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NHR

Test Systems and Instruments for Manufacturers of Electronic Power Conversion Products

2003/2004 Product Catalog



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About NH Research…



NH Research designs and manufactures test equipment used by producers of electronic power supplies, UPSs, DC/DC converters, telecom rectifiers, battery chargers, adapters and other power conversion devices. Its test systems are typically used at our customer's final test station to insure their products meet performance and quality specifications. Located in Irvine, California, NH Research has been in this business over 30 years.

Automatic Test Equipment (ATE)

This group of products consists of computer-based test systems that range from compact, tabletop chassis to full-sized, multi-bay cabinets. Within the customer's facilities, such systems are used for high-volume production testing, engineering design characterization, incoming inspection and field returns repair. NH Research ATE is in use worldwide by many global power conversion product manufacturers.

Test & Measurement Instruments

This group of products consists of digitally programmable test instruments typically used by other manufacturers of test systems for resale or their own internal use. These instruments consist mainly of AC & DC electronic loads plus AC & DC power sources. Many of these same instruments are also used in NH Research's power supply test systems.

Worldwide Support

NH Research test equipment is usually an essential final step in a customer's production lines, therefore, reliability and responsive support are critical. To ensure this capability, the Company is fully staffed with the technical resources, diagnostic tools and replacement parts to resolve problems quickly anywhere in the world. This support system includes knowledgeable application engineers backed up by the actual instrument and system designers, regularly scheduled factory-training programs, turnkey fixture & test program developers, calibration services and now, on-line support.

More than just test equipment, NH Research's commitment is to provide the comprehensive test capability together with the lowest unit-cost-of-test that ensures its customers are competitive in world markets for the future.

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POWER SUPPLY TEST SYSTEMS

Series	*Power*	*Application*	*Key Features*	*Pages*
400	600 W	DC-DC converters, small AC-DC supplies, adapters, chargers	Compact size, modular sources & loads,	2-3
535	1200 W	AC-DC and DC-DC supplies to 8 outputs	Fully-configured	4-5
5600	5 kW	Mid-range AC-DC and DC-DC supplies	Versatile configuration, advanced measurement capability	6-7
8100i	Open	All types, including those requiring special instrumentation	VXIbus-platform, widest configuration options	8-9

UPS TEST SYSTEMS

Series	*Power*	*Application*	*Key Features*	*Pages*
5500	20 kVA	UPSs, Inverters	Programmable AC load, waveform digitizer	10-11

ELECTRONIC LOADS

Series	*Power*	*Application*	*Key Features*	*Pages*
4100/4110	300 to 1800 W	6-module per chassis subsystem for ATE	High accuracy and configuration flexibility	12-13
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4600	3 to 180 kW	AC loading for UPSs & Inverters	Programmable crest & power factor, parallelable	24-25

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Power Supply Functional Test System

Adapter/Converter Tester 400 Series

- ❑ **Full-capability test system in an instrument chassis**
- ❑ **Configurable load and source modules**
- ❑ **Waveform digitizer measurements**



S430 DC-DC Test System

APPLICATION

The S400 Power Supply Test System is a PC-controlled, full-capability system intended for rapid testing of low-power products such as DC-DC converters, AC-DC supplies, adapters, and chargers. All the measurement, control, reporting and test executive capability found in upright, cabinet-sized ATE is contained within the instrument-sized S400. The system is configurable with upper power limits in the range of 600 W and 4 to 6 outputs. Within these limits, it is an ideal solution for manufacturers that require comprehensive test capability and enterprise network compatibility, together with minimum unit test times.

COMPLETE TEST SOLUTION

The tester is available in two models: the S430 for DC-DC testing and the S440 for AC-DC testing. All stimulus and measurement instrumentation, along with a multiplexer, digital stimulus, comparators, timers and relays, are contained within a single chassis. The entire test capability and software features found on the most advanced full-sized production testers are included. The user only needs to add cabling and a test fixture in order to start testing.

CONFIGURABLE WITH INTERCHANGEABLE POWER MODULES

A key to flexibility, as well as compact design, is the Modular Power Subsystem that has been a fundamental component of larger NHR test systems for many years. This is the portion of all testers where flexibility is most often required. What makes this subsystem unique is that the 6-slot chassis will accept any combination of electronic loads and/or DC-source modules, as shown on the accompanying chart. Additional flexibility is gained through the ability to synchronously parallel modules from within a test program to match each supply-under-test's specific stimulus requirements. In this manner, it is possible to configure a wide range of virtual loads & sources within the chassis limits. All modules also have wide operating ranges and constant power operating envelopes to allow covering a maximum range of requirements through a minimum group of modules.

EMBEDDED DIGITIZING MEASUREMENT SYSTEM

A highly advanced measurement system is contained within the chassis. This system digitizes analog signals for DSP analysis, allowing the extraction of both static and transient measurements from a single waveform capture. In this manner, one circuit replaces the essential functions of a Voltmeter, Timing/Noise Analyzer, Power Analyzer, and Oscilloscope, along with associated signal matrixing and interconnect wiring. Beyond the capability, size, and cost advantages, the system's architectural simplicity yields much faster test times and improved tester reliability.

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S430/440 SPECIFICATIONS

EMBEDDED MEASUREMENT SYSTEM

MEASUREMENT	RANGE/BANDWIDTH	RESOLUTION	ACCURACY
DC Volts, DC Peak	± 6.6, 20, 200, 500 V	0.003% FS	0.01% R + 0.01% FS
RMS Noise	0 to 4 V 10 Hz to 99 kHz	0.003% FS	1.5% R + 1.5% FS
Peak to Peak Noise	0 to 0.2, 2.0 V 10 kHz to 0.2, 2.0, 20 MHz	0.003% FS	3% FS
Frequency	1 Hz to 1 MHz	100 ns	0.02% R
Timing	100 ns to 100 s	100 ns	100 ns to 1 µs + 0.02% R
Waveform Display	DC to 25 kHz	0.003%	1% FS
Input Channels	12, external, selectable, differential inputs for UUT measurements		
Threshold Detector	1, ± full DCV range with programmable reference		
Digital Outputs	7, open collector, isolated, 300 mA /100 VDC/1 W-rated		
Digital Inputs	8, four with ± 10 V programmable reference, four with logic level reference		
GP Relays	8, SPDT, 175 VAC/0.25 A /3 W-rated		
Frequency Generator	10 kHz to 2 MHz, programmable pulse width		

POWER MODULES OPTIONS

MODULE TYPE	AC SOURCE	DC SOURCES			DC LOADS		
MODEL NO.	**5400**	**6010**	**6060**	**6080**	**6400**	**4100**	**4110**
Ratings							
Power	700 VA/500 W/1ø	400 W	400 W	400 W	400 W	300 W	300 W
Voltage Range(s)	0 to 140/280/350 Vrms	0 to 10 V	0 to 60 V	0 to 80 V	± 400 V	2.1* to 450 V	0.7* to 80 V
Maximum Current	5.0/2.5/2.0 A	60 A	16 A	12 A	3 A	60 A *Current reduces linearly to 0.1 V	60 A
Frequency	40 to 500 Hz						
Measurements							
Voltage							
Range(s)	0 to 175/350 Vrms	0 to 10 V	0 to 60 V	0 to 80 V	± 400 V	0 to 120/450 V	0 to 8/80 V
Accuracy	0.1% R + 0.1% FS	0.1% + 10 mV	0.1% + 60 mV	0.1% + 80 mV	0.1% +400 mV	0.025% + 0.01% FS	0.025% + 0.01% FS
Resolution	0.1% FS	5 mV	30 mV	40 mV	200 mV	16/60 µV	33/330 µV
Current							
Ranges	0 to 0.025/0.5/2.5/5 Arms	0 to 60 A	0 to 16 A	0 to 12 A	0 to 3A	0 to 0.6/6/60 A	0 to 0.6/6/60 A
Accuracy	0.1% R + 0.1% FS	0.1% + 60 mA	0.1% + 16 mA	0.1% + 12 mA	0.1% + 3mA	0.3/5/15 mA	0.3/5/15 mA
Resolution	0.1% FS	15 mA	4 mA	3 mA	0.75 mA	2.5/25/250 µA	2.5/25/250 µA
Power							
Range(s)	70/700 VA	0 to 400 W	0 to 400 W	0 to 400 W	0 to 400 W	0 to 50/500 W	0 to 50/500 W
Accuracy	0.1% R+ 0.2% FS	0.25% + 1 W	0.25% + 1 W	0.25% + 1 W	0.25% + 1W	0.1% + 0.1% FS	0.1% + 0.1% FS
Resolution	0.1% FS	0.1 W	0.1 W	0.1 W	0.1 W	5 mW/50 mW	5 mW/50 mW
Instrument Features	Additional measurements: peak current, crest factor and power factor Programmable cycle drop-outs, turn-on phase angle, cycle transient and current limit Line & load regulation: 0.1%R+0.1%FS w/remote sense 4:1 crest factor Non-repetitive peak current in 140 V range: 20 A 1% THD @ 50/60 Hz Load power factor: 0-1, lead or lag Protection: OC, OV, OP, OT, SC	Constant Power Operating Envelope Protection: over-voltage, under-voltage, current limit, over-current trip, over-temperature, UUT discharge, short-circuit				Modal Operation: constant current, constant voltage, constant resistance, constant power, transient generator, short-circuit Remote sense OVPS relay Self-test Closed-cover calibration Fully parallelable Protection: over-power, over-current, over-voltage, reverse-voltage, over-temperature		

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Power Supply Functional Test System

Mid-Range, Fully-Configured Tester
POWERTEST® 535

- ❑ **Optimizes Test Capability, Throughput and Cost**
- ❑ **Powerful MS Windows™ Test Executive plus Test Library**



APPLICATION
The POWERTEST 535 is a mid-range power supply test system that includes the entire complement of hardware and software necessary to perform complete production testing, including test result data collection and analysis. It is specifically targeted for both AC-DC and DC-DC supplies up to 1200 W and 8 outputs. For power supplies within its capability, the 535 delivers exceptional value due to its comprehensive test and reporting capability, high-throughput and attractive pricing.

FULLY-CONFIGURED TEST SYSTEM
In order to provide the capability to perform all standard functional tests on typical mid-range power supplies, the 535 includes 8 loads totaling 1200 W, a 4.5 kVA/3 kW AC/DC Source with 200A of peak current capability, over-voltage supply, full measurement instrumentation, digital logic inputs & outputs, and general-purpose relays. This unique approach of a fully configured system allows significant cost and integration advantages over custom configured systems comprised of an assortment of GPIB-controlled, single-function instruments.

READY-TO-RUN TEST EXECUTIVE
The new *em*Power® Test Executive is optimized for power supply test either as a stand-alone tester or within a computer-controlled manufacturing environment. It is a ready-to-run application that assures the fastest path to testing power supplies. Straightforward factory integration is achieved with software interfaces based on Microsoft® ActiveX/COM (Common Object Model) standards. These interfaces make it compatible with internal network communication and reporting protocols, as well as third-party extensions. Faster test program development is achieved through an intuitive, notebook-like guide that leads one through the entire sequence of building a test program and data-logging the results. If time-to-production-test is critical, there simply isn't a faster method of accomplishment.

INDUSTRY-LEADING THROUGHPUT
The key to fast test times is the very high degree of integration achieved from utilizing only task-essential portions of all power stimulus and measurement instruments. This results in a compact, minimum-parts tester that internally looks more like a single instrument than a collection of separate instruments. Eliminated are the extra costs, additional rack space, and reliability compromises from redundant front panels, displays, switches, connectors, power supplies, and fans. Because of the high level of integration, the 535 eliminates most of the communication overhead that burdens traditional GPIB systems. This allows testing to be executed at faster speeds, typically in half the time required by competitor testers.

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POWERTEST 535 SPECIFICATIONS

SOURCE INSTRUMENTATION

AC/DC Source

AC Output

Power: 4500 VA

Voltage: 0 to 140, 280 V

Accuracy: 0.1% + 0.1% FS

Resolution: 16 bits

Regulation: 0.75, 1.5 V

RMS Current: 0-25, 12.5 A

Peak Current: 200, 100 A

Frequency: 40 to 500 Hz

DC Output

Power: 3000W

Voltage: 0 - ± 100, 200, 400 VDC

Accuracy: 0.1% + 0.1% FS

Resolution: 16 bits

Regulation: 25, 50, 100 mV

DC Current: 50, 25, 12.5 A

Peak Current: 200, 200, 160 A

Additional Programmability: Current Limit, Turn-On Phase Angle, Cycle Drop-Out, AC/DC Present

Over-Voltage DC Source

Voltage: 0 to 80 VDC

Accuracy: 0.5% setting ± 10 mV

Resolution: 14.7 mV

Current: 3 A

Protection: Over-temperature, over-current

Electronic Loads

Voltage: 1.5 to 80 VDC

Current: Two ranges with autoranging

Qty	Power	Current	Resolution
1	500 W	100 A	39 mA, 391 mA
1	250 W	50 A	20 mA, 200 mA
6	75 W	12.5 A	5 mA, 50 mA

Accuracy: 1% FS

Additional Programmability: Slow/fast response, constant current/constant resistance, constant voltage, short-circuit on/off

Protection: Over-temperature, reverse-voltage. Capable of 100% over-power for 30 sec

MEASUREMENT INSTRUMENTATION

Measurement	Range	Resolution	Accuracy
UUT Output			
DC Voltage	0 – 20, 200 VDC	16 bits	0.02% FS
DC Current			
100 A load	0 – 10.4, 104 A	16 bits	0.5% FS
50 A load	0 – 5.2, 52 A	16 bits	0.5% FS
12.5 A load	0 – 1.3, 13 A	16 bits	0.5% FS
RMS Noise (1 MHz) Pk-Pk Noise (20 MHz)	0.2, 1.0, 5.0 V	0.01% FS	1% FS
Counter/Timer	100 nS - 13.4 S	100 nS	0.02%
UUT Input			
AC RMS Voltage	280V	16 bits	0.05% + 0.1% FS
AC RMS Current	2, 5, 12.5, 25 A	16 bits	0.1% + 0.1% FS
AC Peak Current	15, 30, 75, 200 A	16 bits	1% FS
AC Power	4500 W	16 bits	0.2% + 5 W
DC Voltage	± 100, 200, 400 V	16 bits	0.05% + 0.1% FS
DC Current	50, 25, 12.5 A	16 bits	0.1% + 0.1% FS
DC Peak Current	200, 200, 100 A	16 bits	1% FS
DC Power	3000 W	16 bits	0.2% + 5 W

SOFTWARE

Operating System: MS Windows™ 98, ME, 2000, XP

Test Executive: *em*Power®- an integrated environment for creating, debugging, running and collecting data during functional testing of power supplies. Includes a test routine library and interactive instrument panels. Fully network-compatible.

Custom Test Programming Languages: To extend the user-modifiable test routine library written in Visual Basic, test programs can also be written in any language supporting the Microsoft™ ActiveX control interface, including LabVIEW and LabWindows CVI.

SYSTEM CONTROL

PC: 1.7 GHz Processor

Memory: 128 MB

Drives: 20 GB HD, 1.44 MB FD, 48 X CD-ROM

I/O: 6 USB, 2 Serial, 1 Parallel, 1 RJ-45 network port

Monitor: 15-inch

Mouse & Keyboard: PS/2 compatible

CONTROL

Measurement Matrix

Input Channels: 12, externally (front panel) selected, differential inputs for measurement of DC voltages, RMS noise, and peak noise

12, internally selected differential inputs for measurement of AC or DC input voltage, current, peak inrush current, AC power, and load current

Output Channels: One to measurement module and front panel monitor

General Purpose Relays

Quantity & Type: 8, DPDT

Rating: 5 A, 130 VAC or 40 VDC

Digital Outputs

Quantity & Type: 8, open collector, isolated

Rating: 300 mA, 70 VDC, 0.5 W

PHYSICAL

Size (HWD): 58 x 23 x 24-inch

Weight: 500 lb

Operating Temperature: 10° to 35° C

Facility Power: 240 VAC ± 10%, single phase, 25A, 50 or 60 Hz

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Power Supply Functional Test System

Advanced Measurement Capability Tester 5600 Series

- ❑ **Waveform digitizing measurement system**
- ❑ **Fast test speeds**
- ❑ **Enterprise-ready Test Executive**



APPLICATION

The 5600 Series Power Supply Test System is a high performance ATE platform that makes all critical measurements through a waveform digitizer. This allows more comprehensive measurements, higher test speeds, smaller cabinet/footprint size and ultimately, a simpler, more reliable system. The 5600 targets mid-to-large AC-DC or DC-DC power supplies and can be configured from a wide variety of power stimulus options.

GREATER TESTING CAPABILITY

More complete testing of power supplies, bulk converters, and rectifiers is now possible through the Digital Measurement System (DMS) that is core to the 5600 System. The DMS works by immediately digitizing analog signals for digital processor analysis. Through this technique, the DMS replaces several single-function instruments and extracts extensive information on UUT performance in a single pass.

LOWER TESTING COSTS

The 5600 establishes a new standard in lowering unit-testing costs by dramatically improving tester throughput. Because there is a minimum ensemble of instruments required to perform testing, switching between instruments is minimized and test speed is significantly improved. Further gains are achieved with the powerful 32-bit, multi-threaded test executive that contains a speed-tuned execution engine.

READY-TO-RUN TEST EXECUTIVE

The new *em*Power® Test Executive is optimized for power supply test within a computer-controlled manufacturing environment. It is a ready-to-run application that assures the fastest path to testing power supplies. Straightforward factory integration is achieved with software interfaces based on Microsoft® ActiveX/COM (Common Object Model) standards. These interfaces make it compatible with internal network communication and reporting protocols, as well as third-party extensions. Faster test program development is achieved through an intuitive, notebook-like guide that leads one through the entire sequence of building a test program and data-logging the results.

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5600 SERIES SPECIFICATIONS

SYSTEM CONTROL

PC: 1.7 GHz Processor
Memory: 128 MB
Drives: 20 GB HD, 1.44 MB FD, 48 X CD-ROM
I/O: 6 USB, 2 Serial, 1 Parallel, 1 RJ-45 network port
Monitor: 15-inch
Mouse & Keyboard: PS/2 compatible

SOFTWARE

Operating System: MS Windows™ 98, ME, 2000, XP

Test Executive: *em*Power®- an integrated environment for creating, debugging, running and collecting data during functional testing of power supplies. Includes a test routine library and interactive instrument panels. Fully network-compatible.

Custom Test Programming Languages: To extend the user-modifiable test routine library written in Visual Basic, test programs can also be written in any language supporting the Microsoft™ ActiveX control interface, including LabVIEW and LabWindows CVI.

DIGITAL MEASUREMENT SYSTEM

MEASUREMENT	RANGE/BANDWIDTH	RESOLUTION	ACCURACY
DC Volts	± 2, 20, 200, 500 V	0.003% FS	0.01% R + 0.01% FS
AC Volts RMS	14, 140, 350 Vrms	0.004% FS	±1.0% R + 0.065% FS
DC Peak Volts	± 20, 200, 500 V	0.012% FS	1.0% R + 0.02% FS
RMS Noise 10Hz-1MHz	70 mV, 350 mV, 3.5 V	0.012% FS	1.0% R + 0.5% FS
Peak to Peak Noise 5 kHz to 100 MHz	100 mV, 500 mV, 5 V	0.02% FS	1.0% R + 2.0% FS
Frequency	10 Hz, 5 MHz	1/100 ns	0.016% R
Timing	0 to 7 minutes	100 ns	0.02% R + 200 ns
Waveform Capture	DC to 100 MHz	0.003%	1% FS
Phase Angle	0 to 360°	1°	± 1% @ 50/60 Hz
THD (2-64th)	0 to 100%	0.01%	1% R

I/O MODULE (EXPANDABLE TO 8)

MULTIPLEXER
Input channels: 16, differential
Output channels: 2, differential
Bandwidth (-3db)
Output 1: 100 MHz
Output 2: 10 MHz
Max voltage: ± 500V
Max current: 100 mA

GENERAL PURPOSE RELAYS
Quanity: 8 DPDT
Contact rating: 5 A, 30 VDC or 120/240 VAC

RELAY DRIVERS
Quantity: 16
Rating: 48 V@ 500 mA

DIGITAL DRIVERS
Quantity: 16
Rating: 100 mA, 70 VDC, 0.5 W

DIGITAL RECEIVERS
Quantity: 8 total consisting of two groups of four, each group with a common programmable threshold
Input Voltage: ± 10 VDC
Accuracy: 1%

STIMULUS INSTRUMENTATION OPTIONS

AC/DC SOURCE
Power: 4.5 kVA/3000 W/1ø
AC Voltage: 140/280 Vrms
DC Voltage: 100/200/400 VDC
Current: 25 Arms/50 ADC
Peak Current: 200 A
Frequency: 40 to 500 Hz

AC HIGH-POWER SOURCES
Power: 5, 10 kVA, 1 or 3ø
Voltage: 400 Vrms

DC HIGH-POWER SOURCES
Power: 5, 10, 15 kW
Voltage: *to* 500 V
Current: *to* 500, 1000, 1400 A

DC HIGH-POWER LOAD
Power: 6 kW (parallelable for higher power)
Voltage: 0.25 to 6.6, 20, 66, 120 V
Current: 0 to 120, 1200 A
Modes: CC, CV, CP, CR, SC & Pulse

MODULAR POWER SUBSYSTEM
(6 any type modules/chassis, like modules parallelable)

DC Sources
Power: 400 W
Voltage/Current: 10 V/60 A, 60 V/16 A, 80 V/12 A or 400 V/3 A

DC Loads
Power: 300 W
Voltages: 0.7 to 80 V or 2.1 to 450 V
Current: 60 A

PHYSICAL

CONFIGURATION	SIZE (HWD)	WEIGHT	OPERATING TEMP	FACILITY POWER
Single Bay	57 x 23 x 30-inch	~ 500 lb	0° to 50° C	US & Intl. options available
Dual Bay	57 x 46 x 30-inch	~1000 lb	max power derates > 38°	

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Power Supply Functional Test System

VXIbus-based Tester Family 8100i

- ❑ **Widest selection of instrumentation and cabinetry**
- ❑ **Field-proven history**



8100*i* 8107*i* 8105*i*

APPLICATION

The POWERTEST 8100*i* Family ATE platform is based on a core VXIbus Measurement & Control Subsystem. The 8100*i* systems are completely configurable and offered in several cabinet styles, from benchtop to multi-bay. A wide variety of NH Research and third-party instruments are available. This has been NH Research's most popular line of power supply ATE over the past decade. If a versatile, field-seasoned type system seems appropriate, the 8100*i* Family won't disappoint.

INDUSTRY STANDARD ARCHITECTURE

VXIbus card-level instruments are now widely adopted throughout the ATE industry for performance, flexibility, and space-saving reasons. To meet this popular approach to test station design, all 8100*i* Family systems contain a 13-slot, C-sized VXIbus chassis for measurement and control functions.

WIDEST CHOICE OF INSTRUMENTS

NH Research offers several VXIbus multi-function measurement modules, along with a wide range of chassis-contained power stimulus instruments. To supplement these, over 50 third-party instruments are supported for special testing needs.

MANY PACKAGING CHOICES

While the most popular package is the 3-half-bay/desktop cabinet shown to the far left, other options include one or more upright cabinets (8100*i*'s), along with the benchtop DC-DC tester (8107*i*) and 3/4-height 8105*i*. 8100*i*'s include a central connection interface panel that can be expanded to include a Quick-Change Interface Connector Assembly.

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8100*i* FAMILY SPECIFICATIONS

MEASUREMENT INSTRUMENTATION OPTIONS

Parallel Measurement Module (PMM)

The VXI PMM combines the essential functions of a DVM together with a Transient Analyser and Threshold Detector/Timer on four independent channels.

System Digital Multimeter

A HP 34401A (6-1/2 digit) DMM makes all critical pass/fail voltage measurements and serves as the primary calibration reference for the system.

Measurement Multiplexer Module

Type: Wide band differential
Input Channels: 16
Output Channels: 3
Bandwidth: 100 MHz (output 1)
Maximum Voltage: 500 VDC or peak AC

Multi I/O Module

Digital Response
Channels: 16
Maximum Voltage: ± 15V
Programmable Threshold: ± 10V
Digital Stimulus
Channels: 16
Voltage: 0 to 60V
Current: 150 mA maximum
General-Purpose Relays
Quantity: 16
Type: DPDT
Rating: 5 A, 240 VAC, 30 VDC

Digitizing Oscilloscope (DSO)

400 MHz Tektronix 430. Includes two-channel signal isolator and full software support.

Transient Analyser
Measurement: Peak to peak noise, overshoot/undershoot
Bandwidths: 7 ranges, to 50 MHz
Operating modes: Single event or continuous
AC voltage: 5 ranges, *to* 100 V
DC voltage: 4 ranges, *to* 500V
Test window: 10 µsec to 8 sec,1 µsec resolution
Threshold Detector/Timer
Analog comparators: 2, isolated
Input voltage: 500 V in 4 ranges
Timer: to 168 sec in 3 ranges
Resolution: 100 nsec, 1 µsec, 10 µsec

SYSTEM CONTROL

PC: 1.7 GHz Processor

Memory: 128 MB

Drives: 20 GB HD, 1.44 MB FD, 48 X CD-ROM

I/O: 6 USB, 2 Serial, 1 Parallel, 1 RJ-45 network port

Monitor: 15-inch

Mouse & Keyboard: PS/2 compatible

SOFTWARE

Operating System: MS Windows™ 98, ME, 2000, XP

Test Executive: *em*Power®- an integrated environment for creating, debugging, running and collecting data during functional testing of power supplies. Includes a test routine library and interactive instrument panels. Fully network-compatible.

Custom Test Programming Languages:
To extend the user-modifiable test routine library written in Visual Basic, test programs can also be written in any language supporting the Microsoft™ ActiveX control interface, including LabVIEW and LabWindows CVI.

PHYSICAL

8100i (HWD):
3-half bay, desk-height,
41 x 69 x 30-inch
1, 2 or 3-bay upright,
71 x 23 x 30-inch
8105i:
1-bay, upright: 58 x 23 x 30-inch
8107i:
Benchtop, 24 x 21 x 30-inch

STIMULUS INSTRUMENTATION OPTIONS

TYPE	8100*i*	8105*i*	8107*Ii*	DESCRIPTION
AC/DC Source	x	x		4.5 kVA/3 kW, 140/280 Vrms, 100/200 /400 VDC
AC Sources	x	x		2.4 kVA, 1ø, 140/280 Vrms
	x			5.0 k VA, 1/3ø, 400 Vrms
	x			10 kVA, 1/3ø, 400 Vrms
DC Sources	x	x		400 W, 5 A, 0 to 80 V (OVPS)
	x	x		800 W, 10 A, 0 to 80 V
	x	x		1600 W, 20 A, 0 to 80 V
	x			4000 W, 50 A, 0 to 80 V
	x			2200 W, 5 A, 4.5 to 450 V
	x			4500 W, 10 A, 4.5 to 450 V
	x			9000 W, 20 A, 4.5 to 450 V
Loads	x	x	x	50 W, 1 A, 1.5 to 75 V, VXI card
	x	x	x	50 W, 10 A, 1.5 to 75 V, VXI card
	x	x		250 W, 5 A, 1.5 to 75 V
	x	x		250 W, 50 A, 1.5 to 75 V
	x	x		1000 W, 50 A, 1.5 to 75 V
	x	x		1000 W, 200 A, 1.5 to 75 V
	x			2500 W, 500 A, 1.5 to 75 V
	x			250 W, 2 A, 45 to 450 V
	x			1000 W, 5 A, 45 to 450 V
Modular Power Subsystem				(6 any type modules/chassis, like modules parallelable)
Loads	x	x	x	300 W, 60 A, 0.7 to 80 V
	x	x	x	300 W, 60 A, 2.1 to 450 V
DC Sources	x	x	x	400 W, 60 A, 0 to 10 V
	x	x	x	400 W, 16 A, 0 to 60 V
	x	x	x	400 W, 12 A, 0 to 80 V
				400 W, 3 A, 0 to 400 V

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UPS Functional Test System

Universal UPS Tester 5500 Series

- ❑ **Advanced UPS testing capability**
- ❑ **Faster test speeds**
- ❑ **Enterprise network-ready**



APPLICATION

The 5500 UPS Test System is an advanced ATE test platform similar to the 5600 Power Supply Tester, but targeted exclusively for uninterruptible power supplies (UPSs). It contains two unique instruments: a Digital Measurement System and an Electronic AC Load, the combination of which provides far more comprehensive testing of UPS than ever before possible.

ADVANCED TESTING CAPABILITY

To insure that the UPS is tested with a variety of "real-world" loading conditions, an electronic AC load is provided. Through programmable control of both power-factor and crest-factor, the load allows checking UPS performance at a number of operating envelope or worst-case limits, rather than just at nominal ratings. Complementing the Load is the Digital Measurement System (DMS). This instrument replaces several single-function measurement instruments through its ability to extract multiple measurements from a single digitized waveform. Accordingly, the two instruments combine to allow more thorough testing of UPSs than ever before possible in a production tester.

LOWER TESTING COSTS

The 5500 establishes a new standard in lowering unit-test costs. Significantly improved tester throughput is achieved by combining a minimum ensemble of instruments tightly integrated into a powerful 32-bit, multi-threaded test executive containing a speed-optimized test execution engine. Unit test times are often cut to half that of older-generation test systems.

ENTERPRISE NETWORK-READY

In today's manufacturing environment, a tester must interface seamlessly with the enterprise network that increasingly controls both test program delivery and test results data collection. Global manufacturers, in particular, need real-time status of productivity and quality from remote facilities. All of this is now available with the *em*Power® Test Executive; an open-architectured application specifically designed with such enterprise needs in mind.

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5500 SERIES SPECIFICATIONS

SYSTEM CONTROL

PC: 1.7 GHz Processor
Memory: 128 MB
Drives: 20 GB HD, 1.44 MB FD, 48 X CD-ROM

I/O: 6 USB, 2 Serial, 1 Parallel, 1 RJ-45 network port
Monitor: 15-inch
Mouse & Keyboard: PS/2 compatible

SOFTWARE

Operating System: MS Windows™ 98, ME, 2000, XP

Test Executive: *em*Power®- an integrated environment for creating, debugging, running and collecting data during functional testing of power supplies. Includes a test routine library and interactive instrument panels. Fully network-compatible.

Custom Test Programming Languages:
To extend the user-modifiable test routine library written in Visual Basic, test programs can also be written in any language supporting the Microsoft™ ActiveX control interface, including LabVIEW and LabWindows CVI.

STIMULUS INSTRUMENTATION OPTIONS

AC Electronic Loads	AC Sources
Power: 4.5, 9.0 and 13.5 kVA	**Power:** 6.0 (1/3ø), 10 (1/3ø) kVA
RMS Current: 30, 60, 90 A	**Voltage:** 135/270, 200/400 (opt) VAC
Peak Current: 90, 180, 270 A	**RMS Current** @ 135V: 44, 74 A
RMS Voltage: 50 to 350 V	**Peak Current:** 170, 180 A
Max Peak Voltage: 500V	**Frequency:** 45 to 5000 Hz
Frequency: 45 to 440 Hz	**DC Sources (Bulk)**
Modes: CC, CV, CR, CP, SC	**Power:** 5.0, 10, 15 kW
Crest Factor: 1.414 to 3.5	**Voltage**: *to* 500 V
Power Factor: 0 to 1, lead/lag	**Current:** *to* 500, 1000, 1400 A
DC Electronic Loads	**DC Sources (Bias)**
Power: 300 W modules, up to 6 per chassis	**Power:** 400 W, up to 6 per chassis
Voltage: 0.7 to 80 V, 2.1 to 450 V	**Voltage:** 10, 60, 80, 400 V
Current: 60 A	**Current:** 60, 16, 12, 3 A

SYSTEM MEASUREMENT

MEASUREMENT	RANGE	RESOLUTION	ACCURACY	INSTRUMENT	USE
UUT Input					
AC RMS Volts	14, 140, 350 V	0.004% FS	0.1% R + 0.065% FS	DMS	PF Compliance
AC RMS Current	40, 400 A	0.01, 0.1 A	0.25% FS	AC Source	Crest Factor, PF Compliance
AC RMS Current	35, 70, 100 A	1, 2, 3 mA	0.2% R + 0.05% FS	DMS[1]	Crest Factor, PF Compliance
AC Peak Current	50, 100, 150 A	1, 2, 3 mA	0.2% R + 0.05% FS	DMS[1]	Crest Factor, UUT Peak Inrush
AC True Power	2, 20 kW	1, 10 W	0.5% FS	AC Source	Efficiency
AC True Power	5, 10, 15 kW	0.15, 0.3, 0.45 W	0.25% R + 0.1% FS	DMS[1]	Efficiency
UUT Output					
DC Volts	± 2, 20, 200, 500 V	0.003% FS	0.01% R + 0.01% FS	DMS	Battery Charger Loading, Serial Port Levels
Peak to Peak Noise	± 100 mV,500 mV, 5 V	0.02% FS	1.0% R + 2.0% FS	DMS	Battery Charger Output Noise
Ripple RMS	70 mV, 350 mV, 3.5 V	0.012% FS	1.0% R + 0.5% FS	DMS	Battery Charger Output Noise
DC Peak Voltage	± 20, 200, 500 V	0.012% FS	1.0% R + 0.02% FS	DMS	Battery Charger Output Transient
AC RMS Volts	14, 140, 350 V	0.003% FS	0.1% R + 0.065% FS	DMS	Output Accuracy
AC RMS Current	30 A[2]	30 mA[2]	0.2% FS	AC Load	Output Loading Tests
AC Peak Current	90 A[2]	180 mA[2]	0.5% FS	AC Load	Output Loading Tests
AC True Power	3000 W[2]	3 W[2]	0.5% FS	AC Load	Efficiency, Output Loading Tests
Power Factor	0 to 1 lead / lag	0.001	0.5% FS	AC Load	Compliance
Crest Factor	1.0 to 3.5	0.0035	0.5% FS	AC Load	Output Loading Tests
Timing	0 to 7 minutes	100 nS	0.02% R + 200 ns	DMS	General timing
Frequency	10 Hz to 5 MHz	1/100 ns	0.016% R	DMS	Output frequency
Waveform Vertical Horizontal	 See DC specs 512 to 4096 sample	 See DC specs 10 µS	 See DC specs 0.02% R + 20 µS	DMS	Off-line switcher output waveshape test
THD (2-64th)	0 to 100%	0.01%	1% R	DMS	Compliance
UUT Input-to-Output					
Efficiency	0 to 100%	0.13%	1.5% R	AC Load/AC Source	Compliance, process control
Phase Angle	0 to 360°	0.1%	0.5° @ 60 Hz	DMS	Off-line UPS switchover
I/O Module (Expandable to 8)					
Input Channels: 16, external (front panel) selected, differential inputs for UUT measurements. 8 internally selected, differential inputs for measurements of loads and sources. ±500V isolation between channels.					
General Purpose Relays: 8 DPDT with 5 A /30 VDC & 120/240 VAC rating. 16 relay drivers.					
Digital Outputs: 16, open collector, isolated, 100 mA/70 VDC/0.5 W-rated.					
Digital Inputs: 8, two groups of four with common programmable threshold of ± 10V.					

[1]*With optional Isolated Shunts* [2]*If multiple AC loads, multiply by number in parallel*

PHYSICAL

CONFIGURATION	SIZE (HWD)	VPO	WEIGHT	OPERATING TEMP	FACILITY POWER
Single Bay	57 x 23 x 30-inch	49-inch	~ 500 lb	0° to 50° C	US & Intl. options available
Dual Bay	57 x 46 x 30-inch	49-inch	~1000 lb	max power derates > 38°	

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DC Electronic Loads

Ultra-Compact, Modular Loads Model 4100/4110



- ❑ **300 W, 60 A modules**
- ❑ **Up to 6 loads in a 5 1/4-inch high chassis**
- ❑ **Parallelable "virtual" loads**
- ❑ **Below 1 volt operation**

The Model 4100 and 4110 electronic loads are designed for use within the S300 Power Subsystem. These highly versatile loads may be used in any combination together with DC sources within the same 6-slot chassis. The use of such wide-capability modular loads yields more flexibility, less rack space, and lower cost than an assortment of loads each having limited voltage and current range.

BROAD OPERATING ENVELOPE

To cover the full spectrum of supply-under-test output voltages, the Model 4100 load operates at full current from 2.1 to 450 V. To meet newer low voltage requirements, the Model 4110 load operates down to 0.7 V and at reduced current down to 0.1 V. In the constant-current mode, both loads have three ranges in order to assure the necessary low-end resolution for both set and measurement values.

PARALLELED "VIRTUAL" LOADS

To address higher power requirements, the same type (4100 or 4100s) can be paralleled in software to respond as if they were a single larger load. All load functions, including slew rate and short-circuit, are then internally synchronized so that the supply-under-test sees a single "virtual" load without the dynamic discontinuities associated with paralleling older designs. Should the next application require a different load grouping, reconfiguration is quickly achieved through reprogramming, thus extending the system's flexibility with a minimum of load modules.

OPERATION BELOW 1 VOLT

With the clear trend toward lower IC voltages, today's loads must anticipate tomorrow's test requirements. Both the 4100 and the 4110 will operate below 1 V at reduced current levels, with the latter being optimized for operation at these very low voltages.

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MODEL 4100/4110 SPECIFICATIONS

PROGRAMMABLE FEATURES

Current: 0 to 60A

Voltage:

4100	4110
2.1* to 450 VDC	0.7* to 80 VDC

* Full current operation. See graph below for current derating at lower voltages.

Power: 300 W

Modes: Constant current, constant voltage, constant resistance, constant power, transient generator, short-circuit and external analog modulation

Control: GPIB (IEEE 488.2) or RS485

PROTECTION CIRCUITS

Over-power: Maximum power is limited through monitoring of heatsink temperature. Programmable to lower limits.

Over-current: All modes limited to current set in constant current mode

Over-voltage: Output protected for transients over 450 V

Reverse-voltage: Reverse polarity diodes on outputs to short UUT

Over-temperature: Monitor of heatsink temperature

ADDITIONAL FEATURES

Mode Switching: Glitch-free transition when changing between current, voltage, power, and resistance modes

Isolation: ± 500 VDC between input and chassis ground

Remote Sense: 2 VDC max drop between sense and load input

OVPS Relay: DPST, 5A, isolated control

Self-test: Complete built-in hardware self-test of all major functions including each output transistor

Calibration: Closed cover, all adjustments done in software and stored in an on-board EEPROM

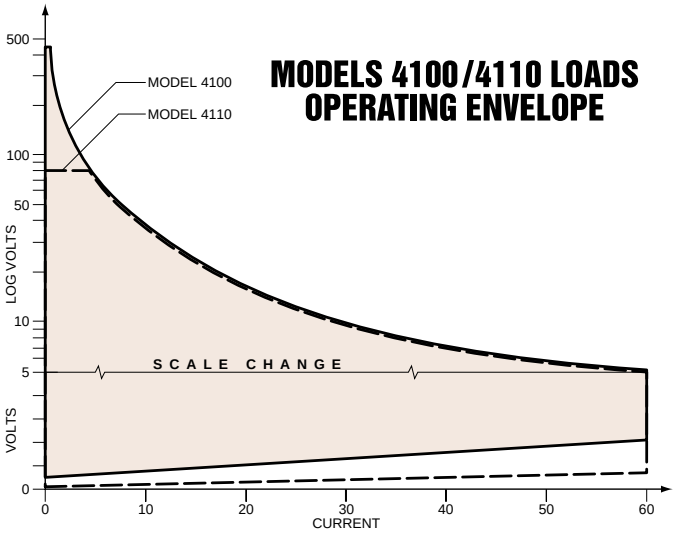
SUPPLEMENTAL CHARACTERISTICS

Size (HWD): Single-slot (six available) of S300 mainframe chassis (5¼ x 19 x 22-inch)

Weight: Module: 6.6 lbs, Chassis: 21 lb

Operating Temperature: 0 to 50° C
All specifications apply for 27° C ± 5° C

Power (loads only): 115 VAC ± 10%, 208 to 264 VAC, 47 to 63 Hz



MODAL OPERATION	4100	4110
Constant Current		
Ranges:	0 to 60 A, 6 A, and 660 mA	0 to 60A, 6A, and 660 mA
Accuracy:	60 mA, 30 mA, 660 µA + 2 µA/V	60 mA, 30 mA, 660 µA + 2 µA/V
Resolution:	0.025% FS	0.025% FS
Constant Voltage		
Ranges:	0.5 to 120 V, to 450 V	0.2 to 8V, 0.75 to 80 V
Accuracy:	0.1% FS	0.1% FS
Resolution:	0.025% FS	0.025% FS
Constant Resistance		
Ranges:	0.035 to 10 kΩ	0.12 to 10 kΩ
Accuracy:	0.5% Set	0.5% Set
Resolution:	0.15% Set	0.15% Set
Constant Power		
Ranges:	0 to 400 W, 40 W	0 to 400 W, 40 W
Accuracy:	1% Set	1% Set
Resolution:	0.1% FS	0.1% FS
Transient Generator		
Pulse		
Current Settings:	3	3
Total Period:	40 µsec to 1 sec (25 kHz to 1 Hz)	40 µsec to 1 sec (25 kHz to 1 Hz)
Delay Between Settings:	20 µsec to 1 sec	20 µsec to 1 sec
Resolution:	10 µsec	10 µsec
Accuracy:	1% + 5 µsec	1% + 5 µsec
Modes:	Single burst, continuous	Single burst, continuous
Rise/Fall Time		
Range:	10 µsec to 1 sec (10% to 90%)	10 µsec to 1 sec (10% to 90%)
Resolution:	2 µsec	2 µsec
Accuracy:	1% of setting + 3 µsec	1% of setting + 3 µsec
External Modulation		
Bandwidth:	DC to 25 kHz	DC to 25 kHz
Programming Voltage:	0 to 5V	0 to 5V
Accuracy:	5% FS	5% FS
Short-circuit		
Resistance:	0.035 Ω @ 60 A	0.012 Ω @ 60 A

READBACK INSTRUMENTATION	4100	4110
DC Current		
Ranges:	0 to 60 A, 6 A, 660 mA	0 to 60 A, 6 A, 660 mA
Accuracy:	15 mA, 5m A, 0.3 mA, + 2 µA/V	15 mA, 5 mA, 0.3 mA, + 2µA/V
Resolution:	250, 25, 2.5 µA	250, 25, 2.5 µA
DC Voltage		
Ranges:	0 to 120, 450 V	0 to 8, 80 V
Accuracy:	0.025% FS	0.025% FS
Resolution:	500, 1.8 µV	33, 330 µV
Power		
Ranges:	0 to 500, 50 W	0 to 500, 50 W
Accuracy:	1%	1%
Resolution:	± 30 mW	± 30 mW

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DC Electronic Loads

Automated Power MiniTester 300 Series

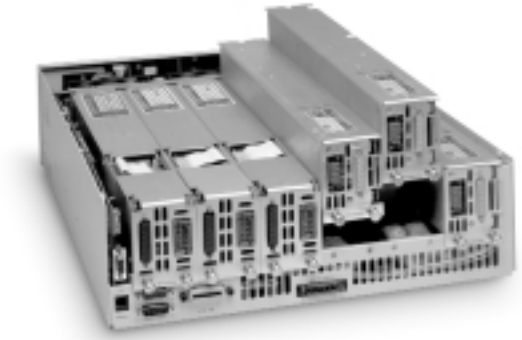
- ❑ **A one-box power test solution replacing several test instruments**
- ❑ **Flexible configuration of DC electronic loads and DC power supplies**
- ❑ **Automatically executes stored command sequences**

APPLICATION

The S300 Power MiniTester is a DC electronic-load-based tester that includes the necessary control and firmware capabilities to make it a complete and self-contained solution for automated functional testing of power devices. Through the front panel, test programs can be created and then repeatedly executed with a single keystroke. Test results can be sent to the front panel, printer or a PC. Think of the MiniTester as a solution halfway between an assortment of benchtop test instruments and a full-capability, PC-controlled power test system. It is ideal for automating manually run, in process test.

A ONE-BOX TEST SOLUTION

The MiniTester replaces stand-alone DC electronic loads, DC power supplies, AC sources, DVMs, current and power meters. This is accomplished all within a chassis that accepts a wide assortment of electronic loads and sources. Each module contains



S310

S320



its own built-in, precision measurement circuitry. Model S310 is intended for DC-input testing. Model S320 is intended for both AC & DC-input testing. Either unit can be used in a stand-alone, benchtop application or as a GPIB-controlled subsystem within a larger automatic test station.

FLEXIBLE CONFIGURATION

The flexibility to test a wide variety of products is accomplished in two ways. First is the unique 6-slot chassis that will accept any combination of modular DC electronic loads and/or programmable DC power supplies. The second is the unusually wide operating ranges of all modules, typically twice that of industry practices. This extended flexibilityassures users the ability to meet a broad varity of stimulus requirements with the fewest number of modules.

EXECUTES FULL TEST PROGRAMS AND LOGS RESULTS

The ability to create and run automatic test programs highlights the powerful macro-recording and playback capabilities of the MiniTester. This keystroke macro-recorder combined with built-in test algorithms, allows non-programmers to automate complex series of instrument operations and measurements. Playback of a saved test program then becomes a one-keystroke operation. Test measurements or PASS/FAIL indications are shown on the front panel display and may also be logged to a printer.

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300 SERIES SPECIFICATIONS

TESTING CAPABILITY

Turn-On/Off Tests
Input Voltage at Turn-On
Input Voltage at Turn-Off
Ramp-up

Steady State Tests
Output Voltage Tolerance
Output Voltage Adjustment
Output Voltage Trimming
Delta Voltage Regulation
Delta Current Regulation
Line Regulation
Load Regulation
AC RMS Input Current
DC Input Current
Step Delay
Pause Message with Operator Response

Protection Tests
Output Over-voltage
Output Over-current
Output Under-voltage
Short-circuit
Input Over-voltage
Input Under-voltage

Charger/Adapter-Specific Tests
Charge Current
Trickle-to-Normal Changeover Voltage
Normal-to-Over-voltage Changeover Voltage
Discharge Current
Discharge-to-Trickle Changeover Voltage

SYSTEM FEATURES

Edit & debugging capability through PC-resident Macro Editor Utility. This allows single-step execute test feature and downloads of a test program to several testers. (Requires Pentium-class PC, Windows 95™ or later, GPIB interface board and cable).

ISO9000 compliance through test program date/time/revision tracking

Test results logging to an optional printer or PC

Password-protected operator screen

Serial numbered test results with auto-increment feature

On-line yield results.

Printer option: 40-column thermal, 11 lines per second

Remote control option: Rear connector for start/stop, pass/fail signals.

Input Power: 115 or 230 VAC (Specify), 1ø, 50/60 Hz

Input Power Factor: > 0.95 (S320)

Physical:

Model	Size (HWD)	Weight
S310	5 1/4 x 19 x 22-inch	21 lb
S320	8 3/4 x 19 x 22-inch	27 lb
Modules	Six per chassis	6 1/2 lb each

Operational Temperature Range: 0 to 50º C. Specifications apply for 25 ± 5º C.

Cooling: Intake at front top, bottom and sides; rear exit

Interfaces: IEEE Std 488.2-1992, SCPI Version 1994.0, RS232C

POWER MODULE SPECIFICATIONS

MODULE TYPE	AC SOURCE	DC SOURCES				DC LOADS	
MODEL NO.	**1251**	**6010**	**6060**	**6080**	**6400**	**4100**	**4110**
Ratings							
Power	600 VA	400 W	400 W	400 W	400 W	300 W	300 W
Voltage Range	0 to 135 V / 0 to 270V	0 to 10 V	0 to 60V	0 to 80V	± 400 V	2.1* to 450 V	0.7* to 80 V
Maximum Current	4 A /2 A	60 A	16 A	12 A	3 A	60 A	60 A
Frequency	16 to 500 Hz					*Current reduces linearly to 0.1 V	
Measurements							
Voltage							
Ranges	0 to 300 V	0 to 10 V	0 to 60 V	0 to 80 V	± 400 V	0 to 120/450 V	0 to 8/80 V
Accuracy	0.05% + 300 mV	0.1% + 10 mV	0.1% + 60 mV	0.1% + 80 mV	0.1% + 400 mV	0.025% + 0.01% FS	0.025% + 0.01% FS
Resolution	100 mV	5 mV	30 mV	40 mV	200 mV	16/60 µV	1/10 µV
Current to							
Ranges	0 to 4A/0 to 0.4A	0 to 60 A	0 to 16 A	0 to 12 A	0 to 3 A	0-0.6/6/60 A	0-0.6/6/60 A
Accuracy	0.3% + 8 mA/0.3% + 0.8mA	0.1% + 60 mA	0.1% + 16 mA	0.1% + 12 mA	0.1% + 3mA	0.3/5/15 mA	0.3/5/15 mA
Resolution	1 mA/0.1mA	15 mA	4 mA	3 mA	0.75 mA	0.1/0.9/9 µA	0.1/0.9/9 µA
Power							
Ranges		0 to 400 W	0 to 400 W	0 to 400 W	0 to 400 W	0 to 50/500 W	0 to 50/500 W
Accuracy		0.25% +1 W	0.25% + 1W	0.25% + 1 W	0.25% + 1 W	0.1% + 0.1% FS	0.1% + 0.1% FS
Resolution		0.1 W	0.1 W	0.1 W	0.1 W	5 mW/50 mW	5 mW/50 mW
Instrument Features	PFC Front End Protection: input over-current & over-voltage transients, output over-current, short-circuit, over-temperature	Constant Power Operating Envelope Protection: over-voltage, under-voltage, current limit, over-current trip, over-temperature, UUT discharge, short-circuit				Modal operation: constant current, constant voltage, constant resistance, constant power, transient generator, short-circuit Remote sense Self-test Closed-cover calibration Fully parallelable Protection: over-power, over-current, over-voltage, reverse-voltage, over-temperature	

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DC Electronic Loads

High-Flexibility Load System L4000

- ❑ **Mix and match up to 16 loads per 10 1/2-inch chassis**
- ❑ **To 10 kW and 500 V**
- ❑ **16 types of DC electronic load modules**
- ❑ **Reconfigurable under program control**



APPLICATION

The L4000 DC Electronic Load System is the most flexible, mid-to-high-power DC electronic load system available. It is intended for applications requiring a great number of different types of modular DC loads that can be either paralleled under program control or physically reconfigured as test requirements change. This high degree of flexibility is achieved through a unique chassis that will accept five different sizes of DC load modules, each of which is available in three maximum voltage limits.

BROAD CONFIGURABILITY

The L4000 DC Electronic Load System can be configured to match an unusually wide assortment of loading requirements by selecting from sixteen types of electronic load modules. These include 150, 300, 600, 1200 and 2500 W power levels at 60, 200, 400 & 500 V maximums. The smaller electronic loads require fewer card slots, thereby allowing up to 16 loads in a single 10 1/2-inch chassis. The user can mix and match electronic load modules and voltage ranges to suit any type of loading requirement. Additional electronic load modules and higher power levels can be provided through a slave chassis controlled through the same GPIB address.

VIRTUAL LOADING

To take flexibility a step further, similar DC electronic load types can be grouped as "virtual loads" under program control thus minimizing the number of different load modules needed to meet a particularly wide variety of requirements. The benefits of this flexibility are lower test station costs, less rack space and ease of adapting to future load requirements.

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L4000 SERIES SPECIFICATIONS

LOAD-MODULE SELECTION

Max Power	Voltages Ranges*	Current Ranges	Card Slots Required
150 W	1.5 to 60 VDC 3 to 200 VDC 10 to 400 VDC	0 to 0.5 A 0 to 2 A 0 to 5 A 0 to 20 A 0 to 60 A	1
300 W	1.5 to 60 VDC 3 to 200 VDC 10 to 400 VDC	0 to 2A 0 to 5 A 0 to 20 A 0 to 60 A	1 (max of 8 per chassis)
600 W	1.5 to 60 VDC 3 to 200 VDC 10 to 400 VDC	0 to 2 A 0 to 5 A 0 to 20 A 0 to 60 A	2
1200 W	1.5 to 60 VDC 3 to 200 VDC 10 to 400 VDC	0 to 2 A 0 to 5 A 0 to 20 A 0 to 60 A	4
2500 W	1.5 to 60 VDC 3 to 200 VDC 10 to 400 VDC	0 to 40 A 0 to 120 A 0 to 240 A	8

*Loads go into feed forward mode below rated voltaget (5% current accuracy).

PROGRAMMABLE FEATURES

Current Mode
- **Accuracy:** 0.2% FS
- **Resolution:** 0.025% FS

Voltage Mode
- **Accuracy:** 0.2% FS
- **Resolution:** 0.038% FS

Resistance Mode
- **Accuracy:** 2% V/I when operating below the programmed nominal voltage

Power Mode
- **Accuracy:** 2%
- **Resolution:** 2.5 W
- **Implementation:** Software

PROTECTION CIRCUITS

Over-power: Load modules will power limit at 100% of maximum rated power. Failure message is provided.

Over-temperature: Load modules will go into a high impedance state. Full shut-down and error message provided if heat sink temperature exceeds 75° C.

Reverse polarity: Load modules contain reverse polarity diode on outputs. Diodes will short-circuit the UUT when in the presence of reverse DC voltage.

Anti-saturation: Load modules will go into a feed-forward-only mode when the voltage supplied by the UUT is less than rated voltage. 5% current programming accuracy is provided down to a few hundred millivolts.

Auto shut-off: Inhibits load current until UUT voltage reaches ≈ 0.5 VDC. Auto shut-off mode eliminates turn-on current spikes.

Over-current: If the current of any load module is greater than 0.5% of specified current setting an error will be indicated. Load module will switch to high impedance state.

Over/under-voltage: If the voltage of any load module is less than 0.5 VDC or greater than 110% of the maximum specified voltage for the load, an error will be indicated. The load module will switch to high impedance state.

Remote inhibit: A switch closure which provides an interlocking means for disabling each load directly.

Self-test: Complete built-in self-test of the controller and all load modules. Firmware cycles each load through a series of confidence tests. Two levels of self-test are available.

Standard: 85% fault detection, bypassing the power drive FETs.

Optional: 100% fault detection. Includes power FETs. Implemented by an internal power supply used to simulate actual UUT.

PARALLEL OPERATION

One controller can control up to 32-load modules. Any load can be used in parallel with any other load(s) or used independently. Controller is integrated in 10½-inch load chassis.

READBACK INSTRUMENTATION

DC Current: 0 to FS current
- **Accuracy:** 0.25% FS
- **Resolution:** 0.03% FS

DC Voltage: 0 to FS voltage
- **Accuracy:** 0.25% FS
- **Resolution:** 0.03% FS

Load Temperature: 15° C to 90° C
- **Accuracy:** 5 degrees
- **Resolution:** 12 bits

POWER DISSIPATION

5000 W continuous power dissipation per chassis with front and rear fans. Load modules will operate at 10% above rated power for short periods.

OPTIONAL FEATURES

Front Panel Keyboard/Display: 20-element, multifunction keypad with 40-character vacuum fluorescent display

Enhanced Self-test: Includes internal 5 A power supply to simulate actual UUT during execution of selftest. Self-test isolates to failed power FET.

MATE (CIIL): MATE-verified hardware

Slide Rails: Per customer specifications

Transient Generator
- **Internal Pulsing:** 10 to 10 kHz
  - **Accuracy:** ± 1Hz
  - **Resolution:** 2.5 Hz
- **Duty Cycle:** 1% to 99%
  - **Accuracy:** 5% of set
  - **Resolution:** 1%
- **Programmable Slew Rate**
  - **Range:** 0.1 mA/μS-10 A/μS
  - **Resolution:** 4 bits

External Modulation: 100 to 10 KHz

Lab Windows™ Software Drivers

PHYSICAL

Chassis with integrated controller and 16-load slots (HWD):
10.5 x 16.88 x 25-inch

Auxiliary Load Chassis (16-load slots):
8.75 x 16.88 x 25-inch

Operating Temperature: 0° C to 50° C

Humidity: 30% to 95% non-condensing

Input: 115 VAC ± 10%, 60 Hz, 4 A

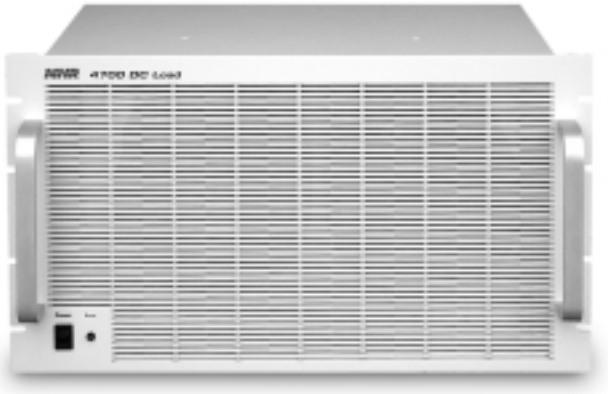
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DC Electronic Loads

High-Power Load 4700 Series

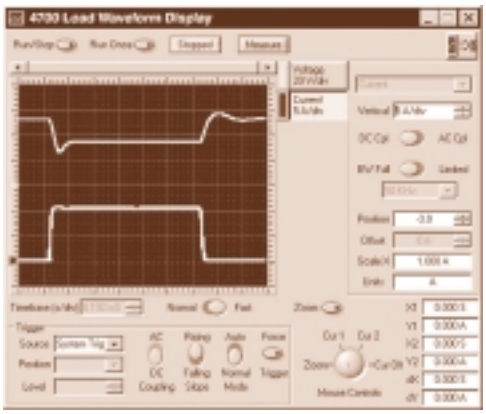
- ❑ **6 kW / 120 V / 1200 A in a 10½-inch chassis**
- ❑ **Full current at 1 V and operation down to 0.15 V**
- ❑ **Field parallelable to 36 kW**



The 4700 Series Electronic Loads are intended for testing applications that require a high-current / high-power load with precision internal measurement capability, exceptional reliability, combined with the inherent simplicity and safety of air cooling. The Load is controlled through a PC soft-panel or within an automatic test station. Typical power conversion products to be tested include higher-power DC supplies, telecom rectifiers, fuel cells and batteries.

PRECISION INTERNAL MEASUREMENTS

The 4700 Load is designed to eliminate the need for separate external instruments to make precision measurements. With an internal measurement system equivalent to a 5½-digit DMM, high accuracy measurements of voltage, current and power are provided. Additional benefits of the built-in measurement capability are faster testing speeds and the cost savings from a more streamlined tester architecture.



LOW VOLTAGE OPERATION

To meet the low voltage testing requirements of newer power subsystems, certain batteries and fuel cells, the 4700 Load delivers full-current down to 1 V. Even lower voltage operation down to 0.15 V can be achieved at linearly reduced current levels.

PARALLELABLE FOR HIGHER POWER/CURRENT

To meet higher power/current applications, a single "master" load can be paralleled and synchronized with up to five "slave" loads for a total capability of up to 36 kW. Special circuitry assures no single load will reach its over-power limits ahead of others. This built-in versatility assures the test engineer need only buy what is required today, knowing that should more power be needed in the future, additional loads can be added with no special modifications.

FAULT TOLERANT

The 4700 Load is designed to be protected and keep running under just about any condition, even certain internal component failures. Protection against over-voltage, over-current, over-power, reverse-voltage, and internal over-temperature have always been standard. New is controller intelligence that monitors subcircuit performance and redistributes the current load as necessary. This fault tolerant technique allows the user to continue testing with proper warning of a fault condition. Further load robustness is assured through an extensive startup self test and a closed-cover calibration capability.

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MODEL 4700 SPECIFICATIONS

RATINGS

Max. Power/Chassis	6 kW
Parallelable Chassis	6 for a total of 36kW
Current/Chassis	1200 A
Voltage	0.15 - 120 V

PROGRAMMABLE MODES

Constant Current	
Range	0 - 120, 1200 A/Chassis
Accuracy (Set)	0.12% S + 0.08% R
Resolution	0.025% R
Constant Voltage	
Range	0.15 - 6.6, 20, 66, 120V
Accuracy	0.05% S + 0.05% R
Resolution	0.025% R
Constant Power	
Range	I R x V R
Accuracy	1% S + 1% R
Resolution	0.025% R
Constant Resistance	
Range	15% - 3000% of VR/IR
Accuracy	2 % S
Slew Rate	
Range	6 A/S - 120 A/µS
Resolution	< 2 µS
Accuracy	1% ± 5µS
Short Circuit	
Range	120A 1200A
Resistance	8.33mΩ 833 µΩ
Current	200A 2000A
Transient Generator	
Repetition	Single Burst or Continuous
Settings	100
Period	40 µS - 20 S (0.05Hz - 25kHz)
Delay	20 µS - 20 S
Resolution	10 µS
Accuracy	1% ± 5 µS

CONTROL

PC	Pentium-class µP with 16 MB RAM, SVGA display 800x600 resolution, 500 MB hard drive
OS	Windows 95, 98, 2000
Communications	RS 232
Drivers	Microsoft ActiveX/COM-compliant (VB, VC++) National Instruments LabVIEW, LabWindows/CVI

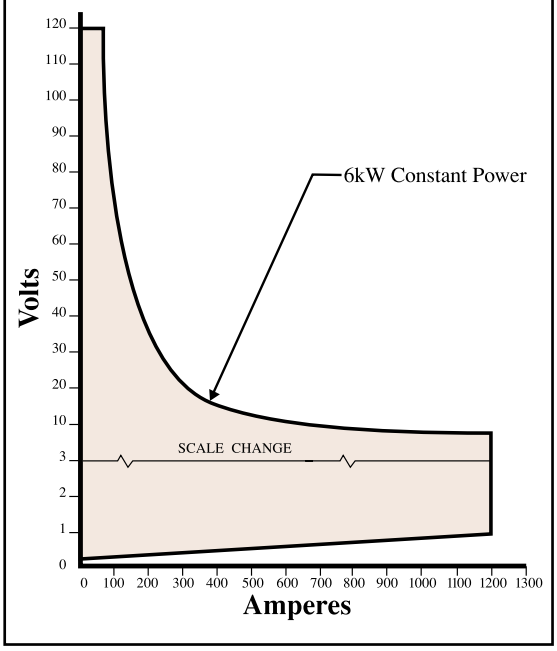
PHYSICAL

Size (HWD)	10.5 x 19 x 22-inch
Weight	130 lbs
Operating Temperature	0 - 40° C at full power and <75% duty cycle
Input Power	115/230 VAC ± 10%, 47 - 63 Hz

MEASUREMENT INSTRUMENTATION

Current	
Range	0 - 120, 1200 A
Accuracy	0.12% M + 0.06% R
Resolution	0.0015% R
DC Voltage	
Range	0-6.6, 66, 166 V
Accuracy	0.01% M + 0.02% R
Resolution	0.0015% R
Power	
Range	IR x VR
Accuracy	I Accuracy + V Accuracy
Resolution	0.0015% R
Waveform Capture	
Bandwidth	12.5 kHz
Accuracy	1% R
Channels	V & I, MUX'd
Digitizing Rate	50 - 50K Samples/S
Memory	4K Samples/Channel
Timebase	20 µS - 8 S
Triggering	System or External

OPERATING ENVELOPE



Specifications apply at 23° +/- 5° C after a 10 minute warm up and are subject to change without notice.

Abbreviation Key
R - Range
S - Set
M - Meter Reading

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DC Electronic Loads

Point-of-Load Converter Test 4800 Series

- ❑ **Slew Rate to 300 A/µS**
- ❑ **200 W Power**
- ❑ **0.5 to 6.0 V, 0 to 160 A**
- ❑ **High Bandwidth Current & Voltage Monitors**



The 4800 Series High Slew Rate DC Electronic Loads are designed for the testing of Point-of-Load DC-DC Converters (i.e., Power Pod VRMs) used for the latest generation of GHz processors. These loads emulate the specific processor power load as accurately as possible, particularly fast transient current changes. Each 4800 Load is remotely controlled by NH Research's Model 430 DC-DC Converter Test System. It is an ideal solution for automated characterization or production testing of this new type of converter.

TIGHT COUPLING

The 4800 Load is packaged in a compact 5-inch cube directly coupled to the converter-under-test through a minimal inductance connector. Each Load must be specified with the appropriate connector to match the target processor interface. Through this immediate coupling, slew rates of up to 300 A/µS along with full current down to 0.5 V are achieved thereby simulating what the processors might demand of the converters. A separate Load would be required for each converter or converter output.

VERSATILE CAPABILITY

In addition to the programmable slew rates, currents and digital control, the 4800 Load accurately measures voltage, current and power. For instance, the increasing important efficiency measurement can now be made to 0.25%. Setup and control is accomplished through an intuitive instrument soft-panel on the S430 Test System PC. With these features, the Load eclipses first-generation, bench-top loads by assuring faster, more accurate and repeatable converter/VRM performance measurements.

FLEXIBLE TEST SYSTEM CONFIGURATION AND CONTROL

Controlling the 4800 Load is the well-proven S430 Converter Test System, a full capability ATE with a powerful Test Executive network-ready and with SPC analysis packages. With this configurable test platform, a variety of stimulus and load configurations are possible to address everything from single unit engineering characterization to multiple unit production testing.

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4800 SERIES SPECIFICATIONS

RATINGS

Power	200 W
Slew Rate	10 A/µS - 300 A/µS
Current	0 - 160 A
Voltage	0.5 - 6.0 V

PROGRAMMABLE MODES

Constant Current	
Range	0 - 160 A
Accuracy (Set)	0.06% S + 0.04% R
Resolution	0.025% R
Transient Generator	
Ramp	10 A/µS - 0.1 A/µS
Fast Transient	0.1 A/µS - 300 A/µS
Repetition	Single Burst or Continuous
Settings	100
Period	1 µS - 10 S
Delay	500 nS - 10 S
Resolution	100 nS
Accuracy	0.1% +/- 200 nS

CONTROL

The 4800 Load is controlled and powered by its individual Controller Module located within a S430 Converter Test System shown below.

Specifications apply at 23* +/- 5* C after a 10 minute warm up.



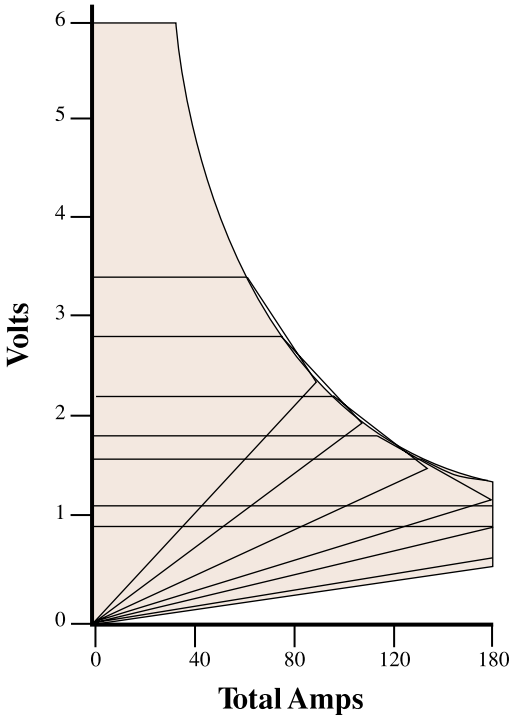
MEASUREMENT INSTRUMENTATION

Current	
Range	0 - 160 A
Accuracy	0.06% M + 0.03% R
Resolution	0.0015% R
DC Voltage	
Range	0 - 6.0 V
Accuracy	0.01% M + 0.02% R
Resolution	0.0015% R
Power	
Range	0 - 200 W
Accuracy	0.25 % Typical
Digital	
Inputs	8 TTL-level
Outputs	7 Open collector (VID)
Noise, Peak, Frequency & Timing	Performed on S430 Test System
Triggering	System or External

PHYSICAL

Size (HWD)	5 x 5 x 6-inch
Weight	3 lbs
Operating Temperature	0 - 35° C at full power
Connectors	Voltage Monitor, Current Monitor, Digital & Test System Remote Controller

OPERATING ENVELOPE



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DC Electronic Loads

VXIbus Loads
Models 81201/81210

- ❑ **50 W/75 V/1 & 10 A-rated**
- ❑ **Glitch-free transitions from constant resistance to constant current operation**
- ❑ **Selectable current slew rates**



VXIbus electronic loads are designed for low-power output loading of DC power supplies or other devices needing loads with either static or dynamic modes of operation. Each load is a self-contained instrument on a single-slot, C-size VXIbus module making them ideal for applications where size is important. The 81201 and 81210 can be integrated into any VXIbus-based test system, but they are particularly well-suited to the 8100*i* Family of automatic power supply test systems from NH Research.

HIGHER POWER APPLICATIONS

Although rated at 50 W continuous power, the 81201 and 81210 can be used at considerably higher ratings. Since most testing is carried out at substantially lower duty-cycles, analog control circuitry is used to continuously monitor internal conditions and permit the load to increase its power handling capability with decreasing duty-cycles. Because the monitoring is realtime, the protection circuitry is tripped only if the load is in danger of being damaged. This allows testing for short periods or at small duty-cycles at power levels in excess of the steady-state specifications. If continuous higher power is required, two or more loads may be operated in parallel.

PROGRAMMABLE TRANSIENT RESPONSE

The 81201 and 81210 offer programmable transient response. Programmable rise-times permit the dynamic characteristics of the load to more closely approximate the operational conditions in which the unit-under-test (UUT) will be expected to function. In applications requiring testing under complex loading profiles, an analog input is provided which allows external control of the load current over the load's full operating ranges. Using an arbitrary waveform generator, almost any required loading profile can be realized.

GLITCH-FREE TRANSITIONS

UUTs such as switching power supplies must be turned on into a constant-resistance load before testing with a constant-current load can begin. The 81201 and 81210 provide a glitch-free transition from one mode to another; the supply under test does not see the load current fall to zero during the mode transition. In the short-circuit mode of operation, an SCR in parallel with the shorting relay is used to give a fast, low-resistance short. It is possible to shift from any mode to any other mode of operation under program control.

ADVANCE PROTECTION AND CALIBRATION

The loads are fully protected against various fault conditions including over-voltage, reverse-voltage, over-current, over-power and over-temperature. All calibration and configuration data is stored in an EE-PROM, resulting in fast, internal "no pots" calibration of setting and metering values with available calibration software. The result is a rugged, highly-reliable load that requires minimal maintenance.

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81201/210 SPECIFICATIONS

LOADS

Power Rating

Continuous: 50 W

Intermittant: See Figure 1

Voltage: 0 to 75 VDC (See Figures 2 & 3)

Operating Modes: Constant-current, constant-resistance, short-circuit, power-limit

Model:	81201	81210
Current:	0 to 1.0 A	0 to 10 A
Constant-current Mode		
Resolution:	250 µA	2.5 mA
Accuracy:	0.4% ± 4 mA	0.4% ± 40 mA
Regulation:	10 mA	10 mA
Constant-resistance Mode		
Resolution:	12 bits	12 bits
Accuracy:	5%	5%
Short-circuit Mode		
Impedance:	0.05 Ω	0.05 Ω
Transition		
Time:	2.0 µsec	2.0 µsec
Metering		
Current		
Resolution:	250 µA	2.5 mA
Voltage		
Resolution:	20 mV	20 mV
Current		
Accuracy:	0.4% ± 2 mA	0.4% ± 20 mA
Voltage		
Accuracy:	0.5% ± 75 mV	0.5% ± 75 mV
Noise (PARD)		
RMS:	0.8 mA	6.0 mA
Peak to Peak:	3.0 mA	20.0 mA

Analog Current Monitor

Range: 0 to 8 VDC (0 to FS)

Accuracy: 5%

Analog Programming Voltage

Bandwidth: 20 kHz

Voltage Range: 0 to -10 VDC (0 to FS)

Accuracy: 5% ± 5 mA (81201)
5% ± 50 mA (81210)

Protection

Over-power: Dynamic monitor

Over-temperature: Heatsink limited to 90° C

Over-voltage: SCR and relay crowbar

Reverse-voltage: 125% of maximum (Constant-resistance Mode)

Error Messages: Error conditions reported to the VXIbus Resource Manager

Programmable Transient Response

Fast: 5 ± 2 µsec

Medium: 50 ± 20 µsec

Slow: 500 ± 200 µsec (transition times, 10% to 90% of final value)

Isolation: ± 500 V between any input and chassis ground

Calibration: Both setting and metering are carried out in software. Calibration constants are stored in internal EEPROM. No mechanical adjustments are required.

VXIbus

Type: VXIbus register-based device

Module Identification: MODID function per VXIbus specification and front panel LED

PHYSICAL

Mechanical: Single-slot C-size

Interface Mating Connectors

Load: Molex 09-50-3061 (6-pin housing)

Control & Measurement: A 87922-1 (10-pin housing)

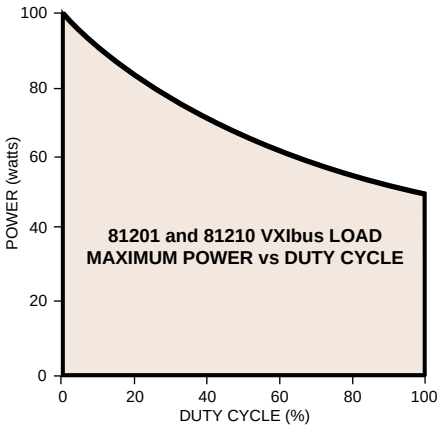


Figure 1

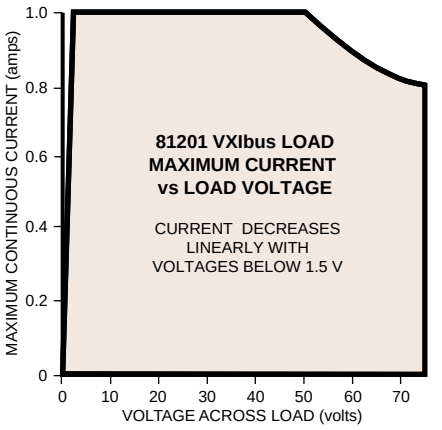


Figure 2

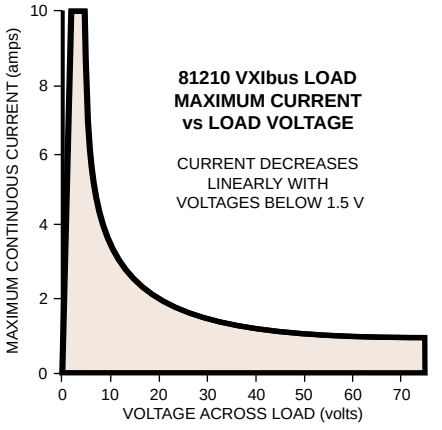


Figure 3

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AC Electronic Loads

Programmable Power & Crest-Factor Loads 4600 Series

- ❑ **3 kW/30 A Module expandable to 180 kW**
- ❑ **12 built-in, high-accuracy measurements**
- ❑ **Graphical User Interface and LabVIEW™ drivers**



4600 Series AC Electronic Loads are intended for applications that require the entire range of non-linear loading in order to thoroughly test AC-output power conversion products such as uninterruptible power supplies (UPS) and inverters. The benefits of such a wide range of load control is to assure product performance under every possible "real-world" operating condition.

NON-LINEAR LOADING

The advantages of testing with a programmable, non-linear (i.e., any power-factor and crest-factor) load are substantial. The most significant being the ability to rapidly test products at every possible loading condition that could ever be encountered in the field. The other major benefit is the ability to instantly switch over to a different set of loading conditions as product testing needs dictate. With such versatility, a higher level of product quality is assured and manufacturing test throughput is increased.

BROAD OPERATING ENVELOPE

To cover the most common UPSs and inverters, the 4600 Series is offered in two power ranges, 3000 W and 6000 W. Higher power levels can be achieved by utilizing additional units in parallel. All units operate from 50 to 350 VAC and in several emulation modes such as constant-current, voltage, resistance, power as well as short-circuit.

A "ONE-BOX" TEST SOLUTION

With a PC controller, everything needed to test most AC-output products is contained within the 4600 Series instrument. In addition to the flexible load control, twelve high-accuracy measurements include voltage, current, peak-current, frequency, crest-factor, power-factor, and true power. Even the real-time voltage, current and power waveforms are displayed on the PC soft-panel. This ability to make all measurements internally eliminates multiple, external measurement instruments plus associated signal matrixing and interconnect wiring. In this manner the 4600 Series provides for a more compact, less costly and considerably faster test solution.

SYSTEM OR MANUAL APPLICATIONS THROUGHOUT THE COMPANY

The applications for the 4600 are many. While primarily designed for final functional test within an automatic test system, the instrument can be used with just a PC for engineering design verification testing, incoming quality inspection and returned unit repairs. To facilitate rapid integration and immediate use, the 4600 is supplied with an intuitive graphic user interface plus LabVIEW™ drivers.

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4600 SERIES SPECIFICATIONS

RATINGS	4600-3	4600-6
Maximum Power	3000 W/ø	6000 W/ø
RMS current	30 A	60 A
Maximum peak current	90 A	180 A
RMS voltage	50 to 350 V	50 to 350 V
Maximum peak voltage	500 V	500 V
Frequency	45 to 440 Hz	45 to 440 Hz
Phase operation	1 and 3	1 and 3

PROGRAMMABLE FEATURES		4600-3	4600-6
Constant current mode	Range (RMS) Accuracy Resolution	0 to 30 A 0.2% FS 0.05% FS	0 to 60 A 0.2% FS 0.05% FS
Constant voltage mode	Range (RMS) Accuracy Resolution	50 to 350V 0.2% FS 0.05% FS	50 to 350 V 0.2% FS 0.05% FS
Constant resistance mode	Range Accuracy Resolution	2.5 to 100 Ω 100 to 1000 Ω 1% FS 5% FS 0.05% FS	1.25 to 50 Ω 50 to 500 Ω 1% FS 5% FS 0.05% FS
Constant power mode	Range Accuracy Resolution	3000 W 0.5% FS 0.1% FS	6000 W 0.5% FS 0.1% FS
Crest factor	Range Accuracy Resolution	1.414 to 3.5/90 A 1% FS 0.1% FS	1.414 to 3.5/180 A 1% FS 0.1% FS
Power factor Two-quadrant operation	Range Accuracy Resolution	0 to 1, lead/lag 1% FS 0.1% FS	0 to 1, lead/lag 1% FS 0.1% FS
Short-circuit mode	Max surge current (up to 50 msec) Max RMS current Max voltage drop	300 A 30 A 2.5 V	600 A 60 A 2.5 V

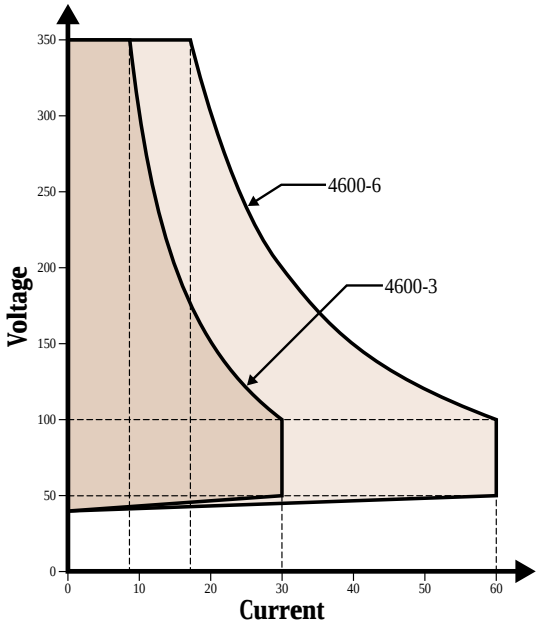
CONTROL REQUIREMENTS	
PC	Pentium-class µp with 32 MB RAM, SVGA Video 800 x 600 resolution, 90 MB HD
Operating System	Windows™ 98, 2000, NT
Communication	RS232

PHYSICAL CHARACTERISTICS	4600-3	4600-6
Size (HWD)	10.5 x 16.9 x 25-inch	21 x 16.9 x 25-inch
Weight	40 lb	80 lb
Remote Sensing	Max 2 V drop between sense & load	
Protection Circuitry	Over-current, voltage, power and temperature	
Isolation	1 kV between input & chassis ground	
Operating Temperature	0° to 50°C Maximum continuous and peak power are derated 20% from 38° to 50°C	
Input Power	115 or 220 VAC ± 10%, 47 to 63Hz	

Notes:
1. All specifications apply for 23° C ± 5° C, except as noted.
2. Consult factory for higher power load.

READBACK INSTRUMENTATION		4600-3	4600-6
RMS current	Range (RMS) Accuracy Resolution	0 to 30 A 0.2% FS 0.1% FS	0 to 60 A 0.2% FS 0.1% FS
Peak current	Range (RMS) Accuracy Resolution	0 to 90 A 0.5% FS 0.1% FS	0 to 180 A 0.5% FS 0.1% FS
RMS voltage	Range Accuracy Resolution	50 to 350 V 0.1% FS 0.05% FS	50 to 350 V 0.1% FS 0.05% FS
Peak voltage	Range Accuracy Resolution	50 to 500 V 0.5% FS 0.1% FS	50 to 500 V 0.5% FS 0.1% FS
Frequency	Range Accuracy Resolution	45 to 440 Hz 0.1% FS 0.05% FS	45 to 440 Hz 0.1% FS 0.05% FS
True power	Range Accuracy Resolution	0 to 3000 W 0.5% FS 0.1% FS	0 to 6000 W 0.5% FS 0.1% FS
Apparent power	Range Accuracy Resolution	0 to 10.5 kVA 0.3% FS 0.1% FS	0 to 21 kVA 0.3% FS 0.1% FS
Reactive power	Range Accuracy Resolution	0 to 10.5 kVAR 0.3% FS 0.1% FS	0 to 21 kVAR 0.3% FS 0.1% FS
Peak power	Range Accuracy Resolution	0 to 45 kW 1% FS 0.1% FS	0 to 90 kW 1% FS 0.1% FS
Resistance	Range Accuracy Resolution	2.5 to 100 Ω 100 to 1000 Ω 1% FS 5% FS 0.05% FS	1.25 to 50 Ω 50 to 500 Ω 1% FS 5% FS 0.05% FS
Crest factor	Range Accuracy Resolution	1.4142 to 3.5 0.5% FS 0.05% FS 0.1% FS	1.4142 to 3.5 0.5% FS 0.05% FS 0.1% FS
Power factor	Range Accuracy Resolution	0 to 1, lead/lag 0.5% FS 0.1% FS	0 to 1, lead/lag 0.5% FS 0.1% FS

OPERATING ENVELOPE



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