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AUTOLAB

Modular

electrochemical

instruments

THE INSTRUMENTS

THE HARDWARE

THE SOFTWARE

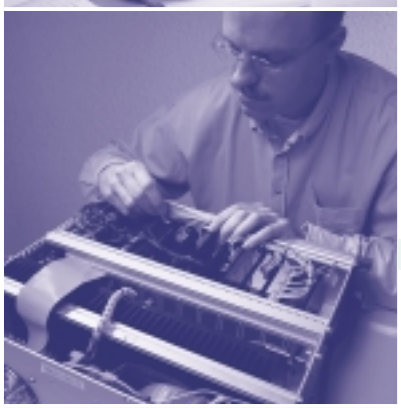
THE MODULES

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The flexibility of the company also reflects itself in the modularity of the Autolab instruments.







Development, production and testing of the Autolab electrochemical instruments.

Eco Chemie B.V.

was founded in 1986 by two electrochemists from the University of Utrecht in *The Netherlands.*

Ever since the foundation, *everyone* within the company has been *dedicated* to the development, production and testing of *Autolab* electrochemical instruments and their *software.*

Eco Chemie has the complete development and production in house and thus is able to control the complete path from the first development to the installation and instruction to the customer.

Over the years the hard- and software of the Autolab instruments have been improved, not only with ideas from within Eco Chemie, but mainly by listening carefully to the users of the instruments. This hard- and software development is an ongoing process and it is the heart of the Eco Chemie philosophy.

The flexibility of the company also reflects itself in the modularity of the Autolab instruments; this makes it possible to serve many electrochemists in a wide area of research.

At Eco Chemie, people in sales and development have a background in electrochemistry. This helps us understanding your needs.



Timoer Frelink and Aart Schild, the Managing Directors of Eco Chemie.

AUTOLAB

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Autolab

is the name of a family of

computer controlled

electrochemical instruments.

Within this family

a large number of *different*

instruments is available.

Thanks to the *modular*

concept, every instrument

can be configured to the

needs of the user.

The Autolab instruments can be controlled from two different software packages:
GPES for electrochemical techniques and FRA for impedance spectroscopy (in combination with a FRA2 module).

The combination of the Autolab hard- and software gives the user an unrivalled instrument to perform a wide range of electrochemical experiments.



µAutolab II

This is a non-modular, compact potentiostat/galvanostat capable of measuring or applying a maximum current of 80 mA and with a current resolution of 30 fA.

In combination with the GPES software, a large number of electrochemical techniques can be used, from standard cyclic voltammetry to AC voltammetry and constant current potentiometric stripping analysis.

The instrument has a built in analog integrator, making it possible to do chrono-coulometry, as well as an analog input to measure an external (voltage) signal and output to control a Rotating Disk Electrode.

In combination with a so called IME interface, mercury electrodes can be attached and controlled from the software.

This instrument is well suited for all low current applications in case no additional modules are required.

Autolab/PGSTAT12

A modular low-current, low noise potentiostat/galvanostat capable of measuring or applying a maximum current of 250 mA, with a compliance voltage of 12 V and the possibility to do iR-compensation.

The instrument basically offers the same possibilities as the µAutolab II, except for the built in Integrator, which is not present in the Autolab PGSTAT12. In combination with one or more of the optional modules, the instrument can be used for any kind of electrochemical research.

All the optional modules, except the BSTR10A/20A, are available for the PGSTAT12. The instrument can operate in three and four electrode mode.

Autolab/PGSTAT30

This is a modular high current potentiostat/galvanostat with a maximum current of 1 A, a compliance voltage of 30 V and the possibility to do iR-compensation.

The instrument offers the same capabilities as the PGSTAT12, has a bandwidth of over 1 MHz and is, in combination with the FRA2 module, especially dedicated to do Impedance Spectroscopy.

The PGSTAT30/FRA2 system is capable of measuring impedances in the range from 1 mOhm up to 100 GOhm and capacitances from 0.1 pF up to 5000 F and can be used in fields like corrosion research, bio-electrochemistry, battery and super-capacitor research and many other areas.

Another possible configuration is the PGSTAT30 with BSTR10A or BSTR20A for experiments at high currents (10A and 20A respectively). This configuration also operates in combination with the FRA2.

Of course all the other modules are available for the PGSTAT30 as well. The PGSTAT30 can operate in four electrode (for liquid-liquid measurements for example) as well as in three electrode mode.

Autolab/PGSTAT100

This is a modular high voltage potentiostat/galvanostat capable of measuring or applying a maximum current of 250 mA, a compliance voltage of 100 V and the possibility to do iR-compensation.

The instrument offers the same possibilities as the PGSTAT12 and PGSTAT30 and is especially suited for experiments in electrolytes with low conductivity.

All optional modules (except the MUX) are available for the Autolab/PGSTAT100.

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Different *modules* are available to expand the *possibilities* of the Autolab main units: PGSTAT12, PGSTAT30 and PGSTAT100.

- **BIPOT**

A module available for all three main units, giving the possibility to use a second working electrode with an applied fixed potential, to do for example rotating ring-disk experiments.

Max current for this working electrode is 50 mA. The module has current ranges from 100 nA to 10 mA, and a potential range of 5V.

- **FI20**

A Filter and Integrator module. The analog integrator gives the possibility to measure charge instead of current and can be used both in Cyclic Voltammetry as well as in potential step experiments.

The third order Sallen-Key filter, with selectable RC times between 0 and 500 ms, can be used to filter out noise. The module is available for all three instruments.

- **ADC750**

A fast sampling module which increases the sampling rate from 50 kHz in the standard instruments to 750 kHz. This gives the user the possibility to get a data point every 1.5 µs.

In combination with the SCAN-GEN module, the ADC750 makes it possible to do cyclic voltammetry with scan rates up to 10 kV/s. The module is available for all three instruments.

- **SCAN-GEN**

An analog sweep generator. With this module the user can apply a true linear sweep in cyclic and linear sweep voltammetry, instead of the staircase sweep that is available in the basic instrument.

This module can be used in cases where for example fast adsorption processes are studied. In combination with the ADC750 module, the sweep rate for cyclic voltammetry can be increased to 10 kV/s. The module is available for all three main units.

- **BSTR10A/20A**

A current booster which increases the maximum current of the PGSTAT30 to 10 A or even 20A.

The compliance voltage of the booster is 20 V. In case the booster is used in combination with the PGSTAT100, the compliance voltage goes down from 100 V to 20 V.

- **FRA2**

A module for Impedance Spectroscopy. With this module in the main unit, both potentiostatic and galvanostatic (during charging and discharging of batteries for example) impedance measurements become available. Frequency limits are from 10 µHz to 1 MHz.

This module in combination with the FRA software also allows the user to modulate the signal from an outside source to do for example Electro-hydrodynamic- or Photo-modulated Impedance Spectroscopy.

An instrument with a PGSTAT30 and FRA2 module in combination with the FRA software gives the user a powerful instrument for Impedance Spectroscopy, capable of measuring a wide range of impedances from 1 mOhm up to 100 Gohm.

This module is also available for the PGSTAT100 and the PGSTAT12.

- **ECD**

A low current amplifier, with current ranges from 100 pA to 100 µA, decreasing the current resolution of the Autolab from 30 fA to 0.3 fA at the lowest current range of 100 pA.

The module has a built in third order Sallen-Key filter and is available for all three main units.

- **MUX**

This multiplexing module allows the user to measure a number of cells or working electrodes in sequence. There are two different possibilities:

The MUX.MULTI to measure a sequence of complete electrochemical cells, with a maximum of 96, and the MULTI.SCNR to measure a sequence of working electrodes in the same cell, with a maximum of 256.

The cell number to perform a measurement can be selected manually, or an automated measurement can be performed on a range of cells. The measurements take place one at a time, so a measurement has to be finished before the software switches to the next channel.

This module is especially useful when routine measurements have to be performed on a large number of samples.

- **pX**

A module that can be used for pH measurements and bi-potentiometric (current-less) measurements.

A pH electrode or ion-selective electrode can be connected to this module, allowing the customer to see the response of these electrodes as an external signal in the software during an electrochemical experiment.

This also allows the customer to do coulometric titration experiments in which the second signal can be used as an indicator signal.

This module can be used with all three main units.

- **ECN**

With this module, Timed Noise Monitoring experiments can be done. In this way the long time behaviour of samples can be followed.
The current noise will be measured between two identical electrodes, while the potential noise is measured with respect to a reference electrode.

The latter is connected to the ECN module, thus providing higher resolution than with the standard instrument. The software allows to see both the mean values as well as the standard deviation of potential and current in time.

This module can be used with all three main units.

- **IME**

This module comes in two different types: IME303 and IME663 and is used to connect mercury electrodes to the Autolab instruments and control them from the software.

The IME303 is used for control of the PAR303 electrodes, and the IME663 for the Metrohm VA Stand 663. This is the only (external) module that is available for the three main units as well as the µAutolab.

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	µAUTOLAB II	AUTOLAB/PGSTAT12	AUTOLAB/PGSTAT30	AUTOLAB/PGSTAT100
• Maximum output current	± 80 mA	± 250 mA	± 1 A	± 250 mA
• Maximum output voltage	± 12 V	± 12 V	± 30 V	± 100 V
• Potentiostat	yes	yes	yes	yes
• Galvanostat	yes	yes	yes	yes
• Potential range	± 5 V	± 10 V	± 10 V	± 10 V
• Applied potential accuracy	± 0.2 % of setting ± 2 mV	± 0.2 % of setting ± 2 mV	± 0.2 % of setting ± 2 mV	± 0.2 % of setting ± 2 mV
• Applied potential resolution	150 µV	150 µV	150 µV	150 µV
• Measured potential resolution	300 or 30 µV	300 or 30 µV	300 or 30 µV	300 or 30 µV
• Current ranges	10 nA to 10 mA in 7 ranges	10 nA to 100 mA in 8 ranges	10 nA to 1 A in 9 ranges	10 nA to 100 mA in 8 ranges
• Applied and measured current accuracy	± 0.2 % of current and ± 0.2 % of current range	± 0.2 % of current and ± 0.2 % of current range	± 0.2 % of current and ± 0.2 % of current range	± 0.2 % of current and ± 0.2 % of current range
• Applied current resolution	0.03 % of current range	0.03 % of current range	0.03 % of current range	0.03 % of current range
• Measured current resolution	0.0003 % of current range	0.0003 % of current range	0.0003 % of current range	0.0003 % of current range
- At current range of 10 nA	30 fA	30 fA	30 fA	30 fA
• Potentiostat bandwidth (1)	500 kHz	500 kHz	> 1 MHz	> 500 kHz
• Potentiostat risetime/falltime (1 V step, 10 - 90 %) (1)	1 µs	< 500 ns	< 250 ns	< 500 ns
• Potentiostat modes	high speed/ high stability	high speed/ high stability	high speed/ high stability	high speed/ high stability
• Input impedance of electrometer	> 100 GΩ // < 8 pF	> 100 GΩ // < 8 pF	> 100 GΩ // < 8 pF	> 100 GΩ // < 8 pF
• Input bias current @ 25˚C	< 1 pA	< 1 pA	< 1 pA	< 1 pA
• Bandwidth of electrometer	> 4 MHz	> 4 MHz	> 4 MHz	> 4 MHz
• iR-compensation	n.a.	depending on selected range: 0 Ω - 20 Ω at 100 mA range to 0 Ω - 200 MΩ at 10 nA range, current interrupt and positive feed-back available	depending on selected range: 0 Ω - 2 Ω at 1 A range to 0 Ω - 200 MΩ at 10 nA range, current interrupt and positive feed-back available	depending on selected range: 0 Ω - 20 Ω at 100 mA range to 0 Ω - 200 MΩ at 10 nA range, current interrupt and positive feed-back available
- Resolution	n.a.	0.025 %	0.025 %	0.025 %
• Four electrode control	no	yes	yes	yes
• Front panel meter	n.a.	potential and current	potential and current	potential and current
• Analog outputs (BNC connector)	potential and current	potential and current	potential and current	potential and current
• Control voltage input	no	yes	yes	yes
• Multichannel option	no	multiple WE option	multiple WE option	no
• Booster option	no	no	yes	yes
• Analog integrator	yes	optionally	optionally	optionally
- Time constants	10 and 100 ms, 1 and 10 s	10 and 100 ms, 1 and 10 s	10 and 100 ms, 1 and 10 s	10 and 100 ms, 1 and 10 s
• Interfacing	USB	USB	USB	USB

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	µAUTOLAB II	AUTOLAB/PGSTAT12	AUTOLAB/PGSTAT30	AUTOLAB/PGSTAT100
• A/D converter	16-bit with software programmable gains of 1, 10 and 100	16-bit with software programmable gains of 1, 10 and 100	16-bit with software programmable gains of 1, 10 and 100	16-bit with software programmable gains of 1, 10 and 100
• Auxiliary input channels • D/A converter • Digital I/O lines	1 16-bit, 3 channels 48	2 16-bit, 4 channels 48	2 16-bit, 4 channels 48	2 16-bit, 4 channels 48
• Dimensions (W × D × H) • Weight • Power requirements	27 × 27 × 8 cm^3 3.2 kg 30 W, 100 ... 240 V, 50/60 Hz	52 × 42 × 17 cm^3 22 kg 120 W, 100 ... 240 V, 50/60 Hz	52 × 42 × 17 cm^3 25 kg 170 W, 100 ... 240 V, 50/60 Hz	52 × 42 × 17 cm^3 25 kg 170 W, 100 ... 240 V, 50/60 Hz

Note: (1) Measured at 1 mA current range, 1 kOhm impedance, high speed mode when applicable. Specifications are subject to change without notice.

	FRA2 MODULE
• Frequency range • Frequency resolution • Applied amplitude	10 µHz to 1 MHz 0.003 % 0.2 mV to 0.35 V(rms) or 1 mV to 1 V(rms); steps of 0.1 mV (1) (potentiostatic mode) 0.0002 to 0.35, steps of 0.0001 times applied current range (1) (galvanostatic mode)
• Output impedance of DSG • Resolution of DSG • Resolution of dual channel ADC • Input range • Input channels	50 Ohm 1 in 65536 (16 bits) 1 in 4096 (12 bits) ± 5 V E and I from potentiostat/galvanostat or X and Y external input signals

Note: (1) Other ranges are optional. Specifications are subject to change without notice.

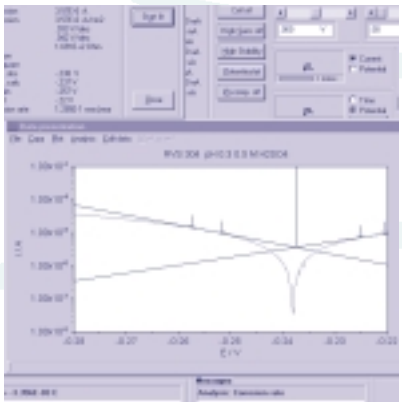
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The GPES *software* package provides the user with almost all *electrochemical* techniques and is, in *combination* with one of the Autolab instruments, an electrochemical *workstation* that can be used in many *different* research areas.

Below a short description of the available techniques is given with their most important possibilities.

Electroanalytical methods
- Sampled DC-Voltammetry.
- Normal Pulse, Differential Pulse and Differential Normal Pulse Voltammetry.
- Definable pulse width, direction and height.
- Square Wave Voltammetry.
- Frequencies from 8 to 2000 Hz, and the possibility to see both I forward, I backward and the resulting current.
- AC-Voltammetry.
- Frequencies from 1 to 250 Hz, the option to measure phase dependent as well as the possibility to measure the second harmonic.

Cyclic and Linear Sweep Voltammetry
- Staircase potentiostatic and galvanostatic voltammetry.
- Scan rates from 1 µV/s to 200 V/s.
- Cyclic Voltammetry with True Linear Sweep (SCAN-GEN only).
- Scan rates up to 10 kV/s.
- Stationary current voltammetry
- A data point is taken every time the current reaches a predefined stationary value.
- Current Integration method (when an Integrator is present)
- An alternative for True Linear Sweep voltammetry.
- Hydrodynamic Linear Sweep Voltammetry,
- A linear sweep experiment is performed at a series of predefined rotation speeds.
- Bi-potentiostatic measurements.
- Recording of an extra analog signal simultaneously, for example from an EQCM or a pH electrode (in combination with a pX module).
- Possibility to measure with respect to the Open Circuit Potential, i.e. for Corrosion Measurements.



- Possibility to show Tafel plots, to define current limits, to pretreat the electrode, to show charge and current simultaneously, and many other options.

Chrono-methods
- Chrono-amperometry, -coulometry and -potentiometry.
- Measurement rates up to 50 kHz (or a data point every 20 µs) with the standard instrument and 750 kHz with the ADC750 module.
- Maximum of ten potential or current levels can be specified.
- Possibility to repeat the steps and save the data automatically.
- Specification of current, charge or potential limits.
- Automated recording of extra data-points with large changes in the response.
- Bi-potentiostatic measurements.
- Measurements at or with respect to the Open Circuit Potential.
- Three pretreatment potentials available.

Electrochemical detection
- Used in HPLC and FIA.
- Pulsed amperometric detection.
- DC-amperometry and differential pulse amperometry.

Potentiometric Stripping Analysis
- Chemical stripping and constant current stripping.
- Measurement rate is 40 kHz.

Electrochemical Noise
- measurement at open circuit of noise in current and potential.

Steps and Sweeps
- A sequence of potential steps and linear sweeps can be programmed.
- Maximum scan rate of 25 V/s and maximum sampling rate of 10 kHz.
- A maximum ten segments is possible.
- No time lags between steps and sweeps.
- Scan rates and step potentials can be varied.
- Use of SCAN-GEN module when present.

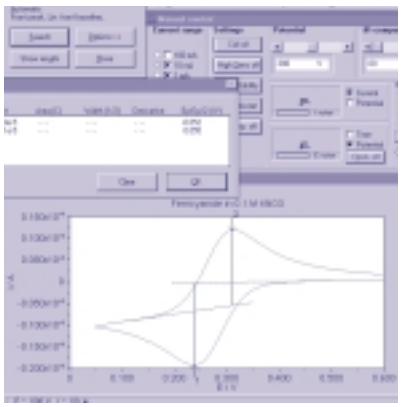
All the parameters for a measurement can be changed in the 'Edit Procedure' window, which is shown together with a 'Manual Control' and a 'Data Presentation' window.

The measurement procedure may be stored separate from the data to make measurements under standardised conditions possible.

Data are saved in ASCII format and can thus easily be transferred to another software package.

The Utilities menu on the main menu bar gives the user the possibility to control a Rotating Disk Electrode, a Mercury Electrode, or a Burette.

The iR-compensation methods Positive Feedback and Current Interrupt are available in this menu as well.



The project menu allows the user to define a sequence of different measurements which will be performed automatically. With this option switching between electro-chemical and impedance techniques is also possible.

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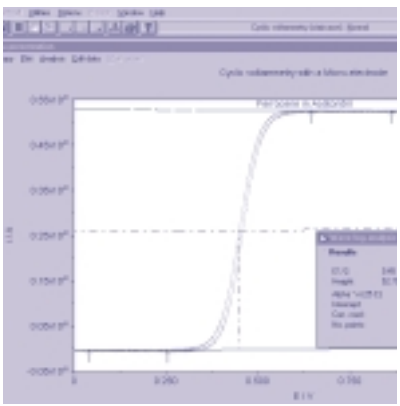
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Measured curves are shown in real time (depending on the sample rate) in the 'Data Presentation' window. The plot format of the data may be changed during and after the measurement, making it possible to show data on a logarithmic, linear, square root or inverse scale for potential, current as well as time axes.

The menu bar of the window can be used to zoom in, set a window, load overlay files, and to perform data-analysis on both the electrochemical as well as the optional second signal.

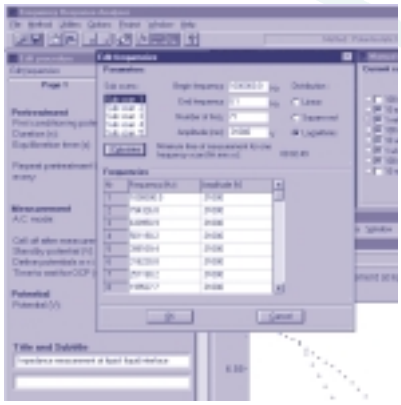
The list below gives a short overview of available data-analysis options.

- Automatic and interactive peak search.
- Linear, exponential and polynomial baseline correction.
- Linear regression.
- Smoothing: FFT and weighted moving average.
- Integration and differentiation.
- Convolution and deconvolution.
- Fitting and simulation of voltammograms.
- Subtraction and addition of curves.
- Kinetic and waveslope analysis for S-shaped voltammograms.
- Automatic corrosion rate and polarisation resistance determination.
- Levich plots.
- Transient time analysis for chrono-potentiometry.
- Chrono-amperometric and chrono-coulometric plots.
- Fourier transformation.
- And many more.



The FRA *software* for Impedance Spectroscopy in *combination* with an Autolab with a FRA2 module allows the user to *perform* potentiostatic as well as galvanostatic Impedance *measurements.*

Measurements are possible at a single potential/current, during a potential or current scan or during a time scan. Below a short overview of the possibilities is given.



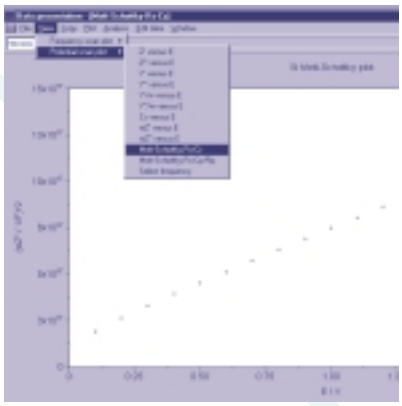
- Frequencies from 10 µHz to 1 MHz with a linear, logarithmic, or square root distribution.
- Frequency scans dividable into sub-scans allowing the user to define different amplitudes for example in different frequency ranges within the same measurement.
- Single sine or super imposed multi-sine (5 or 15) measurements.
- Measurements at, or with respect to, the open-circuit potential.
- Oscilloscope and Frequency spectrum window to follow the applied and measured frequencies during the measurement.
- Change of measurement parameters like: Integration time, Number of Cycles to Integrate, Number of cycles to wait before measurement.
- Possibility to do for example Hydrodynamic Impedance or Photo-Modulated Impedance measurements.
- Possibility to show Z" vs Z' plots isotropically.

During and after the experiment a large number of plot options is available, the most important of which are:

- Z" vs Z'
- Y" vs Y'
- Bode Plot
- Z' and Z" vs f
- Z' and Z" vs √ω or 1/√ω
- Y"/ω vs Y'/ω
- Epsilon Plot
- Z' vs ωZ"
- Z' vs Z"/ω.

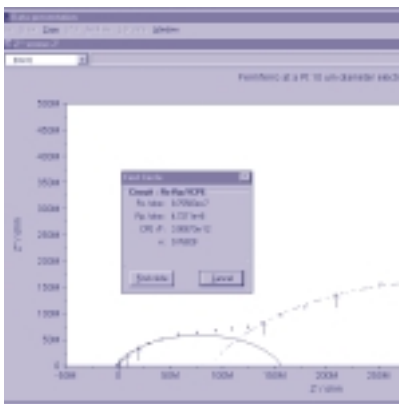
For Potential, Current or Time scans:

- Z' and Z" vs E, I or t
- Y' and Y" vs E, I or t
- Cs vs E, I or t
- ωZ' and ωZ" vs E, I or t
- Mott-Schottky plot.



As in the GPES software extensive options for data analysis are present among which:

- Find Circle, to analyse semi-circles in the Nyquist or Z'-Z" plot.



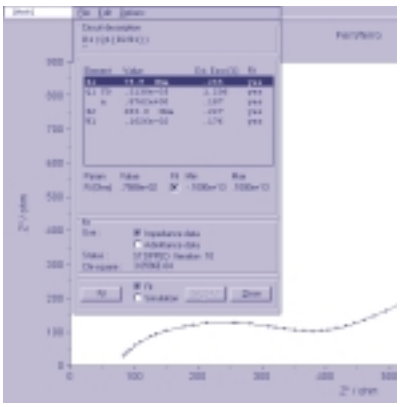
- Equivalent Circuit Fitting, based on the Circuit Description Code by Dr. B.A. Boukamp.

This option allows the user to fit the experimental curve with any equivalent circuit. Possible elements include: Resistance, Capacitance, Inductance, Constant

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Phase Element, Warburg, Gerischer Impedance, Hyperbolic tangent and Hyperbolic co-tangent elements.

- Subtraction of Elements.
- Kramers-Kronig test, to test the validity of the measured data.



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THE SOFTWARE

THE MODULES

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