solartron analytical

Simply the best for materials test

ModuLab SMTS

the ultimate application station for the electrical characterization of materials...

ModuLab MTS (Materials Test System) is a modular, fully integrated research system that is able to test the electrical properties of a wide range of materials from insulators to superconductors.

The system provides:

- Time domain techniques including I-V, constant level, pulse and swept voltage
- AC techniques including impedance, capacitance, permittivity, electrical modulus, C-V, Mott-Schottky
- Option modules extend the measurement range - high voltage, sample / reference, booster and low current amplifier
- High / low temperature and sample holder accessories including cryostats, furnaces etc.

Now one system *truly* does it all.

Many test systems characterize the electrical properties of materials. Typically systems fall into two categories; either they provide time-domain techniques such as constant DC level, pulse and swept voltage (I-V) to examine the overall electrical properties of the materials, or they provide AC techniques such as impedance, capacitance, C-V or Mott-Schottky for more detailed analysis of conduction mechanisms within the material.

In many cases, depending on the type of materials being tested, a wide range of equipment is required, often from several suppliers, including amplifiers, boosters, temperature test equipment (cryostats or furnaces), sensitive current amplifiers etc.

The ModuLab MTS provides a unique approach to materials testing by integratng all of these capabilities in one modular system. The core MAT module provides high-speed time domain test functionality and option modules can be added to the system - for example a frequency response analyzer to provide impedance / C-V capability, analog amplifiers to provide high voltage / low current measurement, and temperature accessories for integrated temperature control.

The modular approach provides the following benefits to the user:

Low startup cost - The MAT core and chassis can be purchased with limited funds and options can then be added when funding allows.

Cost savings - Modules and accessories purchased for the system apply to all measurement techniques. Current and high-voltage amplifiers work for time domain and AC tests, and temperature test equipment works with all techniques.

Ease of use - The same system software is used for all tests, reducing system learning time and increasing familiarity.

System repairs - If for any reason a module fails, the rest of the system can often continue to be operated while the module is repaired.

Designed to work together for optimum performance and flexibility, an extensive range of option modules is available that can be combined to tailor the system for a great diversity of materials including:

	Polymers	Ceramics	Dielectrics	Semiconductors	Solar Cells	Displays	Nanomaterials	Biomaterials	Superconductors
ModuLab MTS modules	**MAT core I-V:** time domain characterization	●	●	●	●	●	●	●	●	●
	MFRA C-V: Mott Schottky, Impedance	●	●	●	●	●	●	●	●	●
	MHV 100: high voltage 100V	●	●	●	●	●	●	●	●	
	MFA: fA current resolution (>100 TΩ)	●	●	●	●	●	●	●	●	
	MREF: sample / reference measurement	●	●	●	●	●	●	●	●	
	MBST 2A: current booster		●		●	●		●		●
Ancillary equipment	**External high voltage amplifier**		●	●				●		
	129610A Cryostat (5 K to 600 K)	●	●	●	●	●	●	●	●	●
	High temperature furnace (RT to 1600°C)		●	●				●		
	12962A, 63A, 64A Sample holder	●	●	●			●	●	●	●
	Semiconductor probe station				●	●		●		

High voltage options include a 10 kV amplifier for testing very high impedance samples such as ceramics and ferroelectrics. Temperature control options include cryostat, high temperature furnace and sample holder accessories.

The range of impedance techniques provided by MFRA option are second to none. Single sine, multi-sine / FFT and harmonic analysis are provided throughout the entire frequency range of the system. The MFRA uses 40x over-sampling for pure impedance measurements throughout its range of operation.

Multiple MAT time domain and MFRA AC modules can be added to each chassis to test multiple samples using the same or different experiment sequences. Multiple chassis can also be added to the system for greater test throughput. All chassis are connected to the PC via Ethernet for full flexibility of PCs and chassis location.

ModuLab MTS: the world's most versatile system for the electrical characterization of materials.

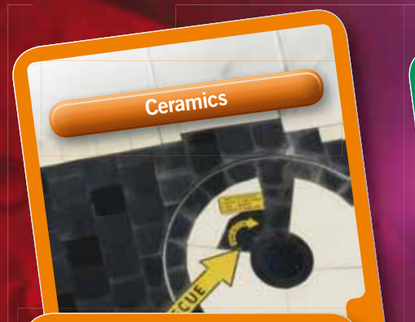
Simply stacks of apps...

The ModuLab MTS system is designed to test virtually any type of material from insulators to superconductors, including:

- Nanomaterials
- Semiconductors
- Photovoltaics
- Ceramics
- Polymers
- Display Technologies
- Ferro / Piezoelectrics
- Dielectrics
- Biomaterials
- Superconductors

The materials may be solids, liquids or powders and can be heated to >1600°C using a furnace or cooled to close to absolute zero using cryostat accessories. Most materials benefit from the use of time domain, impedance and temperature testing to obtain full characterization of their properties.

For examples of how Solartron systems are used for testing these wide ranging materials check out the Solartron website: **http://www.solartronanalytical.com/stacksofapps/**

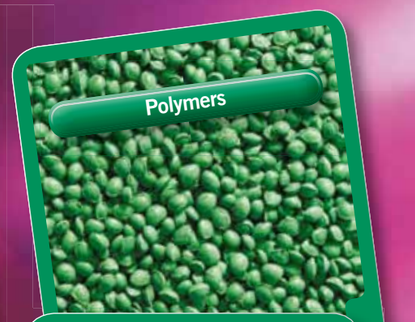


Ceramics are used in many applications where very high temperature operation is required - aerospace (turbine blades, space shuttle tiles), engine nozzles, sensors, disk brakes, etc.

Other applications include electronics (insulators and dielectrics), and bio-implants.

MTS capability:
- MHV 100 high voltage
- External ultra high voltage amplifier (10 kV)
- MREF sample / reference
- MFA femto ammeter for measuring ultra-low current
- High temperature furnace

CERAMICS



Polymers are used in many diverse applications - cable insulation material, substrates for displays, low-k dielectrics for semiconductors, conducting polymers, plastic coatings etc.

Impedance is widely used to test the dielectric properties of polymers.

MTS capability:
- MHV 100 high voltage option
- MREF sample / reference
- MFA femto ammeter for measuring ultra-low current
- MFRA to test AC properties
- Cryostat for glass transition testing

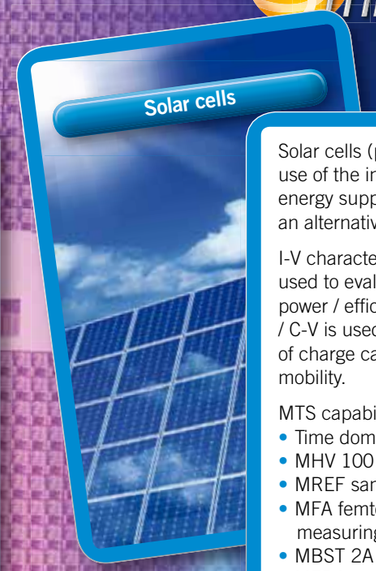
POLYMERS

Nanomaterials are being developed that combine existing ceramics, polymers etc. with nanostructures to produce composites with amazing mechanical, thermal and electrical properties.

There are many diverse applications - semiconductors, solar cells, aerospace, medicine, superconductivity...

MTS capability:
- MHV 100 high voltage
- MREF sample / reference
- MFA femto ammeter for measuring ultra-low current
- Cryostat
- MFRA to test AC properties

NANOMATERIALS



Solar cells (photovoltaics) make use of the inexhaustible, free energy supply from the sun as an alternative to fossil fuels.

I-V characterization is widely used to evaluate maximum power / efficiency. Impedance / C-V is used for the analysis of charge carrier density and mobility.

MTS capability:
- Time domain and AC
- MHV 100 high voltage
- MREF sample / reference
- MFA femto ammeter for measuring ultra-low current
- MBST 2A for high current
- MFRA to test AC properties

SOLAR CELLS

Superconductors are materials that have zero resistance below a critical temperature. They are used in powerful electromagnets, for example in MRI, NMI and mass spectrometer applications.

The ability to measure extremely low impedance while accurately controlling temperature is essential for researching these materials.

MTS capability:
- MBST 2A, high current needed to measure low resistance
- Cryostat
- MFRA to test AC properties

SUPERCONDUCTORS

New display technologies are enabling great advances in portable computers, cell phones and thin screen TVs.

For mobile devices there is a continuous push for improved battery life (low power), lighter weight and brighter screens and new display technologies including OLED and AMOLED are providing much improved performance.

MTS capability:
- MHV 100 high voltage
- MREF sample / reference
- MFA femto ammeter for measuring ultra-low current
- MFRA to test AC properties

DISPLAYS

Semiconductors are devices that change resistivity depending on an applied electric field, with applications in PCs, rectifiers, solar cells, amplifiers etc.

Capacitance changes with bias voltage, frequency and temperature giving information about charge carrier density / mobility, dopant levels etc.

MTS capability:
- I-V, C-V, Mott-Schottky
- MHV 100 high voltage
- MREF sample / reference
- MFA femto ammeter
- MBST 2A for high current
- Cryostat
- MFRA to test AC properties

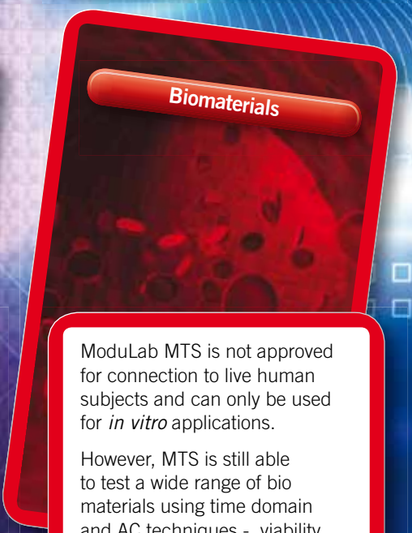
SEMICONDUCTORS

Dielectrics are non-conductors of electricity (electrical insulators) that are able to support an electric field.

Ferroelectrics (used in electronic applications - PC memory) and piezoelectrics are examples of dielectric materials, also many polymers, ceramics, oils, glass and porcelain.

MTS capability:
- I-V, Impedance
- MHV 100 high voltage
- MREF sample / reference
- MFA femto ammeter for measuring ultra-low current
- Furnace or cryostat
- MFRA to test AC properties

DIELECTRICS



ModuLab MTS is not approved for connection to live human subjects and can only be used for *in vitro* applications.

However, MTS is still able to test a wide range of bio materials using time domain and AC techniques - viability of transplant organs, medical implant materials, blood, virus or tissue cells and for testing drug delivery systems.

MTS capability:
- MREF sample / reference
- MFA femto ammeter for measuring ultra-low current
- Cryostat
- MFRA to test AC properties

BIOMATERIALS

The system that holds all the cards...

MAT materials core module

The core of the ModuLab MTS system is the MAT core module 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 MAT module 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 the smoothness of analogue techniques.
- High-speed data acquisition up to 1 MS/s used for pulse and fast swept voltage I-V techniques.
- High bandwidth for accurate and reliable high-speed I-V, pulse and impedance measurements at all frequencies and impedance levels (using the MFRA option).
- Floating electrode capability for measurements on grounded samples
- Flexible experiment sequencing that allows high data acquisition rates at those specific points in the experiment where measurement speed is needed, e.g. for pulse analysis or high speed I-V.
- Instantaneous switching between experiment techniques e.g. C-V, I-V, pulse, impedance etc, provides a great deal of flexibility for defining experiment protocols for testing a wide range of materials.

MFRA frequency response analyzer

The MFRA frequency response analyzer used in the ModuLab MTS system provides impedance, admittance, permittivity, electrical modulus, C-V and Mott-Schottky analysis using multiple measurement techniques across its entire frequency range (from 10 µHz to 1 MHz):

- **Single sine correlation** provides unbeatable measurement accuracy and repeatability. Thousands of research papers have been written around the use of Solartron impedance analyzer technology. The MFRA 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 high 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 fast low frequency analysis and for measurements of time-variant or unstable cells. Multi-sine / FFT measurements are so fast that they can often be taken before the sample response changes.
- **Harmonic Analysis** utilizes the FFT analysis technique together with single or multiple frequency stimulation in order to investigate linearity and distortion.
- **C-V (capacitance vs. DC voltage) and Mott-Schottky measurements** may be performed using single sine or multi-sine techniques over the full frequency range.

MHV 100 high voltage option

The standard MAT core module provides up to ±8 V stimulus to the sample. For many applications however, higher voltage is needed, for example when testing high impedance insulator materials.

The MAT option works together with the MHV to provide ultra-smooth swept voltage, I-V, DC and pulse waveforms over the extended voltage range of ±100 V and automatically attenuates the sample voltage for MAT core measurement.

The MHV can also supply up to 100 V peak AC waveforms for impedance analysis by amplifying the output of the MFRA module. DC and AC signals can be combined for high voltage C-V, Mott-Schottky, capacitance and impedance analysis.

MREF sample / reference option

The MREF sample / reference option provides improved accuracy AC measurements of dielectric samples by first measuring the sample and then measuring a known calibrated reference capacitor of similar impedance, using identical cables.

The reference capacitor measurements provide information about the systematic errors due to connection cables and measurement circuits, which is used to cancel similar errors on the sample material measurement.

Multiple calibrated reference capacitors are provided internally with this option to provide a close match to the sample impedance. Calibrated external references can also be used if required.

MFA low current option

The standard ModuLab MAT core module has 1 pA current resolution. This is sufficient for many types of materials but for more demanding applications, for example for insulators, dielectrics, ceramics, nanomaterials (carbon nano-tubes) and semiconductors, more sensitive current measurement resolution may be needed. The femto ammeter option is designed to resolve extremely low current levels to 150 aA.

The MFA option may be used in combination with the MHV high voltage option or an external ultra high voltage amplifier to measure extremely high impedance materials (>100 Tohms).

The MFA option also works well with the MREF option for improved accuracy and repeatability.

MBST 2A high current option

The standard MAT core module is able to provide current output of up to ±100 mA. For some applications higher current levels may be required, for example for characterization of semiconductors when biased in the on region, or for testing superconductors.

The MBST option provides up to ±2 A current output combined with reduced output impedance. This makes it much easier for the system to measure the voltage drop across the sample, providing impedance resolution in the 10 µΩ region.

Using the latest Digital Signal Processing (DSP) technology, the deck is loaded in your favour...

Software

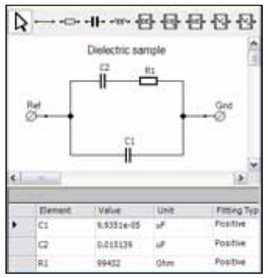
The software provided with ModuLab MTS is comprehensive, flexible and very easy to use. A large selection of test types is provided, from standard open circuit, I-V, C-V and Mott Schottky to complicated multistep sequences that include sample preparation, advanced experimental techniques and integrated impedance analysis.

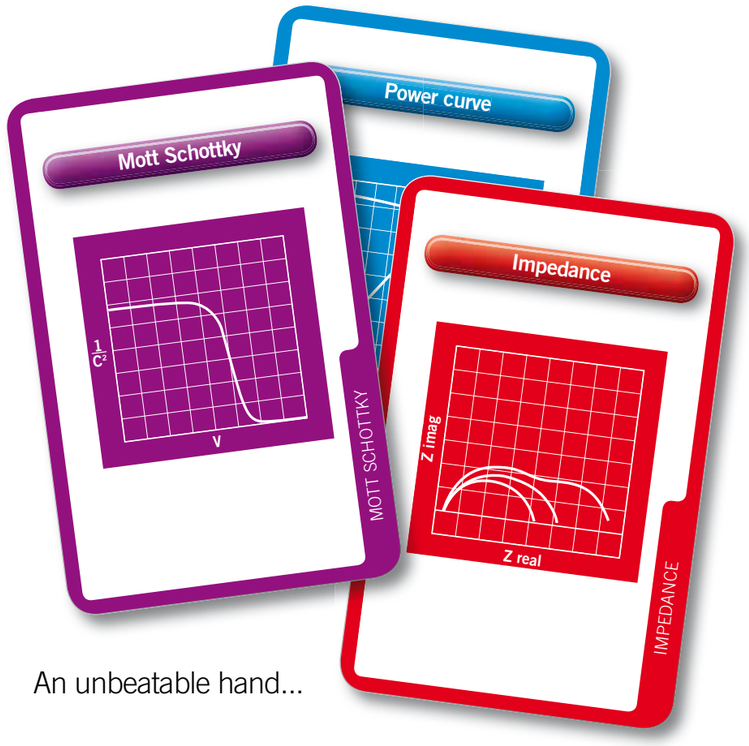
ModuLab MTS software makes use of diagrams at all stages of experiment development so that the user knows exactly what tests will be applied to the sample. As parameters are entered into the software, waveform diagrams display the actual timing and levels that will be applied to the sample when the experiment is run.

Connection diagrams are also shown so the user can check that the sample is connected correctly and make any adjustments before running the test.

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 voltage pulse experiments so that the actual shape of the pulses (voltage and current) may be analyzed to select optimal measurement points.

Extensive loop facilities are provided allowing the user to sequence AC, DC, temperature and impedance tests.





An unbeatable hand...

Navigation Tree

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

Integrated DC / Impedance

Experiments can consist of single or multiple step sequences. Time domain and AC steps are fully integrated allowing constant voltage level, I-V, C-V, Mott Schottky and voltage pulse to be automatically sequenced. The software even provides swept sine, harmonic analysis and multi-sine / FFT functions for AC tests, allowing complete DC and impedance sample characterization.

Data Analysis

Data fitting routines are fully integrated into the ModuLab software including line, circle and equivalent circuit AC fitting. Equivalent circuit models may be constructed using a range of components including resistors, capacitors, inductors, distributed elements, constant phase elements and diffusion 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 modelling of impedance phenomena for a great variety of materials.

Report Builder

A built-in report generator takes the experimental results and outputs them together with graphs, diagrams and analysis information into your word processor, making reports very simple to construct.

Accessories

A wide range of accessories are available for use with the ModuLab MTS, including sample holders, cryostats, furnaces and amplifiers.

Temperature control

The properties of most materials change widely as a function of temperature - for example polymers at their glass temperature, superconductors at their zero resistance critical temperature, semiconductors over their range of working temperature and aerospace ceramics at extremely high operating temperature.

The ModuLab MTS provides fully integrated temperature test functionality using cryostat and furnace accessories to enable complete characterization of these materials.

The Solartron 129610A cryostat uses liquid nitrogen or liquid helium to test solid, liquid or powder materials samples over a wide temperature range (5 K to > 600 K). This system ensures that the sample is not exposed to cryogen vapor which may cause it to crack or swell by positioning the sample in a separate chamber where it is heated or cooled via an inert thermal exchange gas (usually dry helium gas).

For very high temperature tests a furnace system is available. The furnace is able to operate from room temperature up to 1600°C utilizing a special high temperature sample holder. This system can test the most demanding high temperature aerospace materials.

Semiconductor probe stations

Various third party probe stations can be used with the ModuLab MTS for testing semiconductor wafers. Probe stations provide accurate positioning of probes on the surface of the wafer to allow precision measurements of the wafer's electrical properties. In some cases cryostatic control can be added to provide combined temperature and electrical characterization.

Sample holders

In addition to the purpose-built sample holders that are provided as part of the cryostat and furnace systems, Solartron also provide additional sample holders that can be used at room temperature or in temperature controlled ovens.

The newly configured 12962A sample holder is designed to operate over medium temperature range and measures solid materials. The sample holder can be used in two terminal or four terminal modes to test high or low impedance samples.

The 12963A is an optional kit of additional electrodes for testing samples of different sizes and the 12964A is an accessory for the 12962A that enables it to be used for testing liquids.

Voltage amplifier

Using the plug-in chassis option modules that are available for the ModuLab MTS, it is possible to run time domain and AC tests over the voltage range of the MHV 100 option (±100 V).

This is sufficient for many materials but there are examples of materials where much higher voltage is required. In this case external amplifiers may be added to the system providing a voltage range of up to ±10 kV.

When using external high voltage options it is important to protect the equipment from possible damage that may occur should the sample break down and become short circuit. The high voltage amplifier is therefore provided with a protection device that fits between the MTS and the high voltage amplifier and sample.

...for a truly integrated system.

Modules specification

MAT, High Voltage MHV 100, Booster MBST 2A, Femto Ammeter MFA

General	MAT 1MHz Core Module	Internal Chassis Options		
		MHV 100 High Voltage	MBST 2A Booster	MFA Femto Ammeter
Chassis slots taken	Single	Single	Double	Single
Measurement mode (internally switched)	2 or 4 terminal	2 or 4 terminal	2 or 4 terminal	2 or 4 terminal
Sample connections from module	Gen, VHi, VLo, I	Gen, VHi, VLo MAT- I	Gen, I MAT- VHi, VLo	I MAT- Gen, VHi, VLo
Sample connection cables (1 m length)	4 x BNC to BNC	MAT cables	MAT cables	Triax to BNC
Floating	Yes, to 1 V	Yes, to 1 V	Yes, to 1 V	Yes, to 1 V
Generator Output - (Gen)	**MAT 1MHz**	**MHV 100**	**MBST 2A**	**MFA**
Maximum waveform generator sample rate	64 MS/s interpolated/filtered	Uses MAT	Uses MAT	N / A
Maximum voltage (open-circuit load) DC + peak AC (subject to slew rate limit)	±8 V	±100 V	±8 V with MAT ±20 V with MHV	N / A
Maximum voltage resolution	150 µV (< 3 V) 400 µV (≥ 3 V)	2 mV (< 37 V) 5 mV (≥ 37 V)	1.5 mV	N / A
Maximum output current	±100 mA	±100 mA	±2 A	N / A
Output impedance (nominal)	50 Ω	50 Ω	< 1 Ω	N / A
Applied voltage error (open-circuit load)	±0.2% setting ±800 µV (< 3 V) / ±2 mV (≥ 3 V)	±0.2% setting ±12.5 mV (< 37 V) / ±35 mV (≥ 37 V)	±0.2% setting + ±10 mV (< 3 V) / ±25 mV (≥ 3 V)	N / A
Voltage sweep rate	1.6 MV/s to 1 µV/s	10 MV/s to 1 µV/s	1.6 MV/s to 1 µV/s	N / A
Recommended maximum sweep rate (using 1 MS/s acquisition rate)	25 kV/s	150 kV/s	25 kV/s	N / A
Minimum pulse duration	1 µs	Uses MAT	Uses MAT	N / A
Maximum slew rate	>10 V/µs	>15 V/µs	>10 V/µs	N / A
Voltage Measurement - (VHi / VLo)	**MAT 1MHz**	**MHV 100**	**MBST 2A**	**MFA**
Maximum voltage	±8 V	±100 V	N / A	N / A
Voltage ranges	8, 3, (V) 300, 30, 3 (mV)	100, 37.5, 3.75 (V) 375 , 37.5 (mV)	N / A	N / A
Voltage measurement error	±0.1% reading + ±0.05% range + ±100 µV	±0.1% reading + ±0.05% range + ±100 µV	N / A	N / A
Maximum time domain measurement rate	1 MS/s	N / A	N / A	N / A
Maximum time record	Unlimited	N / A	N / A	N / A
Current Measurement - (I)	**MAT 1MHz**	**MHV 100**	**MBST 2A**	**MFA**
Maximum current	±100 mA	N / A	±2 A	±100 mA
Current ranges	100 mA, 30 mA to 30 nA in decades	N / A	2 A plus MAT ranges	100 mA, 30 mA to 3 pA in decades
Maximum resolution	1.5 pA	N / A	1.5 pA (MAT)	0.15 fA
Current measurement error	±0.1% reading + ±0.05% range + ±100 pA	N / A	±0.1% reading + ±0.05% range + ±0.1 mA	±0.1%** reading + ±0.05% range + ±30 fA
Auxiliary Voltage Inputs	**MAT 1MHz**	**MHV 100**	**MBST 2A**	**MFA**
Number of auxiliary DC channels	Four	N / A	N / A	N / A
Voltage ranges	8 V, 3 V to 3 mV	N / A	N / A	N / A
Maximum Resolution	1 µV	N / A	N / A	N / A
Synchronised to VHi, VLo measurement	Yes	N / A	N / A	N / A

** **MFA** Femto Ammeter current measurement "reading %" error term is 0.2% for 300 pA range, 2% for 30 pA range and 5% for 3 pA range

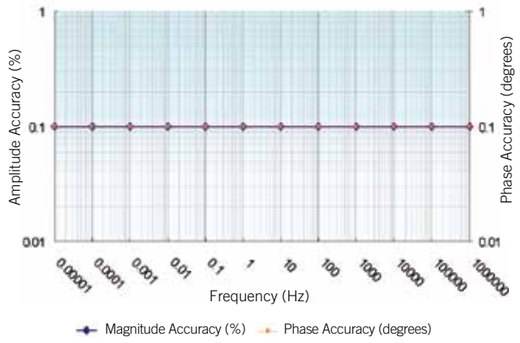
Sample / Reference MREF

Sample / Reference Option	MREF
Chassis slots taken	Single
Reference modes	Internal / External
Connections to MAT, MHV, or MFA	Gen, I
Connection to sample	1 m BNC cables
Connection to internal / external reference	1 m BNC cables
Calibrated reference capacitors	10nF to 1pF (3 per decade)

Frequency Response Analyzer MFRA

Frequency Response Analyzer Option	MFRA 1MHz
Chassis Slots taken	Single
Maximum sample rate	40 MS/s
Frequency Range	10 µHz to 1 MHz
Frequency resolution	1 in 65,000,000
Frequency error	±100 ppm
Minimum measurement integration time	10 ms
Analysis modes (10 µHz to 1 MHz) Fixed frequency Single sine Multi-sine / harmonic frequencies	 Linear / logarithmic All or selected
Accuracy (ratio)	±0.1%, ±0.1°
Anti-alias, digital filters, DC bias reject	Automatic

Frequency Response Analyzer Accuracy



Chassis specification

Chassis type	8 slot or 4 slot
Modules per chassis	8 maximum
Line voltage	90 V to 264 V AC 47 - 63 Hz
Power	600 VA maximum
Communications	Ethernet 100BASE-T
Digital input / output	1 / 3 per MAT channel
Dimensions w x h x d 8 slot / 4 slot	450 / 310 x 275 x 460 mm 17.7 / 12.2 x 10.8 x 18.1 in
Weight 8 slot / 4 slot	37 / 21 kg - 82 / 46 lb
Safety complies with:	BS EN 61010
EMC complies with:	BS EN 61325
Temperature range Operating Specified Accuracy Storage	 5° to 40°C (41° to 104°F) 10° to 30°C (50° to 86°F) -25° to 70°C (-13° to 158°F)

Typical PC configuration

PC requirement	Pentium IV 1 GHz, 1 Gb RAM
Disk space	>10 Gbyte
Communications	Ethernet 100BASE-T
Display	17 " or larger SVGA
Operating system	Windows XP Professional or Vista Business or Windows 7 Professional

Ordering information (hardware)

Module	Description
MAT 1MHz (2096A)	MAT core, 1 MHz bandwidth
MREF (20965A)	Sample / reference option
MBST 2A (209610A)	2A booster option
MHV 100 (20961A)	100 V high voltage option
MFA (20963A)	Femto ammeter option
MFRA 1MHz (2065B)	1 MHz FRA option
Chas 08 (2100A)	8 slot chassis
Chas 04 (2101A)	4 slot chassis

Ordering information (software)

Module	Description
ModuLab MTS	Software included with the system controls chassis, options and temperature accessories

Optional accessories

Module	Description
129610A	5K - 600K Cryostat with solid / liquid sample holder
12962A, 63A, 64A	Solid / liquid sample holder
TBA	High temperature furnace with sample holder
TBA	Ultra high voltage amplifier

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.

Solartron Analytical's Quality System is approved to BS EN ISO 9001: 2008

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...part of AMETEK® Advanced Measurement Technology

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