PAD4
HC, LC, HZ

Parallel AD Converter Addon Card for Synchronous Prallel Measurements

(Operation Manual)

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Caution!!!

Please read the risk assessment document before operating the potentiostat.

Prevent the inputs of the potentiostat from electrostatic discharge (ESD)! ESD may damage the potentiostat. ESD-related damages are not covered by the warranty of the potentiostat. The user must make sure to discharge his-/herself from any electrical charge before touching the potentiostat (TIP: use grounded ESD-matts).

Maintain the maximum input voltage of the device and the selected voltage range.

Use electrically insulated thermocouples.

Do not expose the PAD4 card to heat.

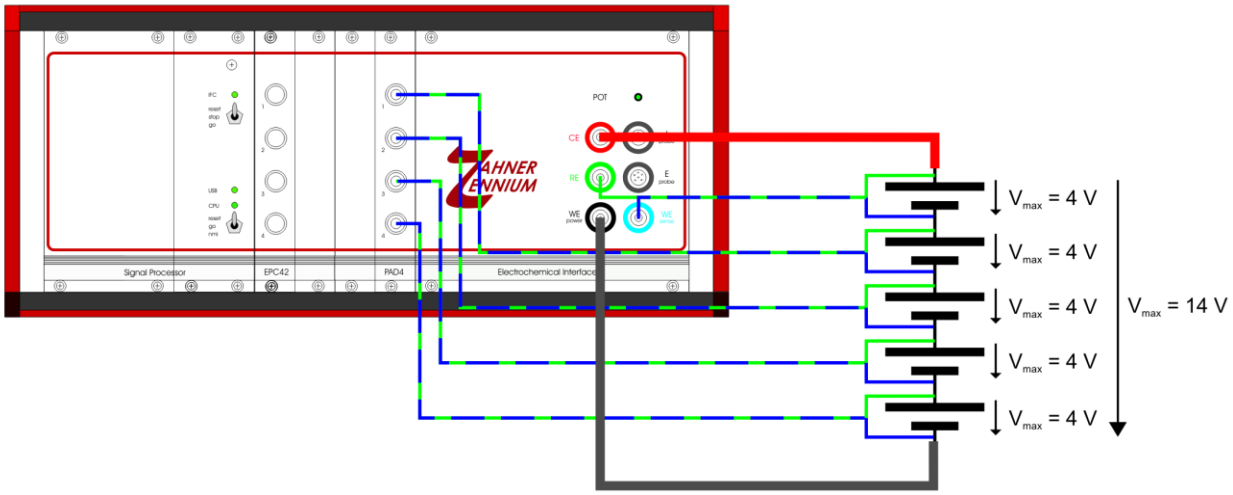
1 Introduction

The PAD4 was designed for the investigation of stacked objects like batteries and fuel cells, where the impedance, defined by one common current through the object, but several voltages accessible on several taps must be acquired in parallel. Compared to the usual solution with multiplexers like the PMUX series, the PAD4 has the advantage of real parallel acquisition, saving measurement time and avoiding time lags between the acquisitions of different channels.

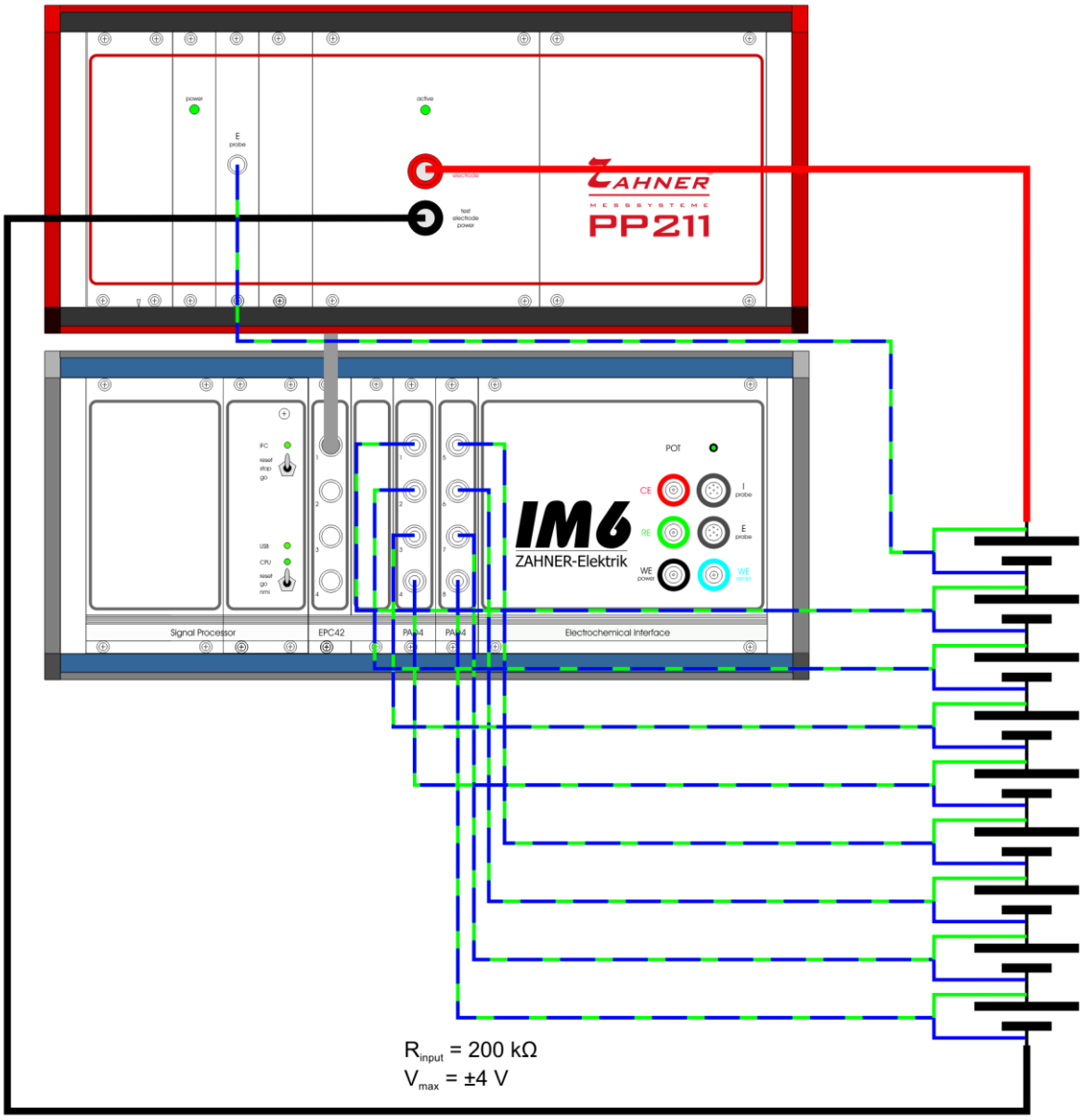
PAD4 is a plug-and-play card for an extension slot of the *Zennium Pro/X*. It allows connecting four different potential sense inputs for parallel impedance measurements.

With four PAD4 add-on cards up to 16 channels synchronous measurements can be done in parallel to the main channel.

The *Zennium Pro* can control one PAD4 add-on card with 4 additional parallel sense channels. The *Zennium X* can control up to four PAD4 add-on cards with up to 16 additional parallel sense channels.

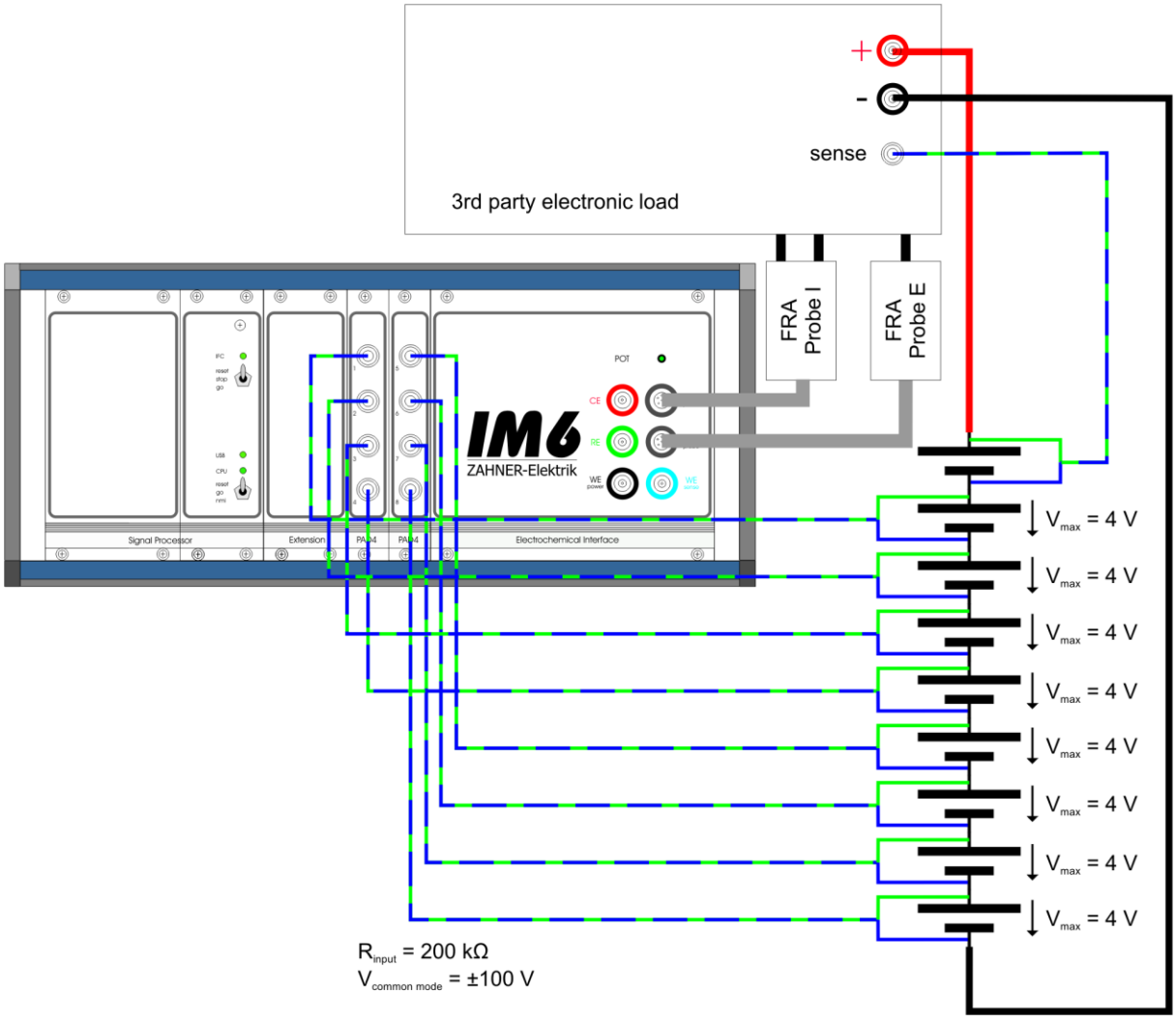


Connection scheme for 4 channel PAD4 with a 5 cell battery stack. The maximum input voltage of each PAD4 channel is limited to ±4 V with a compliance voltage range of ±100V. The output voltage and current is limited by the electrochemical workstation. For example the *Zennium* has a compliance voltage of ±14 V.



Connection scheme for 8 channel PAD4 with an external power potentiostat *PP211* (20 V / 10 A) connected via EPC42 to an IM6.

The PAD4-HC and PAD4-LC cables follow the same color scheme as shown in the schematic. In contrast, the shielded PAD4-HZ cables consist of red and transparent cables. In the schematics, the green and blue color lines corresponds to red and transparent cables of the PAD4-HZ, respectively.



The PAD4 AD converter card is also compatible with a 3rd party electronic load interfaced from the ZENNIUM by means of the *FRA-Probe*.

1.1 Packing List

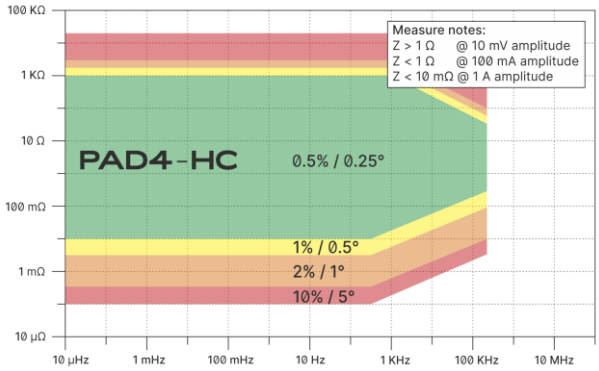
- PAD4 addon card
- 4 sense cables (Lemosa plug to blue & green twisted cables)
- This manual

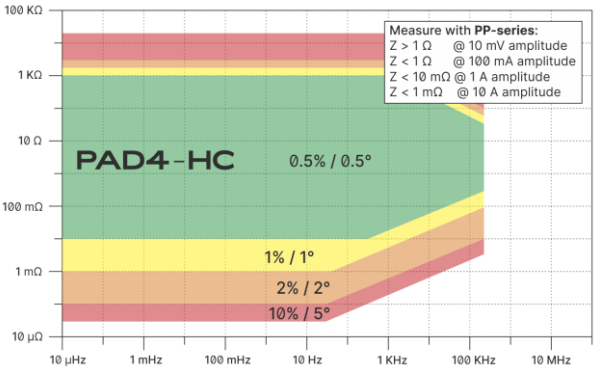
2 PAD4: Technical Data

2.1 PAD4-HC Specifications

Socket:	4x Lemosa EGA.0B.307.CLL
Input Impedance:	200 KΩ
Input Range:	±4 V (standard configuration) ±5 V, ±10 V, ±12 V, ±20 V or ±24 V on demand
Input Voltage Accuracy[1]:	±250 µV ±0.05% full scale
Common Mode Range[1]:	±100 V
Common Mode Rejection Ratio[1]:	86 dB (66 dB @ 100 kHz)
Frequency Range:	10 µHz - 250 KHz
Resolution:	18 bit
Input AC Voltage Resolution[1]:	500 nV @ 4 mV AC amplitude
Maximum PAD4 Supported:	1 (ZENNIUM PRO) 4 (ZENNIUM X)

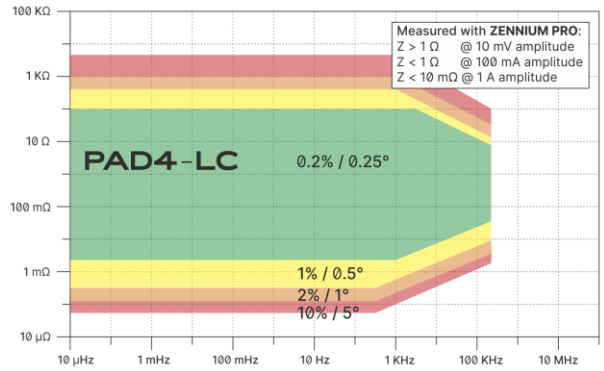
[1] Specified for the standard configuration

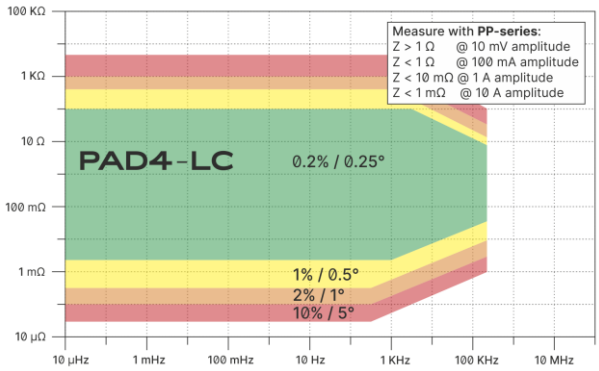




2.2 PAD4-LC Specifications

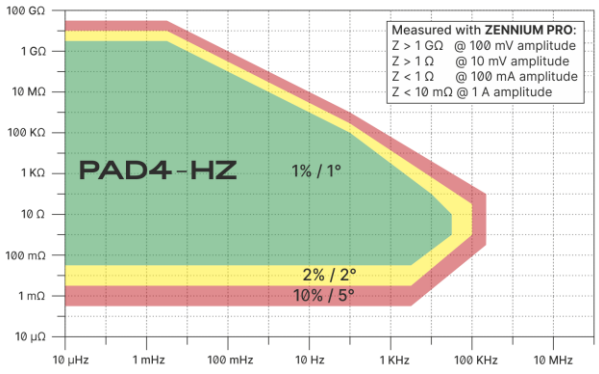
Socket:	4x Lemosa EGA.0B.307.CLL
Input Impedance:	50 KΩ
Input Range:	±1 V
Input Voltage Accuracy:	±250 µV ±0.05% full scale
Common Mode Range:	±25 V
Common Mode Rejection Ratio:	86 dB (66 dB @ 100 kHz)
Frequency Range:	10 µHz - 250 KHz
Resolution:	18 bit
Input AC Voltage Resolution:	125 nV @ 4 mV AC amplitude
Maximum PAD4 Supported:	1 (ZENNIUM PRO) 4 (ZENNIUM X)





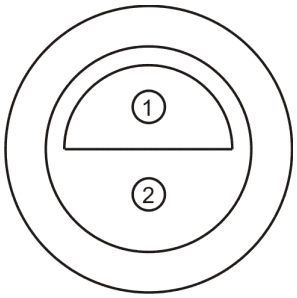
2.3 PAD4-HZ Specifications

Socket:	4x Lemosa EGA.0B.307.CLL
Input Impedance:	>100 GΩ
Input Leakage Current:	< |30 pA|
Input Range:	2x ±5 V 2x ±1 V
Offset Voltage:	±1.0 mV ±0.1% full scale
Common Mode Range:	2x ±10 V (±5 V range inputs) 2x ±2 V (±1 V range inputs)
Frequency Range:	10 µHz - 250 KHz
Resolution:	18 bit
Input AC Voltage Resolution:	2x 625 nV @ 4 mV AC amplitude 1x 125 nV @ 4 mV AC amplitude
Maximum PAD4 Supported:	1 (ZENNIUM PRO) 4 (ZENNIUM X)



2.4 PAD4 Input Jack Pinout

2.4.1 2-Pole LEMO Jack (effective until July 2015)

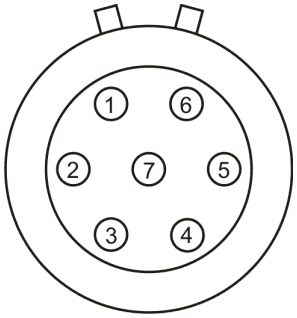


1: upper connector female: + green
(reference electrode)

2: lower connector male: - blue
(working electrode sense)

corresponding connector:
LEMO push-pull connector
FFA.0S.302.CLAC32

2.4.2 7-Pole LEMOSA Jack (effective from August 2015)



1: + green (reference electrode)

2: not connected

3: -5 V supply

4: +5 V supply

5: not connected

6: - blue (working electrode sense)

7: GND supply

!	**Note:** ±5 V supply (pin 3,4,7) only required by CIMPS-MDTR photosense preamplifier.

corresponding connector:
LEMO push-pull connector
FGA.0B.307.CLAD56

PAD4-HZ

The PAD4-HZ is designed for investigations of batteries. It features high ohmic input resistances, minimizing leakage currents and, by that, self-discharge of batteries when they are connected over a long period of time. However, these inputs are sensitive towards over-voltage or ESD (for more information, please see our manual "Installation & Getting Started").

The ±1 V inputs of a PAD4-HZ can only be used with a ZENNIUM potentiostat only when the ZENNIUM is **grounded** and in **low compliance mode**.

From the ±1 V inputs of the PAD4-HZ, **one cable must be connected at the same point to the test object where the WE cable is connected (at grounded 0 V)**. The voltage difference between both cables of a ±1 V input channel **must not exceed 1 V** for accurate measurements.

The ±1 V inputs are designed for measurements on half cells where the total voltage difference between both electrodes (anode/cathode and reference electrode) is lower than 1 V.

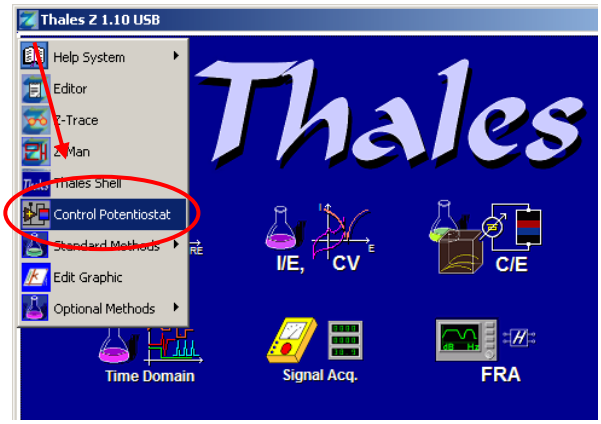
The object voltage vs. ground must never exceed ±2 V for the ±1 V input channels and ±10 V for the ±5 V input channels of the PAD4-HZ. At relatively higher common mode voltages the input channels may get damaged. Such damages will invalidate the warranty of the PAD4-HZ card, hence please make sure that the suitable channels are connected to the correct electrodes when connecting the PAD4-HZ.

For a typical NMC-type lithium-ion battery that would for example mean, that the anode should be connected to the WE/WE-sense channel of the ZENNIUM series potentiostat. The ±1 V channel can be connected between the anode and lithium reference electrode.

The ±1 V inputs of a PAD4-HZ can neither be used with a ZENNIUM potentiostat in high compliance mode nor with the PP2x2 or EL1002.

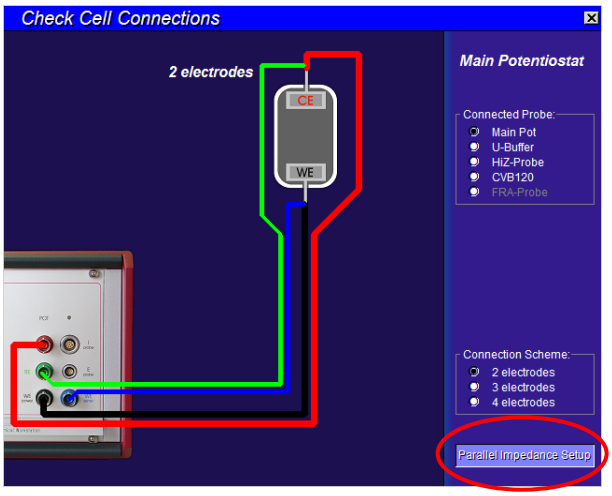
Read before using PAD4-HZ

3 Configuration

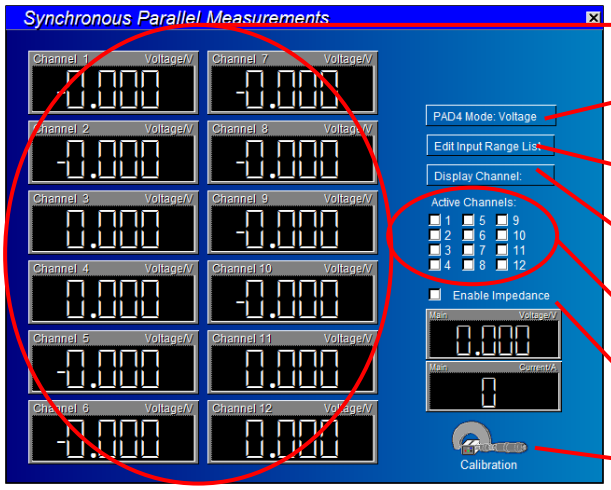


Click on the Z icon at the upper left edge of the Thales software window and switch to *Control Potentiostat* page.

Click on *Check Cell Connections*.



The *Thales* software detects the PAD4 cards automatically and shows the button *Parallel Impedance Setup*. Click on that button to switch to *Synchronous Parallel Measurements* page.



DC voltage displays

Select PAD4 input type meaning

Setup customized input potential ranges

Select channel for AC display.

Activate/deactivate PAD4 channels.

Enable activated channels for *EIS*.

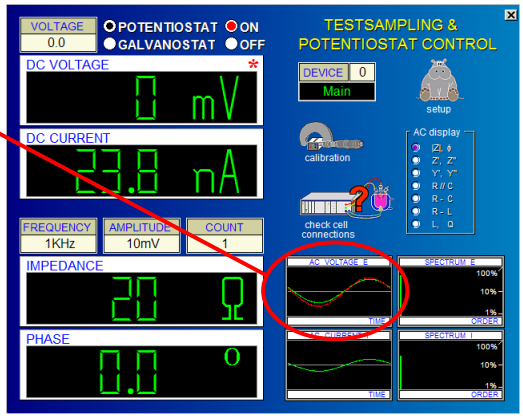
PAD4 calibration only for.

3.1 Select PAD4 Channel for AC Voltage Display

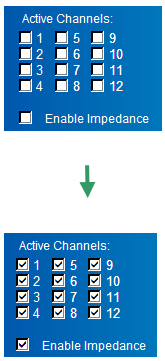
Select channel for *EIS* AC voltage display

green: main potentiostat

red: selected PAD4 channel



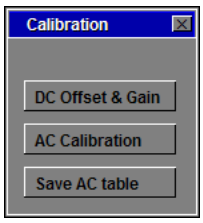
3.2 Select PAD4 Channels for EIS Measurement



Activate PAD4 channels for *EIS* measurements and enable impedance measurement.

!	**Note:** PAD4 channels are only measured when impedance is enabled.

3.3 PAD4 Calibration

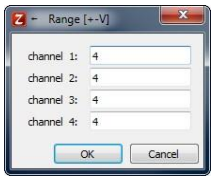


Offset voltages can slightly drift when the system warms up. This will be calibrated automatically after a few seconds.

To activate Calibration button press button 2 (number two) of your keyboard to highlight the calibration icon and press ENTER to show the Calibration menu. Select DC Offset & Gain to perform a DC calibration.

!	**Note:** Calibration is only allowed for service personal. For DC and AC calibration reference elements are required.

3.4 Setup Customized Input Ranges



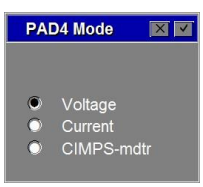
The standard input range of the PAD4 addon cards is ±4 V. This range can be increased with adapted sense cables including additional input resistors on customer demand.

This input range list normalizes nonstandard input ranges for correct impedance analysis.

In current mode, the input range list is defined as a shunt resistor list of the used I/U converter.

!	**Note:** Special sense cables with additional input resistances are always customized solutions. This range extension reduces the common mode rejection of the input channels and therefore the signal to noise ratio.
!	**PAD4-LC:** current input range = 4x shunt resistor value

3.5 Setup PAD4 Mode

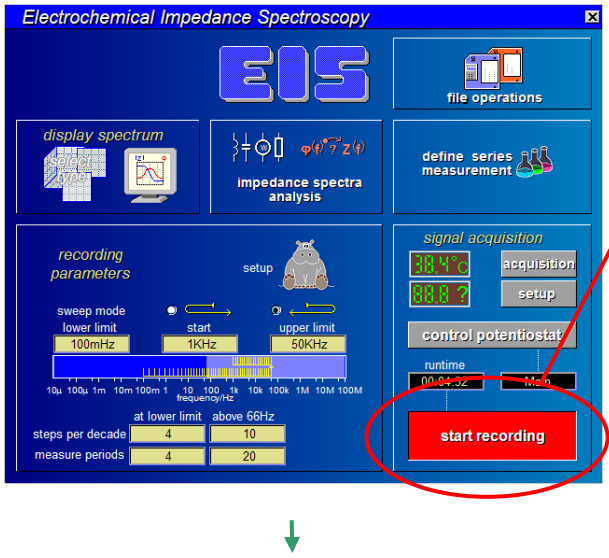


The standard mode of PAD4 input channel is voltage mode.

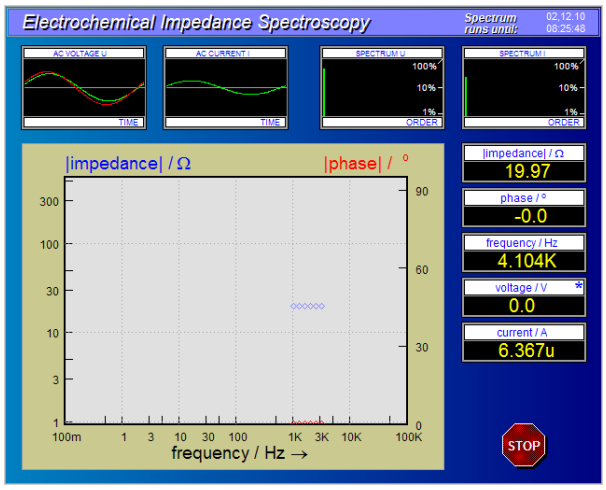
When using current voltage converter frontends the PAD4 channels can be configured to current mode. The current range is set in range list (chapter 3.4) as a shunt resistor value. The input signal is still limited to the ±4 V range.

!	**Note:** A current voltage converter probe is required for this mode.

4 Parallel Impedance Measurements



If PAD4 channels are activated and impedance is enabled *EIS* and *FRA* measurements are automatically done for all activated channels. For detailed information refer to *EIS* manual.

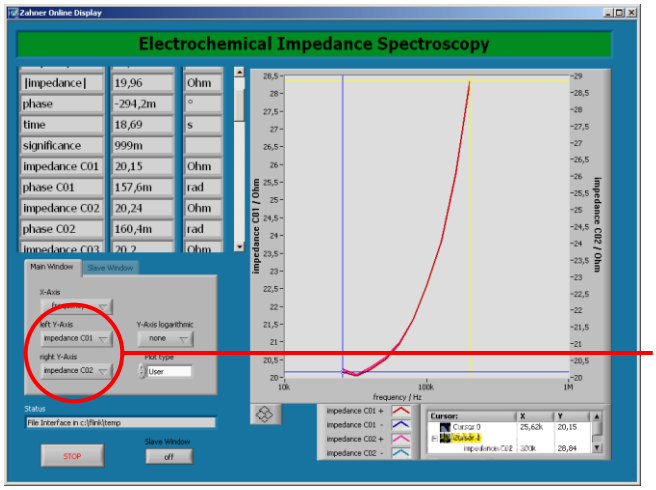


Realtime AC voltage display

green: main potentiostat

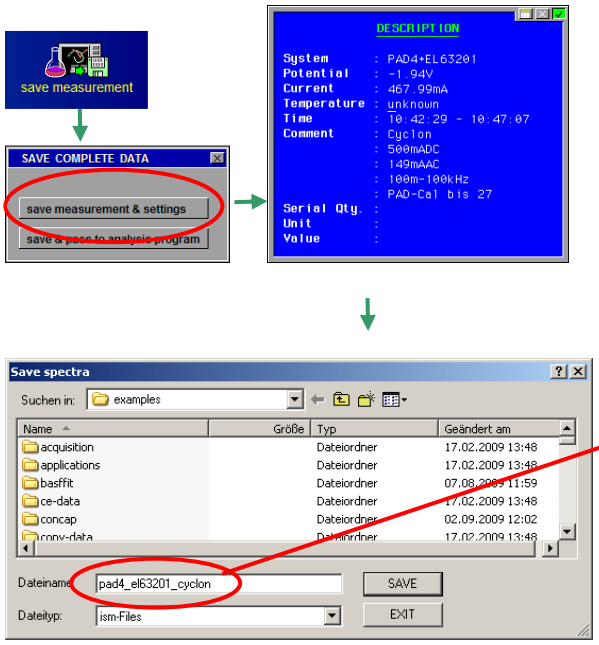
red: selected PAD4 channel

Data display, realtime frequency domain displays and numerical displays only show measure data of the main potentiostat channel.



A realtime impedance plot of the PAD4 channels during measurement can easily be done with the *Online Display*.

Select PAD4 channels (impedance [C01..C16], phase[C01..C16])



Save measured *EIS* data. Please refer to *EIS* manual.

Each single spectrum is saved individually so that you may analyse it individually or in the context of the complete parallel measurement.

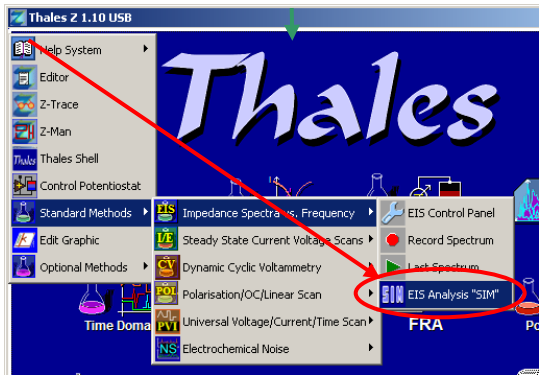
The file name of each spectrum is complemented by a two-digit number which specifies the number of the PAD4 channel (00: main channel).

If any of the file names to be created already exist, you will be asked for overwriting the files or cancel saving.

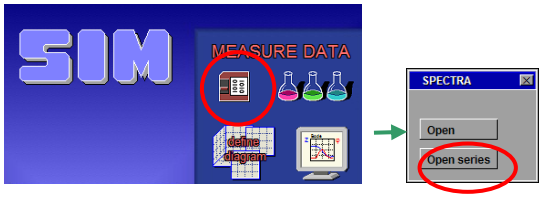
The PAD4 channels can be customized of a voltage range of ±4 V, ±5 V, ±10 V, ±12 V, ±20 V, and ±24 V. The compliance voltage range is also different for PAD4 with different voltage ranges. The compliance voltage range of a PAD4 channel can be calculated by the equation below

Compliance voltage range (V) = PAD4 voltage range (V) * 25.

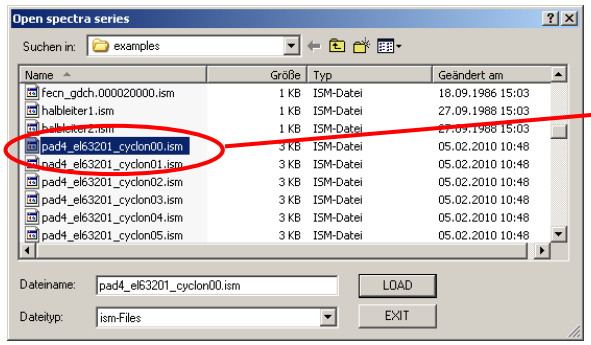
5 Parallel Impedance Analysis



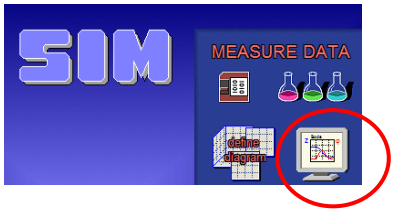
Click on the Z icon at the upper left edge of the Thales software window and navigate to *EIS Analysis "SIM"*.



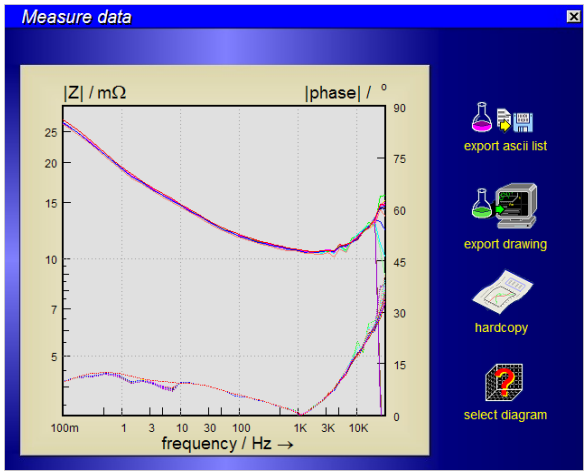
Select open series measurements.



Select first impedance spectra measurement [*filename*]00.ism to open the hole parallel measurement data.



Click on the ***Display Diagram*** button to display the diagram of the loaded and selected parallel *EIS* data.



For further information on analysis parallel impedance data please refer to ***SIM*** manual.

6 DC Measurements and Signal Acquisition

Select/deselect input channel for acquisition display.

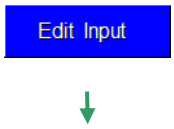
Edit or create input channel.

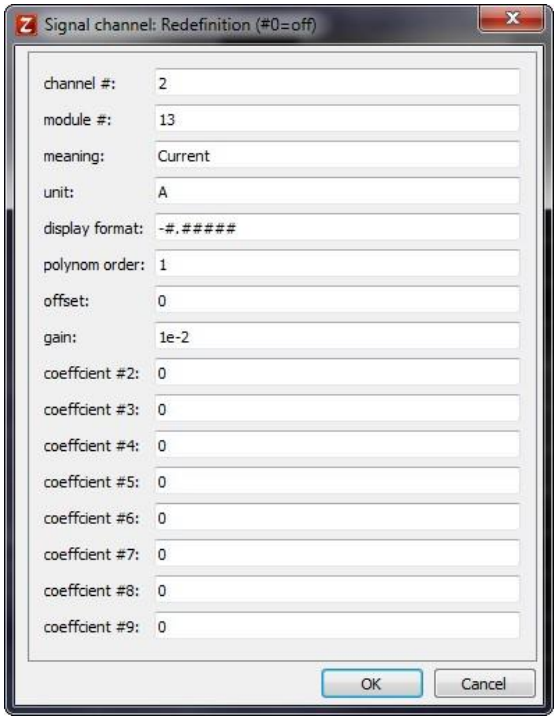
Shows order of display data.

Acquire data page.

Here you can switch on/off acquisition data for all methods (logging on/off).

6.1 Create ACQ Channels for PAD4





Select "Edit Input" and click into the table below to open channel definition box.

channel: [2..17] for PAD4 channel [1..16]

module: 13 (fixed value)

meaning: title for the ACQ channel

unit: unit of the channel data

display format: -#.#####

order: 1 for linear input signals (common)

gain:

voltage mode: gain= voltage range/4
example: gain=1 for ±4 V inputs
current mode: gain= 1/shunt resistor value
example: gain=1e-2 for 100R shunt

PAD4-LC: gain= 1/(4x shunt resistor value) *example: gain=2.5e-3 for 100R shunt*

Hint: Input channels can be deleted by typing in channel # 0 and confirm input box.