Simultaneous multi-point EIS using the peripheral port

Introduction

A typical potentiostat measures EIS at the working electrode (WE). In 2-electrode measurement configuration, where WE+S and CE+RE are paired, the EIS result will be the total cell impedance. However, when measuring in the 3 electrode configuration, when a discrete reference point or electrode is used, the connections are WE+S, RE and CE. In this case the EIS will be measured between WE+S and RE, resulting in the impedance of the 'half-cell'.
There are various applications where it can be useful to measure EIS at multiple points in your cell, simultaneously. For example, if you wish to measure not only the impedance between WE+S and RE (the 'half-cell'), but also the the impedance of the total cell (between WE and CE). Or even at multiple points in a cell or cell-stack.
For these applications Ivium offers the solution to use the peripheral port (analog input(s)) to measure additional impedances.

Ivium peripheral port

Most Ivium potentiostats are equipped with a peripheral port, i.e. a connector that gives access to extra signals, such as analog inputs, an analog output and digital I/O. The analog inputs of this peripheral port can be used to measure additional impedances. An additional module may be required for this application.

Some Ivium potentiostats are not equipped with a specific connector to access the peripheral port. However, an analog input may be available through the cell connector. In this case the WE2 pin of the HD15 cell connector gives access to the analog input 1. Your instrument specifications (see IviumSoft helpfile for specifications) will list if this option to connect to the analog input 1 is available (note that the option to access analog input 1 through the cell connector may also be available for Ivium potentiostats that do have a separate 15pin peripheral port connector).

Cell-PDA

The Cell-PDA module connects between your Ivium potentiostat and the cell cable and gives access to the analog input 1.

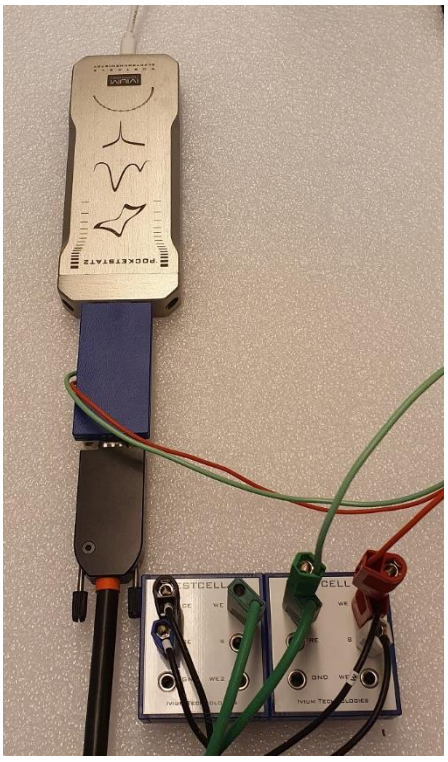
The cell-PDA module creates 1 high impedance differential analog input signal. A terminal block allows connection of your leads of choice.

Using the Cell-PDA for a multi-point simultaneous EIS measurement will result in 2 impedance signals:

- 1 EIS signal from the cell cable
- 1 EIS signal from the Cell-PDA

Example 1: resistor measurement

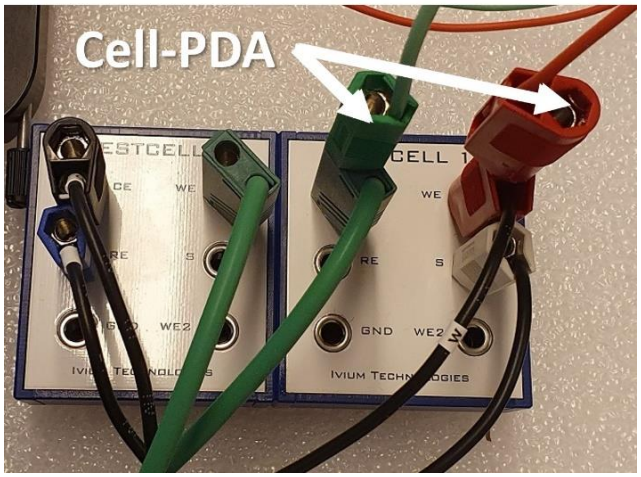
In this example a PocketSTAT2 potentiostat + Cell-PDA is connected to 2 x Testcell1 in series (each 1kOhm).



Note that the Cell-PDA is up-side down in the picture because of the orientation of cell connector of the pocketSTAT2.

The CE+RE of the cell cable are connected to the TestCell1 to the left, the WE+S of the cell cable are connected to the Testcell1 to the right.

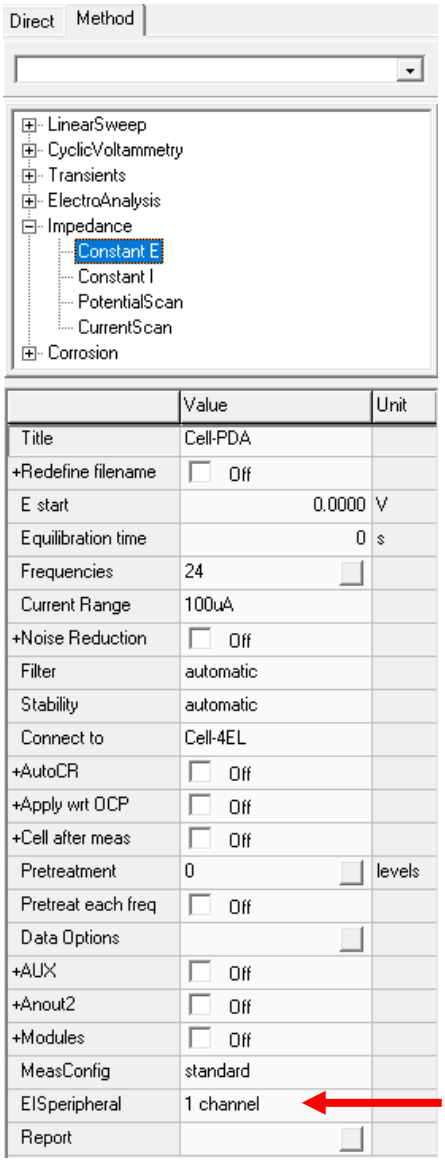
The Cell-PDA is connected across the Testcell1 to the right.



This connection should result in 2 impedance signals of 2kOhm and 1kOhm respectively.

IviumSoft

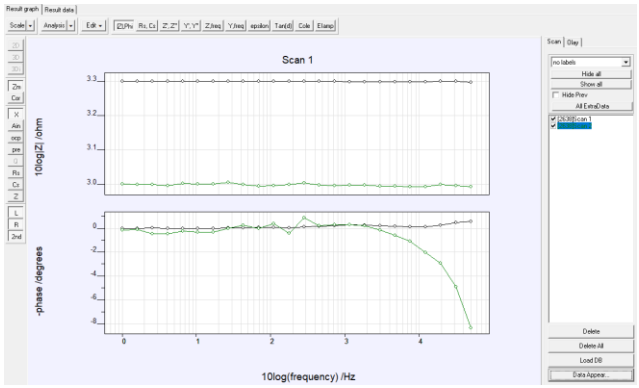
The measurement is done using the technique Impedance Constant E (50kHz to 1Hz, 50mV amplitude, 5 freq/decade):

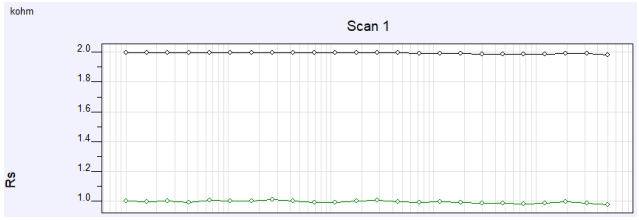


To activate the EIS measurement on the Cell-PDA (analog input) select the method parameter "EISperipheral" and choose "1 channel".

Measurement

Running the measurement will result in 2 EIS signals in the same graph. Each signal will be stored separately in its own scan in the Legend panel. Each scan can be analysed in the Sigview window and can be fitted in the Equivalent circuit evaluator.



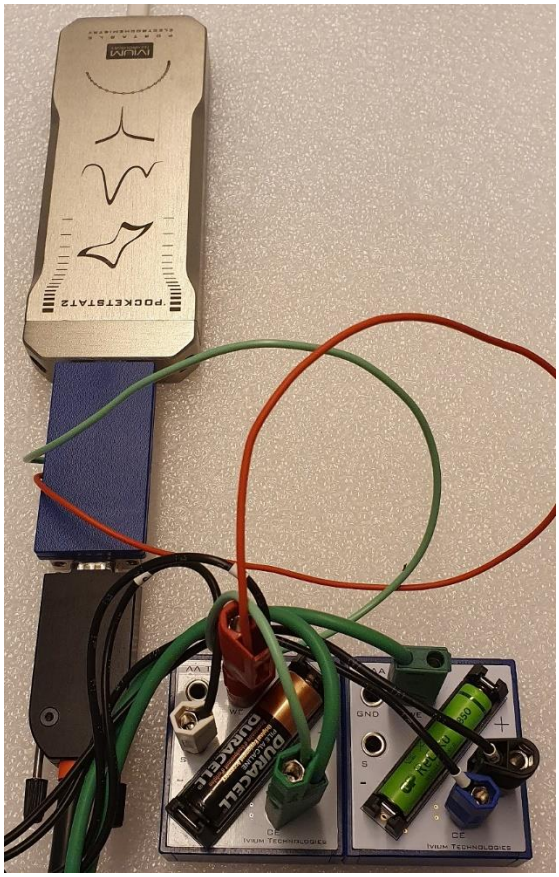


Scan 1 is the primary signal, i.e. the cell cable.
Scan 2 is Cell-PDA signal

As can be seen, the measured signals correspond to the connections:
Scan 1: Cell cable - 2 x Testcell1 in series - 2kOhm
Scan 2: Cell-PDA - Testcell1 to the right - 1kOhm

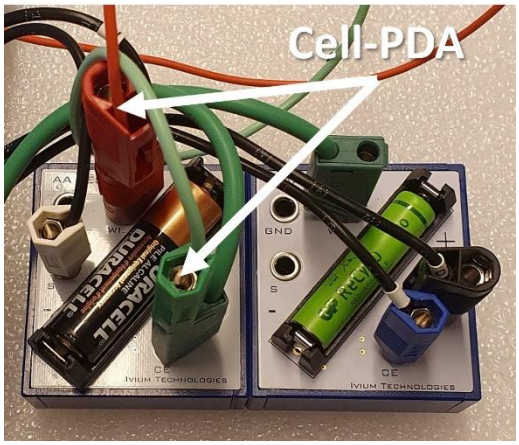
Example 2: measurement on 2 batteries

In this example a PocketSTAT2 + Cell-PDA is connected to 2 batteries in series, an AA-battery and an AAA-battery.



The WE+S are connected to the + of the battery to the left. The CE+RE are connected to the - of the battery to the right. The cell cable will thus measure the impedance of the total (= the two batteries in series).

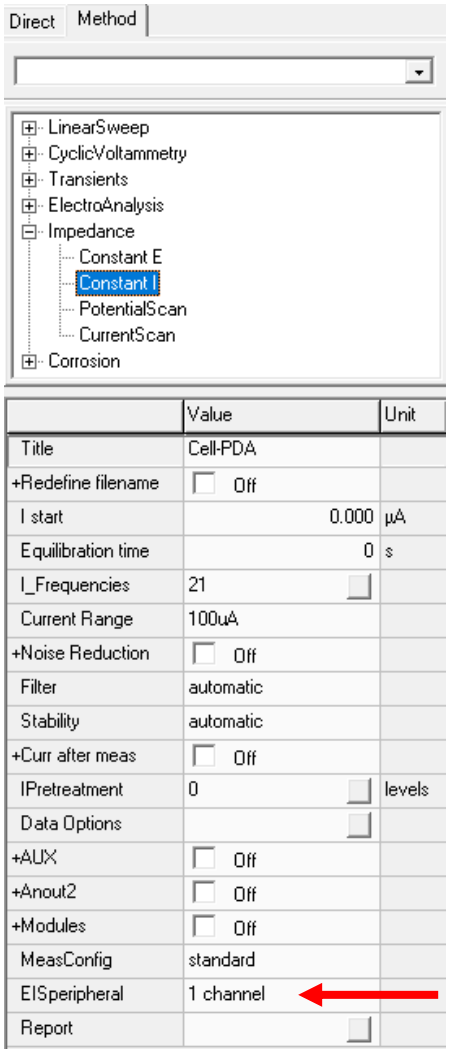
The Cell-PDA is connected across the battery to the left.



(Note that a typical potentiostat works with a grounded WE, where the signal is inversely applied to CE. This will ensure the measurement of the current with the best noise behaviour. Because the WE is grounded, the Ch- and Ch+ of the Cell-PDA need to be connected with the correct polarity).

IviumSoft

The measurement is done using the technique Impedance Constant I (10kHz to 1Hz, 20mA amplitude, 5 freq/decade):



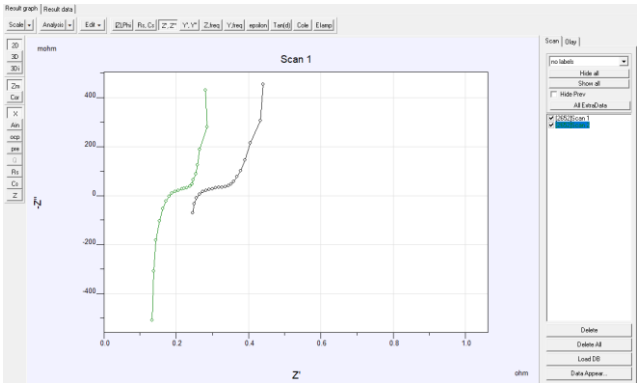
	Value	Unit
Title	Cell-PDA	
+Redefine filename	Off	
I start	0.000	µA
Equilibration time	0	s
I_Frequencies	21	
Current Range	100uA	
+Noise Reduction	Off	
Filter	automatic	
Stability	automatic	
+Curr after meas	Off	
IPretreatment	0	levels
Data Options		
+AUX	Off	
+Anout2	Off	
+Modules	Off	
MeasConfig	standard	
EISperipheral	1 channel	
Report		

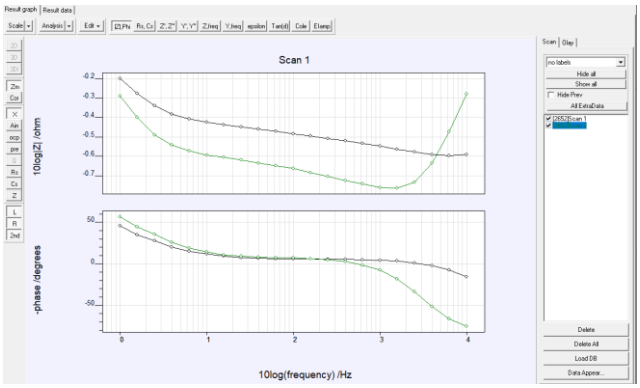
To activate the EIS measurement on the Cell-PDA (analog input1) select the method parameter "EISperipheral" and choose "1 channel". Now the analog input 1 is measured via the Cell-PDA.

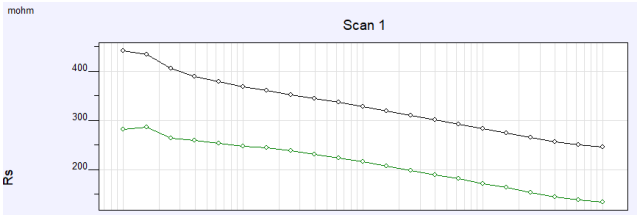
Measurement

Running the measurement will result in 2 EIS signals in the same graph. Each signal will be stored separately in its own scan in the Legend panel. Each scan can be analysed in the Sigview window and can be fitted in the Equivalent circuit evaluator.

In the result graphs below the Nyquist plot, Bode plot and Rp results are shown.







In the measurement results, the different impedances can clearly be distinguished between the total (black line, scan1) and the AA-battery to the left (green line, scan2).

sPDA

Most Ivium potentiostats that are equipped with a peripheral port have a 15pin subD connector to interface with this port. The sPDA is a module that connects to the 15pin peripheral port.

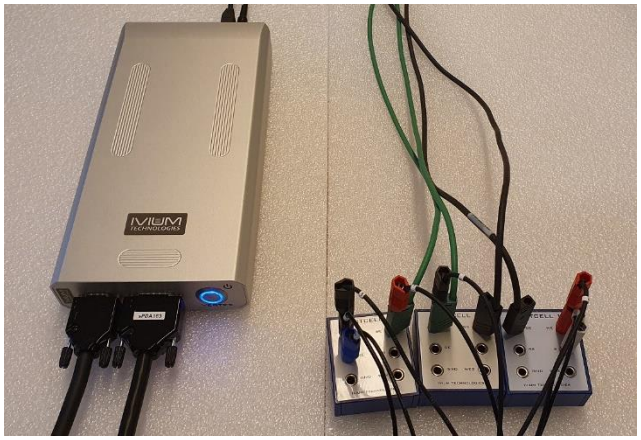
It creates 2 high impedance differential analog input signals (Ch1 and Ch2) that can be connected directly to the cell using 4mm bananas.

Using the sPDA for a multi-point simultaneous EIS measurement will result in up to 3 impedance signals:

- 1 EIS signal from the cell cable
- up to 2 EIS signals from the sPDA

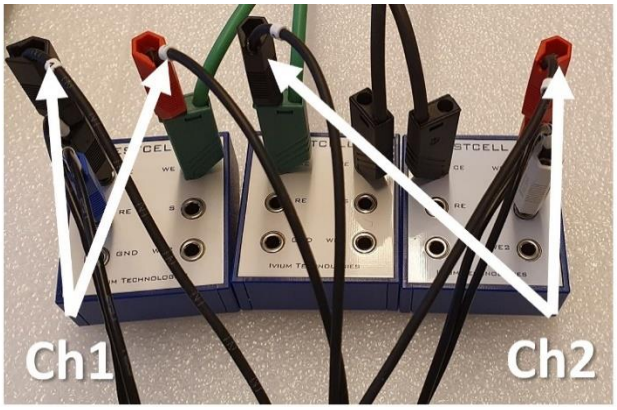
Example 3: resistor measurement

In this example a Vertex.1A.EIS potentiostat + sPDA is connected to 3 x Testcell1 in series (each 1kOhm).



The CE+RE of the cell cable are connected to the TestCell1 to the left, the WE+S of the cell cable are connected to the Testcell1 to the right.

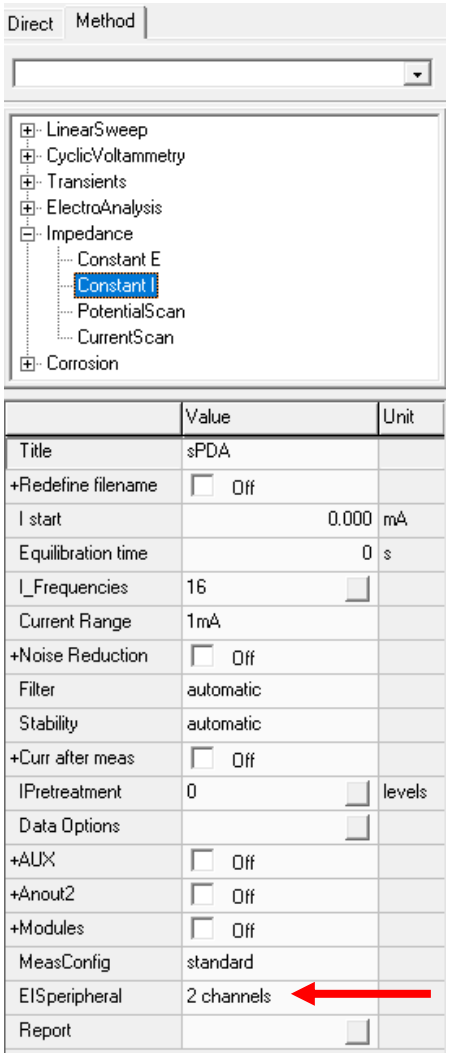
On the sPDA, Ch1 is connected across Testcell1 to the left, Ch2 is connected across the 2 x Testcell1 to the right.



This connection should result in 3 impedance signals of 3kOhm, 1kOhm and 2kOhm respectively.

IviumSoft

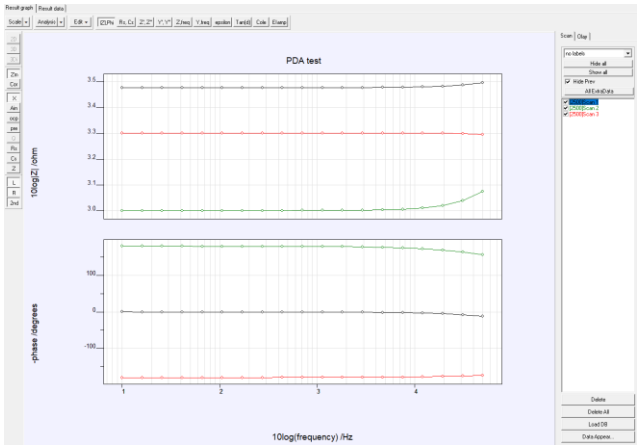
The measurement is done using the technique Impedance Constant I (10kHz to 10Hz, 1mA amplitude, 5 freq/decade):

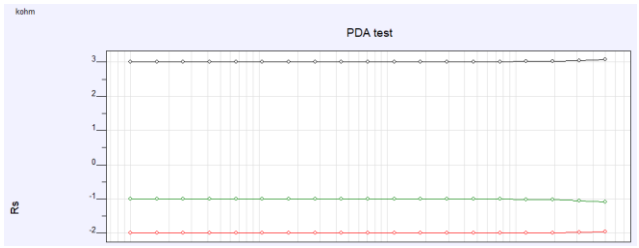


To activate the EIS measurement on the sPDA (analog inputs) select the method parameter "EISperipheral" and choose "1 channel" or "2 channels". Now both Ch1, or both Ch1 and Ch2 of the sPDA will be used.

Measurement

Running the measurement with 2 channels will result in 3 EIS signals in the same graph. Each signal will be stored separately in its own scan in the Legend panel. Each scan can be analysed in the Sigview window and can be fitted in the Equivalent circuit evaluator.





Scan 1 is the primary signal, i.e. the cell cable.
Scan 2 is Ch1 of the sPDA
Scan 3 is Ch2 of the sPDA.

As can be seen, the measured signals correspond to the connections:
Scan 1: 3xTestcell1 - 3kOhm
Scan 2: Testcell1 to the left - 1kOhm
Scan 3: 2xTestcell1 to the right - 2kOhm

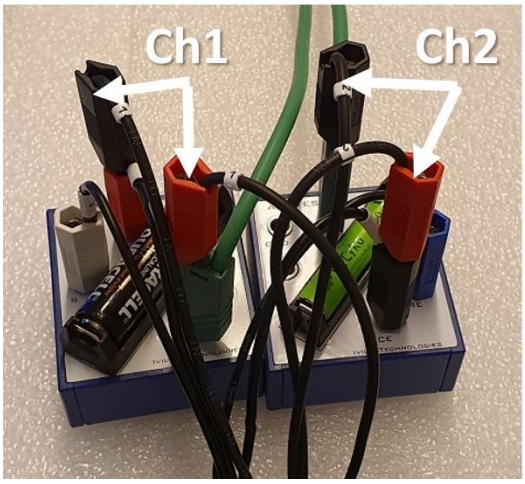
Example 4: measurement on 2 batteries

In this example a Vertex.1A.EIS + sPDA is connected to 2 batteries in series, an AA-battery and an AAA-battery.

The WE+S are connected to the + of the battery to the left. The CE+RE are connected to the - of the battery to the right. The cell cable will thus measure the impedance of the total (= the two batteries in series).

The sPDA is connected with Ch1- to the + of the battery to the left and with the Ch1+ to the - of the battery to the left.

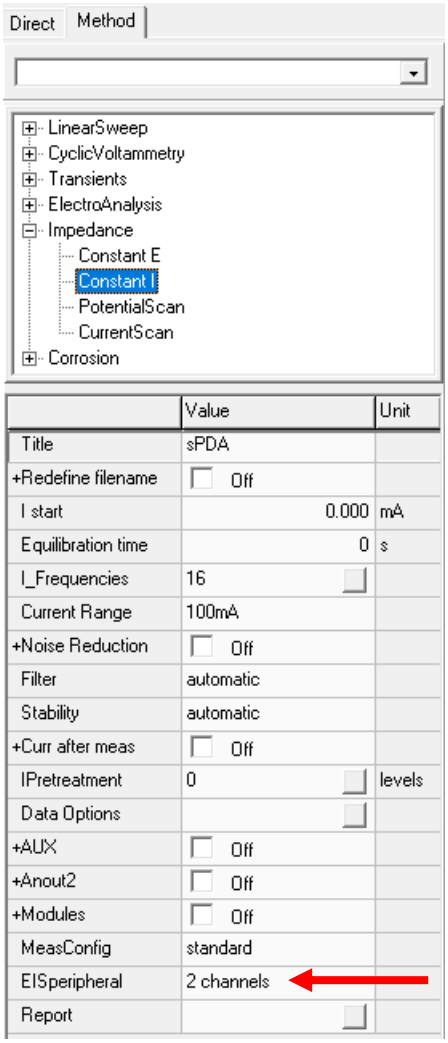
The sPDA is connected with Ch2- to the + of the battery to the right and with the Ch2+ to the - of the battery to the right.



(Note that a typical potentiostat works with a grounded WE, where the signal is inversely applied to CE. This will ensure the measurement of the current with the best noise behaviour. Because the WE is grounded, the Ch1 and Ch2 of the sPDA need to be connected with the polarity as described above).

IviumSoft

The measurement is done using the technique Impedance Constant I (10kHz to 10Hz, 50mA amplitude, 5 freq/decade):



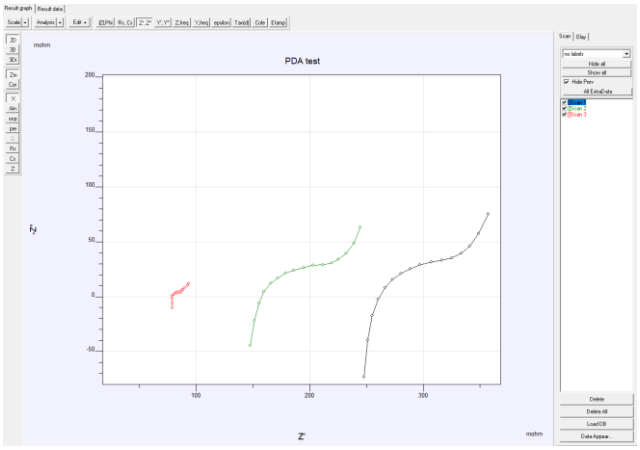
	Value	Unit
Title	sPDA	
+Redefine filename	Off	
I start	0.000	mA
Equilibration time	0	s
I_Frequencies	16	
Current Range	100mA	
+Noise Reduction	Off	
Filter	automatic	
Stability	automatic	
+Curr after meas	Off	
IPretreatment	0	levels
Data Options		
+AUX	Off	
+Anout2	Off	
+Modules	Off	
MeasConfig	standard	
EISperipheral	2 channels	
Report		

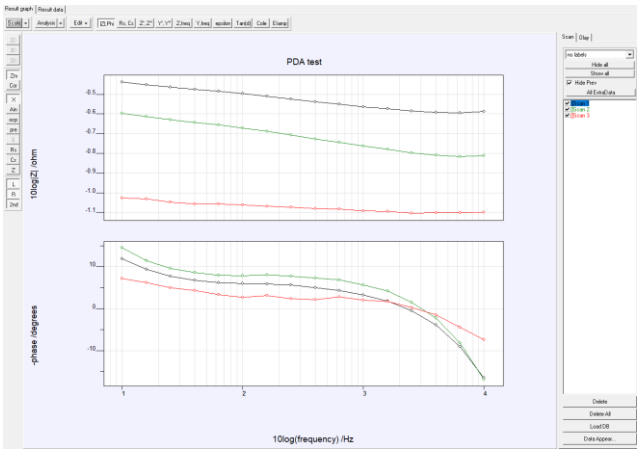
To activate the EIS measurement on the sPDA (analog inputs) select the method parameter "EISperipheral" and choose "2 channels". Now both Ch1 and Ch2 of the sPDA will be used.

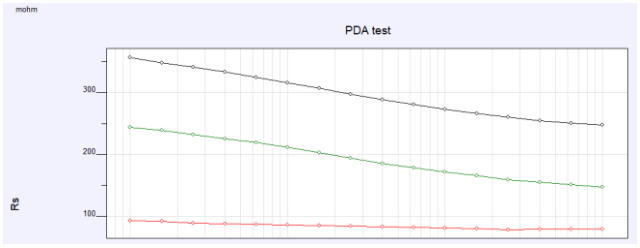
Measurement

Running the measurement will result in 3 EIS signals in the same graph. Each signal will be stored separately in its own scan in the Legend panel. Each scan can be analysed in the Sigview window and can be fitted in the Equivalent circuit evaluator.

In the result graphs below the Nyquist plot, Bode plot and Rp results are shown.







In the measurement results, the different impedances can clearly be distinguished of the total (black line, scan1), battery1 (green line, scan2) and battery2 (red line, scan 3).

StackAnalyser

The StackAnalyser is a module that can be connected to the 15pin peripheral port of an Ivium potentiostat.

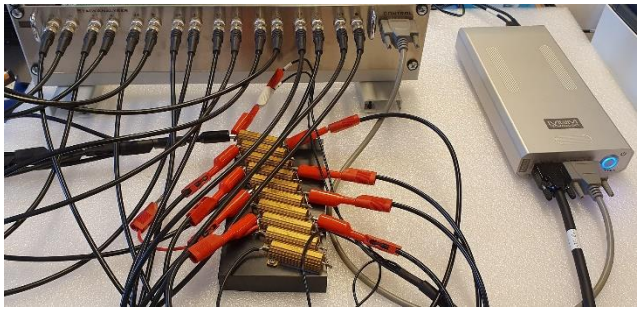
The module is powered from a 5V DC power supply and connects to the 15pin subD connector of the peripheral port. At the front the StackAnalyser has 8 channels, each with 2 BNC connectors for the Ch- and Ch+ respectively. In this case, each of the 16 BNCs has its own BNC to 4mm banana cable.

The Ch- and Ch+ connections of each of the 8 channels can be connected to any point of the cell or cell-stack.

When the StackAnalyser is connected, the user can make a choice to measure 1, 2, 4 or all 8 channels. Together with the primary cell cable, this results in a maximum of 9 EIS signals.

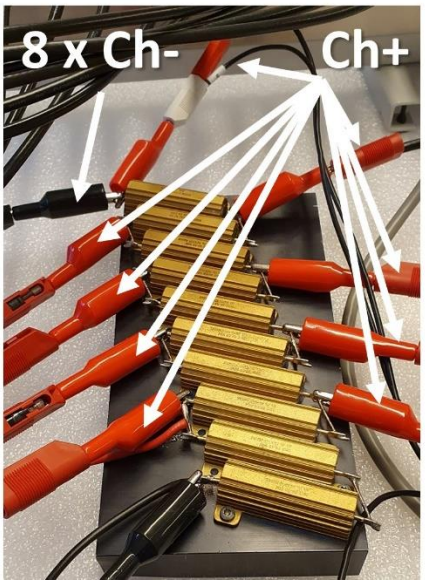
Example 5: resistor measurement

In this example a Vertex.1A.EIS potentiostat + StackAnalyser is connected to 10 x 1Ohm resistors in series.



The WE+S of the cell cable are connected to the resistor to the left, the CE+RE of the cell cable are connected to the resistor to the right.

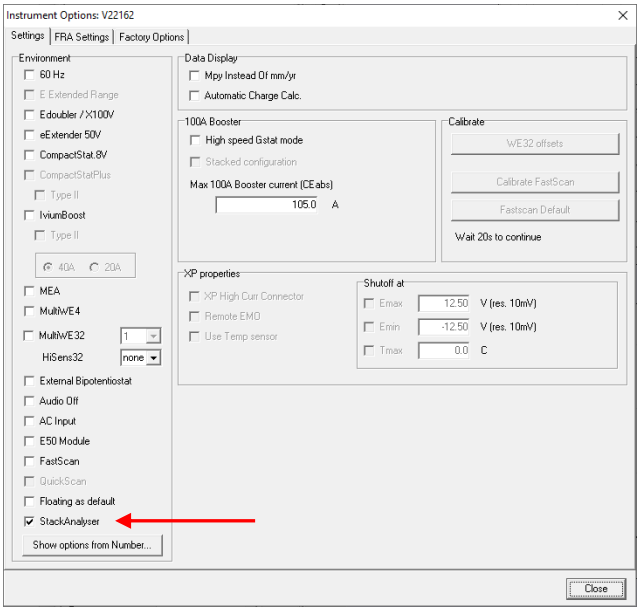
On the StackAnalyser, The Ch- of each of the 8 channels are connected to the resistor to the left; the Ch+ of each channel is connected across each following resistor (i.e. Ch1+ across the resistor to the left, Ch2+ across the next resistor from the left, Ch3+ to the third resistor in line, etc.).



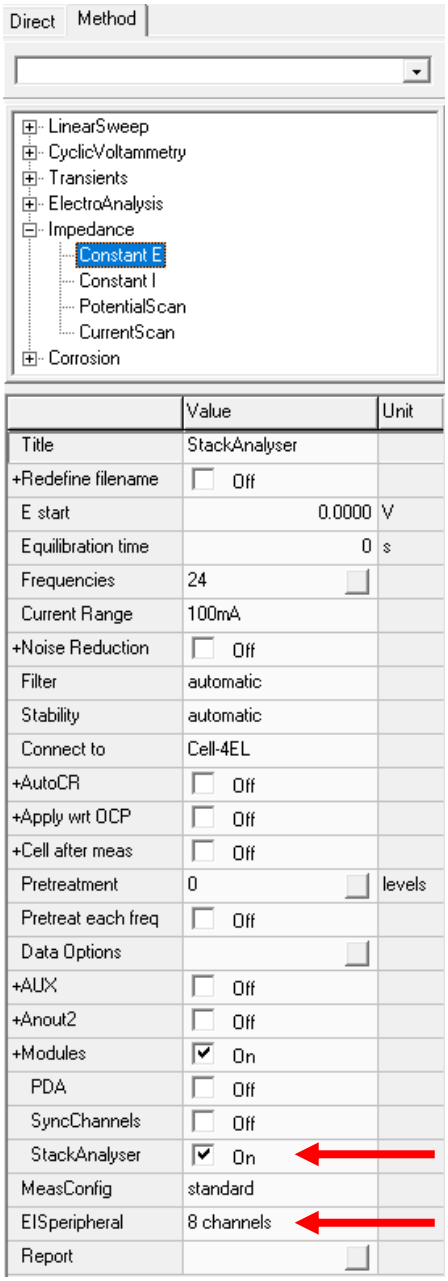
This connection should result in 9 impedance signals of 10 Ohm and 1 Ohm – 8 Ohm respectively.

IviumSoft

In IviumSoft the StackAnalyser needs to be activated in the instrument options (menu Options>Options):



Subsequently, the measurement is done using the technique Impedance Constant E (50kHz to 1Hz, 50mV amplitude, 5 freq/decade):

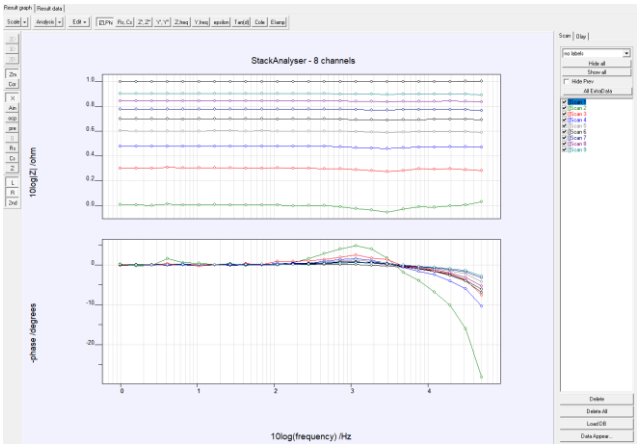


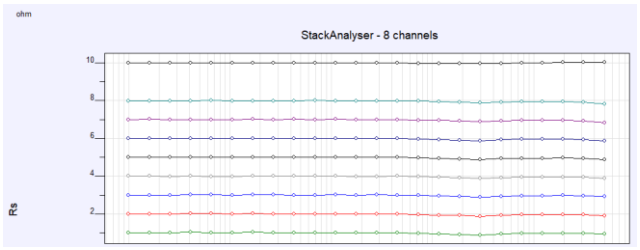
	Value	Unit
Title	StackAnalyser	
+Redefine filename	Off	
E start	0.0000	V
Equilibration time	0	s
Frequencies	24	
Current Range	100mA	
+Noise Reduction	Off	
Filter	automatic	
Stability	automatic	
Connect to	Cell-4EL	
+AutoCR	Off	
+Apply wrt OCP	Off	
+Cell after meas	Off	
Pretreatment	0	levels
Pretreat each freq	Off	
Data Options		
+AUX	Off	
+Anout2	Off	
+Modules	On	
PDA	Off	
SyncChannels	Off	
StackAnalyser	On	
MeasConfig	standard	
EISperipheral	8 channels	
Report		

To correctly measure the analog inputs of the StackAnalyser, in the method parameters the +Modules>StackAnalyser box needs to be checked. At the method parameter "EISperipheral" the number of channels needs to be selected (8 channels in this example). Now all 8 channels of the StackAnalyser will be measured.

Measurement

Running the measurement with 8 channels will result in 9 EIS signals in the same graph. Each signal will be stored separately in its own scan in the Legend panel. Each scan can be analysed in the Sigview window and can be fitted in the Equivalent circuit evaluator.





Scan 1 is the primary signal, i.e. the cell cable.
Scan 2 is Ch1 of the StackAnalyser
Scan 3 is Ch2 of the StackAnalyser
etc.

As can be seen, the measured signals correspond to the connections:
Scan 1: cell cable – 10 Ohm
Scan 2: resistor to the left – 1 Ohm
Scan 3: 2nd resistor from the left – 2 Ohm
etc.