Getting Started with EC-Lab®: **GCPL**: **G**alvanostatic **C**ycling with **P**otential **L**imitation

AIM

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).

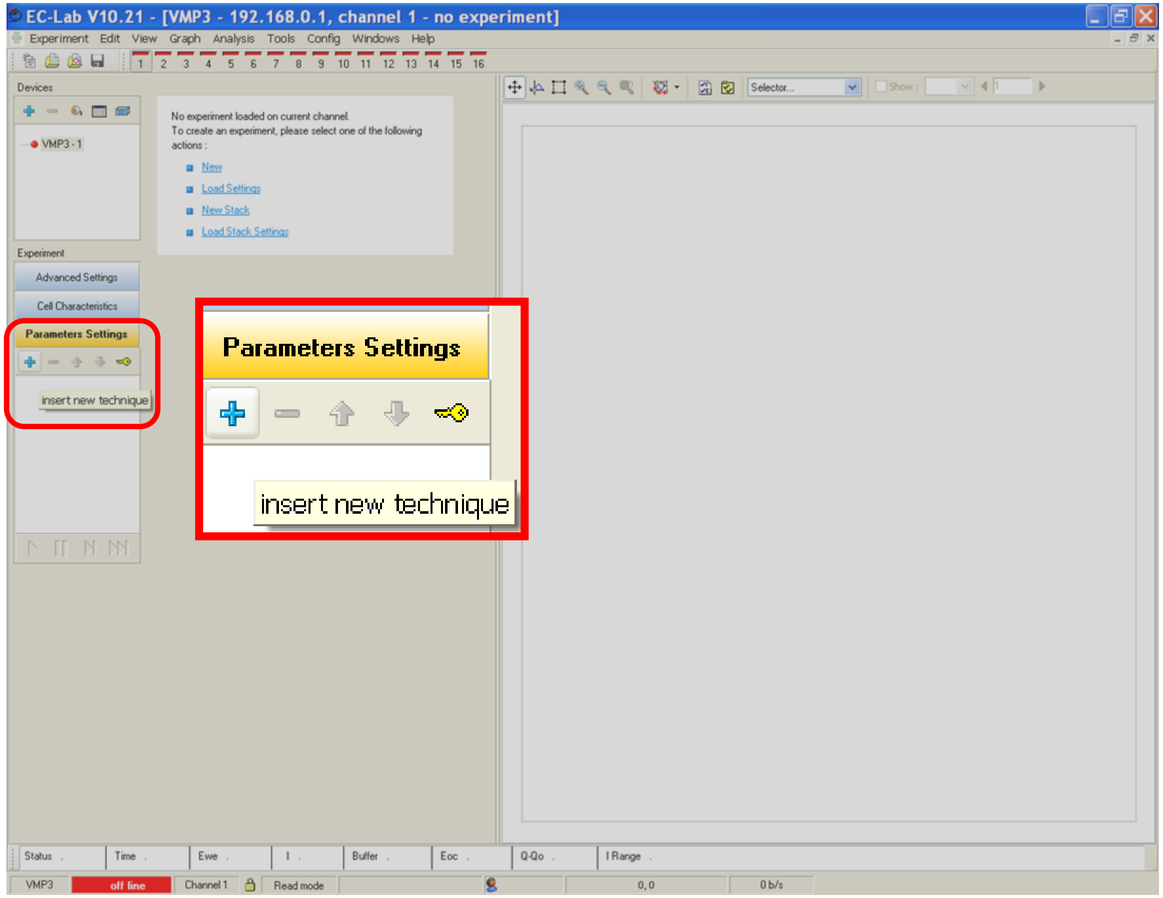
PROCEDURE

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"

1- Insert the GCPL technique

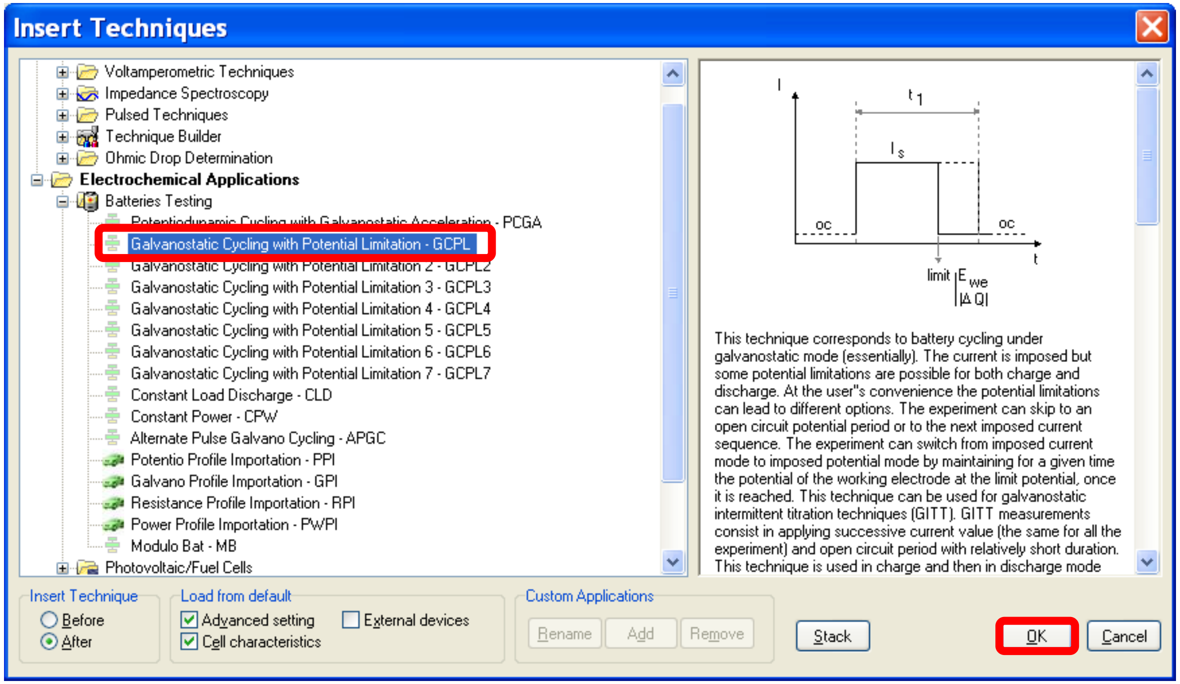
- In the experiment frame, click on the [+] button to insert the new technique.



1- Insert the GCPL technique

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

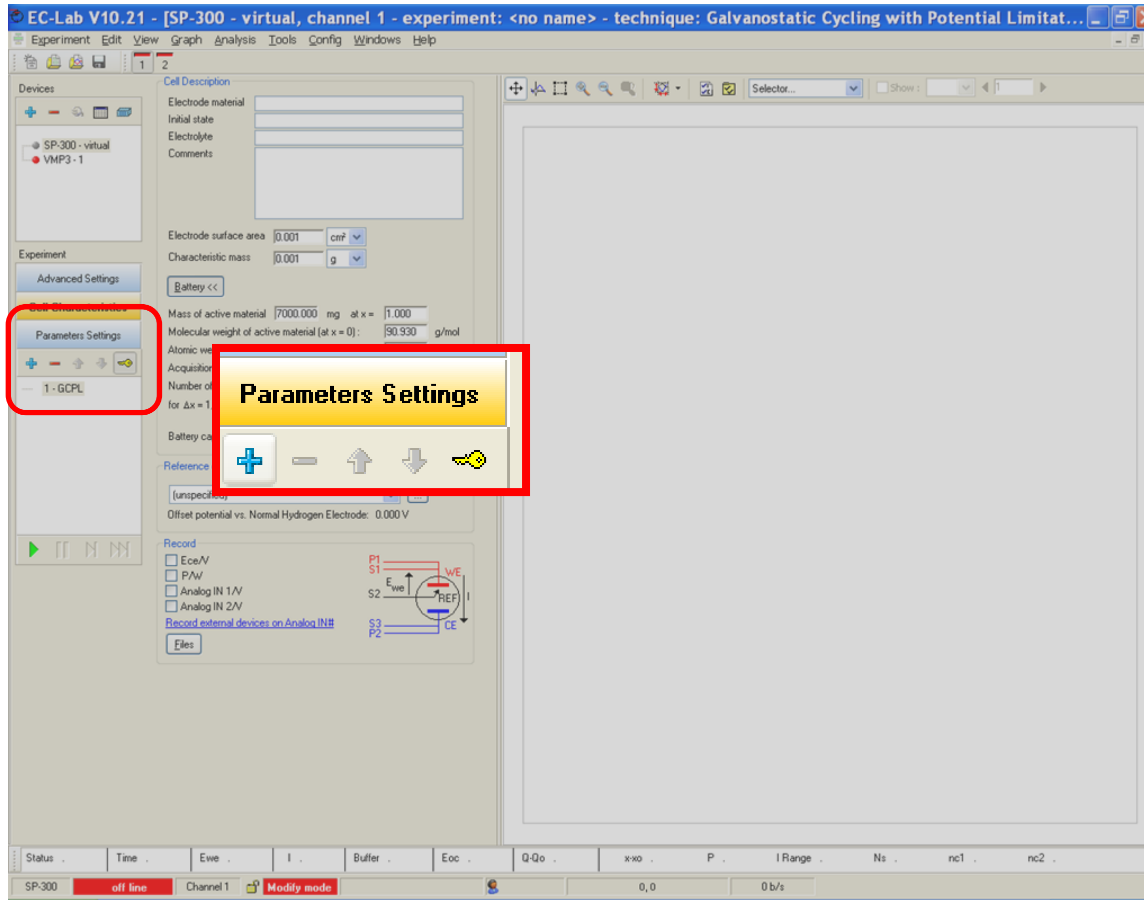
- Click on the ”OK” button



- 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.

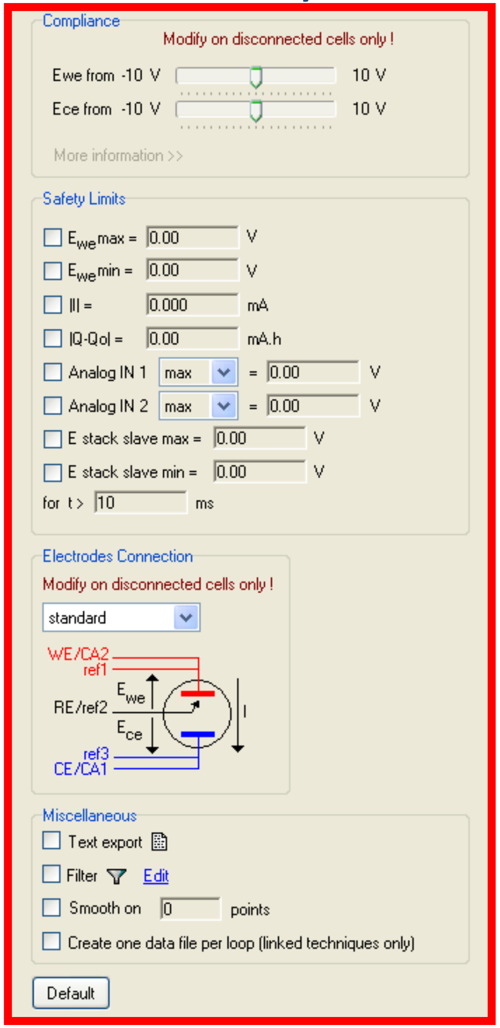
VMP3 family:

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

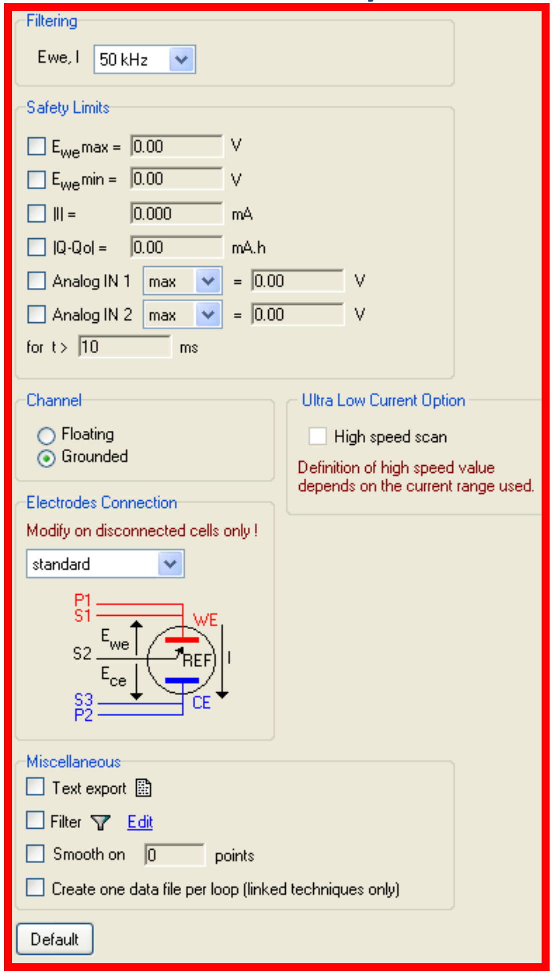
SP-300 family:

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

VMP3 family

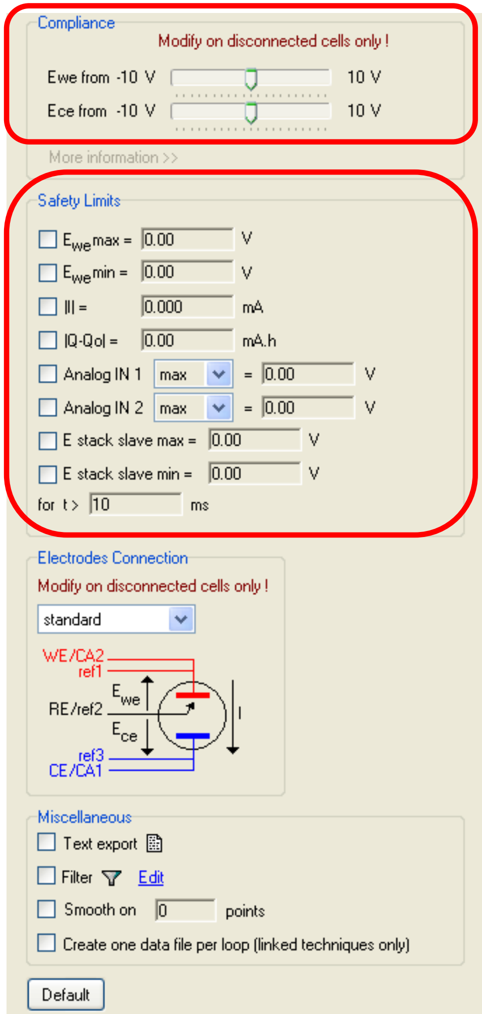


SP-300 family



3- Set the « Advanced Setting » tab

VMP3 family



Safety limits:

This allow the user to set:

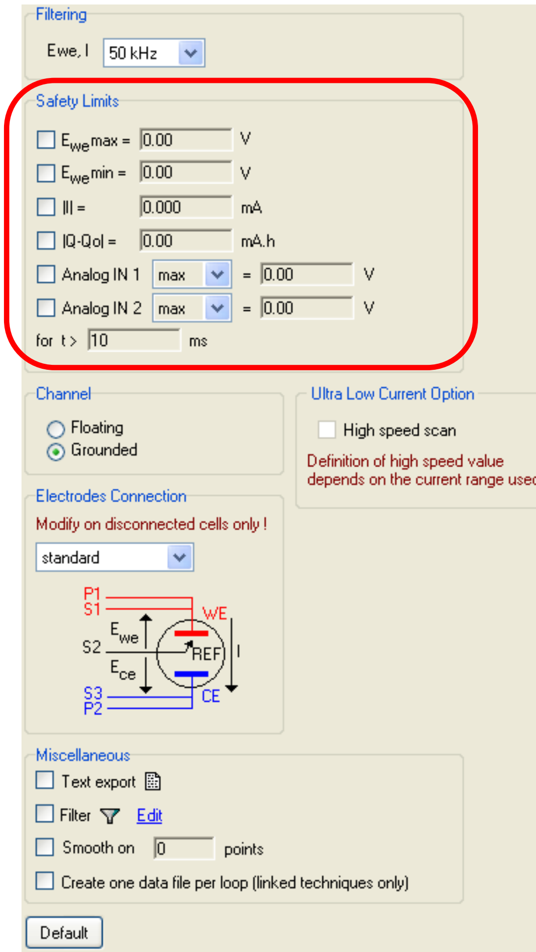
- max and min voltages
- max current in absolute value
- max charge in absolute value
- limit on the analog input, if an external device is configured (described in the slide #23)
- For stack experiment (only available for VMP3 family), it is possible to use the voltage of each cell as safety limits.
- « 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.

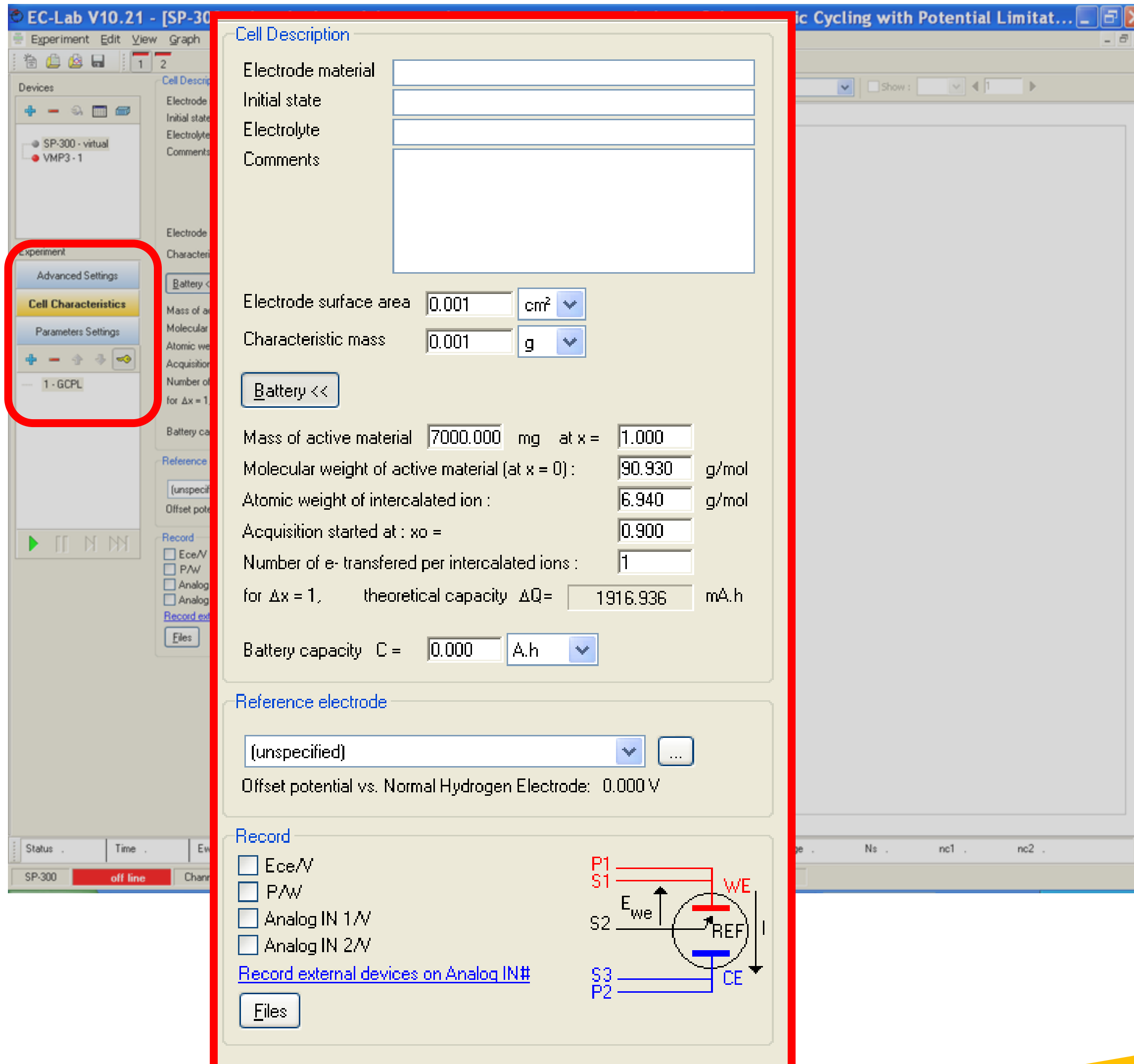
SP-300 family



4- Set the « Cell Characteristics » tab

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

  then the « Cell Characteristics » window is displayed.



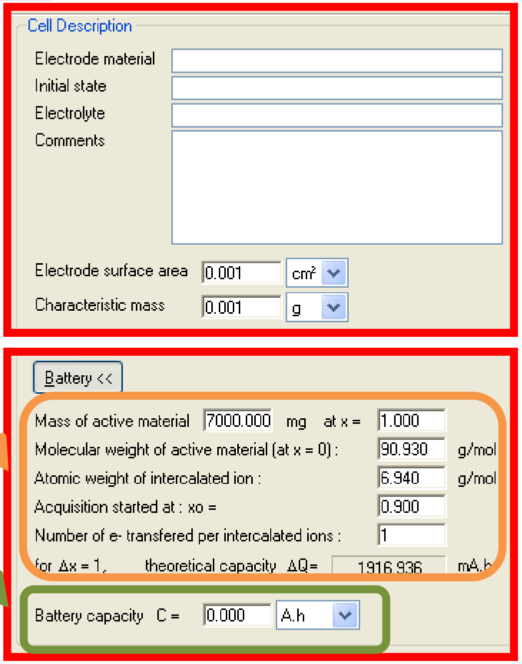
• Information about the cell and some comments.

• Click on the  button to display battery characteristics.

There are two cases:

-you know the materials inside the battery. So several boxes have to be filled to calculated 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 *xmass* in the compound of interest (for example *xmass* = 1 for $LiCoO_2$).

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 $LiCoO_2$, the molecular weight of CoO_2 is 90.93 $g.mol^{-1}$ and the atomic weight of the intercalated ion Li is 6.94 $g.mol^{-1}$.

• The initial insertion rate *xo*.

• *ne* is the number of electrons transferred per mole of intercalated ion.

NOTE:

All these infomation are stored in the data file.

5- Set the GCPL technique

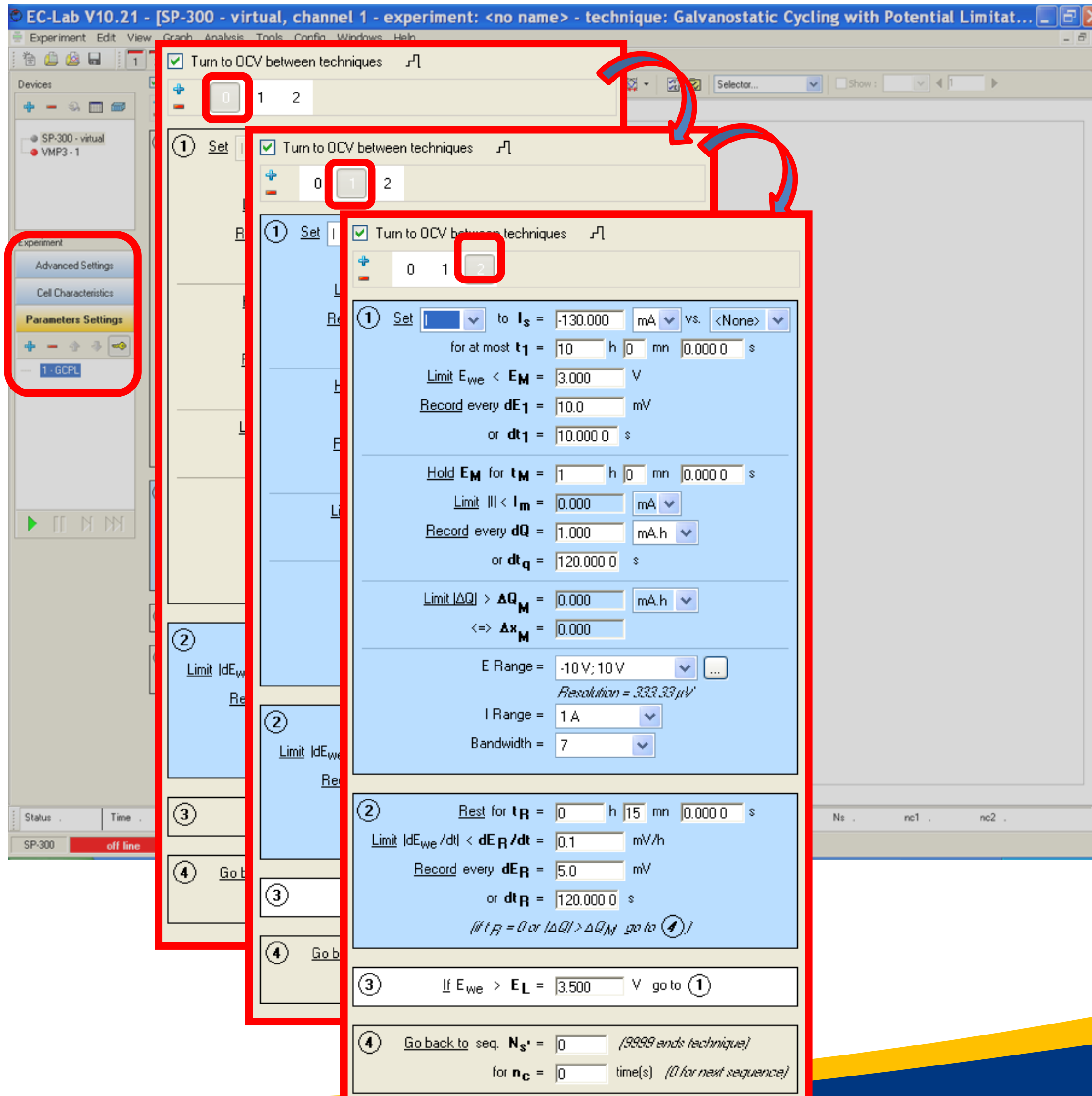
- Click on the **Parameters Settings** tab or directly on the technique GCPL in the list of technique(s). The technique is highlighted in blue.

- 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

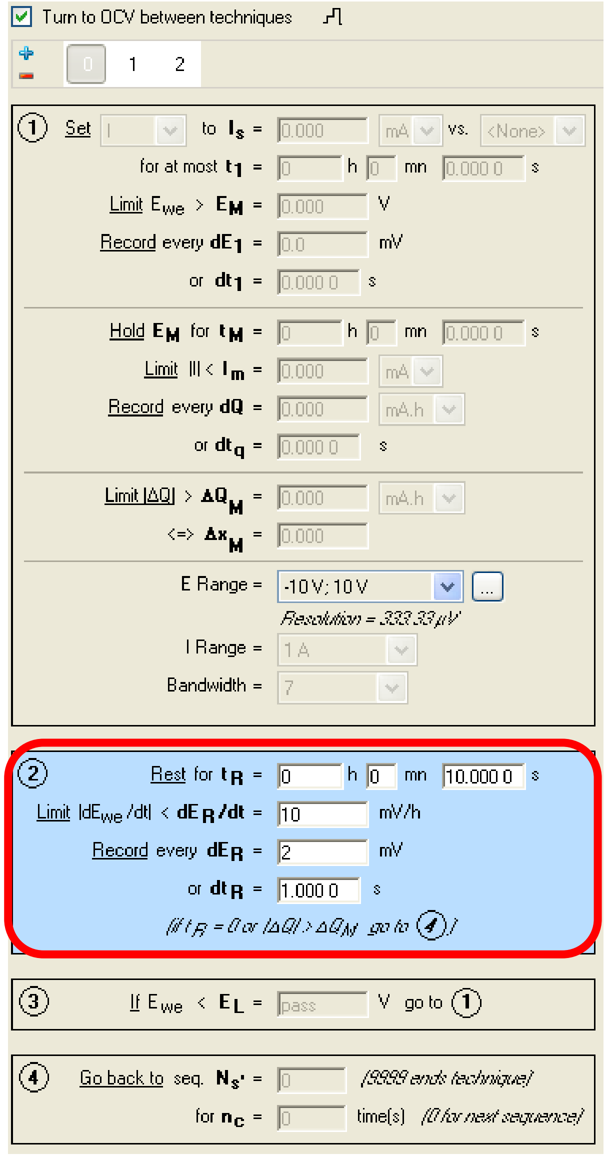
NOTE:

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



5- Set the GCPL technique

- **Rest period sequence**



Only the OCV block is active in sequence #0.

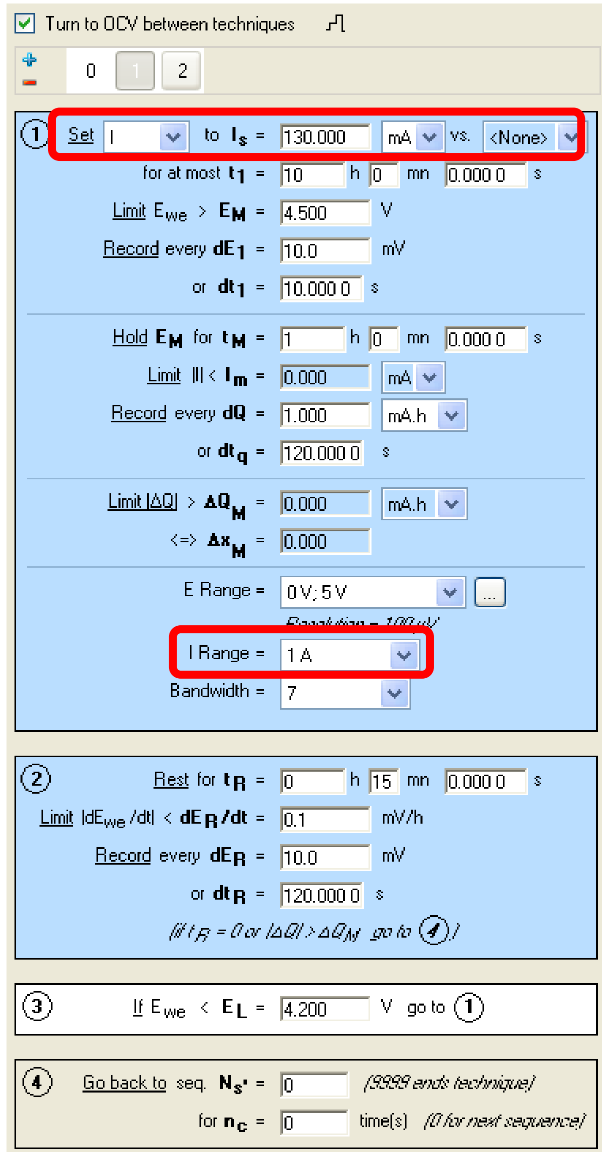
NOTE:
The block is blue, not grey. The non active blocks are in grey.

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

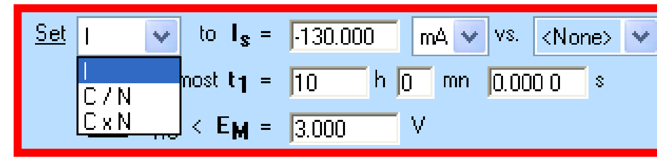
5- Set the GCPL technique

- **Charge/discharge sequence**

CC period
CC: Constant Current



- 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.



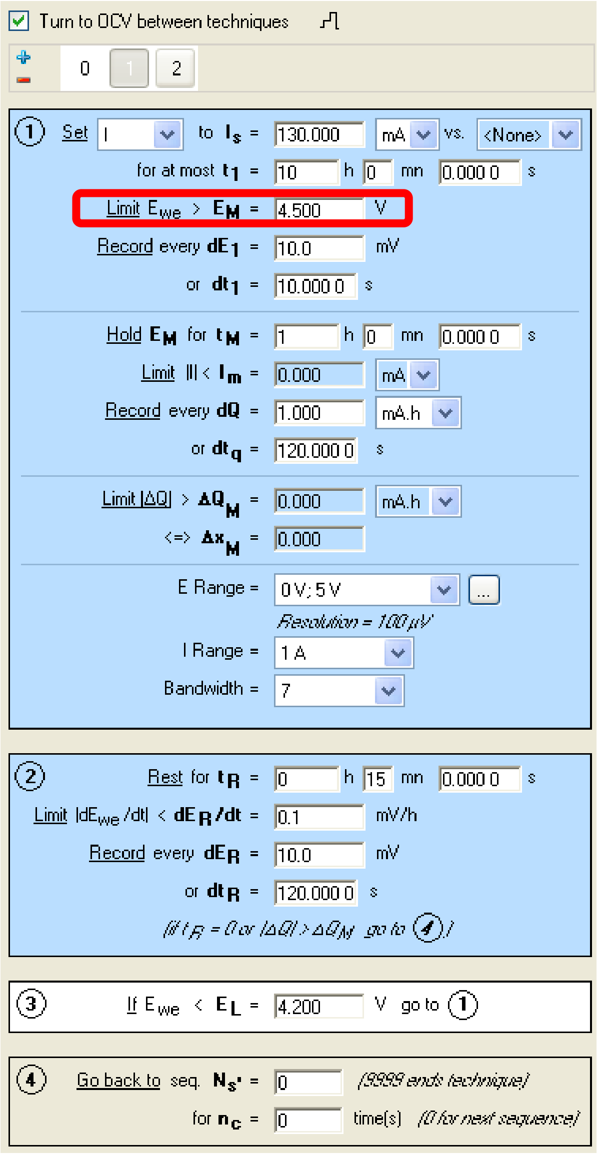
Irange has to be chosen according to the current applied.

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

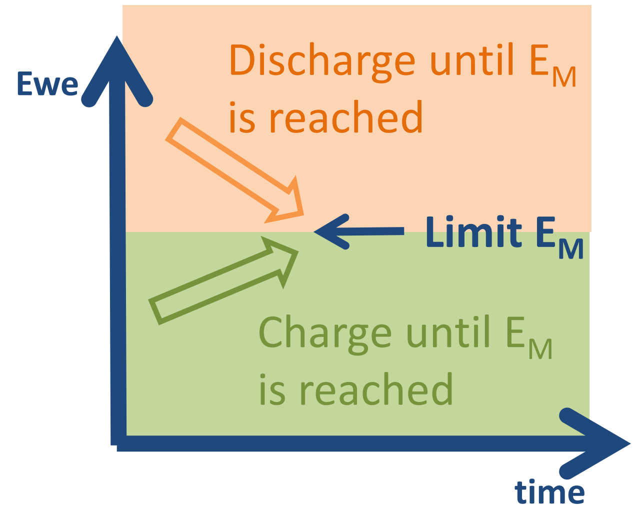
- **Charge/discharge sequence**

CC period
CC: Constant Current



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

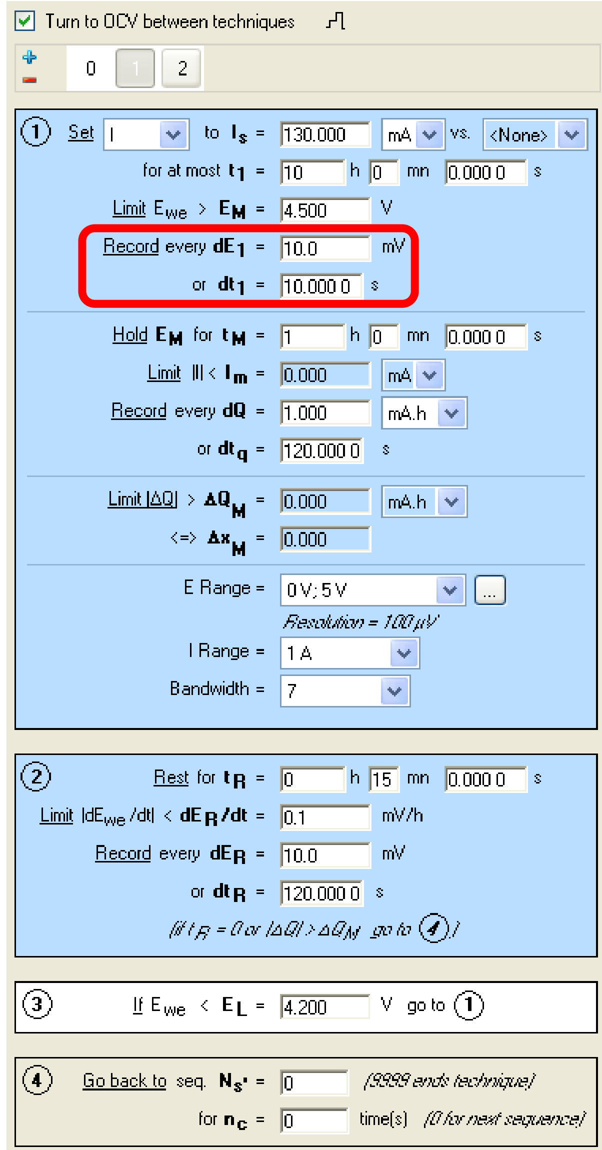
The sign “<“ or “>” is automatically updated according to the sign of the current.



5- Set the GCPL technique

• **Charge/discharge sequence**

CC period
CC: Constant Current



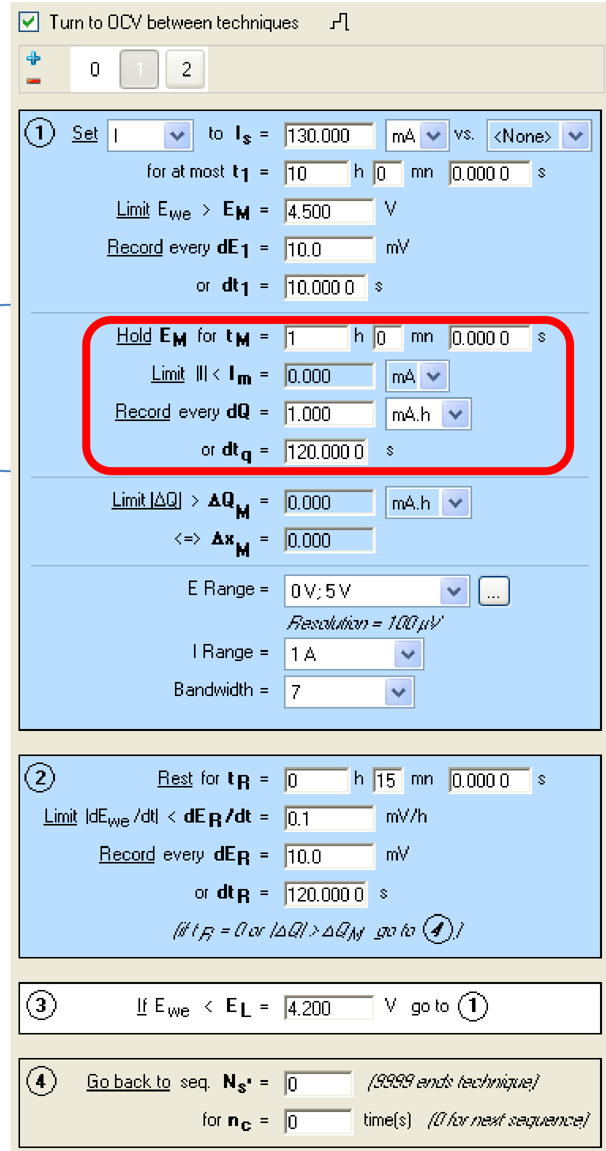
• Defines the sampling rate of the experiment.
As battery testing may take several months and voltage may be very slow, a sampling rate in dE is also offered. Only the relevant points *i.e.* when the variation of potential is equal to dE are recorded.

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 µs) 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



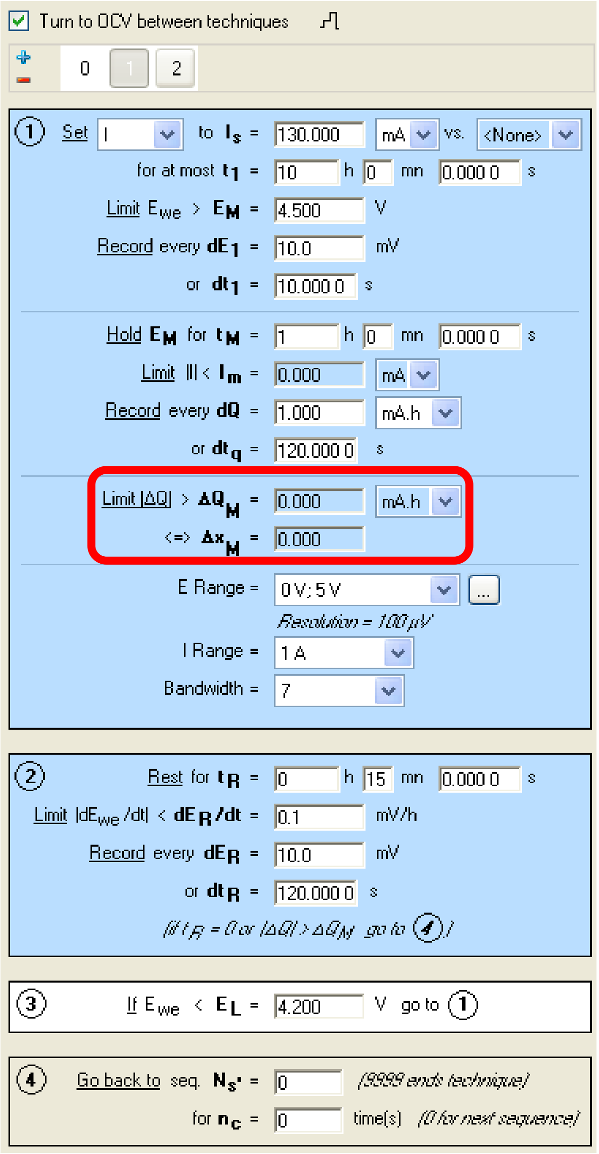
• This block allows the user to complete the charge/discharge in potentiostatic mode (in the first block the charge/discharge was performed in galvanostatic mode).

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 dtq (time) and also a limit on the current.

5- Set the GCPL technique

- **Charge/discharge sequence**

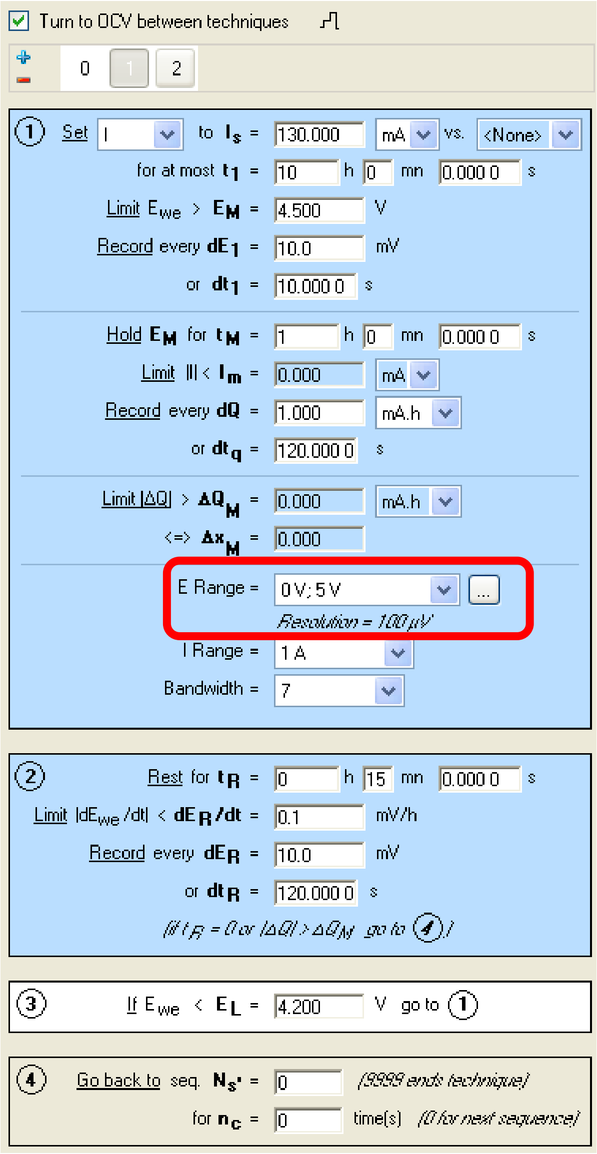


This is the limit on the total charge exchanged during the sequence. This limit can also be defined with the intercalation coefficient.

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

5- Set the GCPL technique

- **Charge/discharge sequence**

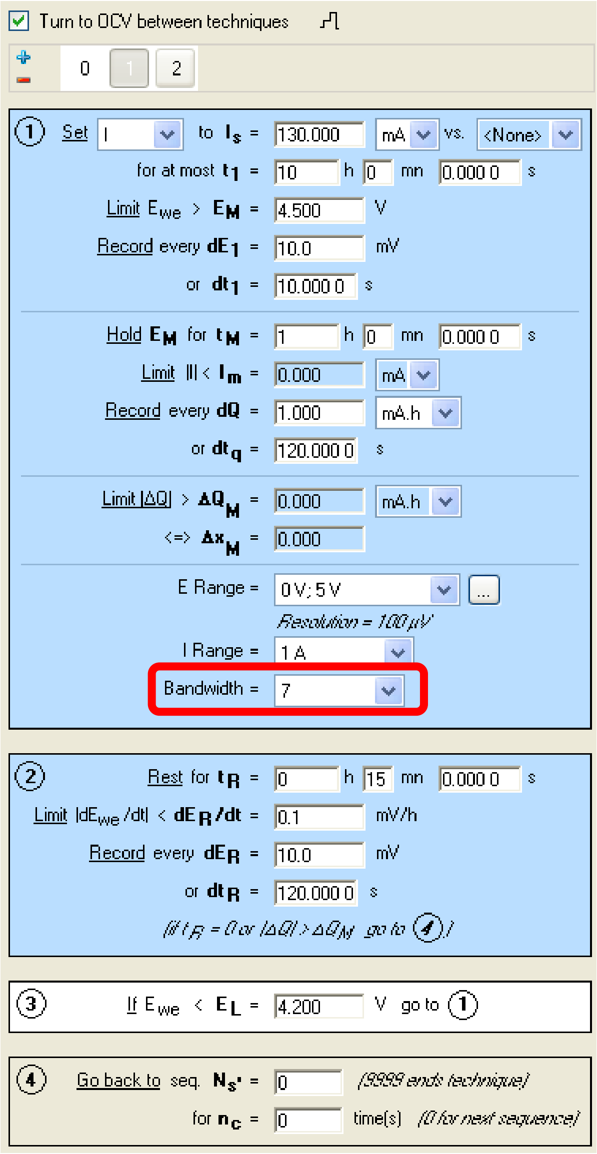


- The Erange has to be wide enough to be in the range of the operating voltage of the battery but narrow enough to get an optimized resolution in the voltage measurement/control.

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

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

- **Charge/discharge sequence**

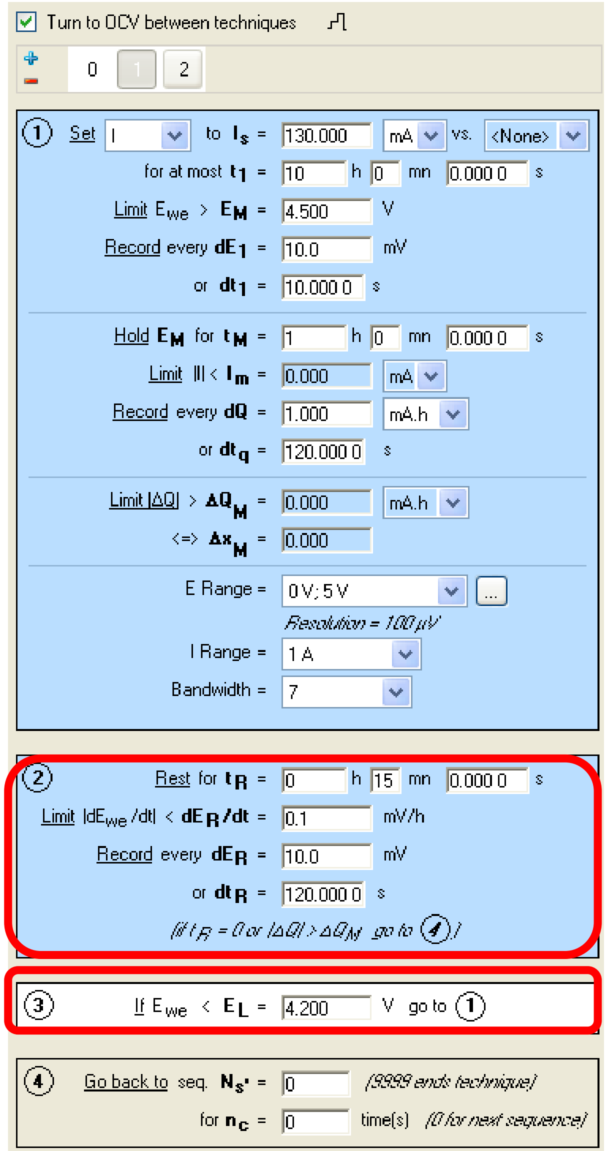


This parameter defines the stability/speed (regulation loop) of the instrument. As battery have a slow response, a slow bandwidth will be appropriate. Bandwidth of 5 for VMP3 family and 7 for SP-300 family is often appropriate. (See manuals and application note for more information bandwidth).

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

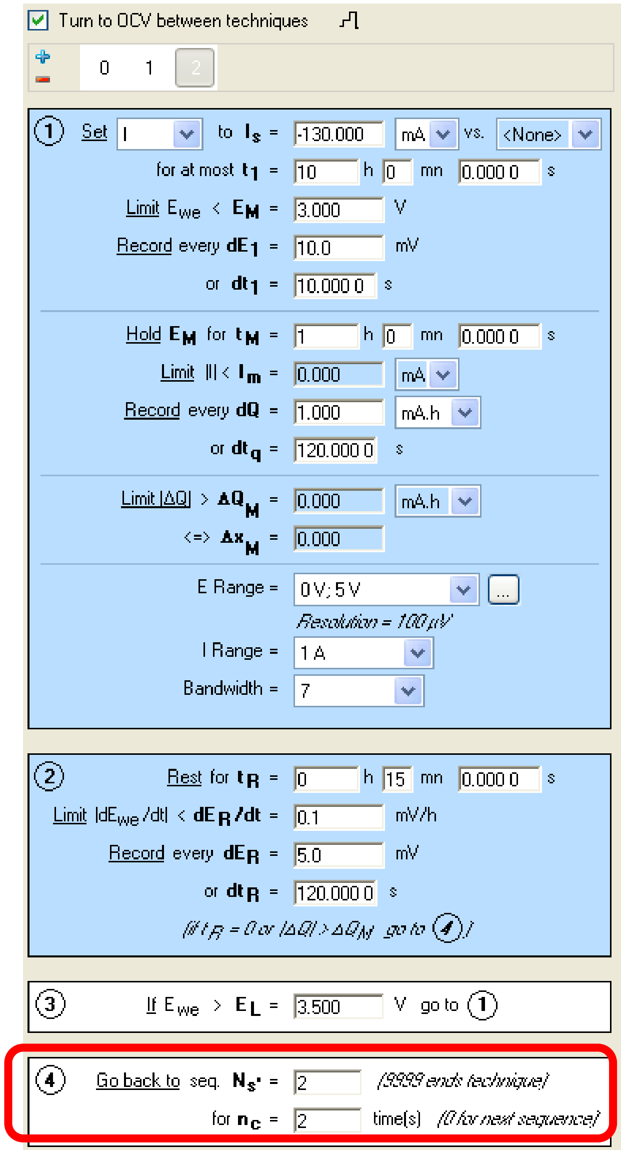
- **Charge/discharge sequence**



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**

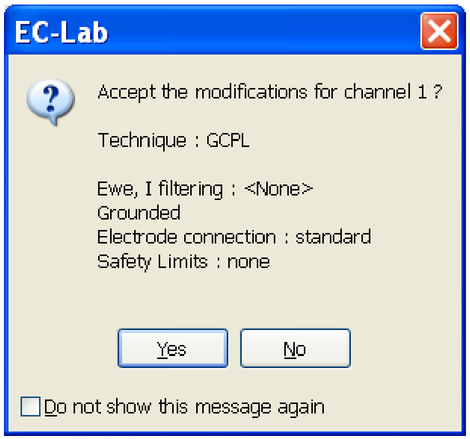


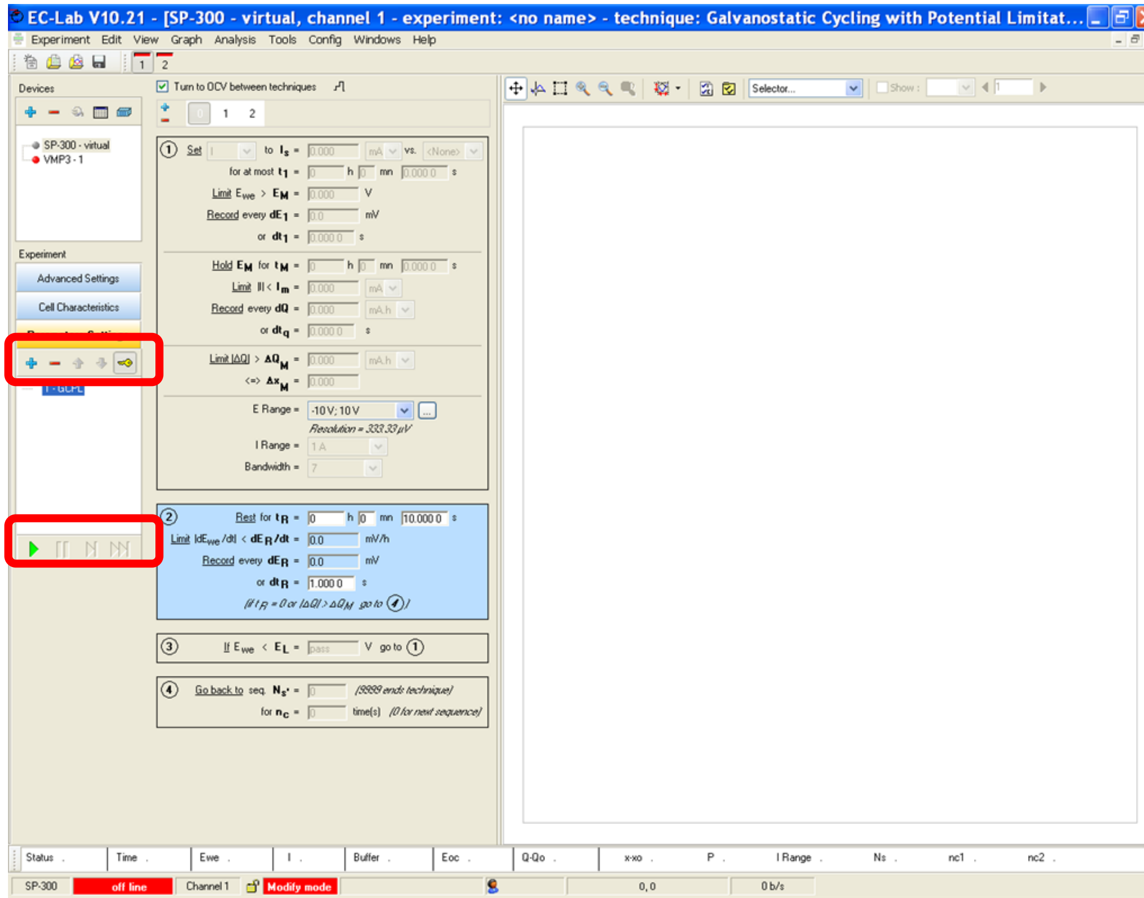
This allows the user to loop on a sequence of charge/discharge within the GCPL technique. The user defines at which sequence the protocol will go back and for how many times.

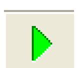
6- Start the experiment

- Click on  button to check if the settings are accepted

- Some warning messages may come up.

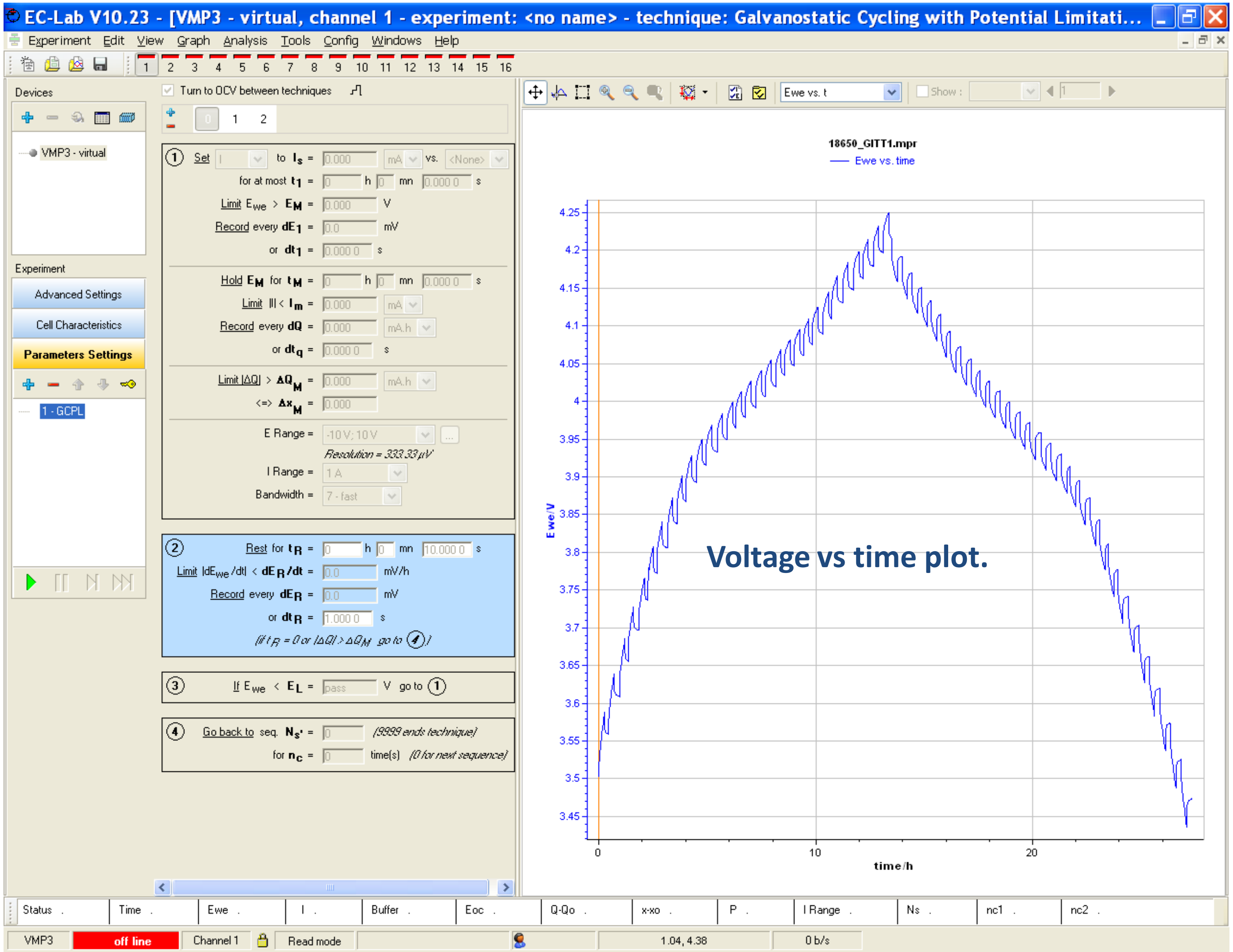




- Click on the  button to start the experiment.

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

Example of resulting data



Getting Started: GCPL

Appendix: Set the « external device »

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.