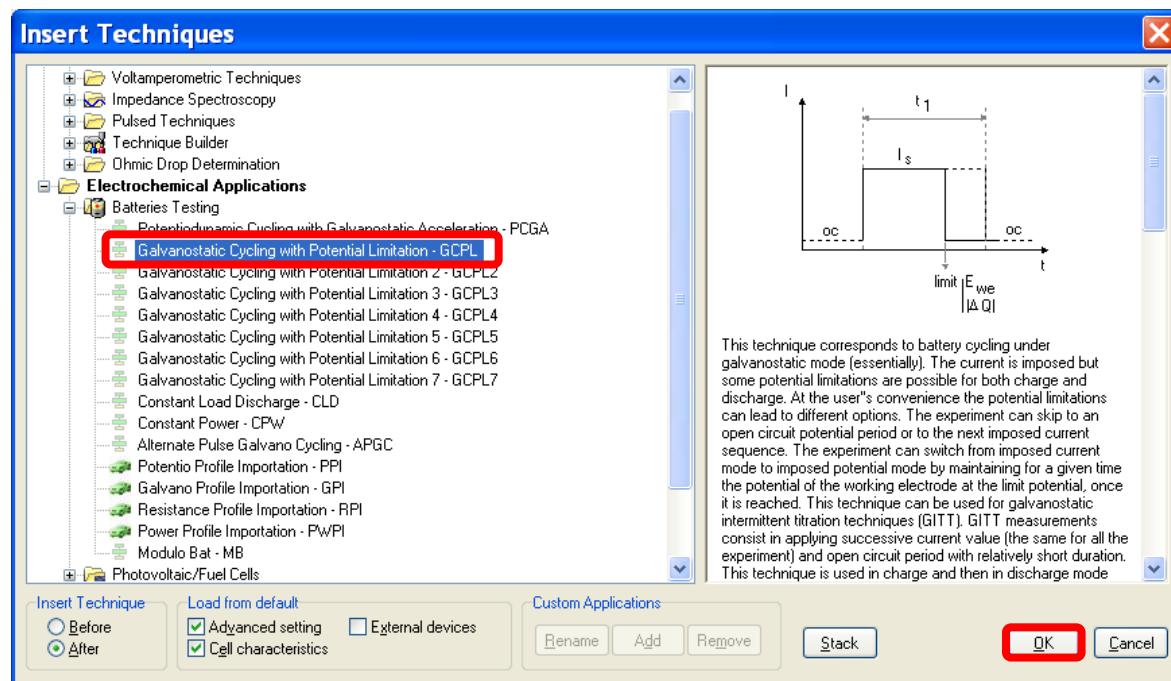
It is assumed that the computer and the instruments are connected. This is explained in the Getting Started named “EC-Lab®: Connection to the instrument(s) & Channel(s) selection”

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



- Select “Galvanostatic Cycling with Potential Limitation – GCPL” technique available in the “Battery Testing” folder. The technique is highlighted in blue when selected

- Click on the “OK” button




**Insert Techniques**

- Voltamperometric Techniques
- Impedance Spectroscopy
- Pulsed Techniques
- Technique Builder
- Ohmic Drop Determination
- Electrochemical Applications**
  - Batteries Testing
    - Potentiodynamic Cycling with Galvanostatic Acceleration - PCGA
    - Galvanostatic Cycling with Potential Limitation - GCPL**
    - Galvanostatic Cycling with Potential Limitation 2 - GCPL2
    - Galvanostatic Cycling with Potential Limitation 3 - GCPL3
    - Galvanostatic Cycling with Potential Limitation 4 - GCPL4
    - Galvanostatic Cycling with Potential Limitation 5 - GCPL5
    - Galvanostatic Cycling with Potential Limitation 6 - GCPL6
    - Galvanostatic Cycling with Potential Limitation 7 - GCPL7
    - Constant Load Discharge - CLD
    - Constant Power - CPW
    - Alternate Pulse Galvano Cycling - APGC
    - Potential Profile Importation - PPI
    - Galvano Profile Importation - GPI
    - Resistance Profile Importation - RPI
    - Power Profile Importation - PWPI
    - Modulo Bat - MB
  - Photovoltaic/Fuel Cells





Before  
 After

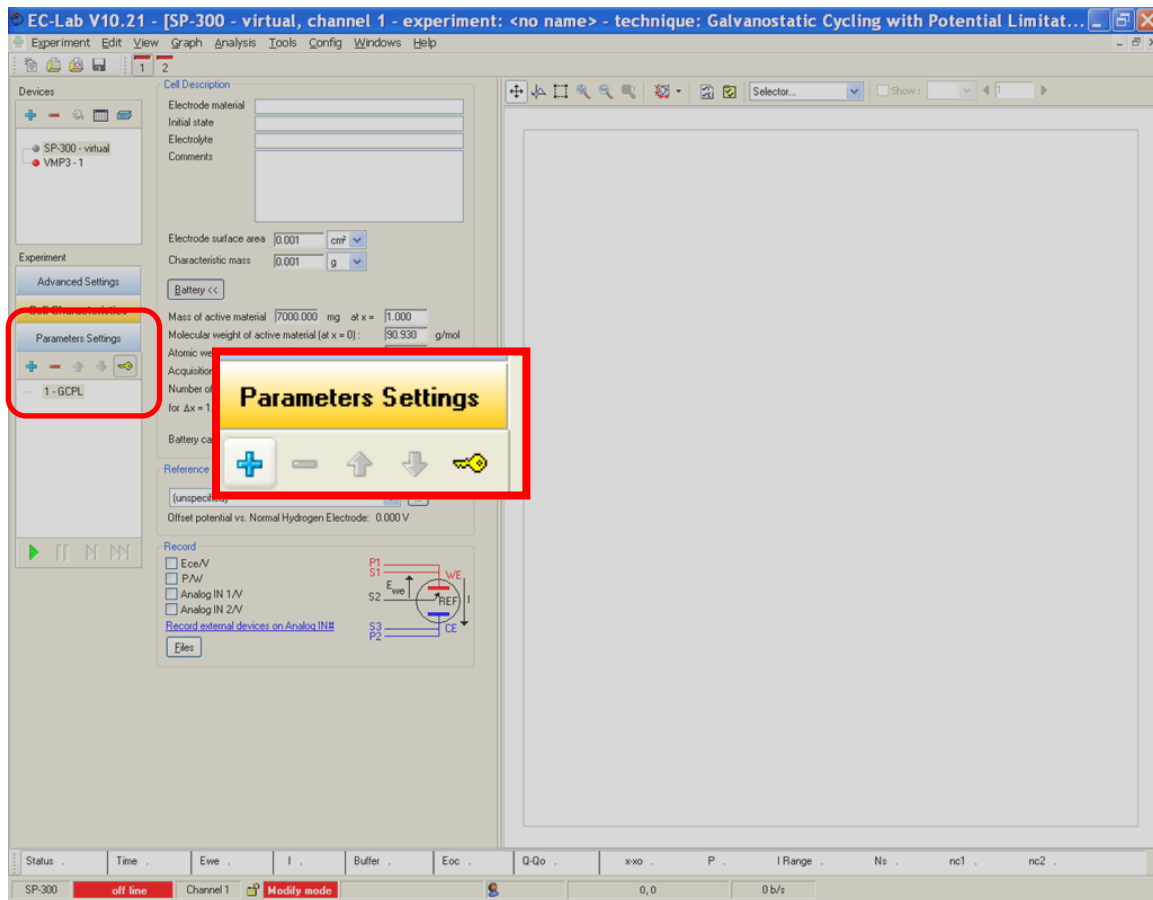
Load from default  
 Advanced setting  
 External devices  
 Cell characteristics

This technique corresponds to battery cycling under galvanostatic mode (essentially). The current is imposed but some potential limitations are possible for both charge and discharge. At the user's convenience the potential limitations can lead to different options. The experiment can skip to an open circuit potential period or to the next imposed current sequence. The experiment can switch from imposed current mode to imposed potential mode by maintaining for a given time the potential of the working electrode at the limit potential, once it is reached. This technique can be used for galvanostatic intermittent titration techniques (GITT). GITT measurements consist in applying successive current value (the same for all the experiment) and open circuit period with relatively short duration. This technique is used in charge and then in discharge mode

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

**Note:** it is possible to remove a 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 click on the appropriate button.

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



### 3- Set the « Advanced Setting » tab

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

Then the « Advanced Settings » window is shown.

The most important parameters to set for battery testing is the « Safety Limits » block. When one of these limits is reached, the experiment is paused (OCV period).

**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<sub>we</sub> max =  V

E<sub>we</sub> min =  V

I<sub>l</sub> =  mA

IQ-Qol =  mA.h

Analog IN 1 max  V

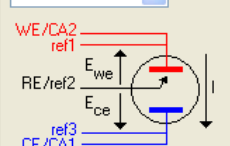
Analog IN 2 max  V

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<sub>we</sub> max =  V

E<sub>we</sub> min =  V

I<sub>l</sub> =  mA

IQ-Qol =  mA.h

Analog IN 1 max  V

Analog IN 2 max  V

for t >  ms

**Channel**

Floating

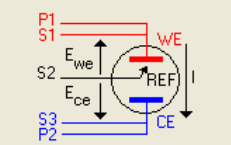
Grounded

**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)

# 3- Set the « Advanced Setting » tab

## Safety limits:

This allow the user to set:

- max and min voltages
- max current in absolute value
- max charge in absolute value
- limit on the analog input, if an external device is configured (described in the slide #23)
- For stack experiment (only available for VMP3 family), it is possible to use the voltage of each cell as safety limits.
- « blink » period, t, means that the limits should be reached during a certain period of time (allow to not consider artifact).

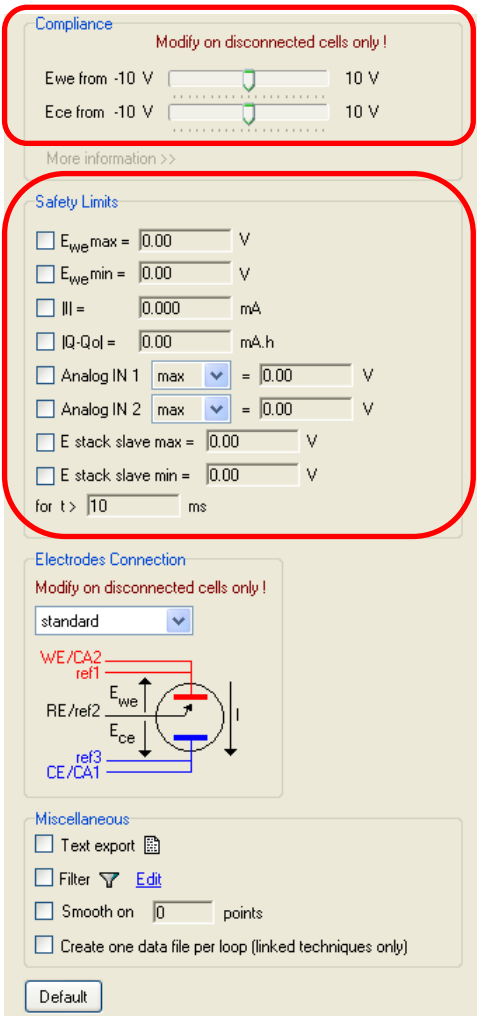
The safety limits are active for the whole experiment (all techniques) not only for one technique. Other limits are available in the GCPL technique itself.

These limits will be shown later in the section 4.

## Compliance (VMP3 family only):

For a single cell, the voltages of a battery are included in the range of [2; 5V] so in standard the compliance of -10 to 10V will be OK. For stack of battery, this may be adjusted from 0 to 20 V to allow measurement up to 20V.

### VMP3 family



**Compliance**  
Modify on disconnected cells only !

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

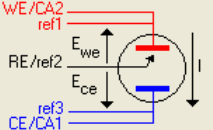
More information >>

**Safety Limits**

E<sub>we</sub> max =  V  
 E<sub>we</sub> min =  V  
 I<sub>l</sub> =  mA  
 |Q-Qol =  mA.h  
 Analog IN 1  =  V  
 Analog IN 2  =  V  
 E stack slave max =  V  
 E stack slave min =  V  
 for t >  ms

**Electrodes Connection**  
Modify on disconnected cells only !

standard



**Miscellaneous**

Text export

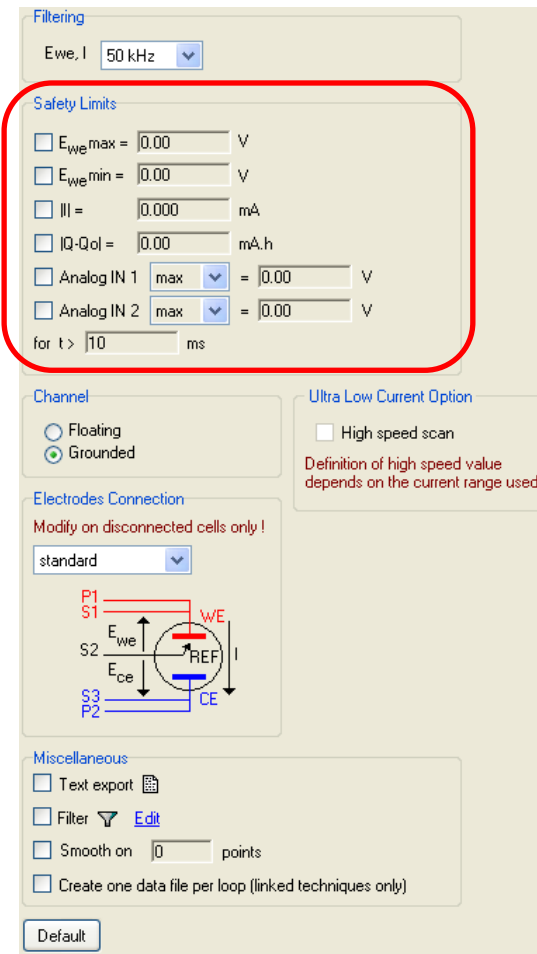
Filter [Edit](#)

Smooth on  points

Create one data file per loop (linked techniques only)

Default

### SP-300 family



**Filtering**

Ewe, I

**Safety Limits**

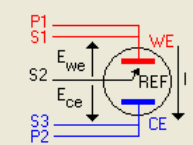
E<sub>we</sub> max =  V  
 E<sub>we</sub> min =  V  
 I<sub>l</sub> =  mA  
 |Q-Qol =  mA.h  
 Analog IN 1  =  V  
 Analog IN 2  =  V  
 for t >  ms

**Channel**

Floating  
 Grounded

**Electrodes Connection**  
Modify on disconnected cells only !

standard



**Ultra Low Current Option**

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

**Miscellaneous**

Text export

Filter [Edit](#)

Smooth on  points

Create one data file per loop (linked techniques only)

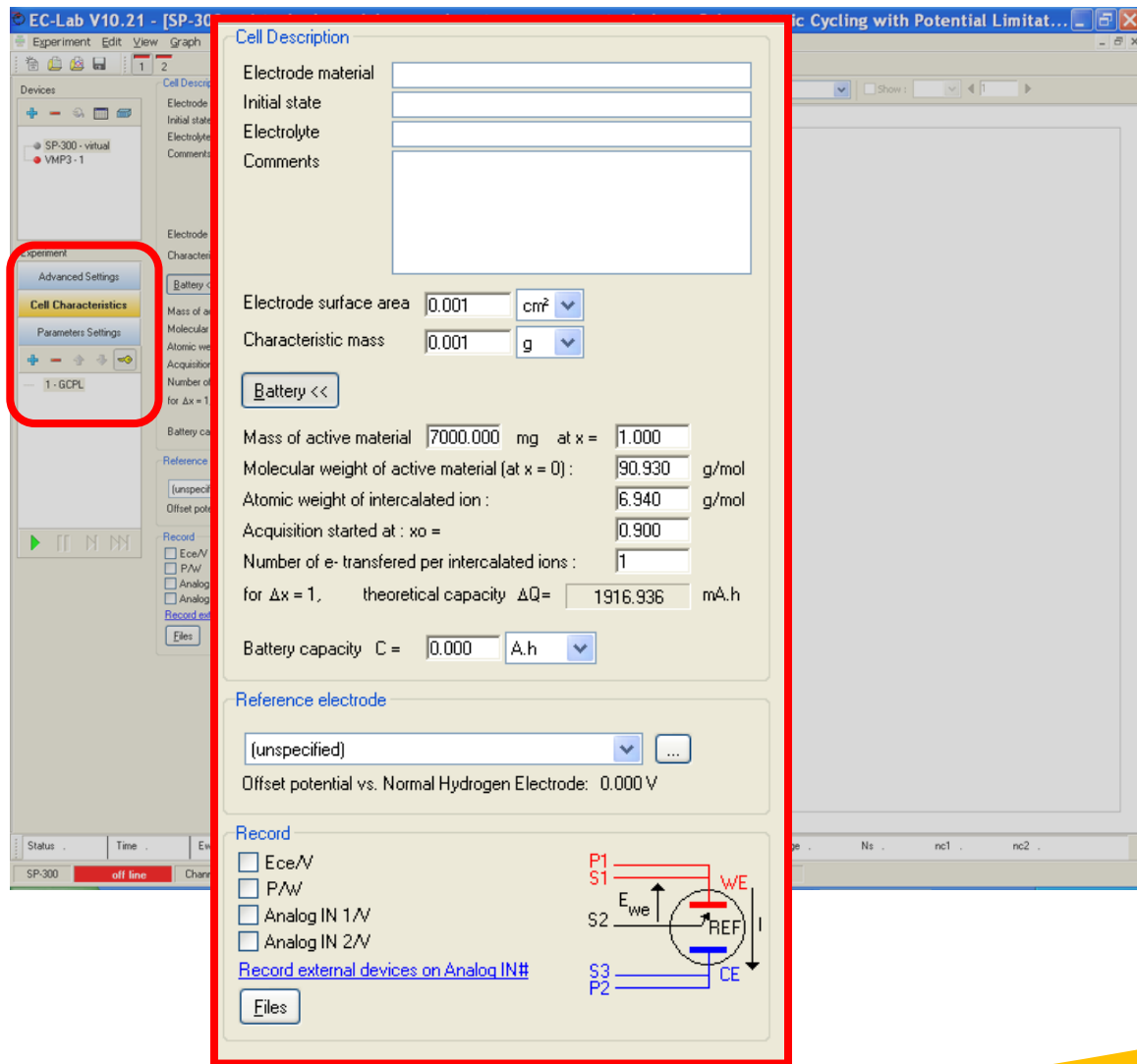
Default



# 4- Set the « Cell Characteristics » tab

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

then the « Cell Characteristics » window is displayed.



**Cell Description**

Electrode material:

Initial state:

Electrolyte:

Comments:

Electrode surface area:

Characteristic mass:

**Battery <<**

Mass of active material:  mg at x =

Molecular weight of active material (at x = 0):  g/mol

Atomic weight of intercalated ion:  g/mol

Acquisition started at: x<sub>0</sub> =

Number of e<sup>-</sup> transferred per intercalated ions:

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

Battery capacity C =  A.h

**Reference electrode**

Offset potential vs. Normal Hydrogen Electrode:  V

**Record**

Ece/V

P/W

Analog IN 1/V

Analog IN 2/V

[Record external devices on Analog IN#](#)

**Schematic Diagram:**


Diagram showing a three-electrode cell with WE (Working Electrode), REF (Reference Electrode), and CE (Counter Electrode). Connections are labeled P1, S1, S2, S3, and P2. The potential E<sub>we</sub> is indicated across the WE and REF electrodes, and current I is shown flowing from the WE to the CE.

## 4- Set the « Cell Characteristics » tab

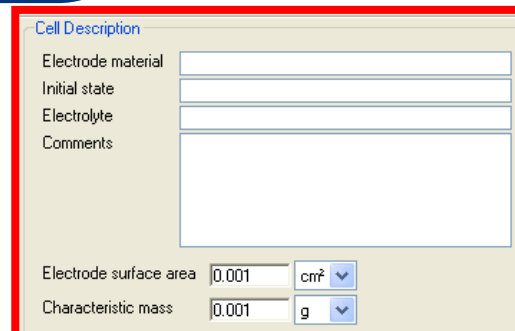
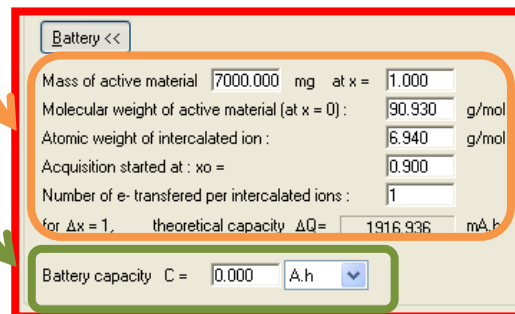
- Information about the cell and some comments.

- Click on the  button to display battery characteristics.

There are two buttons:

- you know the  inside the battery. So several boxes have to be filled to calculate the theoretical capacity of the battery (More explanation below).

- You know the capacity of the battery, so the box « battery capacity » has to be filled.

- The *mass* of active material in the cell has to be set with a given insertion coefficient  $x_{mass}$  in the compound of interest (for example  $x_{mass} = 1$  for  $\text{LiCoO}_2$ ).

**NOTE:**


This mass is not used to calculate the unit per mass (this is the mass set in the Characteristic mass box which is used to calculate the unit per mass).

- *the molecular weight* of the active material without the *atomic weight* of the intercalated ion. For example, for  $\text{LiCoO}_2$ , the molecular weight of  $\text{CoO}_2$  is  $90.93 \text{ g.mol}^{-1}$  and the atomic weight of the intercalated ion Li is  $6.94 \text{ g.mol}^{-1}$ .
- The initial insertion rate  $x_0$ .
- $ne$  is the number of electrons transferred per mole of intercalated ion.

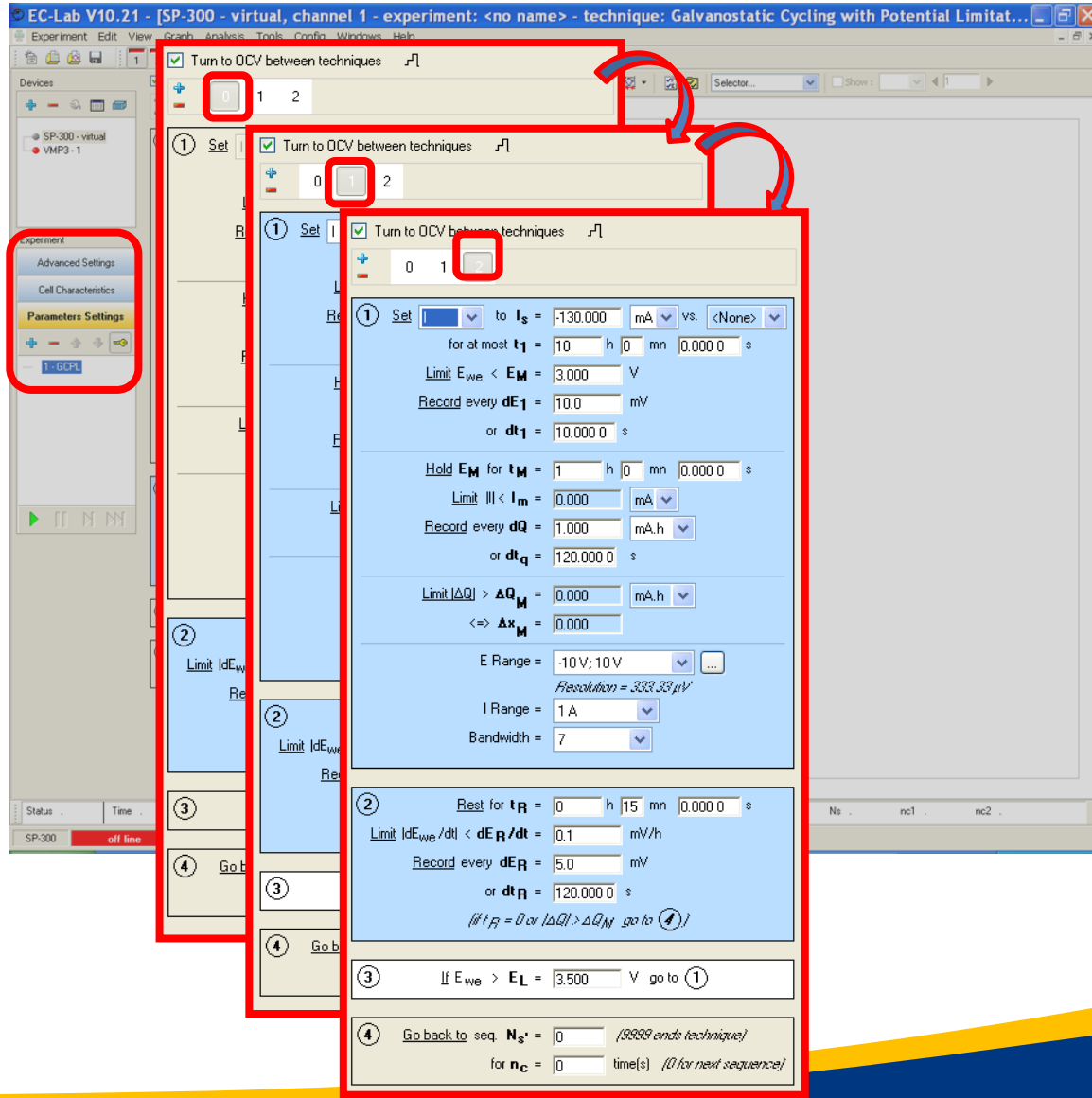
**NOTE:**

All these information are stored in the data file.

## Parameters Settings

- Click on the **Parameters Settings** tab or directly on the technique GCPL in the list of technique(s). The technique is highlighted in blue.
- By default GCPL technique contains three sequences (described in the next slide):
  - Sequence #0 is a rest period
  - Sequence #1 is the charge (positive current). Battery has to be charged first before being discharged.
  - Sequence #2 is the discharge (negative current)
- It is possible to add or remove sequence by clicking on the  buttons

**NOTE:**  
All the parameters may be changed during the experiment (except Irange, Erange, bandwidth).



The screenshot shows the software interface for setting GCPL parameters. The interface is divided into several sections:

- Left Panel:** Shows the 'Parameters Settings' tab selected. Below it, the 'GCPL' technique is highlighted in blue.
- Top Panel:** Shows the 'Turn to OCV between techniques' checkbox checked. A red box highlights the '0' button next to it.
- Sequence List:** A list of sequences is shown on the left. Sequence 1 is highlighted in blue. Red boxes highlight the '1' button next to it and the '0' button next to it.
- Parameter Configuration Panel:** This panel is used to set the parameters for the selected sequence. It includes:
  - Set I<sub>s</sub> to I<sub>s</sub> =** -130.000 mA vs. <None>
  - for at most t<sub>1</sub> =** 10 h 0 mn 0.000 s
  - Limit E<sub>we</sub> < E<sub>M</sub> =** 3.000 V
  - Record every dE<sub>1</sub> =** 10.0 mV
  - or dt<sub>1</sub> =** 10.000 s
  - Hold E<sub>M</sub> for t<sub>M</sub> =** 1 h 0 mn 0.000 s
  - Limit |I| < I<sub>m</sub> =** 0.000 mA
  - Record every dQ =** 1.000 mA.h
  - or dt<sub>q</sub> =** 120.000 s
  - Limit |ΔQ| > ΔQ<sub>M</sub> =** 0.000 mA.h
  - <=> Δx<sub>M</sub> =** 0.000
  - E Range =** -10 V; 10 V
  - Resolution =** 333.33 μV
  - I Range =** 1 A
  - Bandwidth =** 7
- Sequence 2:** Shows parameters for a rest period:
  - Rest for t<sub>R</sub> =** 0 h 15 mn 0.000 s
  - Limit |dE<sub>we</sub>/dt| < dE<sub>R</sub>/dt =** 0.1 mV/h
  - Record every dE<sub>R</sub> =** 5.0 mV
  - or dt<sub>R</sub> =** 120.000 s
  - (if I<sub>R</sub> = 0 or |ΔQ| > ΔQ<sub>M</sub> go to 1)*
- Sequence 3:** Shows a condition: **If E<sub>we</sub> > E<sub>L</sub> = 3.500 V go to 1**
- Sequence 4:** Shows a condition: **Go back to seq. N<sub>s</sub>\* = 0 (9999 ends technique)** for **n<sub>c</sub> = 0 time(s) (0 for next sequence)**

- Rest period sequence

Only the OCV block is active in sequence #0.

**NOTE:**

The block is blue, not grey. The non active blocks are in grey.

Here: This OCV will last 10 s or until the voltage variation versus time reaches 10 mV/h

Turn to OCV between techniques ↶

+ 0 1 2

---

① Set I to  $I_s = 0.000$  mA vs. <None>

for at most  $t_1 = 0$  h  $0$  mn  $0.0000$  s

Limit  $E_{we} > E_M = 0.000$  V

Record every  $dE_1 = 0.0$  mV

or  $dt_1 = 0.0000$  s

---

Hold  $E_M$  for  $t_M = 0$  h  $0$  mn  $0.0000$  s

Limit  $|I| < I_m = 0.000$  mA

Record every  $dQ = 0.000$  mA.h

or  $dt_q = 0.0000$  s

---

Limit  $|\Delta Q| > \Delta Q_M = 0.000$  mA.h

$\Leftrightarrow \Delta x_M = 0.000$

---

E Range = -10 V; 10 V ...

Resolution = 333.33  $\mu$ V

I Range = 1 A

Bandwidth = 7

---

② Rest for  $t_R = 0$  h  $0$  mn  $10.0000$  s

Limit  $|dE_{we}/dt| < dE_R/dt = 10$  mV/h

Record every  $dE_R = 2$  mV

or  $dt_R = 1.0000$  s

*(if  $t_R = 0$  or  $|\Delta Q| > \Delta Q_M$  go to ④)*

---

③ If  $E_{we} < E_L = \text{pass}$  V go to ①

---

④ Go back to seq.  $N_s' = 0$  *(9999 ends technique)*

for  $n_c = 0$  time(s) *(0 for next sequence)*

# 5- Set the GCPL technique

• Charge/discharge sequence

CC period

CC: Constant Current

Turn to OCV between techniques

0 1 2

① Set I to  $I_s = 130.000$  mA vs. <None>

for at most  $t_1 = 10$  h 0 mn 0.000 0 s

Limit  $E_{we} > E_M = 4.500$  V

Record every  $dE_1 = 10.0$  mV

or  $dt_1 = 10.000 0$  s

Hold  $E_M$  for  $t_M = 1$  h 0 mn 0.000 0 s

Limit  $|I| < I_m = 0.000$  mA

Record every  $dQ = 1.000$  mA.h

or  $dt_q = 120.000 0$  s

Limit  $|\Delta Q| > \Delta Q_M = 0.000$  mA.h

$\langle \Rightarrow \rangle \Delta x_M = 0.000$

E Range = 0 V; 5 V

I Range = 1 A

Bandwidth = 7

② Rest for  $t_R = 0$  h 15 mn 0.000 0 s

Limit  $|dE_{we}/dt| < dE_R/dt = 0.1$  mV/h

Record every  $dE_R = 10.0$  mV

or  $dt_R = 120.000 0$  s

(if  $t_R = 0$  or  $|\Delta Q| > \Delta Q_M$  go to ④)

③ If  $E_{we} < E_L = 4.200$  V go to ①

④ Go back to seq.  $N_s = 0$  (9999 ends technique)

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

• Defines the applied current. It is positive for charge and negative for discharge. If the capacity of the battery is defined in the “Cell characteristics”, the user may select a rate instead of a current.

Set I to  $I_s = -130.000$  mA vs. <None>

most  $t_1 = 10$  h 0 mn 0.000 0 s

$< E_M = 3.000$  V

C / N

C x N

Irange has to be chosen according to the current applied.

**Note:**

If several Iranges are set in the technique (one Irange for one sequence 1 and another one for the following sequence), an OCV period (block 2) has to be set between the two sequences. This will allow the instrument to change the Irange.

# 5- Set the GCPL technique

- Charge/discharge sequence

CC period  
CC: Constant Current

Turn to OCV between techniques  $\uparrow$

0 1 2

① Set  $I$  to  $I_s = 130.000$  mA vs. <None> for at most  $t_1 = 10$  h 0 mn 0.0000 s

**Limit  $E_{we} > E_M = 4.500$  V**

Record every  $dE_1 = 10.0$  mV or  $dt_1 = 10.0000$  s

Hold  $E_M$  for  $t_M = 1$  h 0 mn 0.0000 s

Limit  $|I| < I_m = 0.000$  mA

Record every  $dQ = 1.000$  mA.h or  $dt_q = 120.0000$  s

Limit  $|\Delta Q| > \Delta Q_M = 0.000$  mA.h

$\langle \Rightarrow \rangle \Delta x_M = 0.000$

E Range = 0 V; 5 V Resolution = 100  $\mu$ V

I Range = 1 A

Bandwidth = 7

② Rest for  $t_R = 0$  h 15 mn 0.0000 s

Limit  $|dE_{we}/dt| < dE_R/dt = 0.1$  mV/h

Record every  $dE_R = 10.0$  mV or  $dt_R = 120.0000$  s

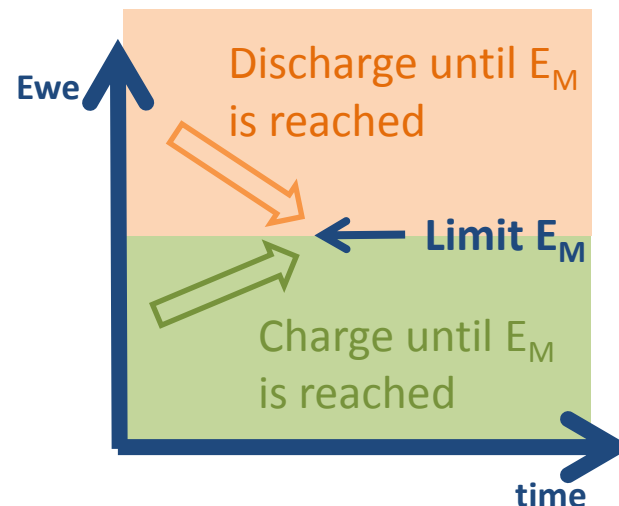
(if  $t_R = 0$  or  $|\Delta Q| > \Delta Q_M$  go to ④)

③ If  $E_{we} < E_L = 4.200$  V go to ①

④ Go back to seq.  $N_s = 0$  (9999 ends technique) for  $n_c = 0$  time(s) (0 for next sequence)

Define the **max** voltage until which the **charge** has to be performed.  
Define the **min** voltage until which the **discharge** has to be performed.

The sign “<” or “>” is automatically updated according to the sign of the current.



# 5- Set the GCPL technique

- Charge/discharge sequence

CC period  
CC: Constant Current

Turn to OCV between techniques  $\uparrow$

0 1 2

① Set  $I$  to  $I_s = 130.000$  mA vs.  $\langle \text{None} \rangle$   
 for at most  $t_1 = 10$  h  $0$  mn  $0.0000$  s  
 Limit  $E_{we} > E_M = 4.500$  V  
 Record every  $dE_1 = 10.0$  mV  
 or  $dt_1 = 10.0000$  s

Hold  $E_M$  for  $t_M = 1$  h  $0$  mn  $0.0000$  s  
 Limit  $|I| < I_m = 0.000$  mA  
 Record every  $dQ = 1.000$  mA.h  
 or  $dt_q = 120.0000$  s

Limit  $|\Delta Q| > \Delta Q_M = 0.000$  mA.h  
 $\langle \Rightarrow \Delta x_M = 0.000$

E Range =  $0$  V;  $5$  V  
 Resolution =  $100 \mu V$

I Range =  $1$  A  
 Bandwidth =  $7$

② Rest for  $t_R = 0$  h  $15$  mn  $0.0000$  s  
 Limit  $|dE_{we}/dt| < dE_R/dt = 0.1$  mV/h  
 Record every  $dE_R = 10.0$  mV  
 or  $dt_R = 120.0000$  s  
*(if  $t_R = 0$  or  $|\Delta Q| > \Delta Q_M$  go to ④)*

③ If  $E_{we} < E_L = 4.200$  V go to ①

④ Go back to seq.  $N_s = 0$  (9999 ends technique)  
 for  $n_c = 0$  time(s) (0 for next sequence)

- Defines the sampling rate of the experiment.  
As battery testing may take several months and voltage may be very slow, a sampling rate in dE is also offered. Only the relevant points *i.e.* when the variation of potential is equal to dE are recorded.

**TIP:**  
This dE has to be set according to the noise of the experiment. If the dE is inferior to the noise of measurement (induced by the battery itself or the setup), all the points will be recorded. This will fill the buffer (every 200  $\mu s$ ) with non-relevant data points.  
The user has also to pay attention to the voltage resolution (defined thanks to the Erange box, discussed in slide #18).

# 5- Set the GCPL technique

- Charge/discharge sequence

CV period  
CV: Constant voltage

Turn to OCV between techniques  $\uparrow$

0 1 2

① Set  $I$  to  $I_s = 130.000$  mA vs. <None>

for at most  $t_1 = 10$  h 0 mn 0.000 0 s

Limit  $E_{we} > E_M = 4.500$  V

Record every  $dE_1 = 10.0$  mV

or  $dt_1 = 10.000 0$  s

**Hold  $E_M$  for  $t_M = 1$  h 0 mn 0.000 0 s**

Limit  $|I| < I_m = 0.000$  mA

Record every  $dQ = 1.000$  mA.h

or  $dt_q = 120.000 0$  s

Limit  $|\Delta Q| > \Delta Q_M = 0.000$  mA.h

$\langle \Rightarrow \rangle \Delta x_M = 0.000$

E Range = 0 V; 5 V Resolution = 100  $\mu$ V

I Range = 1 A

Bandwidth = 7

② Rest for  $t_R = 0$  h 15 mn 0.000 0 s

Limit  $|dE_{we}/dt| < dE_R/dt = 0.1$  mV/h

Record every  $dE_R = 10.0$  mV

or  $dt_R = 120.000 0$  s

(if  $t_R = 0$  or  $|\Delta Q| > \Delta Q_M$  go to ④)

③ If  $E_{we} < E_L = 4.200$  V go to ①

④ Go back to seq.  $N_s = 0$  (9999 ends technique)

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

• This block allows the user to complete the charge/discharge in potentiostatic mode (in the first block the charge/discharge was performed in galvanostatic mode).

The applied voltage is the voltage  $E_M$  defined in the first block.

This block has its own sampling rate  $dQ$  (charge change) and/or  $dt_q$  (time) and also a limit on the current.



# 5- Set the GCPL technique

- Charge/discharge sequence

Turn to OCV between techniques  $\uparrow$

0 1 2

① Set  $I$  to  $I_s = 130.000$  mA vs. <None>

for at most  $t_1 = 10$  h 0 mn 0.000 0 s

Limit  $E_{we} > E_M = 4.500$  V

Record every  $dE_1 = 10.0$  mV

or  $dt_1 = 10.000 0$  s

Hold  $E_M$  for  $t_M = 1$  h 0 mn 0.000 0 s

Limit  $|I| < I_m = 0.000$  mA

Record every  $dQ = 1.000$  mA.h

or  $dt_q = 120.000 0$  s

Limit  $|\Delta Q| > \Delta Q_M = 0.000$  mA.h

$\langle \Rightarrow \rangle \Delta x_M = 0.000$

E Range = 0 V; 5 V Resolution = 100  $\mu$ V

I Range = 1 A

Bandwidth = 7

② Rest for  $t_R = 0$  h 15 mn 0.000 0 s

Limit  $|dE_{we}/dt| < dE_R/dt = 0.1$  mV/h

Record every  $dE_R = 10.0$  mV

or  $dt_R = 120.000 0$  s

(if  $t_R = 0$  or  $|\Delta Q| > \Delta Q_M$  go to ④)

③ If  $E_{we} < E_L = 4.200$  V go to ①

④ Go back to seq.  $N_s = 0$  (9999 ends technique)

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

This is the limit on the total charge exchanged during the sequence. This limit can also be defined with the intercalation coefficient.

By default, this is not activated (the boxes are colored and not white).

# 5- Set the GCPL technique

- Charge/discharge sequence

Turn to OCV between techniques ↶

0 1 2

① Set  $I$  to  $I_s = 130.000$  mA vs.  $\langle \text{None} \rangle$

for at most  $t_1 = 10$  h  $0$  mn  $0.0000$  s

Limit  $E_{we} > E_M = 4.500$  V

Record every  $dE_1 = 10.0$  mV

or  $dt_1 = 10.0000$  s

---

Hold  $E_M$  for  $t_M = 1$  h  $0$  mn  $0.0000$  s

Limit  $|I| < I_m = 0.000$  mA

Record every  $dQ = 1.000$  mA.h

or  $dt_q = 120.0000$  s

---

Limit  $|\Delta Q| > \Delta Q_M = 0.000$  mA.h

$\langle \rangle \Delta x_M = 0.000$

**E Range = 0 V; 5 V** ...

*Resolution = 100  $\mu$ V*

I Range = 1 A

Bandwidth = 7

---

② Rest for  $t_R = 0$  h  $15$  mn  $0.0000$  s

Limit  $|dE_{we}/dt| < dE_R/dt = 0.1$  mV/h

Record every  $dE_R = 10.0$  mV

or  $dt_R = 120.0000$  s

*(if  $t_R = 0$  or  $|\Delta Q| > \Delta Q_M$  go to ④)*

---

③ If  $E_{we} < E_L = 4.200$  V go to ①

---

④ Go back to seq.  $N_s = 0$  *(9999 ends technique)*

for  $n_c = 0$  time(s) *(0 for next sequence)*

- The E range 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 the voltage measurement/control.

Usually a range of [0 ; 5]V is relevant for battery testing, but his can modified by clicking on v or ....

The resolution is given below the box in *italics*.

- Charge/discharge sequence

Turn to OCV between techniques  $\uparrow$

0 1 2

① Set  $I$  to  $I_s = 130.000$  mA vs. <None>

for at most  $t_1 = 10$  h 0 mn 0.000 0 s

Limit  $E_{we} > E_M = 4.500$  V

Record every  $dE_1 = 10.0$  mV

or  $dt_1 = 10.000 0$  s

Hold  $E_M$  for  $t_M = 1$  h 0 mn 0.000 0 s

Limit  $|I| < I_m = 0.000$  mA

Record every  $dQ = 1.000$  mA.h

or  $dt_q = 120.000 0$  s

Limit  $|\Delta Q| > \Delta Q_M = 0.000$  mA.h

$\langle \Rightarrow \Delta x_M = 0.000$

E Range = 0 V; 5 V Resolution = 100  $\mu$ V

I Range = 1 A

**Bandwidth = 7**

② Rest for  $t_R = 0$  h 15 mn 0.000 0 s

Limit  $|dE_{we}/dt| < dE_R/dt = 0.1$  mV/h

Record every  $dE_R = 10.0$  mV

or  $dt_R = 120.000 0$  s

(if  $t_R = 0$  or  $|\Delta Q| > \Delta Q_M$  go to ④)

③ If  $E_{we} < E_L = 4.200$  V go to ①

④ Go back to seq.  $N_s = 0$  (9999 ends technique)

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

This parameter defines the stability/speed (regulation loop) of the instrument. As battery have a slow response, a slow bandwidth will be appropriate. Bandwidth of 5 for VMP3 family and 7 for SP-300 family is often appropriate. (See manuals and application note for more information bandwidth).

**Note:** the bandwidth 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.

# 5- Set the GCPL technique

- Charge/discharge sequence

Turn to OCV between techniques ↶

0 1 2

① Set  $I$  to  $I_s = 130.000$  mA vs. <None>

for at most  $t_1 = 10$  h 0 mn 0.000 0 s

Limit  $E_{we} > E_M = 4.500$  V

Record every  $dE_1 = 10.0$  mV

or  $dt_1 = 10.000 0$  s

---

Hold  $E_M$  for  $t_M = 1$  h 0 mn 0.000 0 s

Limit  $|I| < I_m = 0.000$  mA

Record every  $dQ = 1.000$  mA.h

or  $dt_q = 120.000 0$  s

---

Limit  $|\Delta Q| > \Delta Q_M = 0.000$  mA.h

$\langle \Rightarrow \rangle \Delta x_M = 0.000$

---

E Range = 0 V; 5 V ...

*Resolution = 100  $\mu$ V*

I Range = 1 A

Bandwidth = 7

---

② Rest for  $t_R = 0$  h 15 mn 0.000 0 s

Limit  $|dE_{we}/dt| < dE_R/dt = 0.1$  mV/h

Record every  $dE_R = 10.0$  mV

or  $dt_R = 120.000 0$  s

*(if  $t_R = 0$  or  $|\Delta Q| > \Delta Q_M$  go to ④)*

---

③ If  $E_{we} < E_L = 4.200$  V go to ①

---

④ Go back to seq.  $N_s = 0$  *(9999 ends technique)*

for  $n_c = 0$  time(s) *(0 for next sequence)*

The rest period gives the time to the battery to reach its steady state. If after the rest period, the voltage required is not reached a test is done and allow user to charge/discharge again the battery (go to the beginning of the sequence).

# 5- Set the GCPL technique

- Charge/discharge sequence

Turn to DCV between techniques  $\uparrow$

0 1 2

① Set  $I$  to  $I_s = -130.000$  mA vs.  $\langle \text{None} \rangle$   
 for at most  $t_1 = 10$  h 0 mn 0.000 0 s  
 Limit  $E_{we} < E_M = 3.000$  V  
 Record every  $dE_1 = 10.0$  mV  
 or  $dt_1 = 10.000 0$  s

Hold  $E_M$  for  $t_M = 1$  h 0 mn 0.000 0 s  
 Limit  $|I| < I_m = 0.000$  mA  
 Record every  $dQ = 1.000$  mA.h  
 or  $dt_q = 120.000 0$  s

Limit  $|\Delta Q| > \Delta Q_M = 0.000$  mA.h  
 $\Leftrightarrow \Delta x_M = 0.000$

E Range = 0 V; 5 V  
 Resolution = 100  $\mu$ V

I Range = 1 A  
 Bandwidth = 7

② Rest for  $t_R = 0$  h 15 mn 0.000 0 s  
 Limit  $|dE_{we}/dt| < dE_R/dt = 0.1$  mV/h  
 Record every  $dE_R = 5.0$  mV  
 or  $dt_R = 120.000 0$  s  
*(if  $t_R = 0$  or  $|\Delta Q| > \Delta Q_M$  go to ④)*

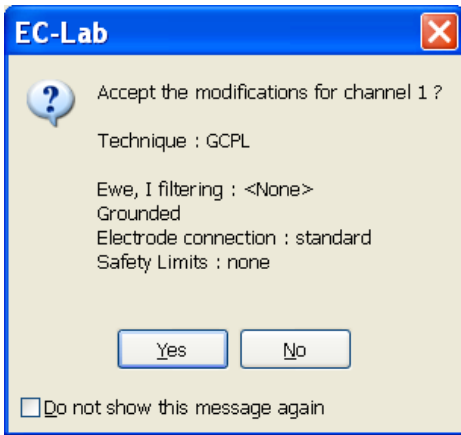
③ If  $E_{we} > E_L = 3.500$  V go to ①

④ Go back to seq.  $N_s = 2$  (9999 ends technique)  
 for  $n_c = 2$  time(s) (0 for next sequence)


This allows the user to loop on a sequence of charge/discharge within the GCPL technique. The user defines at which sequence the protocol will go back and for how many times.

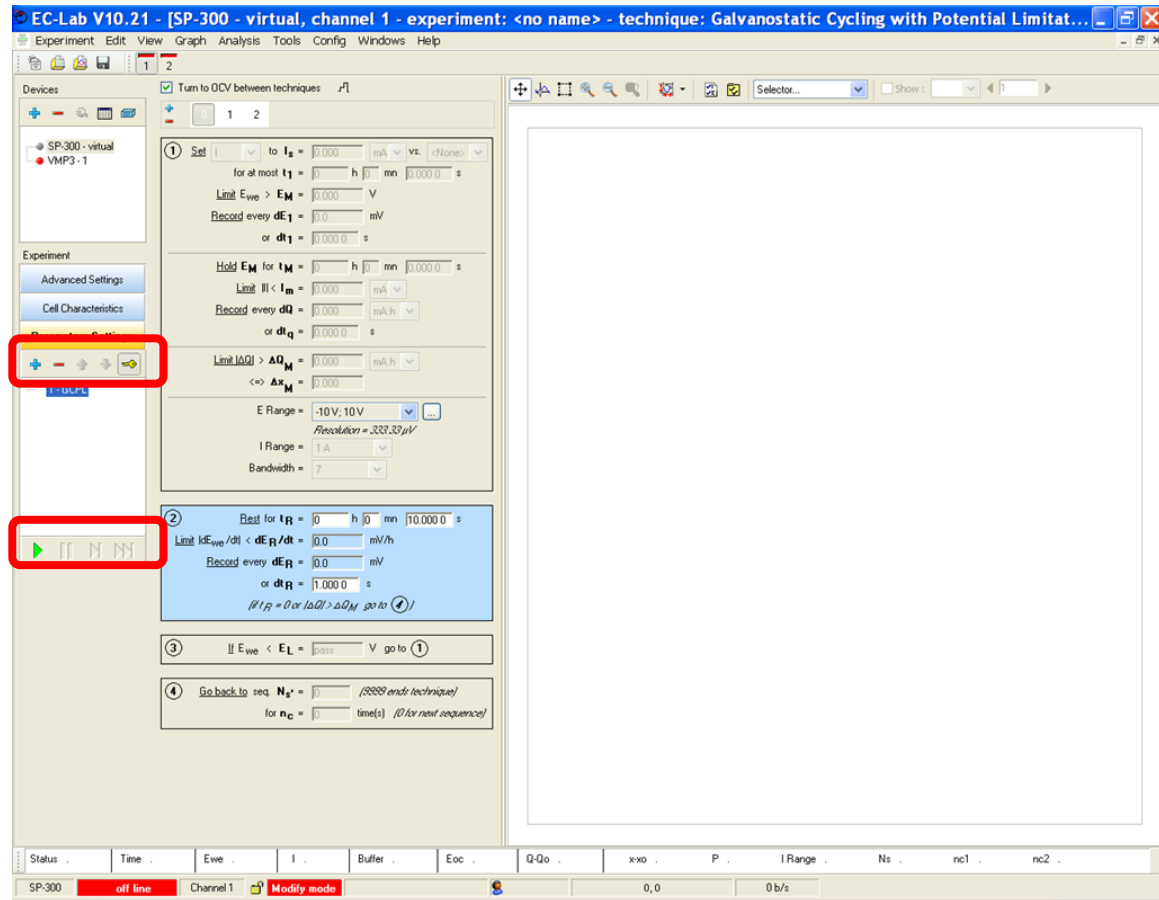
- Click on  button to check if the settings are accepted

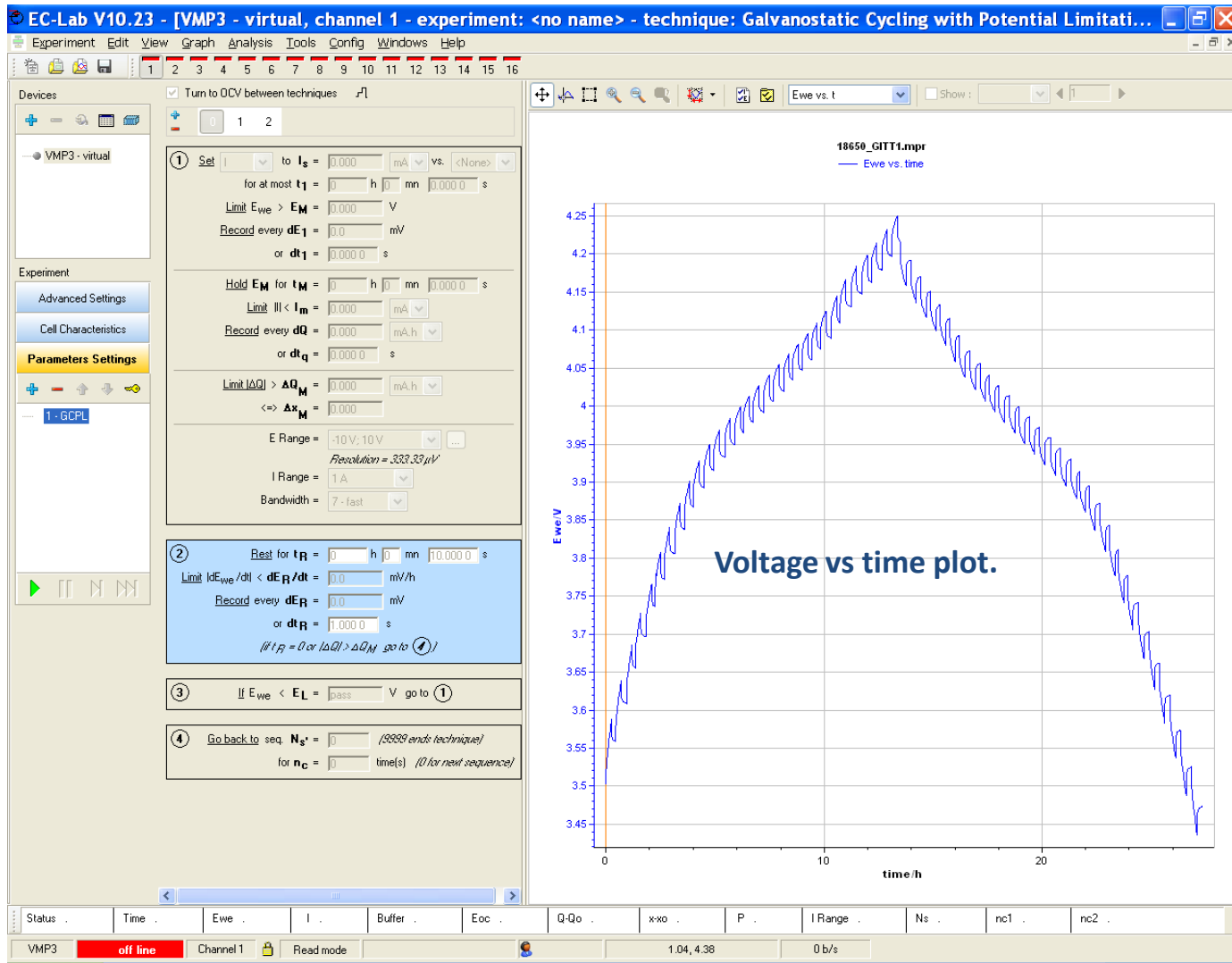
- Some warning messages may come up.



- 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 .





## Set the external device before step 4.

- In the “Config” menu, select “External devices”. (Shift+Ctrl+E)
- Select the channel where the external device is connected.
- Select the device type (usually it is temperature probe)
- Select the type, then analog out (used as power supply) and analog In (measurement) are set.
- Click on the “Apply” and the “OK” buttons.

