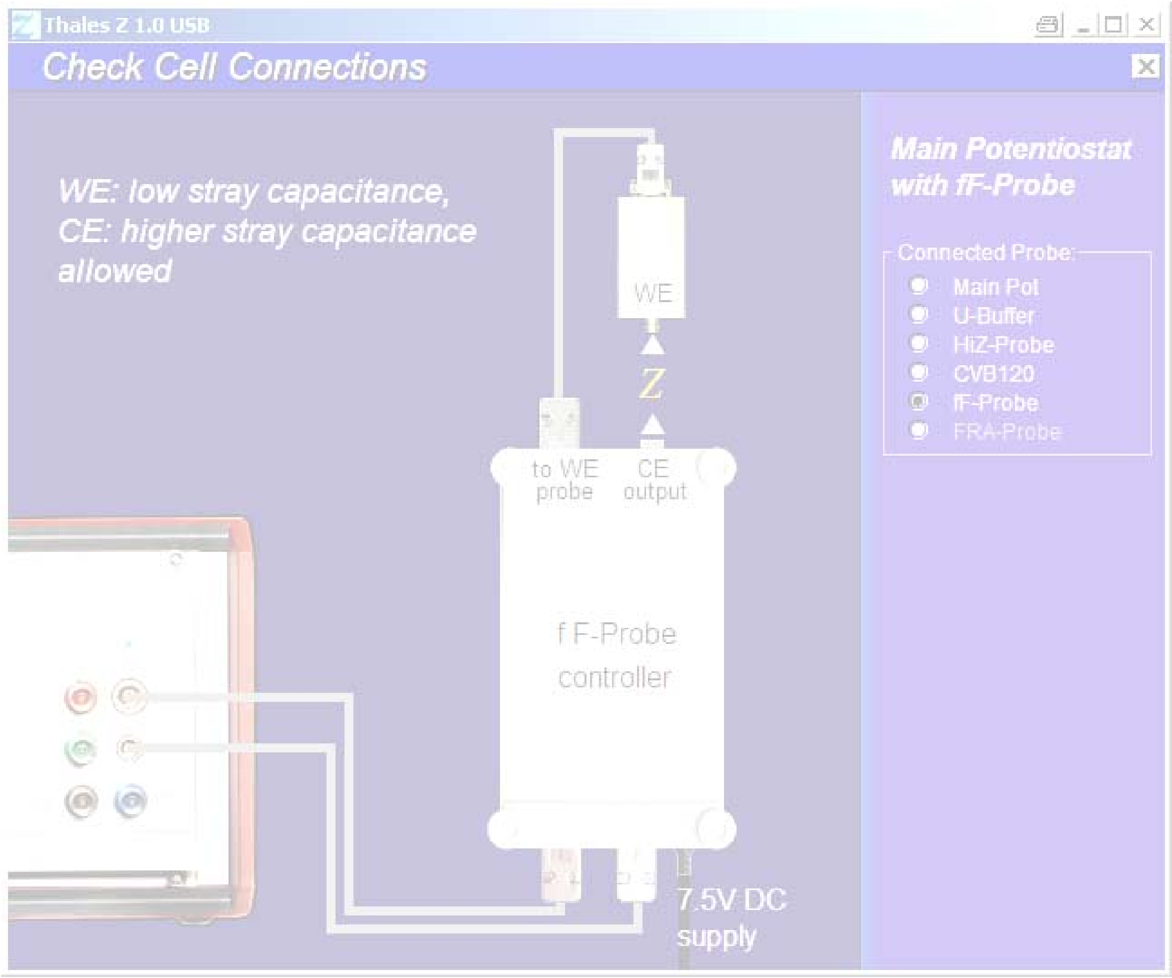
fFP

femto-Farad Probe



Thales Z 1.0 USB

Check Cell Connections

WE: low stray capacitance, CE: higher stray capacitance allowed

Main Potentiostat with fF-Probe

Connected Probe:
- ○ Main Pot
- ○ U-Buffer
- ○ HiZ-Probe
- ○ CVB120
- ● fF-Probe
- ○ FRA-Probe

1. Introduction and Function Principle

Electrochemical Impedance measurement, like the measurement of any physical magnitude, underlies certain restrictions regarding the available dynamic range of the measured magnitude. In EIS it is important to acquire data from very low impedance objects like fuel cells as well as from very high impedance objects like from coatings or passive films. The first requires a force-sense principle known as “Kelvin Scheme” using separate wiring circuits for voltage measurement and test current (Fig. 1) provided by a power operational amplifier called “potentiostat”. The force-sense principle is also necessary in any case, where one has to work with one or even two reference electrodes, what is the case very often in electrochemistry. Under this condition the measurement of high impedance objects like small capacities has to struggle with the influence of the unavoidable stray capacitances from the wiring. Using the best case front end for that purpose from Zahner, the HIZ probe, one may still keep the advantage from the potentiostatic Kelvin principle, but has to accept an uncertainty of ± 0.5 pF nevertheless. This is an extremely competitive accuracy for normal EIS instruments but still insufficient to measure capacities below some pF with sufficient precision.

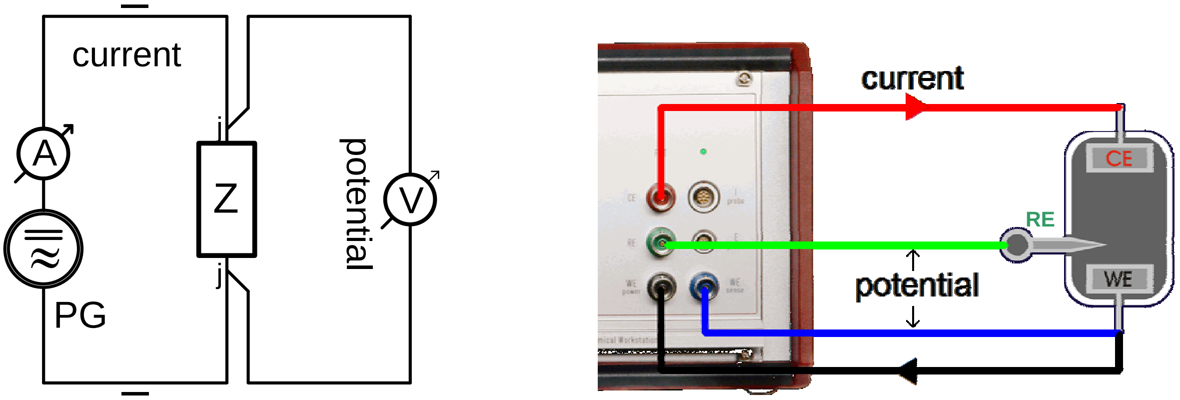


Fig. 1 Potentiostatic Kelvin scheme for EIS measurements. Left hand side: schematic with Potentiostat/Galvanostat PG, current measurement A, potential measurement V and the object under test Z. Right hand side: Kelvin connection of a three electrode cell with working electrode WE, counter electrode CE and reference electrode RE to the IM6/Zennium ECW.

The transimpedance principle (Fig. 2) is more adequate for the determination of small capacities than the Kelvin scheme. It is restricted to two-pole objects: instead of separate voltage-sense and current feed circuits, it is characterised by a voltage source output and a current sense input, both referenced to a common ground.

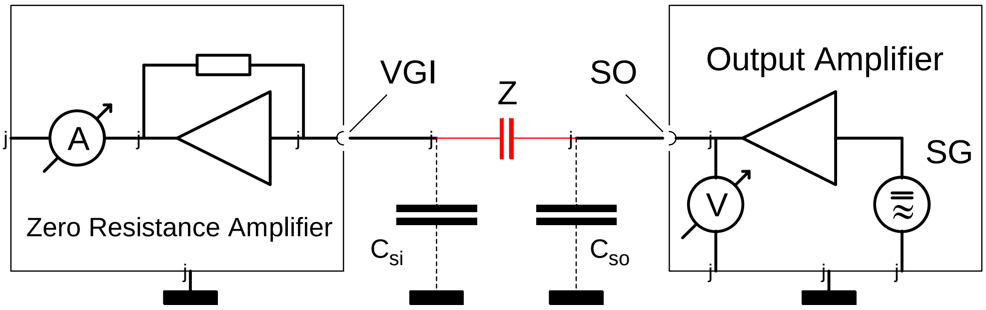


Fig. 2 The trans-impedance principle for the determination of small capacities: SO “hot” test signal output, VGI “virtual ground” signal input, Z device under test, V, A voltage and current measurement, C_{si} and C_{so} parasitic stray capacitance at the input and output terminal.

The current sense input is kept to zero potential (virtual ground). Even high capacitive stray current from the voltage output to ground (through C_{SO}) do not affect the current measurement accuracy at the sense input because the measured current is determined solely by the immediate transadmittance between output and input. The stray capacitive load at the sense input (C_{SI}) on the other hand does not carry any current, because it appears “connected” between ground and virtual ground. Therefore both stray capacities do nominally not affect the measurement accuracy.
For the requirements of the Clemson University, SC, Zahner developed its femto-Farad Probe following this principles with state of the art technology, realized as a subsystem of the IM6/Zennium instruments.

Similar to the HIZ-Probe, the femto-Farad Probe works as a front-end to the IM6/Zennium-potentiostat. Apart from its limited current capability, all basic functionalities of the Thales software are supported. In particular impedance spectroscopy can be applied. Due to the fact, that the primary measurement magnitude is the complex impedance, besides the sample capacity, resistive and DC contributions can be determined as well.

2. Technical Data

Frequency range	10µHz – 1MHz
Current auto ranging, defeatable	
Current ranges	0 - ± 40nA
	± 40 - ± 400nA
	± 400nA - ± 4µA
	± 4 - ± 40µA
Voltage range	± 4V
Resolution of any range	18 Bit

Capacity offset	± 1 fF *)
Capacity resolution	± 0.1 fF *)
Capacity accuracy	± 0.25% of reading ± 2 fF *)

*(current range ± 40nA, AC amplitude ≥ 100mV, zero DC current)

3. Product Contents

The fF-Probe delivery consists of a controller box (μ-controller, test signal output amplifier and input signal conditioning), the current-to-voltage converter box (“fF-Probe”), a 7.5V-DC power supply, cable connectors from the controller box to the ECW potentiostat outputs E-probe & I-probe and a cable connector between controller box and current-to-voltage converter box.

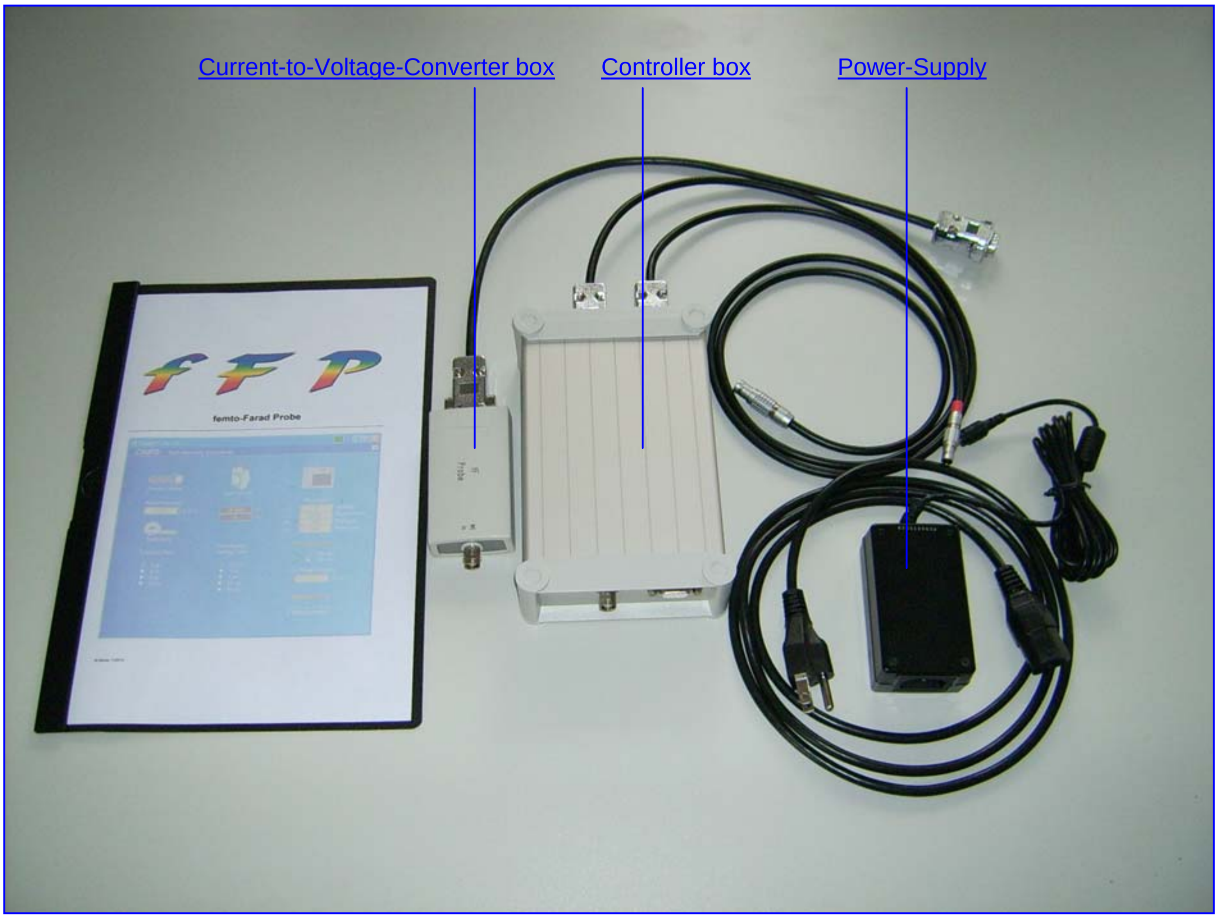


Fig. 3: The delivery contend.

4. Installation and Set Up

4.1. Startup

Be sure, that the controller box is connected to the current-to-voltage converter box and to the 7.5V-DC power supply. Switch on the fF-Probe and let the instrument settle for some seconds.
Enter the ECW potentiostat menu, for instance from the pulldown menu -> “control potentiostat” or from any measuring function panel in order to get access to the “check cell connections” function.
Check the “fF-Probe” entry (Fig. 4).

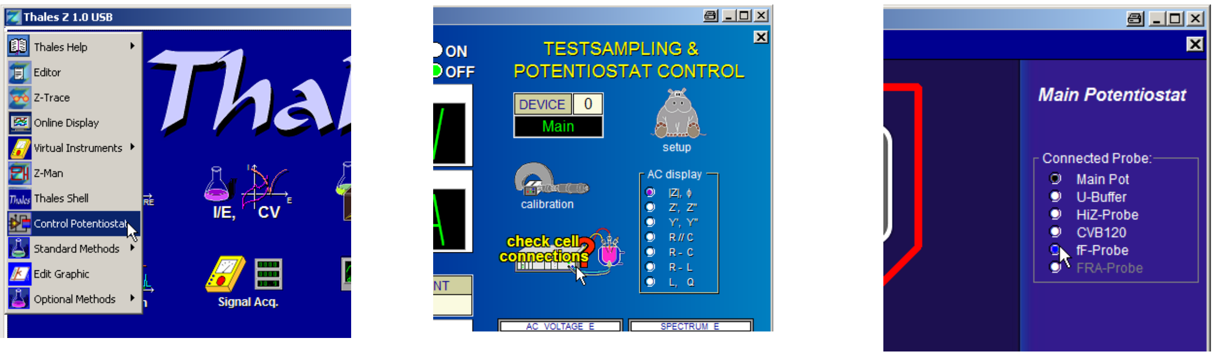


Fig. 4 Activation of the fF-Probe mode through “control potentiostat”->”check cell connections”->”fF-Probe”

A graph appears showing the wiring and the sample connection of the fF-Probe schematically (Fig. 5).

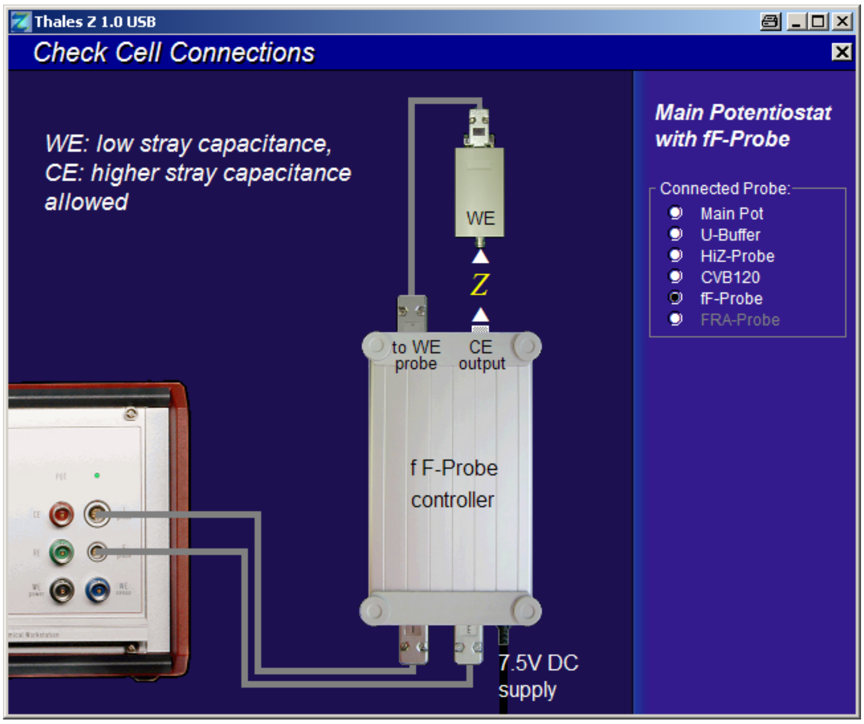


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Fig. 5 fF-Probe page of the “check cell connection” function.

Connect the “E” & “I”-probe cables of the fF-Probe controller box to the corresponding outlets of the potentiostat after quitting the “check cell connections” page. The instrument is now ready for measurement.

5. Sample Object Connection

Avoidance of parasitic transadmittance is the challenge on the way leading to perfect measurement of small capacities. The key role is played by the geometric properties of the arrangement signal output – object – sense input. Due to the fact, that the optimal arrangement usually needs tailored contacting construction, Zahner renounced on providing contact pins, crocodile clamps etc. Instead, input (WE in) and output (CE out) contacts are built by standard BNC connectors. The cables from WE in to the object must not be longer than 10 cm, the cable from CE out to the object must not be longer than 50 cm. Both cables have to be shielded. Fig. 6 illustrates schematically the meaning of the useful and the parasitic transadmittance.

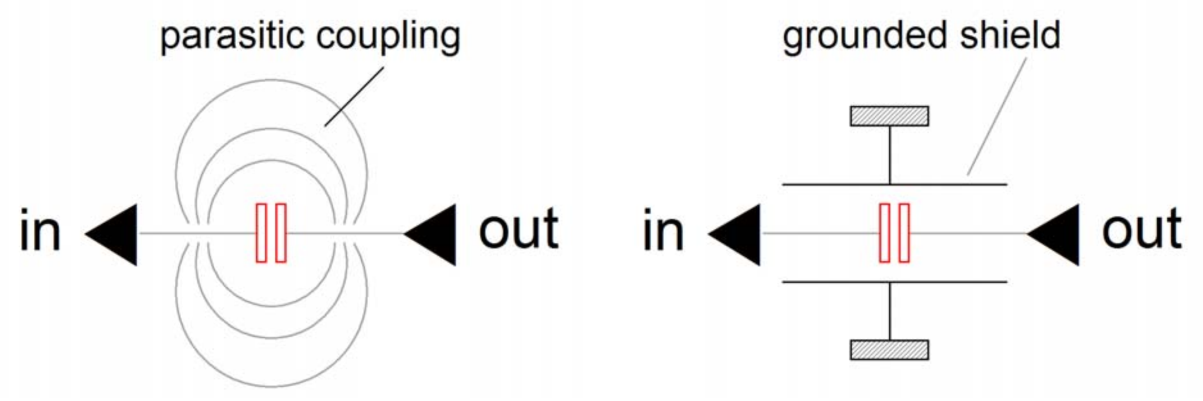

Fig. 6 Unwanted parasitic coupling. Left hand side: High parasitic transadmittance (unshielded), right hand side: optimal low parasitic transadmittance (shielded). The transadmittance of interest is drawn in red.

Fig. 7 shows an example, how the strategy of parasitic transadmittance avoidance is used in the case of the determination of the coupling capacity between two pads on a printed circuit board.

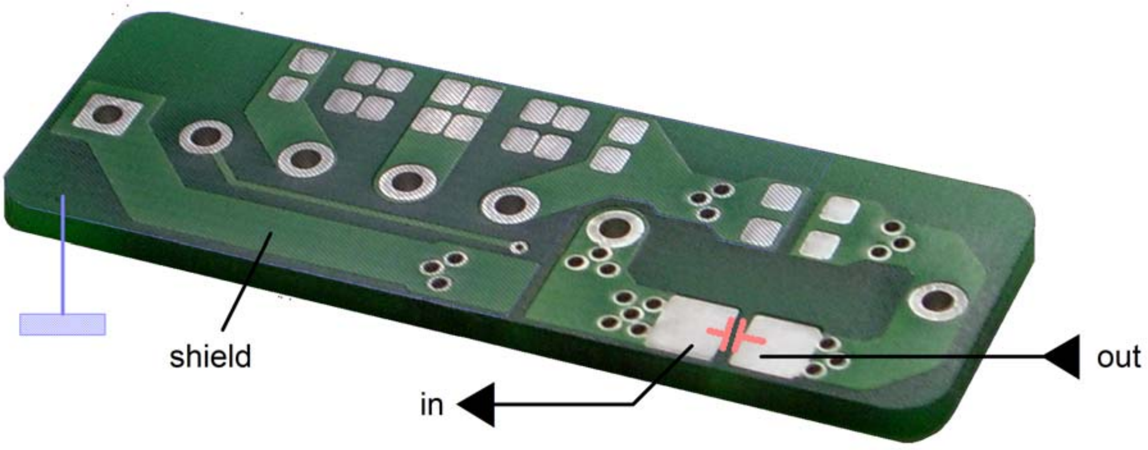

Fig. 7 Determination of the coupling capacity between two adjacent pads on a printed circuit board. All PCB layers except the pads of interest have to be grounded (shaded area in light blue). The transadmittance of interest is drawn in red.