solartron analytical

AMETEK

mxm

ModuLab® XM

electrochemical system

the xm difference

ModuLab® XM

the XM difference

- *Market leading impedance analysis*
- *Widest voltage and current range available*
- *Anode/Cathode and Stack Testing*

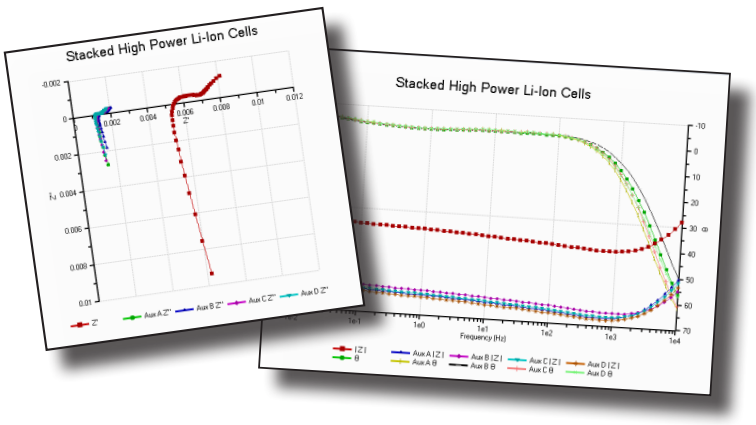
ModuLab® XM ECS is an **X**treme **M**easurement electrochemical test system that is capable of measuring micro-ohm impedance cells (latest generation batteries and fuel cells, for example), while able to accurately characterize corrosion coatings at the other extreme. The system uses a unique AC calibration method that ensures ultimate accuracy in all cases. Each system is independently calibrated, ensuring the accuracy of your results.

The system makes use of ultra-fast sample rate digital electronics to provide:

- Smooth analog waveforms that are applied in all option configurations
- High-speed pulse and measurement capability (for GSM/CDMA cell phone, pulse charge/discharge, and pulse voltammetry profiles)
- Wide range of techniques including CV, CC-CV charge / discharge, Square-Wave Voltammetry, Differential Pulse Voltammetry, Linear Sweep Voltammetry, and the equivalent Potentiometry techniques
- The smoothest AC waveforms delivering highest accuracy AC measurement performance (40x oversampled FRA) – includes impedance, admittance, permittivity / capacitance, electrical modulus, Mott-Schottky, plus many more.

Anode/Cathode/Stack Testing

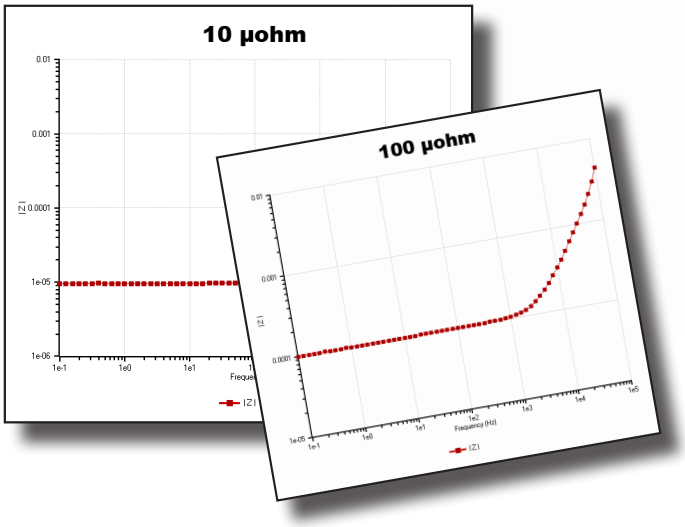
ModuLab XM ECS makes use of a range of high-quality performance modules including power boosters, high voltage modules and differential voltage auxiliary inputs, to provide the most advanced characterization for the latest generation of ultra-low impedance energy devices. XM is able to measure the time domain and impedance properties of cell anodes/cathodes as well as individual cells in a stack (even for high voltage stacks at up to 100 V). XM's high-accuracy measurements enable detection of bad cells well in advance of actual cell failure, saving time and thereby increasing test throughput and profitability.

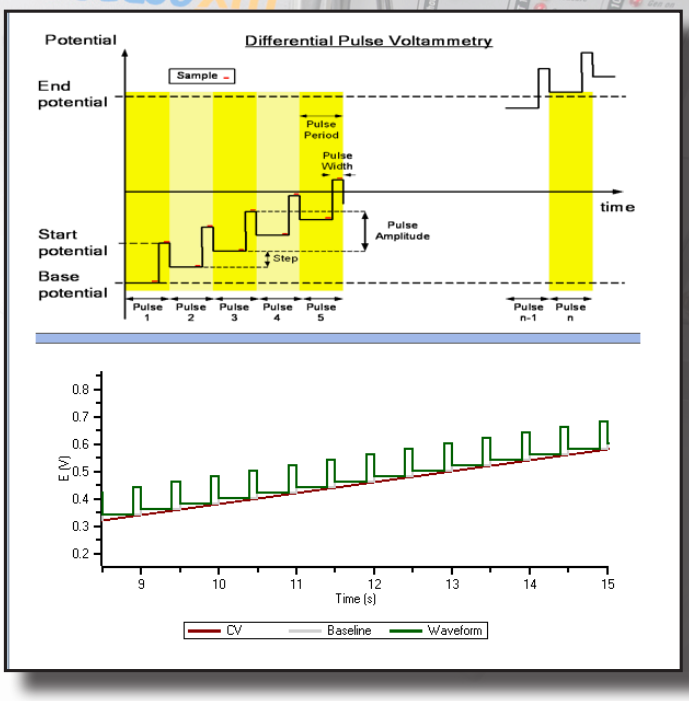


These example low-noise measurements are taken from a stack of Li-Ion cells, and show the impedance of the overall stack and of individual cells in the stack.

Ultra Low Impedance

The ModuLab XM ECS is able to make very accurate, extreme low impedance measurements in the micro-ohm region using a wide range of internal and external power boosters. These example plots show the quality of 10 µohm and 100 µohm data that is available from the system.





Control and Slave Modules

The ModuLab XM system has two ‘intelligent’ Control Modules:

- XM PSTAT 1 MS/s for time domain control
- XM FRA 1MHz for AC measurements

In addition there are several Slave Modules that amplify the signals produced by the Control Modules to provide high voltage/current polarization waveforms to the sample, and provide amplified/attenuated high resolution signals back to the control modules:

- XM HV100 / HV30 – High voltage options (100 V / 30 V)
- XM FEMTO AMMETER – Low current measurement option
- XM BOOSTER 2A – High current option (2 amps)

System and Software

ModuLab XM may be configured as a single or multichannel system depending on which slave options are needed. In multichannel configurations, each channel can be independently controlled from separate PCs, allowing tests on multiple samples to be run in parallel by separate researchers. It is also possible to configure in the same chassis, groups of modules from ModuLab XM ECS and from the XM MTS Materials Test System (refer to the separate brochure). A typical application is where XM MTS modules characterize high impedance SOFC (Solid Oxide Fuel Cell) ionic membrane materials, while XM ECS modules test the complete fuel cells.

All modules are ‘plug and play’ allowing the user to add modules easily, without returning the system to service. Once additional modules or channels have been installed, the software recognizes the modules and enables them for use in future experiments.

The software provides powerful automatic sequencing of time domain and AC techniques and provides a wide range of data analysis facilities including Tafel, and equivalent circuit fitting functions. This powerful combination of hardware and software functionality adds to the **XM** difference…

ModuLab XM

XM control modules

Potentiostat / Galvanostat

XM PSTAT 1 Ms/s makes use of the latest high technology hardware for accurate waveform generation and fast data acquisition.

- Fast auto-sequencing between CV, pulse and all types of potentiostatic/ galvanostatic techniques
- Measurements of highest conductivity / highest impedance cells are available by appropriate choice of ‘plug and play’ option modules
- No matter which option modules are used, ModuLab XM always provides smooth voltage / current ramp waveforms that are essential for many research applications using its ultrafast sampling waveform generator

Frequency Response Analyzer

XM FRA 1 MHz / 300 KHz are the most versatile Frequency Response Analyzers available today, and are fully compatible with all XM slave modules for high voltage, high/low current, and impedance measurements of anodes/cathodes and complete cells in a battery/fuel cell stack.

Multi-sine / Fast Fourier Transform (FFT) Analysis

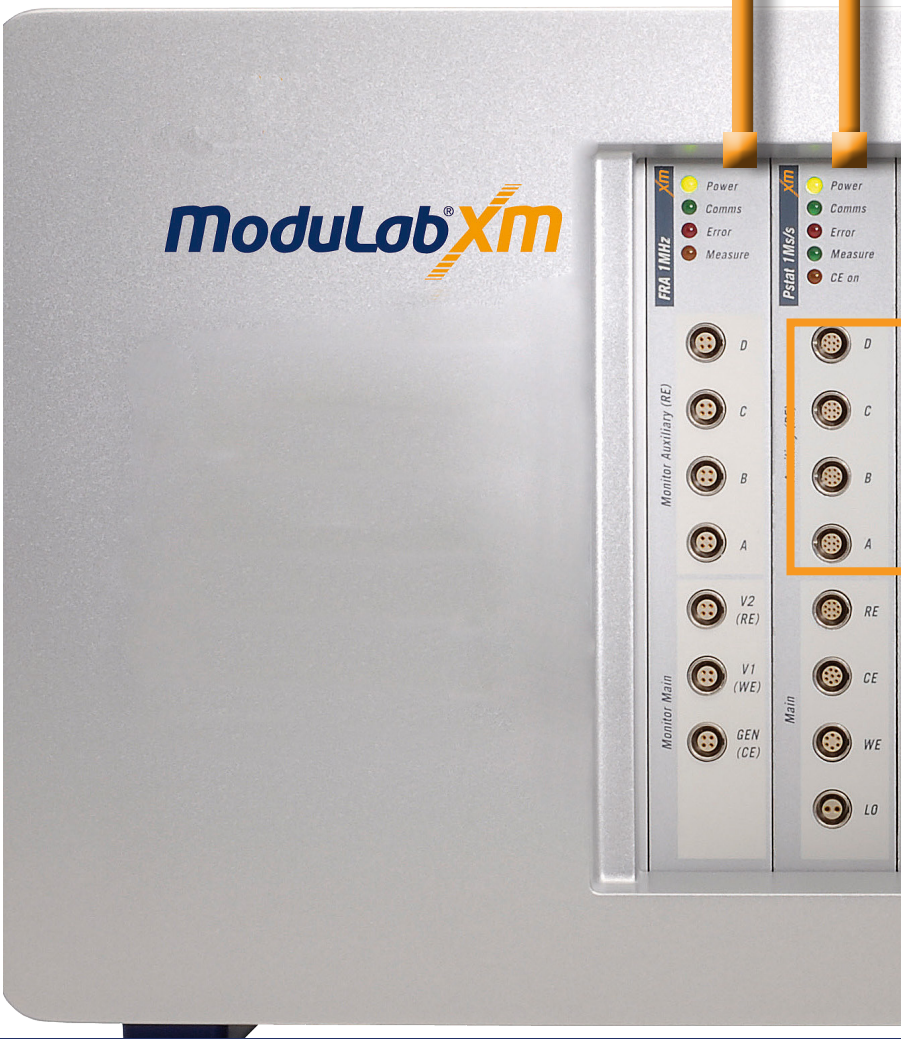
- AC tests include impedance, capacitance, and AC Voltammetry / Potentiometry / Mott -Schottky
- Faster measurements across the whole frequency range saves test time and minimizes errors for time-variant cells

Harmonic / Intermodulation Analysis

- To investigate cell linearity and distortion

Single sine correlation

- AC measurements include impedance, capacitance, AC Voltammetry/Potentiometry/Mott-Schottky (with stepped or smoothly ramped DC)
- Market leading accuracy, speed and repeatability



Auxiliary Voltage Inputs

- Standard on XM HV modules and are optional on the XM PSTAT control module
- Four differential auxiliary voltage inputs provide synchronized time-domain and impedance testing of cell anodes/ cathodes and cells in a stack (12 terminal measurement)
- Synchronized measurement from pH, pressure, light sensors and other transducers

Xtreme Measurement

XM slave modules

PhotoEchem Option

- Range of Frequency and Time Domain Measurement techniques including IMPS, IMVS, Impedance, PhotoVoltage Decay, Charge Extraction techniques, I-V
- 'Auto' analysis of data enabled for calculation of effective Diffusion coefficients and Electron Lifetimes

High Voltage Options

XM HV 100 / 30 high voltage amplifier options extend the XM PSTAT's voltage range to 100 V/30 V for testing fuel cell stacks, battery stacks or other high voltage cells:

- Provides applied cell polarization and compliance at up to 100 V or 30 V

Low Current Options

- Low current amplifier option that extends current measurement resolution to sub fA
- Available for time domain and impedance (with FRA)
- Combined with XM 100V option provides amazing impedance range

Power Booster Options

XM BOOSTER 2A and external boosters extend the system's impedance measurement resolution enabling tests on ultra-low impedance micro-ohm cells.

- For extremely accurate time-domain and impedance tests of ultra-low impedance cells
- Can be used with XM HV100/HV30 for high voltage / high current tests
- External boosters up to 50 V / 25 A may also be added using XM PSTAT or XM HV100/XM HV30 depending on voltage range requirements

Accessories

A wide range of accessories are available for use with the ModuLab XM ECS, including:

Dye-Sensitized Solar Cells (DSSC) - Optical Bench

ModuLab XM DSSC is a fully integrated photoelectrochemical measurement system designed for the characterization of Dye-Sensitzed Solar Cells (refer to separate brochure for more details).

- Range of Frequency and Time domain Measurement techniques including IMPS, IMVS, Impedance, PhotoVoltage Decay, Charge Extraction Techniques, I-V
- 'Auto' analysis of data enabled for calculation of effective diffusion coefficients and electron lifetimes at one click of a button

High Power Boosters

ModuLab XM is compatible with power boosters that are designed to extend its range of operation for testing extreme low impedance (<100 μΩ) batteries, fuel cells, and supercapacitors.

- Floating design - enables tests on ground cells
- Time domain and impedance tests on short stack fuel cells and multi channel batteries - including individual cells within a stack
- Choice of booster models with up to 50 V / 25 A range and 6 V / 100 A
- 100 kHz impedance measurement bandwidth for SOFC and other high frequency applications

Corrosion Cell

The cell permits a series of metal specimens and liquid environments to be tested quickly and uniformly. Most of the common electrochemical techniques for corrosion testing can be employed under aggressive conditions (except for HF) and at ambient or elevated temperatures.

Tait Cell

The Tait Cell was developed to address coatings/corrosion studies on flat specimens where the electrolyte under study cannot support a standard reference electrode. The cell was developed to accept a wide range of working electrode shapes and sizes eliminating the need for machining or special mechanical preparation of the sample.

Flat Cell

The practical design of the Flat Cell makes it simple to use for corrosion and/or coatings research. It can accommodate a wide range of electrode sizes, eliminating the need for machining or special mechanical procedures.

Specifications

General	Control Module Potentiostat XM PSTAT 1MS/s	Slave Modules High Voltage XM HV100/HV30	Slave Modules Low Current XM FEMTO AMMTER	Slave Modules Internal Booster XM BOOSTER 2A
Slots taken	1 slot	1 slot	1 slot	2 slots
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	WE, LO	CE, WE
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	N/A	N/A	N/A
Smooth scan generator	64 MS/s interpolated and filtered	N/A	N/A	N/A
Maximum time record	Unlimited	N/A	N/A	N/A
DC scan rate (potentiostatic)	1.6 MV/s to 1 µV/s[1]	10 MV/s to 1 µV/s[1]	N/A	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]	N/A	400 kA/s to 200 µA/s[1]
Minimum pulse duration	1 µs	N/A	N/A	N/A
IR compensation	yes	N/A	N/A	N/A
Counter Electrode (CE)	**XM PSTAT 1MS/s**	**XM HV100/HV30**	**XM FEMTO AMMETER**	**XM BOOSTER 2A**
Voltage polarization range	±8 V	±100 V / ±30 V	N/A	±20 V[2]
Current polarization range	±300 mA	±100 mA / ±200 mA	N/A	±2 A
Maximum compliance (CE vs. LO)	±8 V	±100 V / ±30 V	N/A	±20 V[2]
Bandwidth (decade steps)	1 MHz to 10 Hz	1 MHz to 10 Hz	N/A	1 MHz to 10 Hz
Polarization V/I error (setting+range)	0.1% + 0.1%	N/A	N/A	N/A
Slew rate	>10 V/µs	>10 V/µs	N/A	>10 V/µs
Reference Inputs (RE)	**XM PSTAT 1MS/s**	**XM HV100/HV30**	**XM FEMTO AMMETER**	**XM BOOSTER 2A**
Connections	Differential input	Differential input	PSTAT or HV	PSTAT or HV
Cable Shields	Driven / Ground[3]	Driven / Ground[3]	N/A	N/A
Maximum voltage Measurement	±8 V	±100 V / ±30 V	N/A	N/A
Ranges	8 V to 3 mV	100 V to 3.75 mV	N/A	N/A
Accuracy (reading % + range % + offset)	0.1%+0.05%+100 µV	0.1%+0.05%+100 µV	N/A	N/A
Maximum resolution	1 µV	1.25 µV	N/A	N/A
Input impedance	>100 GΩ, <28 pF[3]	>100 GΩ, <28 pF[3]	N/A	N/A
Input bias current	<10 pA	<10 pA	N/A	N/A
Working Electrode (WE)	**XM PSTAT 1MS/s**	**XM HV100/HV30**	**XM FEMTO AMMETER**	**XM BOOSTER 2A**
Maximum current	±300 mA	±100 mA / ±200 mA	±300 mA	±2 A
Ranges	300 mA to 30 nA	300 mA to 30 nA	300 mA to 3 pA	3 A to 30 nA
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
Maximum resolution	1.5 pA	1.5 pA	0.15 fA	1.5 pA
Compliance voltage range (floating)	±8 V	±100 V / ±30 V	±100 V	±20 V[2]
Auxiliary electrodes (A, B, C, D)	**XM PSTAT 1MS/s**	**XM HV100/HV30**	**XM FEMTO AMMETER**	**XM BOOSTER 2A**
Connections	4 (each differential)	4 (each differential)	PSTAT or HV	PSTAT or HV
Specification	Same as RE above[3]	Same as RE above[3]	N/A	N/A
DC Measurement	Sychronized to RE	Synchronized to RE	N/A	N/A
Impedance measurement bandwidth	1 MHz (via FRA)	1 MHz (via FRA)	N/A	N/A

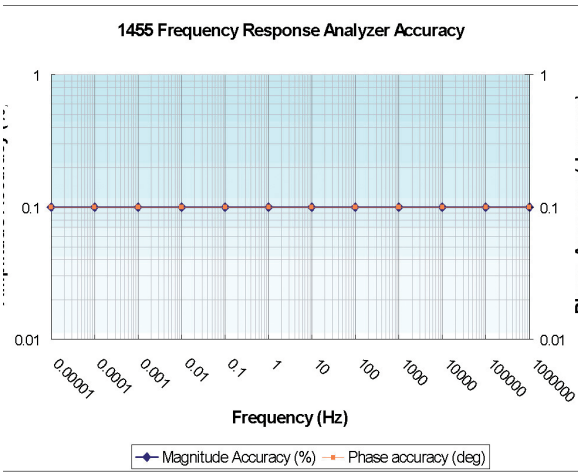
1 Highest scan rates require external data acquisition card, internal ADCs may be used up to 25 kV/s **2** 20 V with HV option fitted, 8 V with core card only
3 Driven shields used in 3-terminal mode, grounded for 4-terminal. Capacitance spec. applies to 3-t mode. **4** The WE Femto Ammeter "reading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

ModuLab XM

FRA Specifications

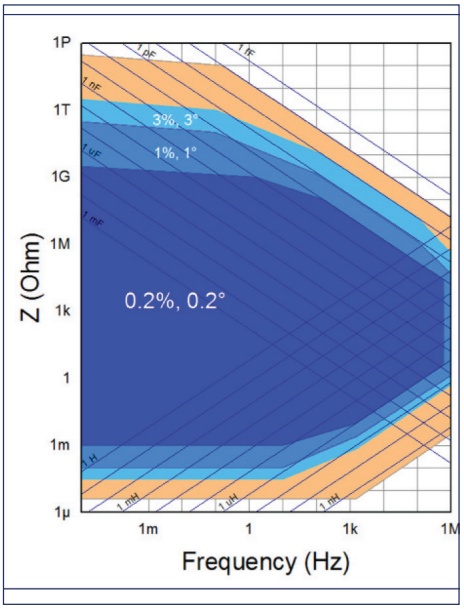
Frequency Response Analyzer	XM FRA 1MHz/300kHz
Maximum sample rate	40 MS/s
Frequency range - FRA 1 MHz - FRA 300 kHz	10 µHz to 1 MHz 10 µHz to 300 kHz
Frequency resolution	1 in 65,000,000
Frequency error	±100 ppm
Minimum ∫ time per measurement (single sine, FFT or harmonic)	10 ms
Signal Output	**XM FRA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

FRA Accuracy



System Impedance Accuracy

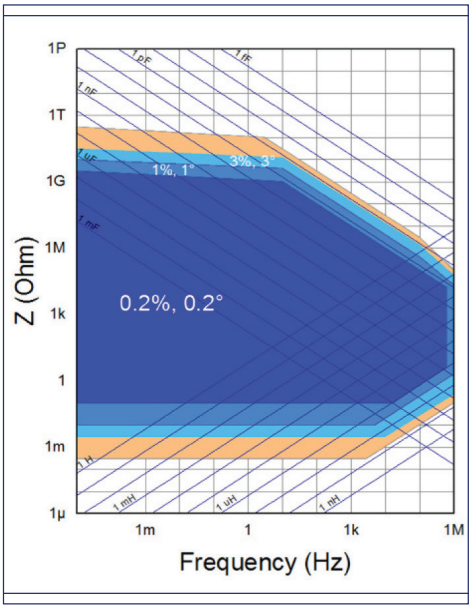
Impedance accuracy specification for PSTAT, Femto Ammeter and 2A Booster combined.



*High voltage option modules provide up to 10X higher impedance than shown
*External high power boosters extend accuracy to 1 µΩ
*3T connections for impedance >1 kΩ, 4T connections otherwise
*Impedance <1 Ω , measured using 4T connection and gstat mode
*Faraday cage and suitable screening recommended

PSTAT Impedance Accuracy

Impedance accuracy specification for PSTAT operating stand alone



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