How to use Bio-Logic products to test batteries ?

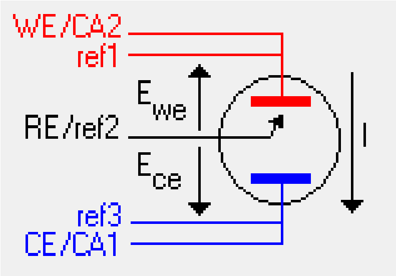
N. Murer

Outline

1. **Configuration**
2. DC techniques
3. Impedance spectroscopy
4. Processing data

Configuration

- REF1 : Red – for the control and the measurement of the working electrode potential.
- REF2 : White – for the control and the measurement of the reference electrode potential.
- REF3 : Blue – for the control and the measurement of the counter electrode potential.
- CA2 (Control amplifier): Red – for the control and the measurement of the working electrode current (standard mode).
- CA1: Blue – for the control and the measurement of the counter electrode current (standard mode).
- GND (Ground): Black



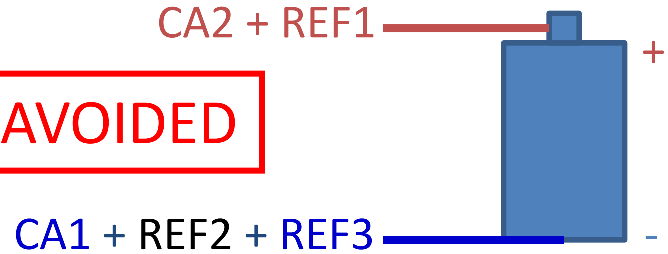
Configuration

Two points connection

+ WE = CA2 + REF1

- CE = CA1 + REF2 + REF3

TO BE AVOIDED

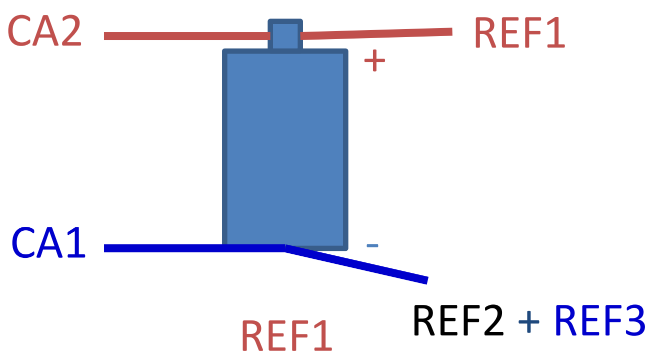


Four points connection

+ WE = CA2 (for current)
REF1 (for potential)

- CE = CA1 (for current)
REF2 + REF3 (for potential)

OK



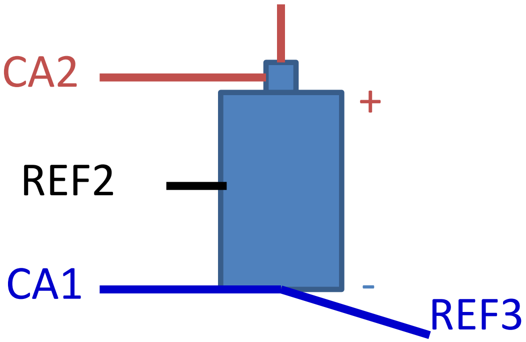
Three points connection

+ WE = CA2 (for current)
REF1 (for potential)

- CE = CA1 (for current)
REF3 (for potential)

REF = REF2

OK

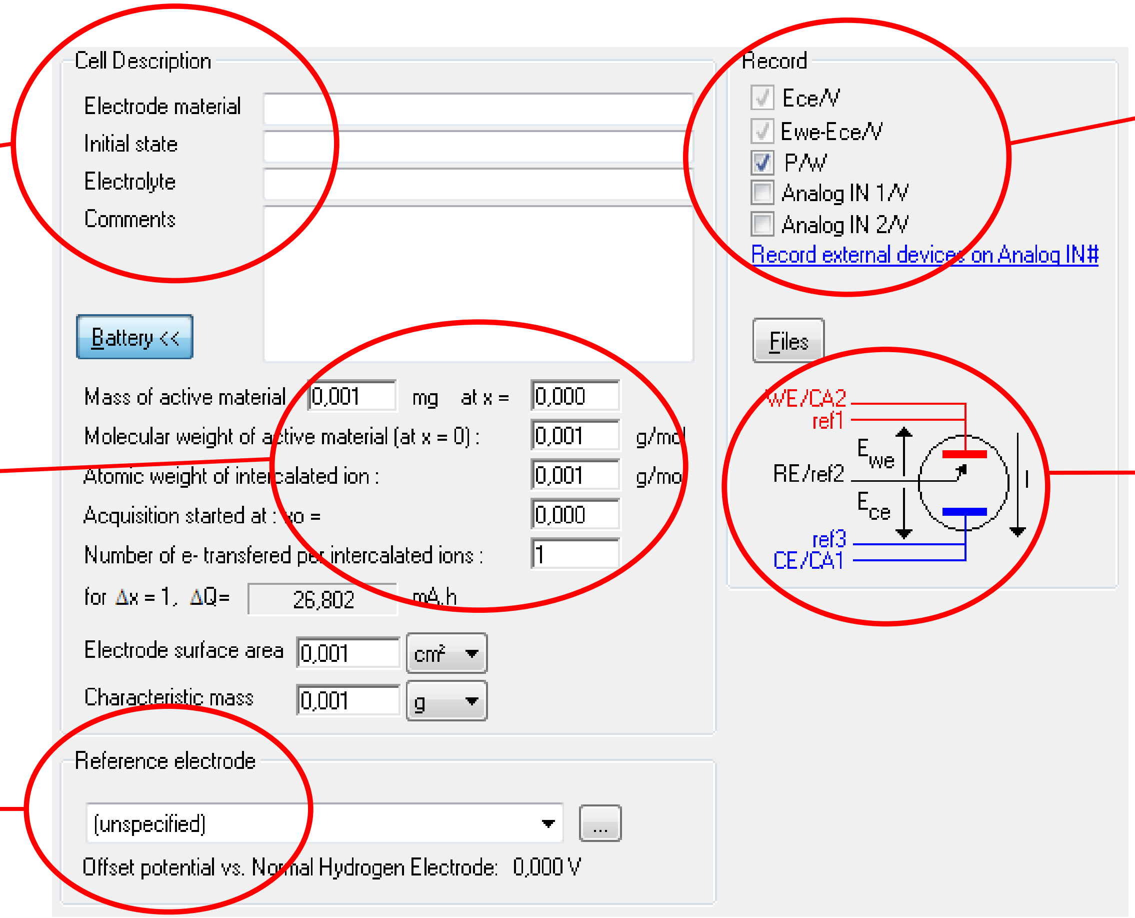


Cell Characteristics

Cell description

Parameters for the intercalation coefficient

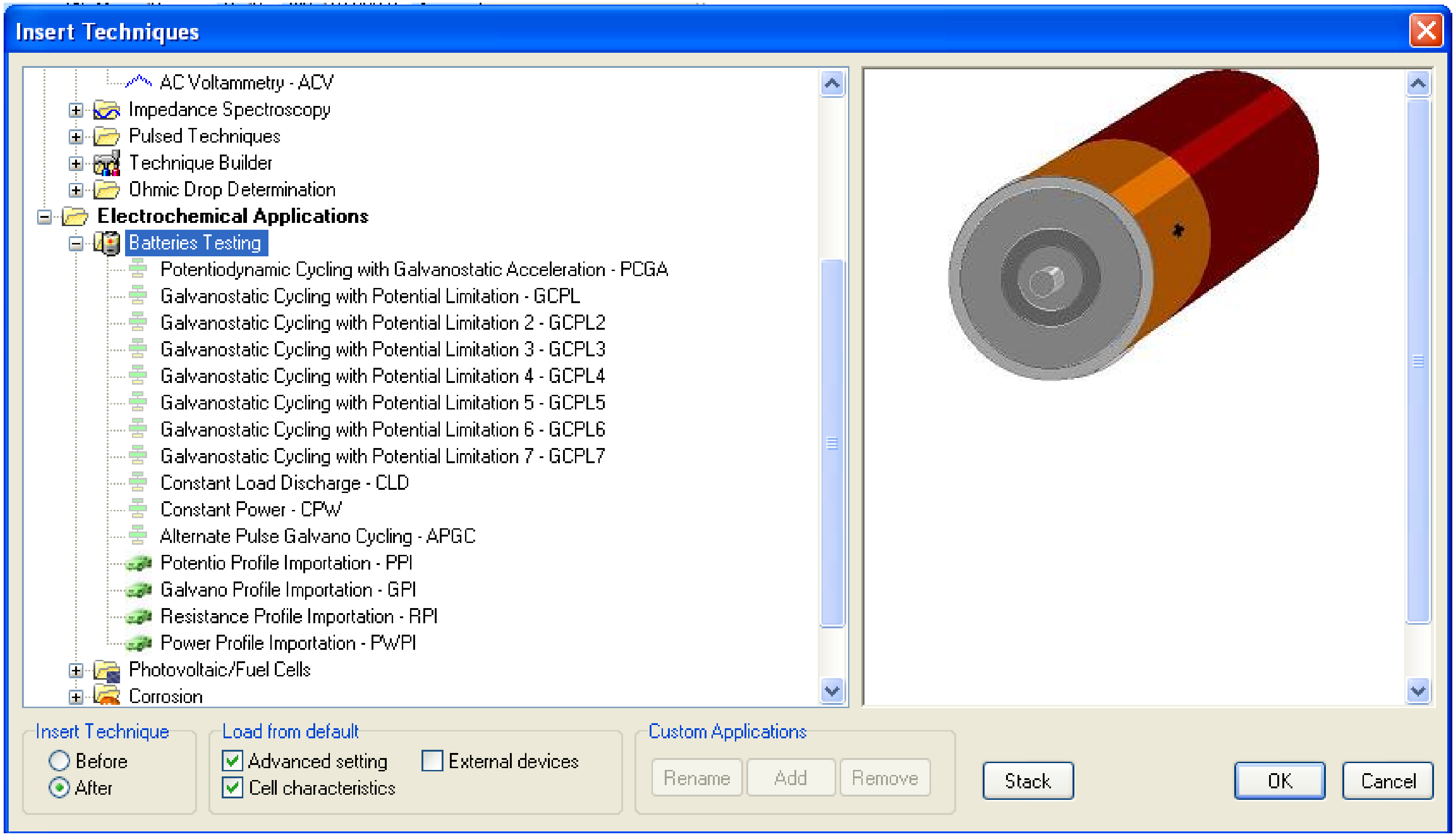
Reference electrode



Additional recording conditions

Cell connection mode

Batteries Testing Applications



Outline

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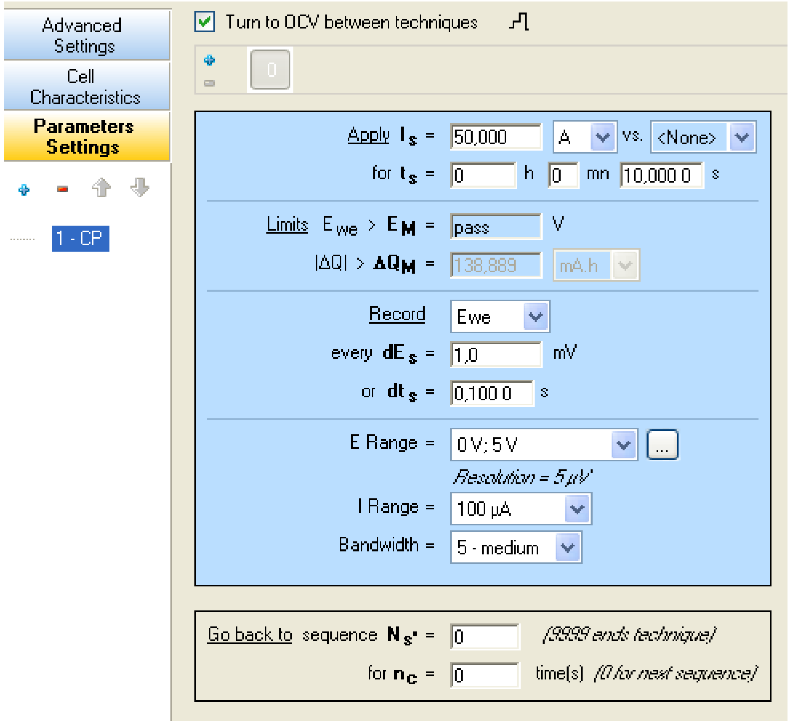
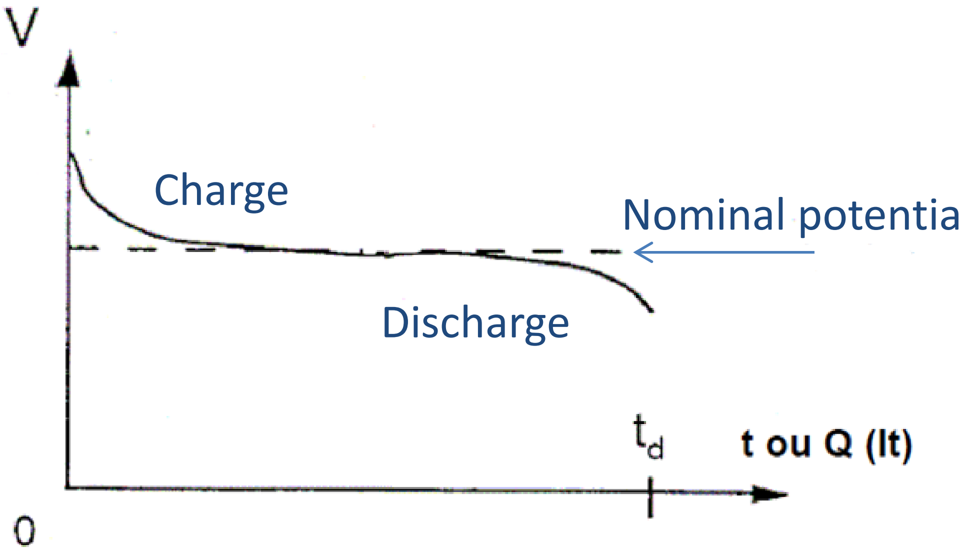
CP

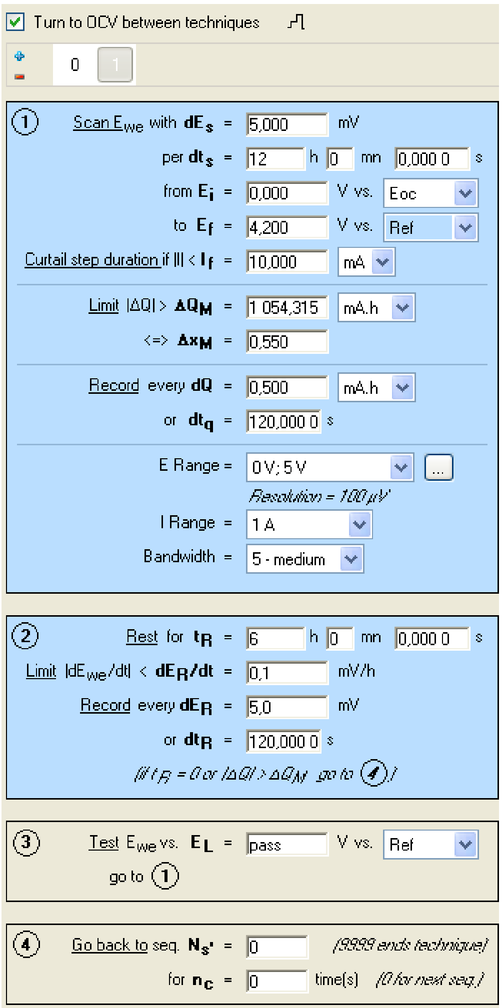
The most basic technique to characterize batteries is CP (ChronoPotentiometry). It consists in applying a positive or negative constant current and recording the evolution of the cell voltage with time.

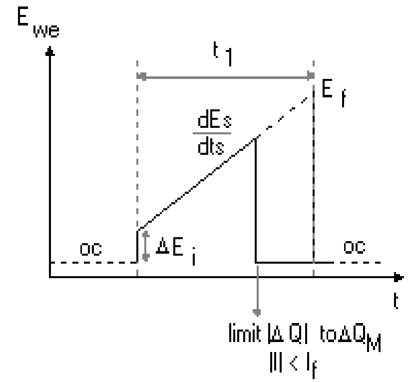




PCGA

Potentiodynamic Cycling with Galvanostatic Acceleration



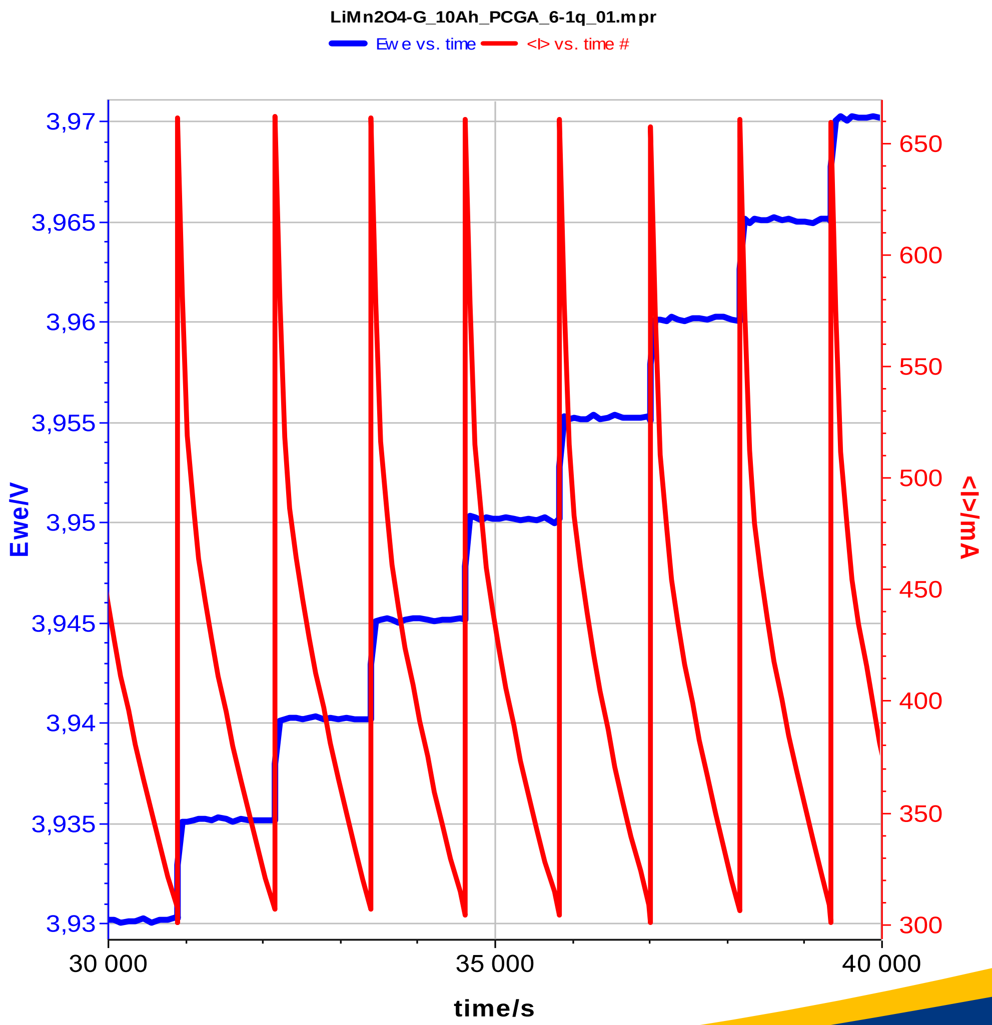


- Cycling under stepwise potentiodynamic mode.
- Potential sweep defined by setting the potential step amplitude and duration.
- Possible limit of the step duration on the charge or discharge currents value.
- Can be used for PITT (Potentiostatic Intermittent Titration Technique)[1] experiments.

1. C. John Wen et al. J. Electrochem. Soc. 126, 12, (1979) pp 2258-2266

PCGA

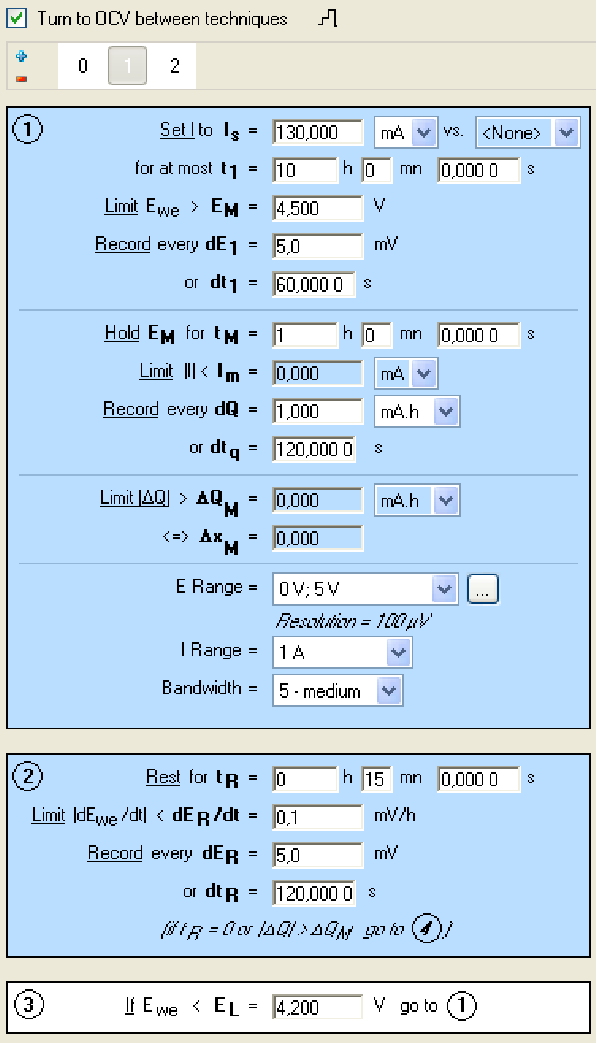
- Successive potential steps with a conditional limit on the minimum current
- Current measured as a function of time, which allows determination of the incremental capacity dx/dV more precisely than CP.
- No relaxation period.
- The magnitude of the current transient can be used to provide a measure of the chemical diffusion flux of the mobile species as a function of time t[1].
- The main drawback is that the ohmic drop across the cell is not eliminated.



1. W. Weppner and R. A. Huggins, J. Electrochem. Soc. 126, 12, (1977) pp 2258-2266

GCPL

Galvanostatic Cycling with Potential Limitation



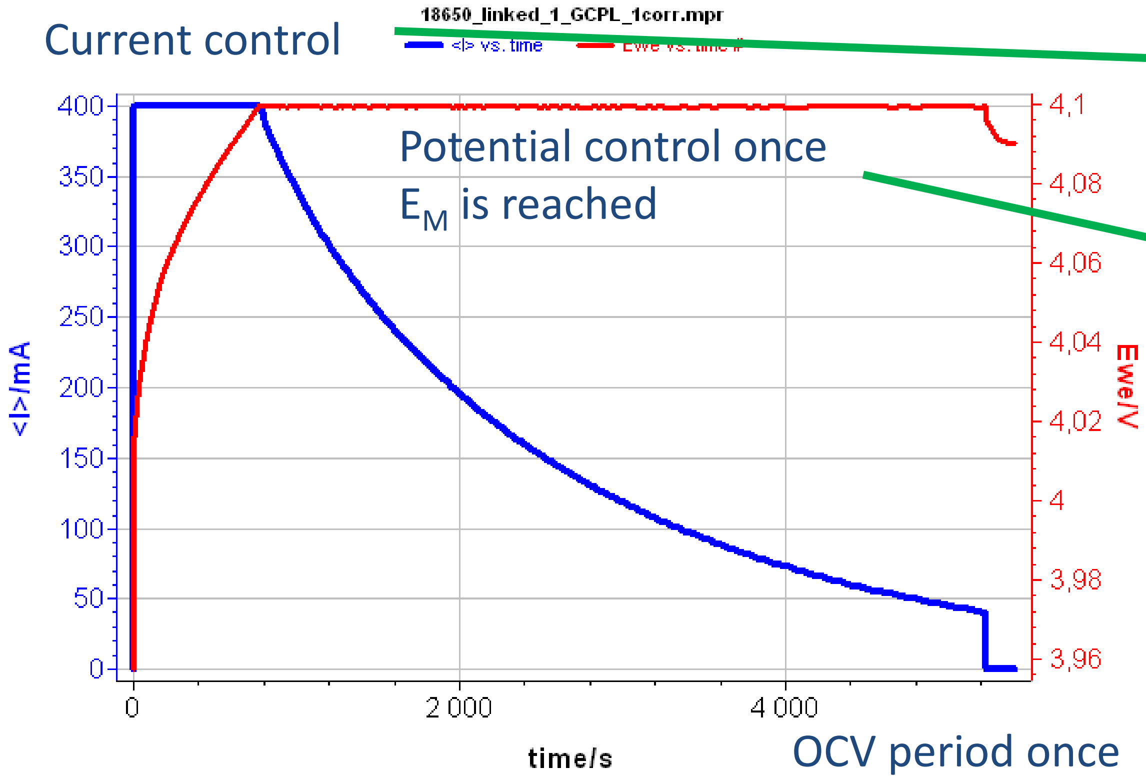
- Battery cycling under galvanostatic mode i.e. with an imposed current
- Possible voltage limitations under current for both charge (positive current) and discharge (negative current)
- GCPL can be used to perform GITT (Galvanostatic Intermittent Titration Technique)[2] experiments.
- Similarly to PITT, GCPL can be used to have the chemical diffusion coefficient of the mobile species in the electrode.

1. C. John Wen et al. J. Electrochem. Soc. 126, 12, (1979) pp 2258-2266

GCPL

Charge sequence

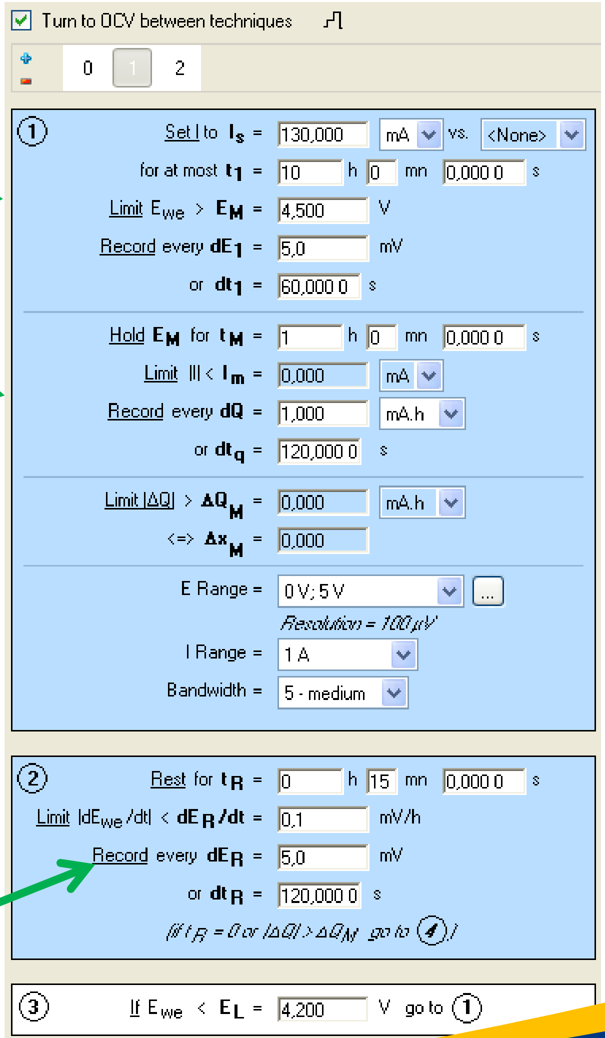
Current control



Potential control once E_M is reached

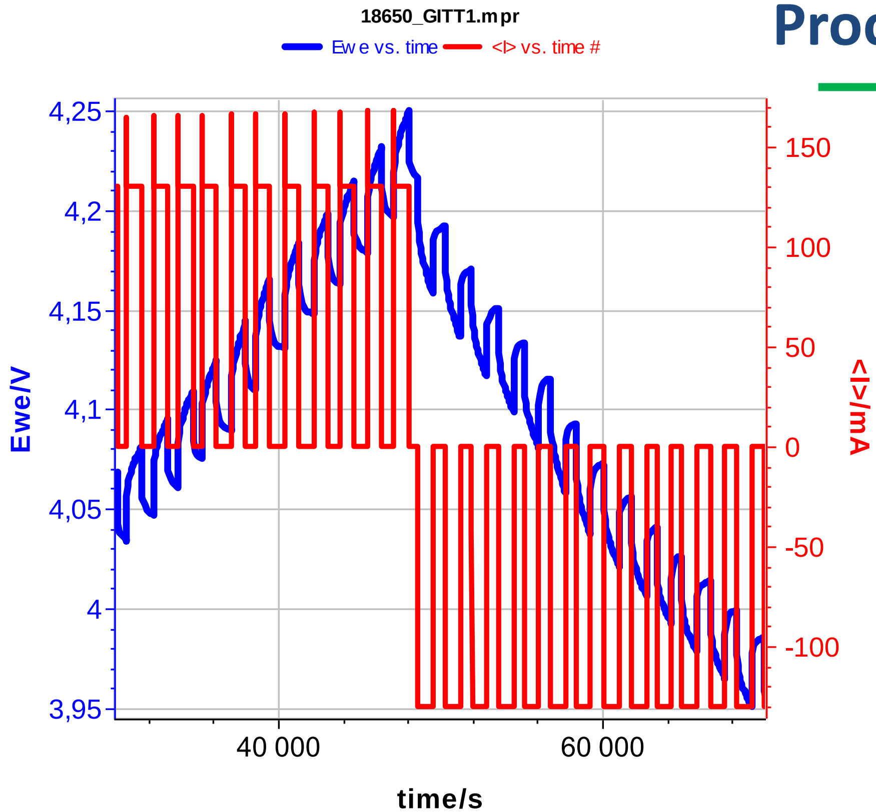
OCV period once the current limit I_m is reached

If Ewe is below E_L after OCV, the charge starts again.

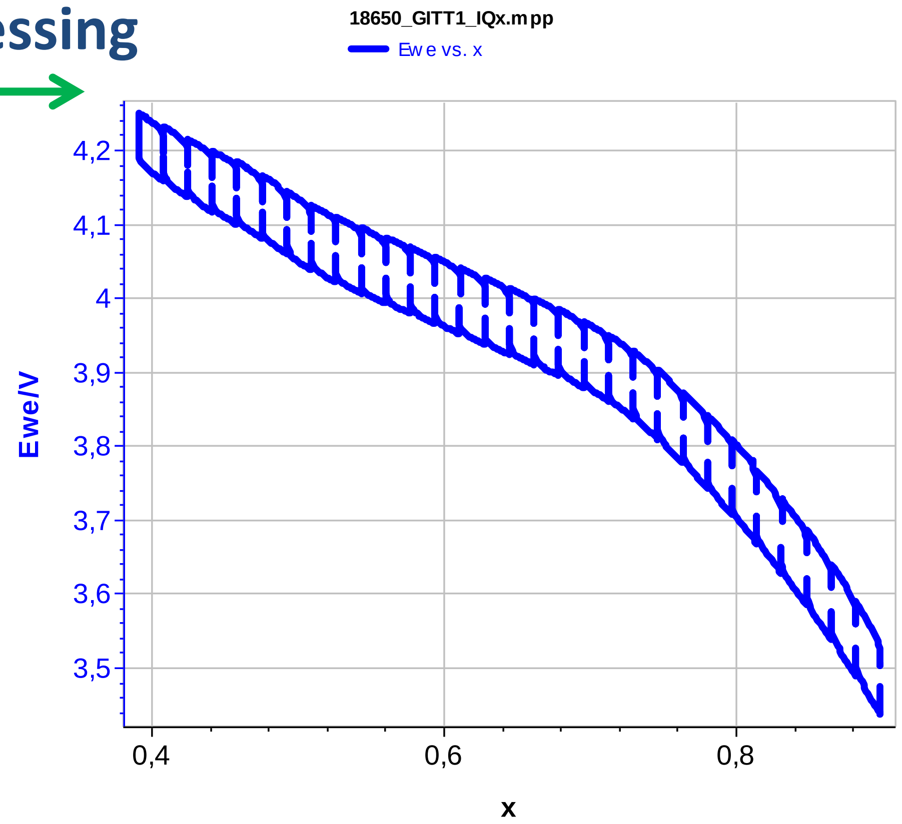


GCPL

In case of a sluggish process, the charge/discharge is performed until E_L is reached.



Processing



It is now possible after processing to see the evolution of E vs x, which is the number of moles of inserted mobile species (Li^+, OH^-...).

Other GCPL techniques

GCPL2 : GCPL with a limitation on the voltage of the working electrode and of the counter electrode.

GCPL3 : GCPL2 with the possibility to hold potential after charge or discharge.

GCPL4 : GCPL with the possibility to set the global time of the charge/discharge period.

GCPL5: GCPL with the possibility to calculate the dynamic resistance at different time .

GCPL6 : GCPL with a voltage control and limit on WE-CE.

GCPL7 : GCPL but the holding period is performed with a current control.

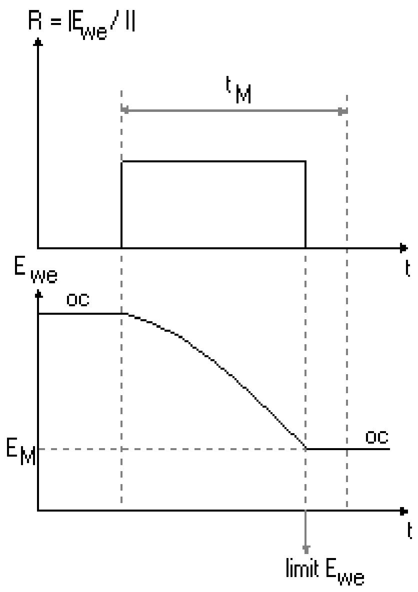
SGCPL : GCPL with a limitation on the external input/output

See Application Note #1, 2, 3
http://bio-logic.info/potentiostat/notesan.html

CLD/CPW

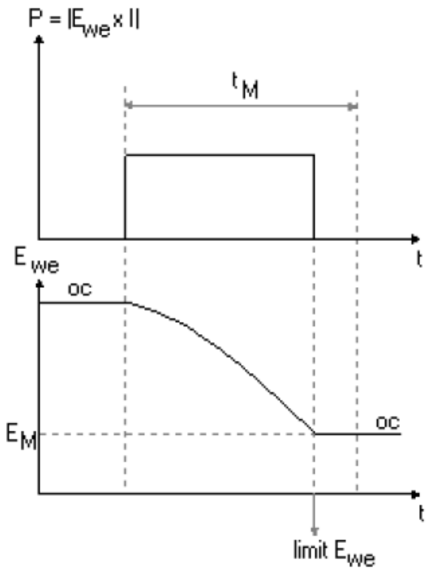
CLD: Constant Load Discharge

- Discharge of a battery at a constant resistance.
- Potentiostat seen as a constant resistor by the battery.



CPW: Constant Power

- The current is controlled to hold E*I constant.
- Used for determination of Ragone plot (power vs. energy).



See Application Note #6, 33, 34

http://bio-logic.info/potentiostat/notesan.html

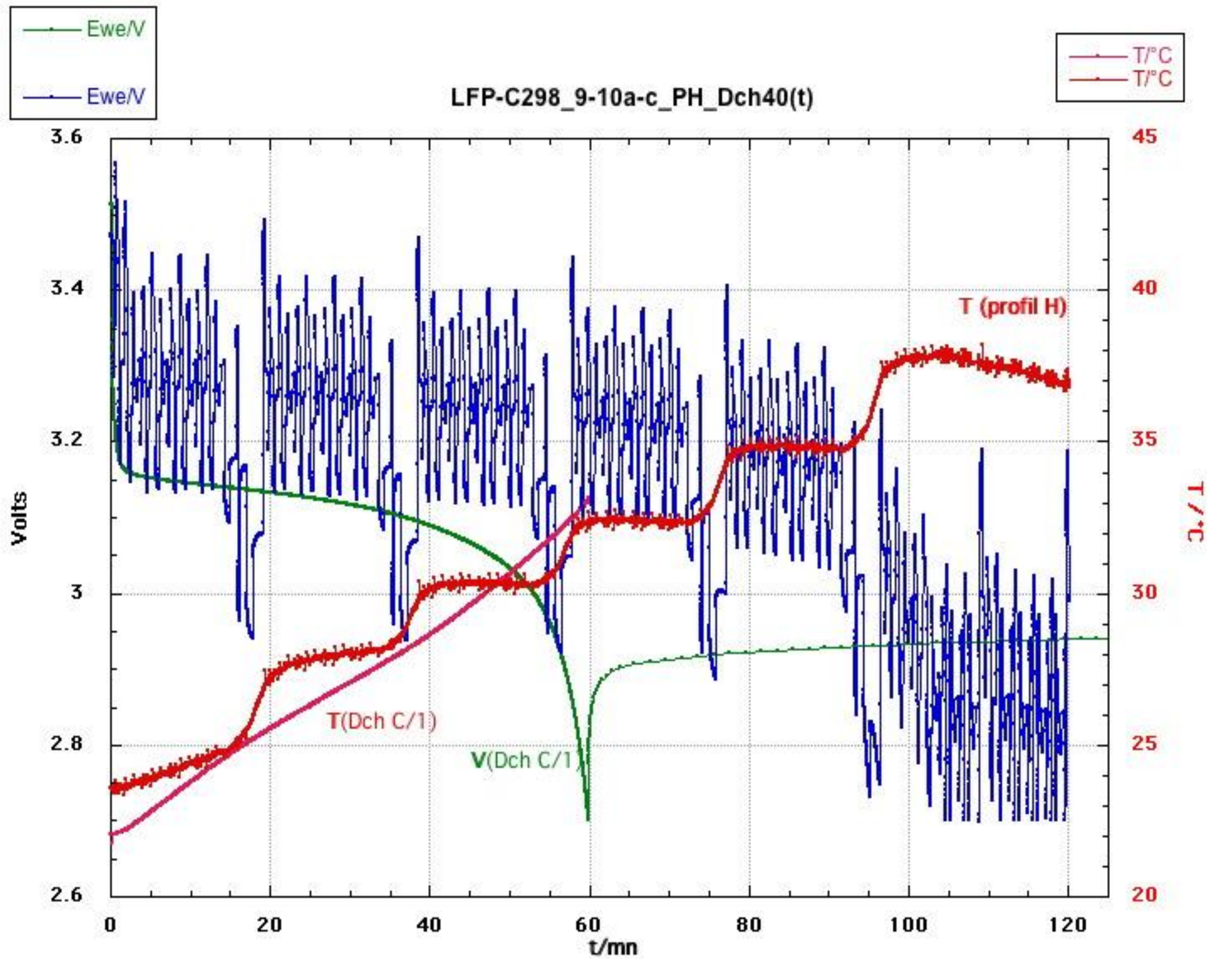
Urban profile importation

GPI	Galvano: I control
PPI	Potentio: E control
RPI	Resistance: R control
PWPI	Power: P control

- Up to 3000 sequences in the same technique
- Possibility to repeat one or several sequences
- Profile created step by step or imported from an ASCII file

Urban profile importation

GPI: European standard profile NEDCL on a 40 A.h LFP cell



- Green: discharge at a constant rate C/1
- Red: Temperature change during the constant discharge C/1
- Blue: discharge profile with 4 urban cycles and 1 extra urban cycle
- Repeated 6 times
- Red: Temperature change during the urban cycles

Outline

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3. **Impedance spectroscopy**
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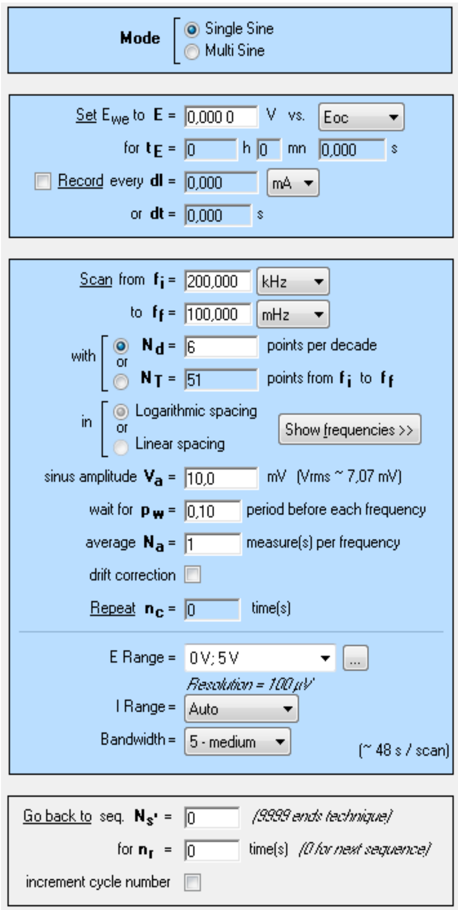
Impedance Spectroscopy

- It can be performed either with an applied current (GEIS) or potential (PEIS) mode.
- It can be performed automatically at different states of charge by linking PEIS to GCPL.
- It is used to study the electrode-electrolyte interfaces.
- It can be used to evaluate the dependence of the impedance with the state of charge (SOC).
- It can be used to study aging of the battery (state of health = SOH).

See Application Note #5, 8, 9, 14, 15, 16, 17, 18, 19, 23
http://bio-logic.info/potentiostat/notesan.html
See Impedance tutorial

Impedance Spectroscopy

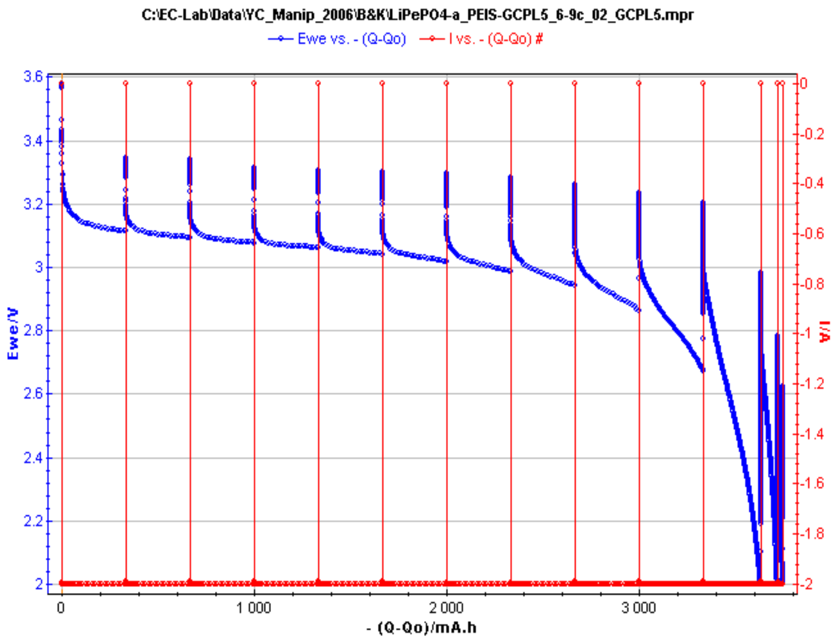
Potentio EIS / Galvano EIS techniques



- EIS can performed with an increasing DC bias voltage and current.
- A patented drift correction can be applied to the battery if the steady state is not reached.
- There is a possibility to set sequences with different sinus amplitudes.
- A multisine mode can be used to reduce the measurement duration.

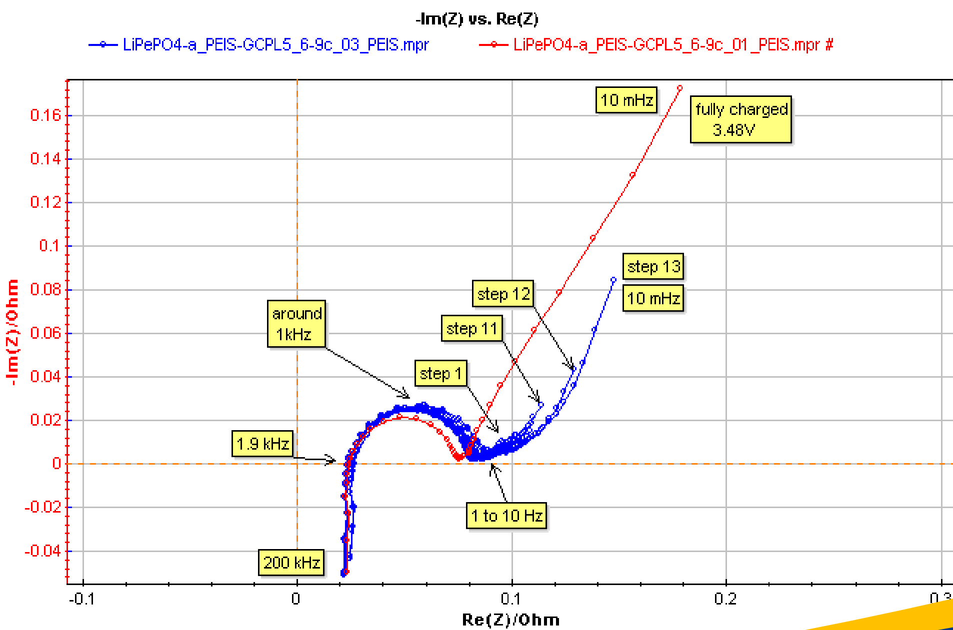
See Application Note #5, 8, 9, 14, 15, 16, 17, 18, 19, 23
http://bio-logic.info/potentiostat/notesan.html
See Impedance tutorial

Impedance Spectroscopy



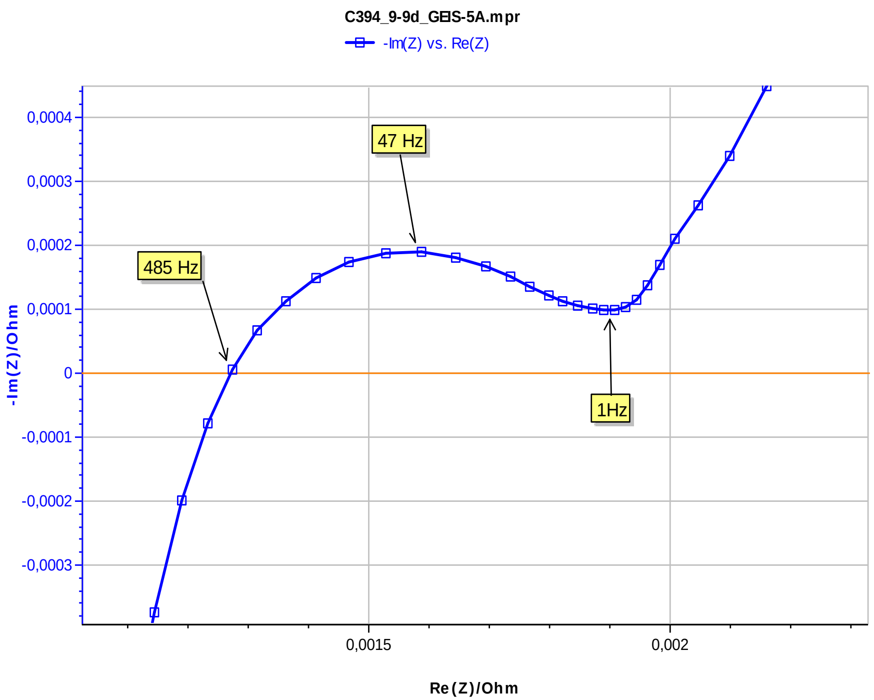
- Materials: Lithium Iron Phosphate $LiFePO_4$ / Graphite
- Nominal potential = 3,1V
- Structure: 3D

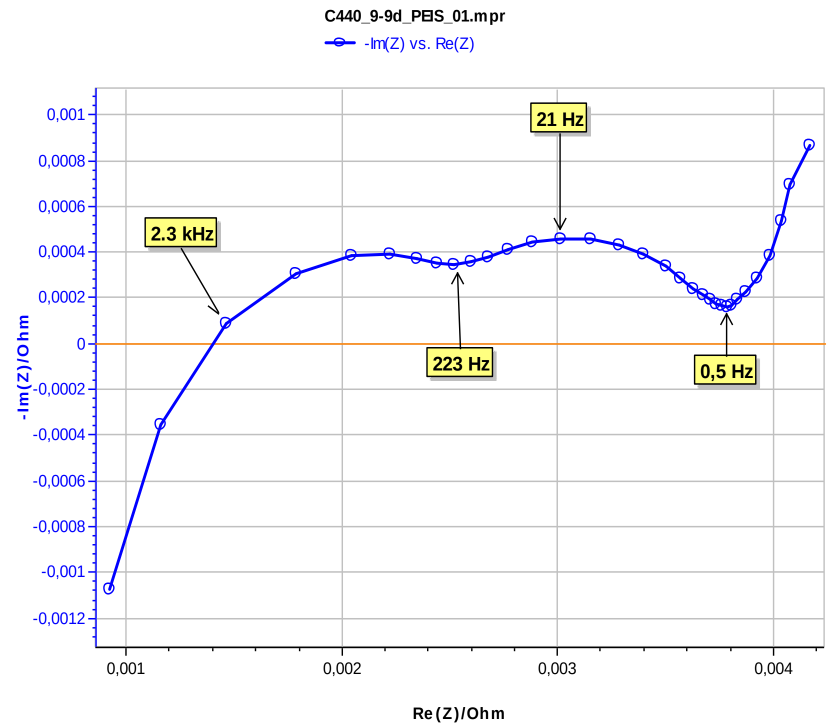
EIS after every discharge increment



After each discharge step, an EIS measurement can be performed at OCV. The corresponding EIS spectrum is changing, highlighting changing electrode/electrolyte interfaces.

Impedance Spectroscopy





Charged state

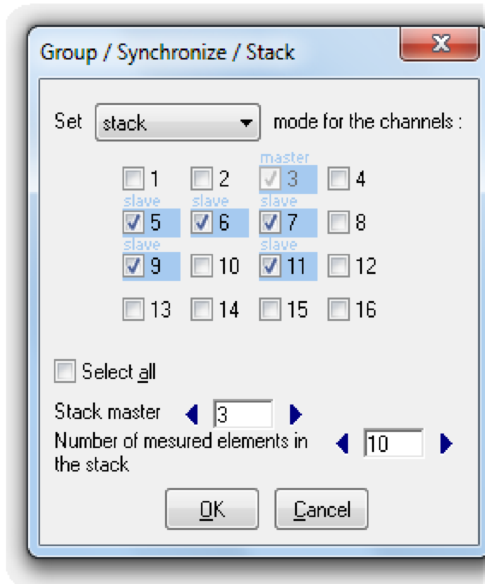
Discharged state

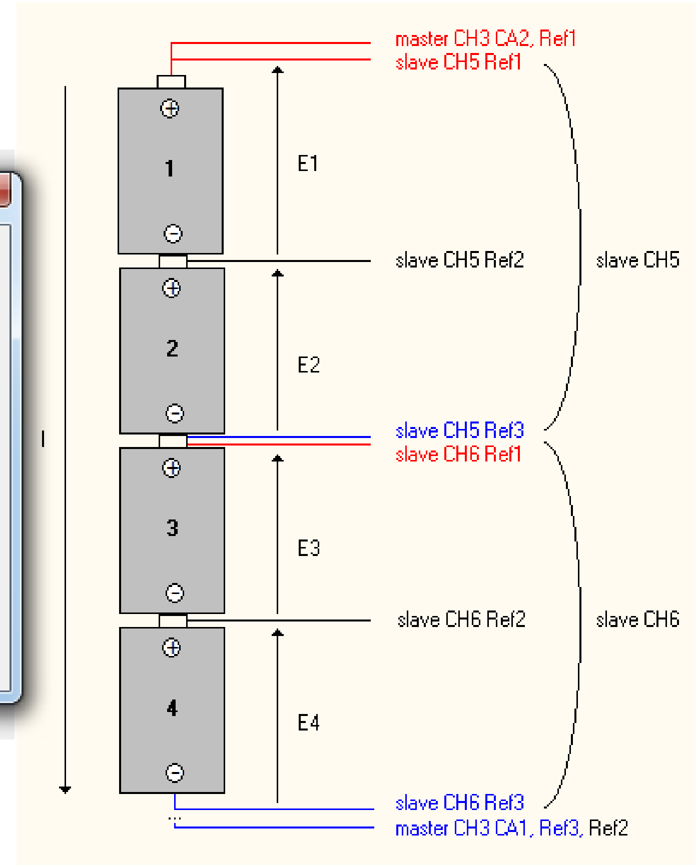
The two impedance graphs can be fitted with an equivalent circuit using ZFit (see Impedance tutorial)

Stacks

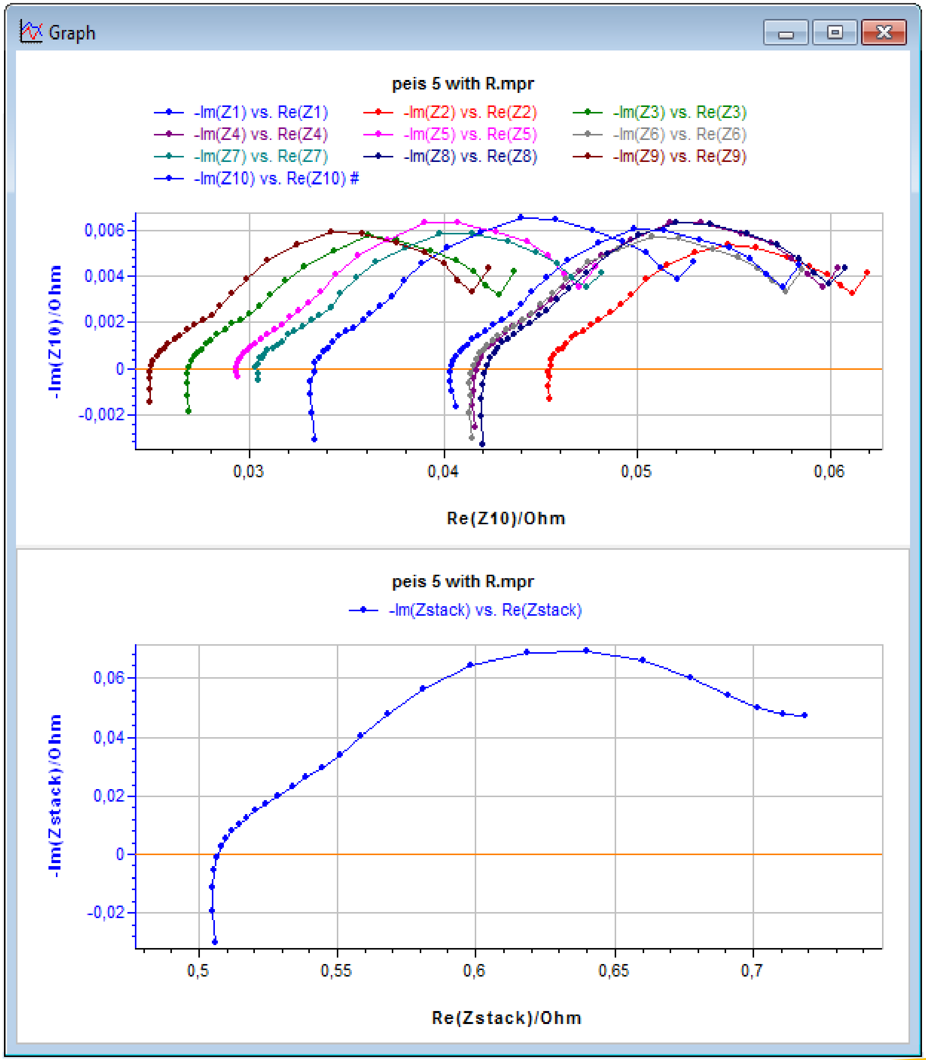
All the battery techniques are also available in stack mode.

- One master Z channel and up to 15 standard slave channels (= 30 cells) with VMP3.
- EIS or DC measurements on each element of the stack
- Possibility of linked experiments





Stacks



- Stack of 10 elements.
- The impedance of the stack is the sum of the impedance of each element.
- It allows to make a quick comparison of the different charging state of he batteries.

Outline

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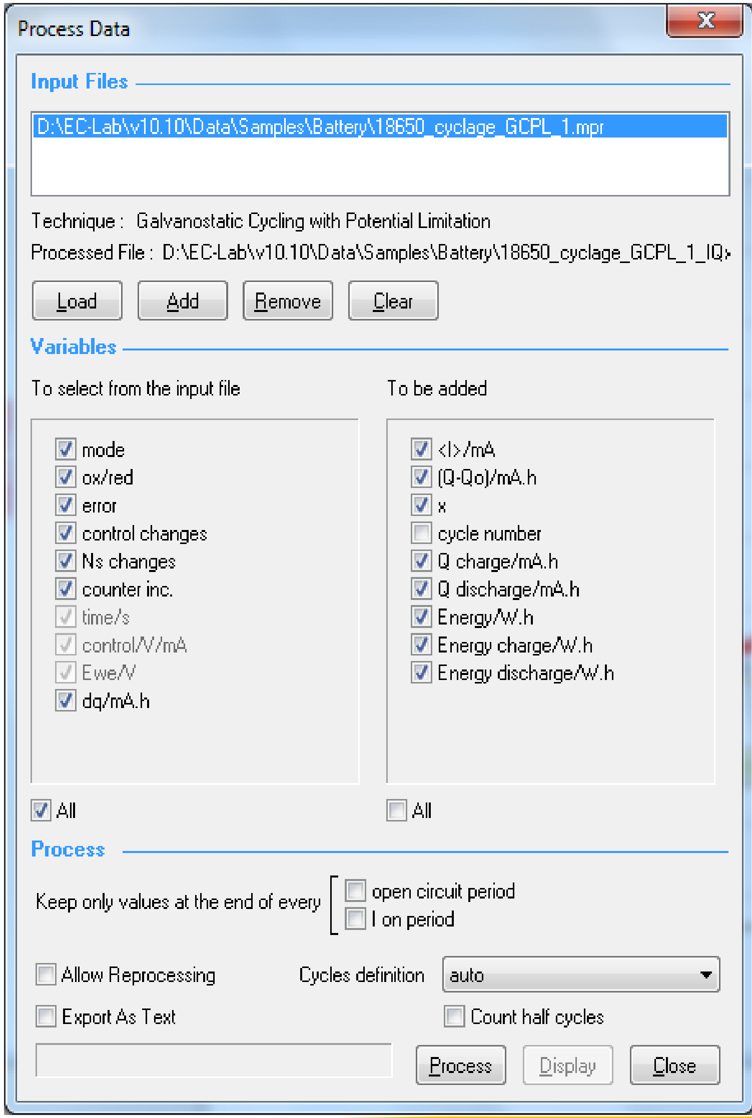
Process Data

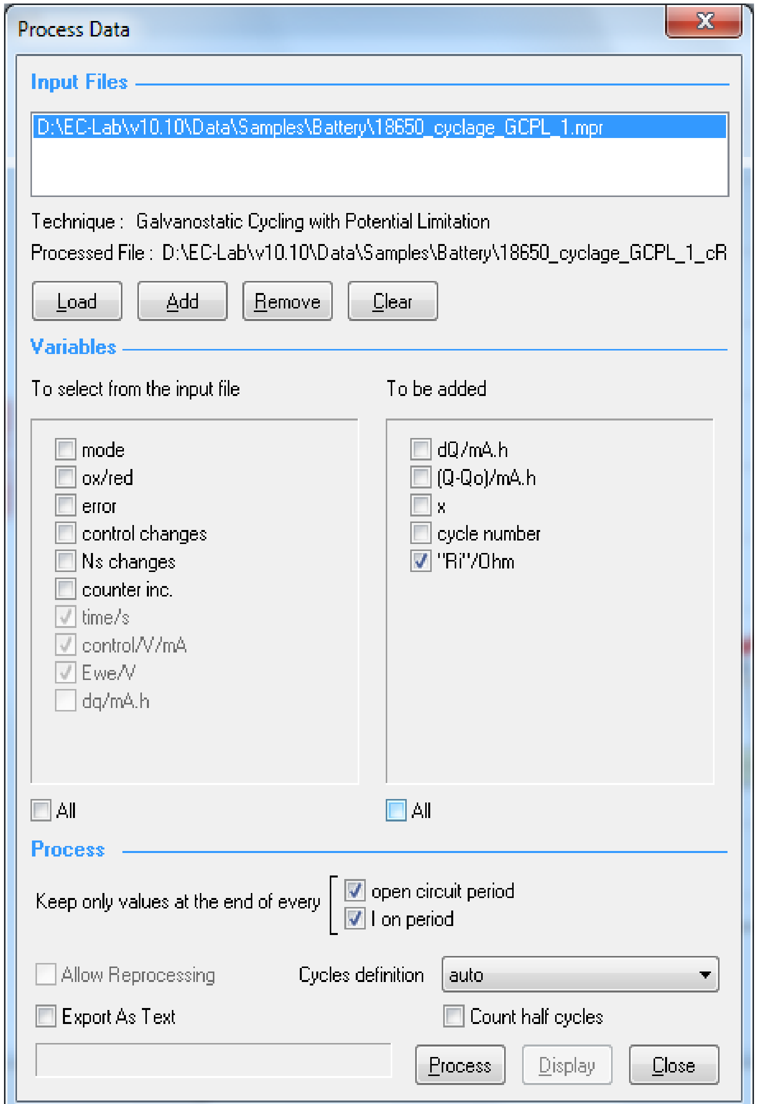


Two processing modes: standard and compact depending on the technique used.

Standard processing mode creates a new .mpp file with additional variables as chosen:

- Energy (charge/discharge)
- Intercalation coefficient x
- Q_{charge} / $Q_{discharge}$
- Cycle number, ...
- The number of data points will be the same as in the initial data file

Process Data



Compact processing mode calculates an averaged or integrated variable on every step (current or voltage depending the technique)

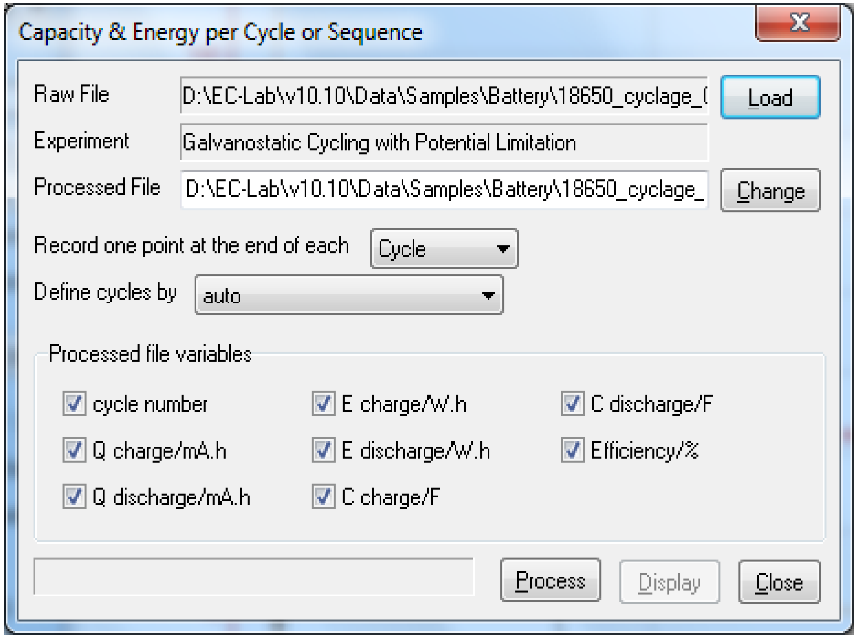
•Determination of the dynamic resistance with the GCPL5 technique

•Determination of the incremental capacity with a PCGA

Process Data

Processing to get capacity and energy per cycle

- Determination of energy, capacity and efficiency
- Separated for charge and discharge periods
- Stored in a .mpp file



Other applications

All these techniques are also available for the study of other energy devices :

- Fuel cells
- Supercapacitors
- Photovoltaic cells

BioLogic Science Instruments

Thank you for your attention