solartron analytical

ModuLab®

Analytical
Battery / fuel cell
Nanotechnology
Microelectrodes
Corrosion and coatings
Fundamental research

Introducing the new gold stand

ModuLab is a fully modular electrochemical research system that is almost limitless in its versatility but remains easy to use for a wide variety of electrochemical applications.

The core of the system is a high-speed, high-performance potentiostat / galvanostat that provides precise measurement and control of the cell. An extensive array of options are available that can be combined to tailor electrochemical test systems for particular applications including fuel cell development, analytical electrochemistry, nanotechnology and corrosion / coatings research. Connection diagrams in the software enhance the modularity and allow the system to be quickly and easily re-configured for any type of test.

Each option in the ModuLab system has been carefully designed to combine seamlessly with the core potentiostat and with other options to extend the system's range of control and measurement.

ard for electrochemical research

The options work together, each complementing rather than compromising the facilities of the other, providing virtually unlimited test capability for the researcher.

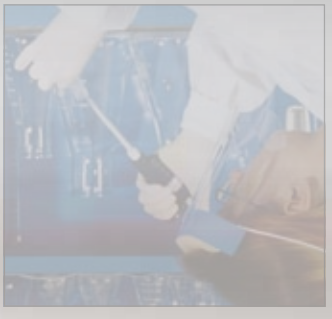
The ModuLab system utilizes the latest state-of-the-art over-sampling signal processing technology to provide ultra-smooth analog cyclic voltammetry waveforms no matter which combination of options are used, even when operating at extreme >10kV/s scan rates. The smooth scan waveform generator capability ensures that cells are not disturbed by undesired steps and transients, for ModuLab "smooth scan" means just that. The high-resolution digital techniques employed ensure precise waveform generation and analysis over the complete range of scan speeds without changing modes of operation or connections.

As you might expect from a Solartron system, the range and capability of impedance techniques provided by ModuLab are second to none. Single sine, multi-sine / FFT and harmonic analysis are provided throughout the entire frequency range of the system. The frequency response analyzer (FRA) uses 40x over-sampled data acquisition and waveform generation to ensure the purity and accuracy of the results. Any of the above impedance analysis techniques may be used for AC staircase (or linear) voltammetry / potentiometry providing complete cell characterization (impedance vs. frequency vs. DC polarization).

System Configuration

The ModuLab system can be "plug and play" configured in many different ways, from a single potentiostat with options in a chassis, to several potentiostats in the same chassis, or multiple chasses each with multiple potentiostats in an extended system. Several potentiostats can be controlled from a single PC, or multiple PCs may be integrated into the system each controlling groups of potentiostats as required. Additional potentiostats and options may be added into a chassis at any time. Each option module carries its own calibration, so it really is as easy as plug and play to add to the system. The front panel of the chassis is easily removed and new modules can then be inserted which are detected by the software when the system powers on.

ModuLab: the world's most flexible modular electrochemical test system



Applications

	Analytical	Battery / fuel cell	Nanotechnology	Microelectrodes	Corrosion and coatings	Fundamental research
High performance 'Plug & Play' modules	●	●	●	●	●	●
64 MS/s smooth scan - LSV, LSP, CV	●		●	●		●
Up to 1 MS/s data acquisition - pulse, CV	●	●	●	●		●
100 aA current resolution	●		●	●	●	●
Up to ±25 A current - scan / pulse		●			●	●
±100 V compliance and polarization	●	●	●			●
10 μΩ impedance measurement		●	●			●
>100 TΩ impedance measurement	●		●	●	●	●
Multiple high-speed EIS techniques	●	●	●	●	●	●

Fuel cells, batteries and supercapacitors

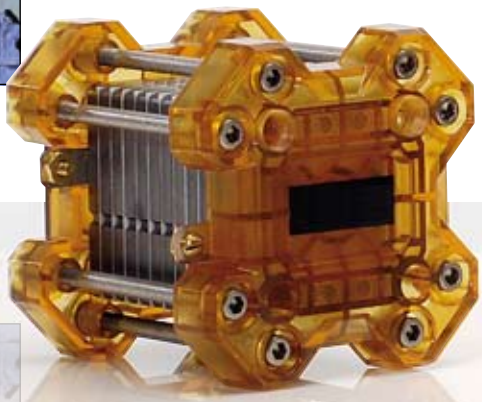
The ModuLab system is able to characterize a wide range of cell technologies at a research and development level. Smaller batteries, supercapacitors and micro fuel cells, such as those used in mobile communications and PC applications can be tested directly by ModuLab. For testing higher power cells, potentiostats may be connected in parallel or external power booster options may be added to the system.

In addition to standard DC multi-channel experimental techniques such as cyclic voltammetry, charge / discharge cycling, and ohmic-drop measurements, ModuLab provides many specialized capabilities including anode / cathode impedance measurements. The capability to provide complete cell impedance characterization is very important for the improvement of cell electrode performance.

There is also interest in harmonic analysis for fuel cells which provides diagnostic information to determine the health of the cell.

Mobile phone device test applications are also fully supported with the ability to run GSM and CDMA pulse applications. High data acquisition rates and flexibility of data capture capabilities are very important facilities for these applications.

Combinations of options such as auxiliary channels, high voltage, power boosters and FRAs are used to run continuous impedance and DC tests on multiple cells in a battery or fuel cell stack, looking for early signs of deterioration in individual cells. Stacks with overall voltage as high as 100 volts may be analyzed in this way.



Corrosion and Coatings

ModuLab is a fully floating system allowing measurements to be taken in the most difficult circumstances. The high voltage and femto ammeter options provide many possibilities for testing extremely high impedance corrosion coatings. The system also provides equivalent circuit and Tafel data fitting techniques, Linear Polarization Resistance measurements and corrosion result displays

The ModuLab system was designed with voltage and current noise experiments in mind, providing accurate and consistent data that may be used in electrochemical noise studies. The ModuLab potentiostat makes use of virtual earth (Zero Resistance Ammeter - ZRA) measurement technology and provides high-speed acquisition and high sensitivity measurements that are a requirement for this application

Nanotechnology
Microelectrodes

From the outset, ModuLab was designed to measure electrode processes on ultra-microelectrodes such as carbon nanotubes and Atomic Force Microscope (AFM) tips. ModuLab's femto ammeter option, coupled with a comprehensive suite of electrochemical measurement techniques, provides ultra-low current potentiodynamic and galvanodynamic DC measurements. In combination with a frequency response analyzer (FRA), extremely high impedance measurements are possible (>100 Tohms).

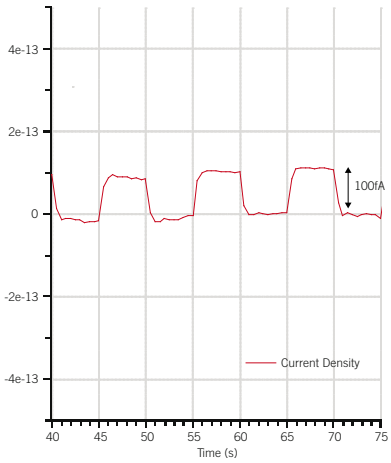
Measurements on nano-devices require careful screening from sources of noise and interference. The femto ammeter option achieves this with double screened shielding for the measurement electronics, triax cabling and high stability reference resistors.

Analytical
Fundamental Research

ModuLab is able to measure at extremely high data acquisition rates (up to 1 MS/s) which is ideal for high speed sweep, pulse or step analytical techniques such as fast cyclic voltammetry CV and normal / differential pulse voltammetry NPV / DPV.

ModuLab provides ultra-smooth scanned waveforms (for example in CV cyclic voltammetry and LSV linear sweep voltammetry). Ultra-high sample rates and interpolation filtering provide the precision and stability of digital waveforms while maintaining the smoothness of analog sweeps. The femto ammeter option may also be utilized for extremely sensitive current measurement applications.

Choice of data acquisition mode is provided for all step types, so the shape of the current response to a sequence of DPV pulses may easily be monitored allowing optimization of data capture. The flexibility of the experiment sequencing allows any combination of techniques to be sequenced automatically and repeated using loops.



There are many other applications including sensor development and bio-research, where the range of facilities and options of ModuLab will undoubtedly prove to be very beneficial.

To discuss how ModuLab could benefit your specific application, contact your local Solartron representative.

Modules

Potentiostat / galvanostat
(Pstat 1 Ms/s)

The core of the ModuLab system is its potentiostat / galvanostat which makes use of the latest Digital Signal Processor (DSP) technology to provide accurate experiment control, high-speed data acquisition, data averaging and responsive safety and step limit detection. The ModuLab potentiostat provides:

- Smooth waveform generation using high sample rates (64 MS/s) and interpolation filtering to deliver the accuracy, stability and control of digital waveform technology with all of the smoothness of analogue techniques.
- High-speed data acquisition up to 1 MS/s used for pulse and fast CV techniques.
- Exceptional bandwidth for accurate and reliable high-speed CV, pulse and impedance measurements at all frequencies and impedance levels (using an FRA option).
- Floating electrode capability for measurements on grounded cells, autoclaves, pipelines and storage tanks.
- Flexible experiment sequencing that allows high data acquisition rates at those specific points in the experiment where it is needed, e.g. for analysis of pulses or high speed CVs.
- An extensive range of analytical electrochemistry techniques, plus the ability to sequence techniques to perform charge / discharge cycling, chronoamperometry and combined DC and impedance experiments.
- Instantaneous switching between experiment steps provides a great deal of flexibility for defining charge / discharge experiment protocols for battery applications and for analytical applications.

Frequency response analyzer options
(FRA 1 MHz / FRA 300 KHz)

The frequency response analyzers (FRA) used in the ModuLab system are the highest performance analyzers available today. The FRA is able to measure in all of the following modes of operation across its entire frequency range (from 10 µHz to 1 MHz):

- **Single sine correlation** provides unbeatable measurement accuracy and repeatability. The ModuLab FRA takes impedance measurement performance to a higher level by combining the best quality analog hardware design with the latest generation high-speed Digital Signal Processor (DSP) technology to provide even greater measurement speed and accuracy (1 MHz to 10 Hz, 10 points / decade in just five seconds).
- **Multi-sine / Fast Fourier Transform (FFT) analysis** provides even faster measurement by stimulating and measuring multiple user selectable frequencies at the same time. This is especially useful for low frequency analysis and for measurements on time-variant or unstable cells. Multi-sine / FFT measurements are so fast that they can often be taken before the cell response changes.
- **Harmonic Analysis** utilizes the FFT analysis technique together with single or multiple frequency stimulation in order to investigate linearity and distortion. This provides information that may be used to optimize the stimulus signal level. The technique is also used in fuel cell state of health diagnostics and for corrosion rate analysis.
- **AC Voltammetry and potentiometry** using any of the above techniques over the full frequency range.

High voltage options
(HV 100 / HV 30)

The standard ModuLab potentiostat can provide up to ±8 V stimulus to the cell. At times however, higher voltage is needed, for example when testing a fuel cell stack. The HV options provide high voltage polarization as well as compliance. The HV options have four auxiliary channels as standard (each operating over the same high voltage range as the main reference inputs) allowing both DC and impedance tests to be performed looking for individual bad cells in a high voltage fuel cell stack. Multiplexers can also be added allowing as many cells as required to be tested (DC and impedance) within the stack. See the auxiliary voltage input option for more details.

Power booster options
(Booster 2A and external)

ModuLab's standard current range can be extended by addition of the Booster 2A option. If higher current is needed, external boosters up to 50 V / 25 A may also be added to the system.

ModuLab makes use of the latest Digital Signal Processing (DSP) technology.

Low current option
(Femto Ammeter)

The standard ModuLab core potentiostat is able to resolve 1 pA. This resolution is sufficient for many types of cell but for more demanding applications, e.g. microelectrode studies, high impedance fuel cell membranes, nanotechnology (carbon nano-tubes) and for corrosion / coatings applications on very high impedance samples, more sensitive DC current measurement may be needed. The femto ammeter option is designed to resolve extremely low current levels (100 aA). It may also be used in combination with the FRA and HV high voltage options to measure extremely high impedance cells (>100 Tohms).

* Auxiliary voltage input option

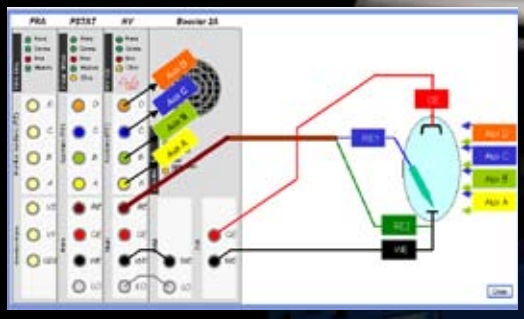
Four (differential) auxiliary voltage inputs are provided as an option for the core potentiostat and are fitted as standard to the HV options. Auxiliary voltage inputs are an extremely flexible addition to the system that provide:

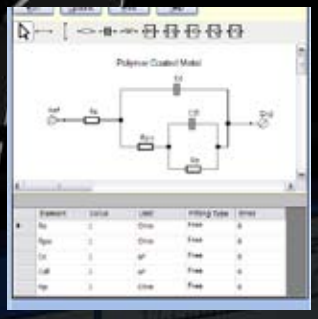
- Synchronized differential DC voltage measurements from parts of a test cell, e.g. across an anode or cathode in a battery or across individual cells in a stack.
- Anode / cathode impedance measurements (FRA option required)
- Synchronized DC voltage measurements from external monitoring equipment such as pH meters, pressure transducers, light sensors etc.

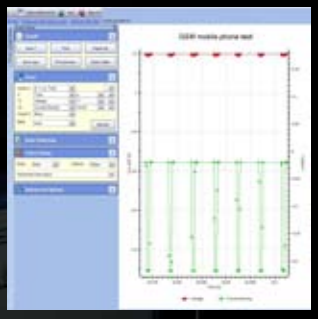
Multiplexers may also be added to the auxiliary voltage inputs with automatic channel switching via the software, providing an almost unlimited number of points in the cell that can be tested.

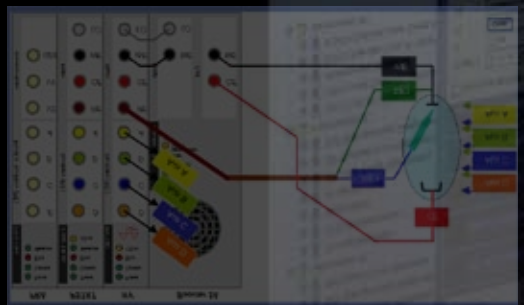
ModuLab

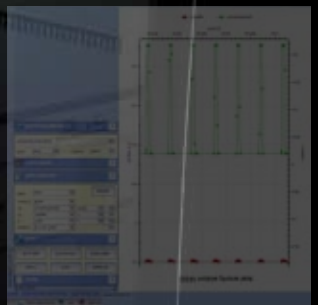
Software







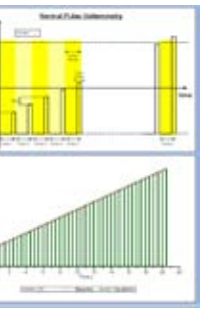




The software provided with the ModuLab system is both flexible and comprehensive, and yet is very easy to use. A large selection of experiment types are provided, from standard open circuit and cyclic voltammetry tests to complicated multistep sequences that include sample preparation, advanced experimental techniques and integrated impedance analysis.

ModuLab software makes use of diagrams at all stages of experiment development so that the user knows exactly what waveforms will be applied to the cell. As parameters are entered into the software, waveform diagrams display the actual timing and levels that will be applied to the cell when the experiment is run. Connection diagrams are also shown so that the user may check that the cell is connected correctly and make any adjustments before running the experiment.

The software allows free choice of data acquisition modes irrespective of the type of experiment that is selected. For example high data sample rates may be selected while running pulse voltammetry experiments so that the actual shape of the pulses (voltage and current) may be analyzed to select optimal measurement points on the pulses.



Navigation Tree

The navigation tree allows the user to setup and display projects, experiments, data files, graphs and reports. Multiple projects may be used and these typically group together series of experiments and files relating to a particular cell or series of cells.

Integrated DC / Impedance

Experiments can consist of single or multiple step sequences. DC and impedance steps are fully integrated allowing complex functions such as linear or cyclic AC voltammetry and stairstep AC voltammetry to be setup and run. The software even allows swept sine, harmonic analysis and multi-sine / FFT functions to operate in AC voltammetry mode, allowing complete DC and impedance cell characterization.

Data Analysis

Data fitting routines are fully integrated into the ModuLab software including line, circle, Tafel and equivalent circuit fitting. Tafel fitting provides analysis of corrosion phenomena and gives information about corrosion rate and anodic / cathodic slopes which may be used for further system analysis. Equivalent circuit models may be constructed using a range of components including resistors, capacitors, inductors, distributed elements, constant phase elements, Gerischer elements, and Warburg open / short elements. Some widely used models are pre-configured in the software. Other models can be constructed very easily using the graphical equivalent circuit model editor. This allows modeling of complex impedance phenomena in many applications including corrosion, microelectrode studies and battery / fuel cell analysis.

Report Builder

A built-in report generator takes the experimental results and outputs them together with graphs, diagrams and analysis information into your favorite word processor.

Zplot.Lab Software

For those customers who are familiar with previous electrochemical test software such as Zplot, CorrWare and MultiStat there is a new and upgraded software package in the same family of products called Zplot.Lab that provides many enhanced electrochemical facilities.

ModuLab software: flexible, comprehensive, yet very easy to use.

Specification

Potentiostat, HV 100 / HV 30, Booster 2A, Femto Ammeter Modules

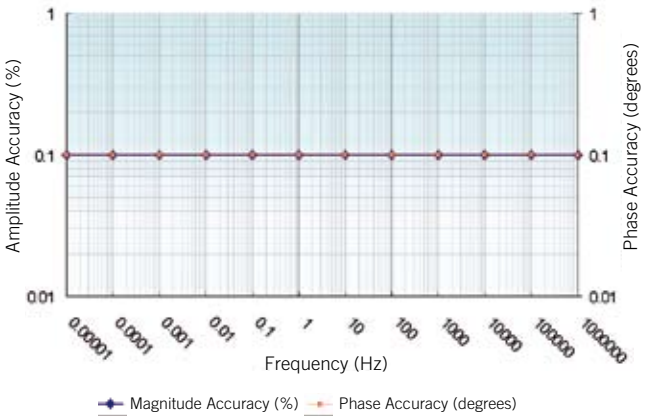
Specification	Core	Internal Options		
General	**Potentiostat**	**HV 100 / HV 30**	**Booster 2A**	**Femto Ammeter**
Slots taken	1 slot	1 slot	2 slots	1 slot
Cell connections	2, 3 or 4 terminal	2, 3 or 4 terminal	2, 3 or 4 terminal	2, 3 or 4 terminal
Instrument Connections	CE, WE, RE, LO	CE, WE, RE, LO	CE, WE	WE, LO
Floating measurements	yes	yes	yes	yes
Impedance measurement bandwidth	1 MHz (via FRA)	1 MHz (via FRA)	1 MHz (via FRA)	1 MHz (via FRA)
Maximum ADC sample rate	1 MS/s			
Smooth scan generator	64 MS/s interpolated and filtered			
Maximum time record	Unlimited			
DC scan rate (potentiostatic)	1.6 MV/s to 1 µV/s [1]	10 MV/s to 1 µV/s [1]	1.6 MV/s to 1 µV/s [1]	
DC scan rate (galvanostatic)	60 kA/s to 200 µA/s [1]	10 kA/s to 200 µA/s [1]	400 kA/s to 200 µA/s [1]	
Minimum pulse duration	1 µs			
IR compensation	yes			
Counter Electrode (CE)	**Potentiostat**	**HV 100 / HV 30**	**Booster 2A**	**Femto Ammeter**
Voltage polarization range	±8 V	±100 V / ±30 V	±20 V [2]	
Current polarization range	±300 mA	±100 mA / ±200 mA	±2 A	
Maximum compliance (CE vs. LO)	±8 V	±100 V / ±30 V	±20 V [2]	
Bandwidth (decade steps)	1 MHz to 10 Hz	1 MHz to 10 Hz	1 MHz to 10 Hz	
Polarization V / I error (setting + range)	0.1% + 0.1%			
Slew rate	>10 V/µs	>10 V/µs	>10 V/µs	
Reference Inputs (RE)	**Potentiostat**	**HV 100 / HV 30**	**Booster 2A**	**Femto Ammeter**
Connections	Differential input	Differential input	Core or HV	Core or HV
Cable shields	Driven / Ground [3]	Driven / Ground [3]		
Maximum voltage measurement	±8 V	±100 V / ±30 V		
Ranges	8 V to 3 mV	100 V to 3.75 mV		
Accuracy (reading % + range % + offset)	0.1%+0.05%+100 µV	0.1%+0.05%+100 µV		
Maximum resolution	1 µV	1.25 µV		
Input impedance	>100 GΩ, <28 pF [3]	>100 GΩ, <28 pF [3]		
Input bias current	<10 pA	<10 pA		
Working Electrode (WE)	**Potentiostat**	**HV 100 / HV 30**	**Booster 2A**	**Femto Ammeter**
Maximum current	±300 mA	±100 mA / ±200 mA	±2 A	±300 mA
Ranges	300 mA to 30 nA	300 mA to 30 nA	3 A to 30 nA	300 mA to 3 pA
Accuracy (reading % + range % + offset)	0.1%+0.05%+30 fA	0.1%+0.05%+30 fA	0.1%+0.05%+30 fA	0.1%+0.05%+30 fA [4]
Maximum resolution	1.5 pA	1.5 pA	1.5 pA	0.15 fA
Compliance voltage range (floating)	±8 V	±100 V / ±30 V	±20 V [2]	±100 V
Auxiliary electrodes (A, B, C, D)	**Potentiostat**	**HV 100 / HV 30**	**Booster 2A**	**Femto Ammeter**
Connections	4 (each differential)	4 (each differential)	core or HV RE used	core or HV RE used
Specification	Same as RE above [3]	Same as RE above [3]		
DC Measurement	Synchronized to RE	Synchronized to RE		
Impedance measurement bandwidth	1 MHz (via FRA)	1 MHz (via FRA)		

1 Highest scan rates require external data acquisition card, internal ADCs may be used up to 25 kV/s **2** 20 V with HV option fitted, 8 V with core card only
3 Driven shields used in 3-terminal mode, grounded for 4-terminal. Capacitance spec. applies to 3-t mode. Aux. electrodes use driven shields.
4 The WE Femto Ammeter "reading %" accuracy term is 0.2% for 300 pA range, 2% for 30 pA range and 5% for 3 pA range

Frequency Response Analyzer (FRA)

Specification	
Maximum sample rate	40 MS/s
Frequency Range - FRA 1MHz - FRA 300kHz	10 µHz to 1 MHz 10 µHz to 300 kHz
Frequency resolution	1 in 65,000,000
Frequency error	±100 ppm
Minimum ∫ time per measurement (single sine, FFT or harmonic)	10 ms
Signal Output	
Waveform	Single sine, multi-sine
Single sine sweep	Linear / logarithmic
Multi-sine	All frequencies or selected frequencies
Analysis channels	
Accuracy (ratio)	±0.1%, ±0.1°
Anti-alias and digital filters	Automatic
Analysis channels	RE, WE, Aux A/B/C/D
Analysis modes:	Single sine, FFT, harmonic
DC Bias rejection	Automatic

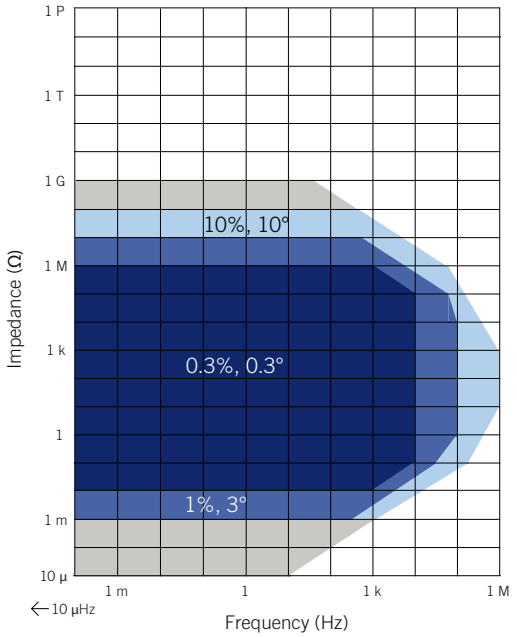
Frequency Response Analyzer Accuracy



Potentiostat Accuracy

This is the accuracy specification for the core potentiostat, core + HV option and the core + 2A option. This specification applies in the following conditions:

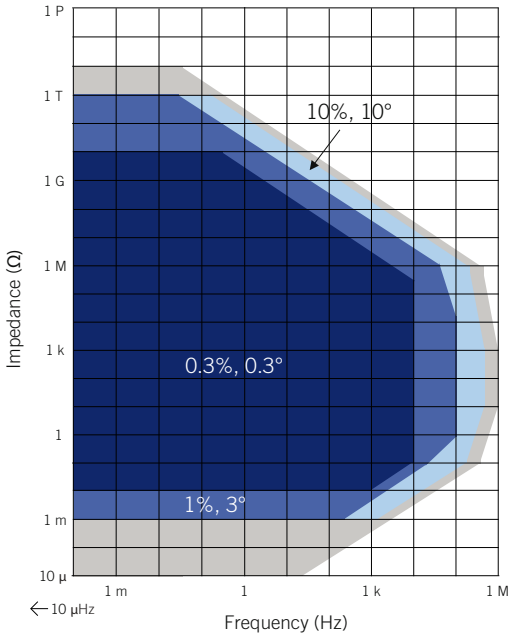
- Potentiostatic mode 10 mV AC stimulus used for core and core + 2A options.
- Higher AC voltage is recommended for core + HV option, since this is often used for testing batteries and fuel cell stacks with multiple cells (each of which typically require 10 mV AC voltage drop).
- Galvanostatic mode is recommended for low impedance cells (1 Ω or less).
- Standard 2 meter cell connection cables.
- 3 terminal mode used for >1 kΩ cell impedance, 4 terminal mode for ≤1 kΩ impedance.
- Faraday cage is required for high impedance cells.
- 2A option recommended for measurements lower than 100 Ω.



Femto Ammeter Option Accuracy

This is the accuracy specification for the core potentiostat + Femto Ammeter option. This specification applies in the following conditions:

- Potentiostatic mode 10 mV AC stimulus used for core and core + 2A options.
- Higher AC voltage is recommended where possible for measurements of high impedance cells, in this case higher impedances than those shown in the accuracy contour may be measured.
- Galvanostatic mode is recommended for low impedance cells (1 Ω or less).
- Standard 2 meter cell connection cables.
- 3 terminal mode used for >100 kΩ cell impedance, 4 terminal mode for ≤100 kΩ impedance.
- Faraday cage is required for high impedance cells.
- 2A option recommended for measurements lower than 100 Ω.



Chassis specification

General	
Chassis type	8 slot / 4 slot chassis
Potentiostats per chassis	8 maximum
Line Voltage	90 V to 264 V 47 - 63 Hz
Power	600 VA maximum
Dimensions w x h x d ( ) = 4 slot	450 (310) x 275 x 460 mm 17.7 (12.2) x 10.8 x 18.1 in
Weight ( ) = 4 slot	37 (21) kg - 82 (46) lb
Safety complies with:	BS EN 61010
EMC complies with:	BS EN 61326
Temperature Range	
Operating	5° to 40°C (41° to 104°F)
Specified Accuracy	10° to 30°C (50° to 86°F)
Storage	-25° to 70°C (-13° to 158°F)

Typical PC configuration

PC requirement	Pentium IV 1GHz, 1Gb RAM
Disk space	>1Gbyte
PC Communications	Ethernet 100BaseT
Display monitor	17" or larger SVGA
Operating system	Windows XP Professional or Vista

Solartron Analytical is a world leader in instrumentation and software for the characterization of materials and electrochemical systems using precision electrical measurement techniques. Solartron is a member of the Advanced Measurement Technology Division of AMETEK, a leading global manufacturer of electronic instruments and electromechanical devices.

Hardware ordering information

Module	Description
Pstat 1MS/s	ModuLab Pstat core card, 1 MS/s
Pstat Aux	ModuLab Pstat Aux Input Option
Booster 2A	ModuLab 2 A Internal Booster Option
HV 30	ModuLab 30 V High Voltage Option
HV 100	ModuLab 100 V High Voltage Option
Femto Ammeter	ModuLab Low Current Option
FRA 1MHz	ModuLab 1 MHz FRA Option
FRA 300kHz	ModuLab 300 kHz FRA Option
Chas 08	ModuLab 8 Slot Chassis
Chas 04	ModuLab 4 Slot Chassis

Software ordering information

Module	Description
ModuLab	Included with the system
ZplotLab DC	Basic package controls a single potentiostat
ZplotLab DCPro	Controls a single potentiostat plus all options excluding FRA
ZplotLab EIS	Controls a single potentiostat plus all options including FRA
ZplotLab MAX	Controls up to four potentiostats and FRAs plus options

External Boosters

Module	Description
Boost 12V20A	+12 V / -3 V, ±20 A Power Booster
Boost 24V/10A	+24 V / -3 V, ±10 A Power Booster
Boost 50V/5A	+50 V / -3 V, ±5 A Power Booster
Boost 50V/25A	+50 V / -3 V, -25 A Power Booster*
BOOSTMODCABLES	Cable set for External Boosters and ModuLab

* Discharge mode only, for fuel cell applications, maximum power 125 W

Solartron Analytical's Quality System is approved to BS EN ISO 9001: 2000

FM01709

...part of AMETEK® Advanced Measurement Technology

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