OPERATOR'S MANUAL

MST-MHT SERIES
POWER MODULE

DIGITALLY CONTROLLED POWER MODULE SYSTEM

1/9 RACK SIZE 200 WATT POWER MODULES
FOR USE WITH KEPCO POWER MODULE CONTROLLERS

KEPCO INC.
An ISO 9001 Company.

CE

MODELS

**MST 6-20MHT, MST 15-12MHT,
MST 25-8MHT, MST 36-5MHT,
MST 55-3.5MHT, MST 75-2.5MHT,
MST 100-2MHT, MST 150-1.2MHT**

IMPORTANT NOTES:

1) This manual is valid for the following Model and associated serial numbers:

MODEL	SERIAL NO.	REV. NO.

2) A Change Page may be included at the end of the manual. All applicable changes and revision number changes are documented with reference to the equipment serial numbers. Before using this Instruction Manual, check your equipment serial number to identify your model. If in doubt, contact your nearest Kepco Representative, or the Kepco Documentation Office in New York, (718) 461-7000, requesting the correct revision for your particular model and serial number.

3) The contents of this manual are protected by copyright. Reproduction of any part can be made only with the specific written permission of Kepco, Inc.

Data subject to change without notice.

P/N 228-1924-r2

KEPCO®
THE POWER SUPPLIER™

KEPCO, INC. ● 131-38 SANFORD AVENUE ● FLUSHING, NY. 11355 U.S.A. ● TEL (718) 461-7000 ● FAX (718) 767-1102
email: hq@kepcopower.com ● World Wide Web: www.kepcopower.com

Conditions of Conformance
MST "Modular" products

When this product is used in applications governed by the requirements of the EEC, the following restrictions and conditions apply:

1. For European applications, requiring compliance to the Low Voltage Directive, 73/23/EEC, this power supply is considered a component product, designed for "built in" applications. Because it is incomplete in construction, the end product enclosure must provide for compliance to any remaining electrical safety requirements and act as a fire enclosure. (EN61010-1:2001 Cl. 6, Cl. 7, Cl.8, and Cl. 9)

2. This power supply is designed for stationary installation, with mains power applied via a KEPCO Rack Adapter.

3. This power supply is considered a Class 1 (earthed) product. It is intended for use as part of equipment meant for test, measurement and laboratory use, and is designed to operate from single phase, three wire power systems. This equipment must be installed in a specifically designed KEPCO rack adapter and within a suitably wired equipment rack, utilizing a three wire (grounded) mains connection. See wiring section of this manual for complete electrical wiring instructions. (EN61010-1:2001 Cl.6.10.1)

4. This power supply has secondary output circuits that are considered hazardous.

5. The output wiring terminals of this power supply have not been evaluated for field wiring and, therefore, must be properly configured by the end product manufacturer prior to use.

6. This power supply employs a supplementary circuit protector in the form of a fuse mounted within its enclosure. The fuse protects the power supply itself from damage in the event of a fault condition. For complete circuit protection of the end product, as well as the building wiring, it is required that a primary circuit protection device be fitted to the branch circuit wiring. (EN61010-1:2001 Cl. 9.5)

7. Hazardous voltages are present within this power supply during normal operation. All operator adjustments to the product are made via externally accessible switches, controls and signal lines as specified within the product operating instructions. There are no user or operator serviceable parts within the product enclosure. Refer all servicing to qualified and trained Kepco service technicians.

SAFETY INSTRUCTIONS

1. Installation, Operation and Service Precautions

This product is designed for use in accordance with EN 61010-1 and UL 3101 for Installation Category 2, Pollution Degree 2. Hazardous voltages are present within this product during normal operation. This product is designed for use in a KEPCO Rack Adapter product. Operation of this product without a rack adapter should never be attempted. The product should never be operated with the cover removed unless equivalent protection of the operator from accidental contact with hazardous internal voltages is provided.

There are no operator serviceable parts or adjustments within the product enclosure. Refer all servicing to trained service technician.

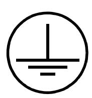
Source power must be removed from the product prior to performing any servicing.

This product is designed for use with nominal a-c mains voltages indicated on the rating nameplate.

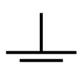
2. Grounding

This product is a Class 1 device which utilizes protective earthing to ensure operator safety.

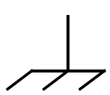
The PROTECTIVE EARTHING CONDUCTOR TERMINAL must be properly connected prior to application of source power to the product (see instructions on installation herein) in order to ensure safety from electric shock.



PROTECTIVE EARTHING CONDUCTOR TERMINAL - This symbol indicates the point on the product to which the protective earthing conductor must be attached.



EARTH (GROUND) TERMINAL - This symbol is used to indicate a point which is connected to the PROTECTIVE EARTHING TERMINAL. The component installer/ assembler must ensure that this point is connected to the PROTECTIVE EARTHING TERMINAL.

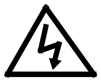


CHASSIS TERMINAL -This symbol indicates frame (chassis) connection, which is supplied as a point of convenience for performance purposes (see instructions on grounding herein). This is not to be confused with the protective earthing point, and may not be used in place of it.

3. Electric Shock Hazards

This product outputs hazardous voltage and energy levels as a function of normal operation. Operators must be trained in its use and exercise caution as well as common sense during use to prevent accidental shock.

This symbol appears adjacent to any external terminals at which hazardous voltage levels as high as 500V d-c may exist in the course of normal or single fault conditions.



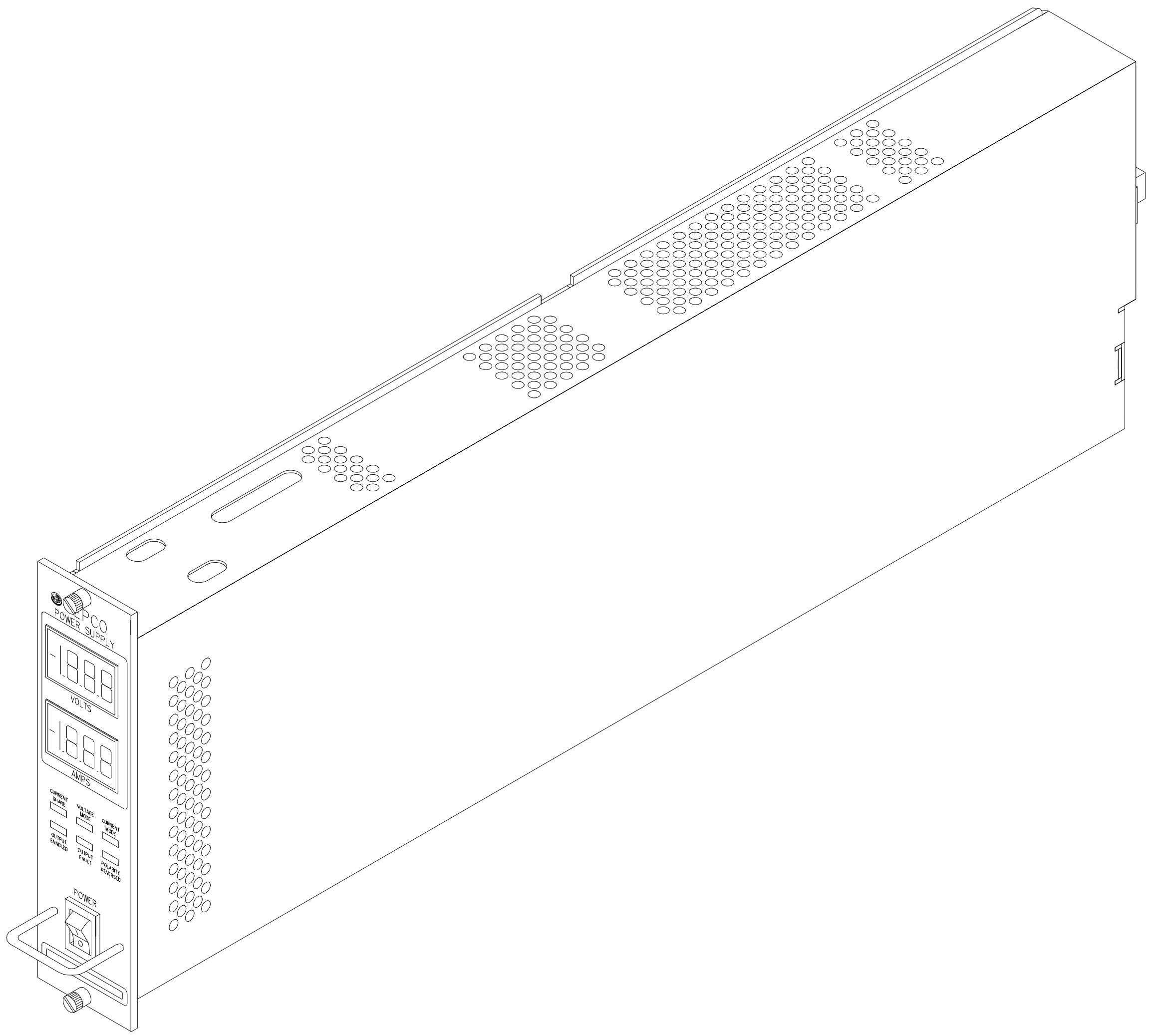
This symbol appears adjacent to any external terminals at which hazardous voltage levels in excess of 500V d-c may exist in the course of normal or single fault conditions.

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES



3041110

FIGURE 1-1. MST POWER SUPPLY

SECTION 1 - INTRODUCTION

1.1 SCOPE OF MANUAL

This manual contains instructions for the installation, operation, and maintenance of the MST-MHT series of 200 Watt, voltage and current stabilized d-c programmable power supplies (power modules) manufactured by Kepco, Inc., Flushing, New York, U.S.A. when controlled by a Kepco Model MST 488-27HT Controller.

Details regarding the MST 488-27HT Controller can be found in the MST 488-27HT Controller Operator Manual which is available for download from the Kepco website at:

www.kepcopower.com/support/opmanls.htm#mst

Details regarding the RA 55 Connector Adapter can be found in the Kit 219-0618 RA 55 Connector Adapter Kit Instruction Sheet which is available for download from the Kepco website at:

www.kepcopower.com/support/opmanls.htm#kit

1.2 DESCRIPTION

The Kepco MST-MHT 200 Watt Series (Figure 1-1) consists of eight, single-output models as shown in Table 1-1. MST-MHT Series Power Modules are designed to provide a functional drop-in replacement for Keysight/Agilent/HP Series 66000A© power modules. These models also include the following additional features: autoranging a-c input, PFC to meet IEC/EN requirements, current share, hot swap, built-in polarity reversal, constant current mode and greater power (180W to 200W).

MST-MHT power modules employ a switch mode preregulator for high efficiency and power density, with linear output stabilization for accuracy and resolution. Their modular, plug-in design with 7" x 1-3/4” cross-section allows nine independently controlled modules to be mounted abreast in a standard (19" x 7" x 20.9") Kepco Model RA 55H rack adapter or 5 modules in a standard (9.6” x 7” x 20.9”) Kepco Model CA 400H case.

Each Power Module is controlled digitally via the IEEE 1118 2-wire serial bus (“Bitbus”) with 12 bits of resolution over the entire voltage and current ranges. Voltage and current are displayed on LED panel meters, and read back over the control bus with an accuracy of 0.06%. Operating status is displayed on front panel LED indicators and read back over the bus.

An MST-MHT Power Module can be removed and installed without powering down the system if the module POWER switch is set to OFF. Employing current-sharing for parallel operation, they may be “hot-swapped” for redundant (N+1) applications. MST-MHT Power Supplies can be operated with universal a-c input power sources (90-264Vac, 47-63Hz) and incorporate power factor correction (0.98) to meet EN 61000-3-2. MST-MHT Power Modules can also be configured in series for higher than rated output voltages (500V d-c maximum)

.

TABLE 1-1. MST-MHT MODEL PARAMETERS

MODEL	OUTPUT VOLTAGE Adjustment Range (V d-c)	OVERVOLTAGE (V d-c)		OUTPUT CURRENT Maximum (Amps)			RIPPLE/NOISE		EFFICIENCY (100% Load 120V a-c)
		Programmable (max.)	Hardware Trigger (See Note)	45° C	55° C	65° C	mV rms	mV p-p	
MST 6-20MHT	0-6	7.2	7.4	20	16	12	2	5	51%
MST 15-12MHT	0-15	18	18.3	12	9.6	7.2	3	7	61%
MST 25-8MHT	0-25	30	30.6	8	6.4	4.8	4	8	62%
MST 36-5MHT	0-36	42	42.8	5	4.0	3.0	5	10	63%
MST 55-3.5MHT	0-55	66	67.3	3.5	2.8	2.1	9	15	64%
MST 75.2.5MHT	0-75	90	91.8	2.5	2.0	1.5	12	20	64%
MST 100-2MHT	0-100	120	122.4	2.0	1.6	1.2	15	35	66%
MST 150-1.2MHT	0-150	180	183.6	1.2	1.0	0.7	20	45	66%
NOTE: Minimum 2% above Programmable (max.),									

1.3 SPECIFICATIONS

The MST-MHT Series electrical and mechanical specifications are listed in Tables 1-1 and 1-2.

TABLE 1-2. MST-MHT GENERAL SPECIFICATIONS

SPECIFICATIONS		RATING/DESCRIPTION	CONDITION
INPUT			
A-C Voltage	nominal	100-250V a-c	Single phase
	range	90-264 Va-c	Brownout Voltage ≤ 85Vrms
Frequency	nominal	50-60 Hz	At >63 Hz, input leakage current exceeds specifications
	range	47 – 63 Hz (400 Hz)	
Input Current	maximum	3.6A rms	90V a-c Input
Current Harmonics		Within EN 61000-3-2 limits	Any source condition, rated load
Efficiency	minimum	See Model Table 1-1	120V a-c, rated output Load
EMI		FCC Class A, CISPR 11 Class A	Conducted Emissions
Leakage Current	120V a-c, 60Hz	<0.5 mA	
	240V a-c, 50Hz	<1.0 mA	
Power Factor		0.98 min.	All source conditions, full load
EMC		Complies with IEC 61326-1, Class A	
OUTPUT			
Source Effect	Voltage	0.001%	90 – 132, 176 – 264V a-c, any load condition
	Current	0.005%	
Load Effect	Voltage	±0.002% or 1mV, whichever is greater	10% to 100% Load at E_{MAX}, any source condition
	Current	±0.005%	10% to 100% Load at I_{MAX}
Temperature Effect	Voltage	0.01%/°C	Any source/load condition (0 – 45° C)
	Current	0.02%/°C	

TABLE 1-2. MST-MHT GENERAL SPECIFICATIONS (CONTINUED)

SPECIFICATIONS		RATING/DESCRIPTION	CONDITION
Time Effect (drift)	Voltage	0.01%	0.5 – 8.5 hours Any source/load condition
	Current	0.02%	
Programming Resolution	Voltage	12 Bits, 0.024%	% of E_{MAX}
	Current	12 Bits, 0.024%	% of I_{MAX}
Data Read Back Accuracy	Voltage	0.1%	% of E_{MAX}
	Current	0.12%	% of I_{MAX}
Transient Recovery Time		100 Microseconds (500 Microseconds for MST 6-20MHT)	Return to within stabilization band from 50% load step
Turn On/Off Overshoot		None	Any source/load condition
Error Sense		0.5V maximum/wire	Any source/load condition
MISCELLANEOUS			
Temperature		0° to +65° C, start from –20°C (see Table 1-1)	Operating
		–40° to +85° C	Storage
Humidity		0 to 95% RH	Non-condensing Operating & Storage
Shock		20G 11 msec ±50% half sine	3 axes, 3 shocks each axis, non-operating
Vibration		5 – 10Hz 10mm double amplitude	Non-operating, 1 hour each axis
		10 – 55 Hz 2G	
Altitude		Sea level to 10,000 ft.	Any source/load condition
Isolation (Output – Case)		±500 V d-c	
Display	Voltage	3.5 Digit LED, red	Front panel, For reference only
	Current	3.5 Digit LED, red	
Status Indicators		Voltage Mode	Green LED
		Current Mode	Amber LED
		Current Share	Amber LED
		Output Enabled	Green LED
		Polarity Reversed	Green LED
		Output Fault	Red LED
Output Enable		Built in power and sense relay	
Polarity Reversal		Built in power and sense relay	
Parallel Connection		N+1 redundancy, forced current share	Currents divided equally
Overvoltage protection (OVP)		Programmable: Up to 120% of nominal voltage	See Par. 3.7.3
	Hardware Trigger:	Tracks output setting, power shutdown if OVP > 120% of nominal voltage	See Par. 3.7.2
Overcurrent Protection (OCP)		Tracks output current. Shutdown selectable upon either exceeding rated current by 10% or immediate	See Par. 3.7.3
Overtemperature		Thermostat	See PAR. 3.7.4
Open sense wire		Automatic detection with power shutdown	See PAR. 3.7.6
Backup current limit		Tracks output current at 110%	

TABLE 1-2. MST-MHT GENERAL SPECIFICATIONS (CONTINUED)

SPECIFICATIONS		RATING/DESCRIPTION	CONDITION
PHYSICAL			
Type of Construction		Enclosed, plug-in style includes status LEDs, two digital meters, handle and ON/OFF switch	
Cooling		Internal D-C Cooling Fans	Exhaust to rear
Module Dimensions	English	7” x 1.83” x 20”	Refer to Figure 1-1
	Metric	178 x 46.5 x 508 mm	
Weight	English	8 lbs.	
	Metric	3.6 Kg.	
Load Connection		Mates with Positronic POW-R-LOK Series 6 pin connector, Kepco P/N 143-0458 (See Figure 2-6 and Table 2-5),	Mating connectors provided with MST-MHT compatible rack adapters
Source Connection		Mates with Molex Minifit, Jr. Series 10 pin connector, Kepco p/n 143-0544 (See Figure 2-6)	Mates with a-c backplane in MST-MHT compatible rack adapters

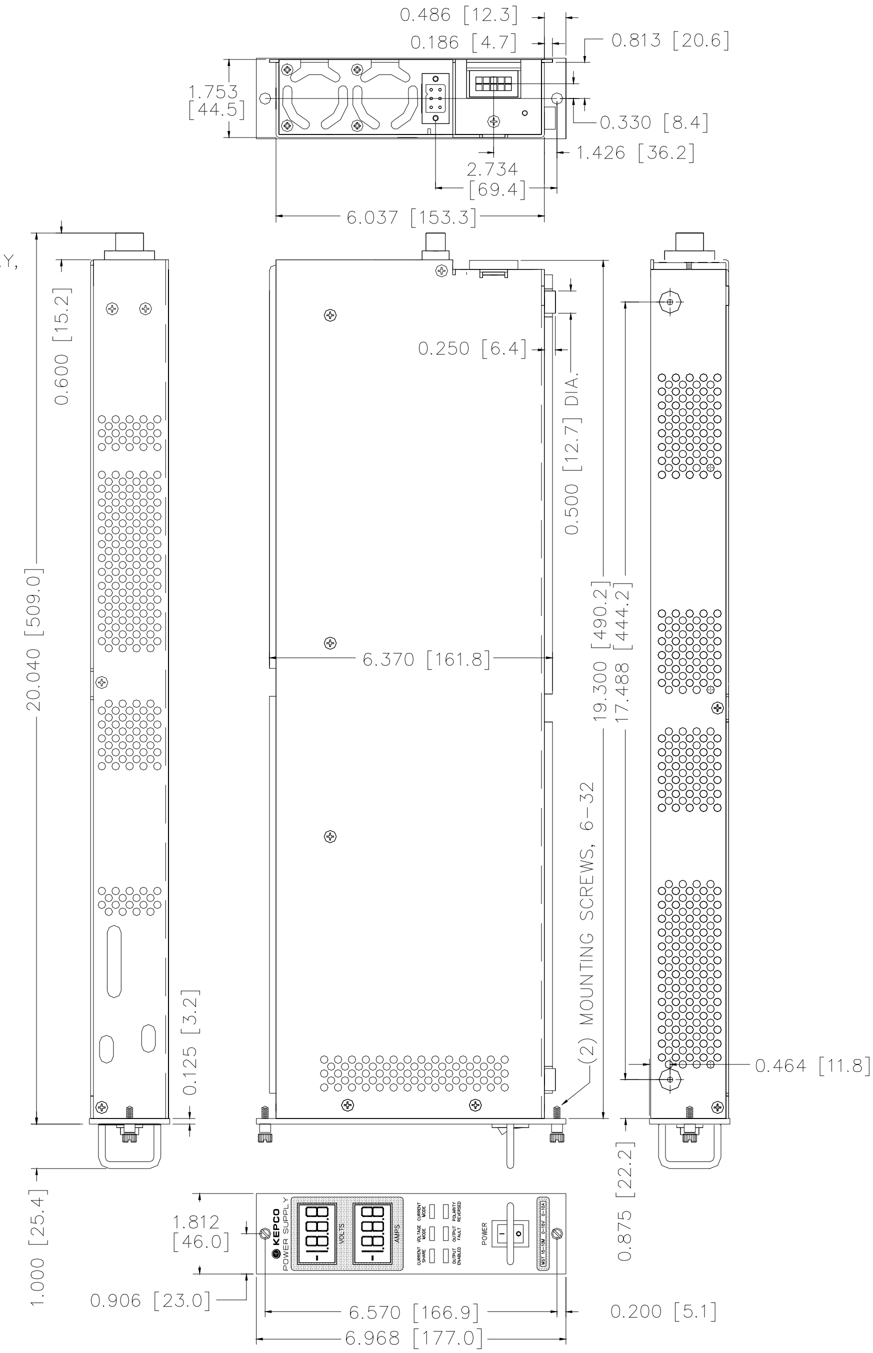
1.4 FEATURES

1.4.1 CONTROL/PROGRAMMING

Control of the MST-MHT Power Module is via the IEEE 1118 2-wire serial bus operating at 375KHz; as many as 27 separate modules of the MST-MHT Series can be addressed via the bus. Decoders for RS232, IEEE-488 and VXI are available in modular form and stand-alone types. Controller Model MST 488-27HT plugs into a slot in a Model RA 55H Rack Adapter and allows host computers designed for RS232 or IEEE 488 bus communication to control the MST-MHT via the IEEE 1118 bus compatible with Keysight/Agilent/HP 66000© Series.

NOTES:

1. MATERIAL:
   A) CHASSIS & COVER: 0.064 THK. ALUM. 5052–H32.
   B) FRONT PANEL: 0.125 THK. ALUM. 6061–T6.
2. FINISH:
   A) CHASSIS & COVER: YELLOW IRIDITE.
   B) FRONT PANEL: KEPCO GRAY, HARTIN PAINT #15–22493.
3. DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS.
4. TOLERANCES:
   A) BETWEEN MOUNTING HOLES: ±1/64(±0.4).
   B) ALL OTHER DIMENSIONS: ±1/32(±0.8) EXCEPT AS NOTED.



3040955

FIGURE 1-1.   MST-MHT POWER SUPPLY, MECHANICAL OUTLINE DRAWING

1.4.2 STATUS INDICATORS

Six status indicators at the front panel provide operational information (see Table 2-2):

- VOLTAGE MODE
- CURRENT MODE
- CURRENT SHARE
- OUTPUT ENABLED
- POLARITY REVERSED
- OUTPUT FAULT

1.4.3 FRONT PANEL METERS

Two digital meters at the front panel provide displays of output voltage and current. These displays show 3.5 digits and are provided for reference only, accurate to 0.5% (typical) for voltage and 1.5% (typical) for current.

1.4.4 OUTPUT ENABLE/DISABLE AND POLARITY REVERSAL

The MST-MHT Power Module features integral relays to enable/disable the output. Separate relays are provided for power and sense connections. Disabling the MST-MHT as a voltage source means opening the connection between the power supply and its load. Disabling the MST-MHT as a current source means shorting the power supply's output terminals. Polarity reversal relays are installed, but not supported at this time. If polarity reversal is needed, refer to Kepco's MST Series.

1.4.5 PROTECTION

The MST-MHT Power Module incorporates the following protection circuits which cause the MST-MHT to automatically isolate the load and force power module output voltage and current to zero.

- Overvoltage protection: Automatic (non-adjustable) power shutdown if the output exceeds hardware trigger value specified in Table 1-1.
- Overcurrent protection: Programmable, tracks output current; disables output if output current exceeds programmed value (see PAR. 3.7.2).
- Overtemperature: Activated when the internal temperature exceeds a safe operating threshold (see PAR. 3.7.4).
- AC loss: Activated if loss of source power detected (see PAR. 3.7.5).
- Open power lead and sense wire: Activated if an open sense wire or open power lead is detected (see PAR. 3.7.6).

1.4.6 SERIES CONFIGURATIONS

The output of the MST-MHT Power Module “floats;” so that MST-MHT Power Modules can be connected in series to obtain higher output voltages, up to a maximum of ± 500 Volts d-c (±400 Volts d-c when Adapter KIT 219-0618 is installed on the OUTPUT connector at the rack adapter) referenced to the chassis (see PAR. 3.6).

1.4.7 PARALLEL CONFIGURATION

A parallel configuration may be employed for higher output current and for N + 1 redundant, “hot-swap” applications. When connected in a parallel configuration, MST-MHT Power Modules employ forced current sharing to ensure equal distribution of the load among all power modules, improving performance, reducing component stress, and increasing reliability (see PAR. 3.5).

1.5 OPTIONS

The HT option (HT appended to the Model Number, e.g., MST 6-20MHT) incorporates additional filtering to provide significant output noise reduction in the range of 1KHz to 10MHz, compatible with Keysight/Agilent/HP 66000© mainframe. Contact Kepco Sales Engineering for additional information regarding performance and availability of other options such as output current monitoring where a 0 to 2V signal corresponds to 0 to I_{NOM}.

1.6 ACCESSORIES

The MST-MHT Power Module is designed for installation in Kepco Rack Adapter Model RA 55H which accommodates nine 1/9 rack size power modules. With a 1/9 rack Controller module installed, the RA 55H will accommodate eight 1/9 rack power modules. Connecting cables and IEEE 1118 bus daisy chain terminations are supplied with the RA 55H Rack Adapter. Additional accessories are listed in Table 1-3.

TABLE 1-3. ACCESSORIES

ACCESSORY	PART NUMBER	USE
OUTPUT LOAD CONNECTOR ADAPTER (supplied with RA 55H Rack Adapter)	KIT 219-0618	Allows output load connections of up to 20 Amperes to MST-MHT power module not installed in RA 55H Rack Adapter (for advanced troubleshooting). Adapter is terminated at one end with mating connector for MST-MHT module output connector. The opposite end is terminated with 6 terminals having crimp-ready ring lugs used for output power, sensing, ground and load sharing connections. This adapter is typically used in conjunction with 118-0850 Input Power/ Communication Cable.
INPUT POWER/COMMUNICATION CABLE (Used for stand-alone module Communication/ calibration)	118-0850	Allows power and communication connections to MST-MHT power module not installed in RA 55H Rack Adapter (for advanced troubleshooting). Cable length is approximately 7 feet, terminated at one end with mating connector for MST-MHT module a-c input/control bus connector. The opposite end of the cable is split into two terminations, one a NEMA 5-20P a-c mains plug and the other a 9-pin D-sub connector that mates with the control bus connector of RA 55H (as well as CA 400H and MST 488-27HT). This cable is typically used in conjunction with Kit 219-0618 Output Load Connector Adapter.
MATING CONNECTOR (DC OUTPUT) (Used for Calibration)	142-0372	Mates with DC OUTPUT connector, Kepco P/N 143-0457 (Positronic POW-R-LOK Series 6 pin connector). This item is typically used in conjunction with 118-0850 Input Power/Communication Cable.
LOAD CONNECTOR PINS (Used for Calibration)	107-0327	Replacement pins for DC OUTPUT connector. This item is typically used in conjunction with 118-0850 Input Power/Communication Cable.

SECTION 2 - INSTALLATION

2.1 UNPACKING AND INSPECTION

This instrument has been thoroughly inspected and tested prior to packing and is ready for operation. After careful unpacking, inspect for shipping damage before attempting to operate. Perform the preliminary operational check as outlined in PAR. 2.7. If any indication of damage is found, file an immediate claim with the responsible transport service.

NOTE

If the Power Modules are shipped pre-installed in the RA 55H Rack Adapter, each module is secured to the RA 55H Rack Adapter by two shipping screws. These screws must be removed from the bottom of the rack adapter, otherwise the modules cannot be removed from the rack adapter.

2.2 TERMINATIONS AND CONTROLS

a. Internal Calibration Controls: Refer to Figure 2-2 and Table 2-1.

b. Front Panel: Refer to Figure 2-1 and Table 2-2.

c. Rear Panel: Refer to Figure 2-1 and Table 2-3.

TABLE 2-1. FUNCTIONS OF INTERNAL CONTROLS

REFERENCE DESIGNATION	CONTROL	PURPOSE
R49	+5 V REF	This is a primary adjustment for the analog circuits.
R11	E_O Zero	This control is used to adjust the output voltage of the Power Module to zero. E_O Zero calibrates the Power Module in the Voltage mode.
R51	I_O Zero	This control is used to adjust the output current of the Power Module to zero. I_O Zero calibrates the Power Module in the Current mode.
R50	Current Sensing Zero	This adjustment calibrates the current monitor amplifier to zero.
R52	Full Scale Current Adjust	This adjustment calibrates the programmed full scale value.
R47	V_{REF}	This is a full scale voltage adjustment.
R48	I_{REF}	This is a current read back accuracy adjustment.

2.3 A-C INPUT REQUIREMENT

MST-MHT Power Modules operate from single-phase a-c mains power over the specified voltage and frequency ranges without adjustment or modification.

2.4 COOLING

The power transistors and rectifiers in the MST-MHT Power Module are maintained within their operating temperature range by means of internal heat sink assemblies cooled by internal fans. PANEL OPENINGS AND THE TOP OF THE CASE MUST BE KEPT CLEAR FROM OBSTRUCTIONS TO INSURE PROPER AIR CIRCULATION. Maximum ambient temperature for installed MST-MHT modules is 45°C. See technical manuals for RA 55H or CA 400H rack adapters for detailed cooling requirements. Periodic cleaning of the power module interior is recommended.

TABLE 2-2. FRONT PANEL CONTROLS AND INDICATORS

CONTROL/INDICATOR	FUNCTION
POWER switch	Turns a-c power ON/OFF. CAUTION: DO NOT repeatedly toggle the POWER On/Off switch as this may cause unit to fault.
VOLTAGE MODE indicator - green LED	Goes on to indicate MST-MHT is operating as a voltage source (see PAR. 3.2.1).
CURRENT MODE indicator -amber LED	Goes on to indicate MST-MHT is operating as a current source (see PAR. 3.2.2).
POLARITY REVERSED indicator - green LED	Goes on when negative output programmed while the output is enabled (see PAR. 3.3).
OUTPUT ENABLE indicator - green LED	Goes on to indicate power relays are closed and output regulator is enabled (see PAR. 3.4).
OUTPUT FAULT indicator - red LED	Goes on to indicate internal power module fault detected (see PAR. 3.7).
CURRENT SHARE indicator - amber LED	Goes on to indicate that unit is operating as “slave” module when used in a parallel configuration (see PAR. 3.5).
VOLTS meter	Displays output voltage.
AMPS meter	Displays output current.

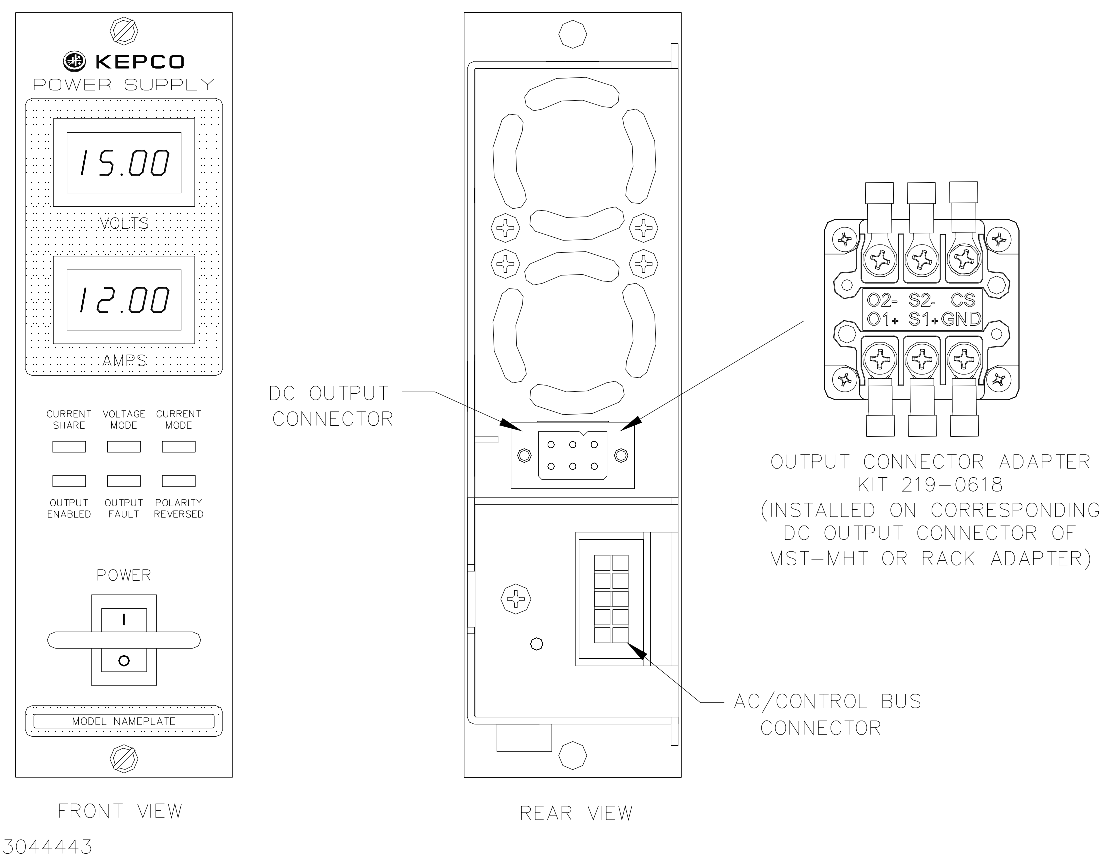


FIGURE 2-1. FRONT AND REAR VIEWS OF THE MST-MHT POWER MODULE

TABLE 2-3. REAR TERMINATIONS

REAR TERMINATION	FUNCTION
AC Input/Control Bus connector	Connects the MST-MHT Power Module to single-phase a-c power, safety ground, and two-wire IEEE 1118 bi-directional Control Bus.
DC output connector (mates with Connector Adapter Kit 219-0618, installed on either MST-MHT power module or RA 55-H rack adapter.	Connects the MST-MHT Power Module output lines, sensing lines, frame ground lines and current share bus to the load via Kit 219-0618 Connector Adapter. Kit 219-0618 provides enhanced filtering of the output and 6-32 screws for lug wiring.

2.5 INSTALLATION/REMOVAL

The MST-MHT Power Module is designed to be rack-mounted in an RA 55H Rack Adapter. Refer to Figure 1-1 for outline dimensions. For installation in confined spaces, care must be taken that the surrounding environment does not exceed the maximum specified ambient temperature (45° C); see PAR. 2.4. The MST-MHT Power Module may be shipped either individually, or already installed in an RA 55H Rack Adapter. Follow power module installation procedures in RA 55H Instruction Manual.

2.5.1 CHANGING CONTROL BUS ADDRESS (NODE OR CHANNEL NUMBER)

Each MST-MHT Power Module connected to the IEEE 1118 bus must have a unique address (also referred to as node or channel number). For MST-MHT modules, this address is a secondary address. The primary address is reserved for the MST 488-27 Controller which then addresses the MST-MHT modules on the bus using the secondary address. The secondary address from 0 to 30 is selected by DIP selector switch S1 accessed through the top of the unit (see Figure 2-2) and can be changed in accordance with Table 2-4. This address is set at Kepco to 1.

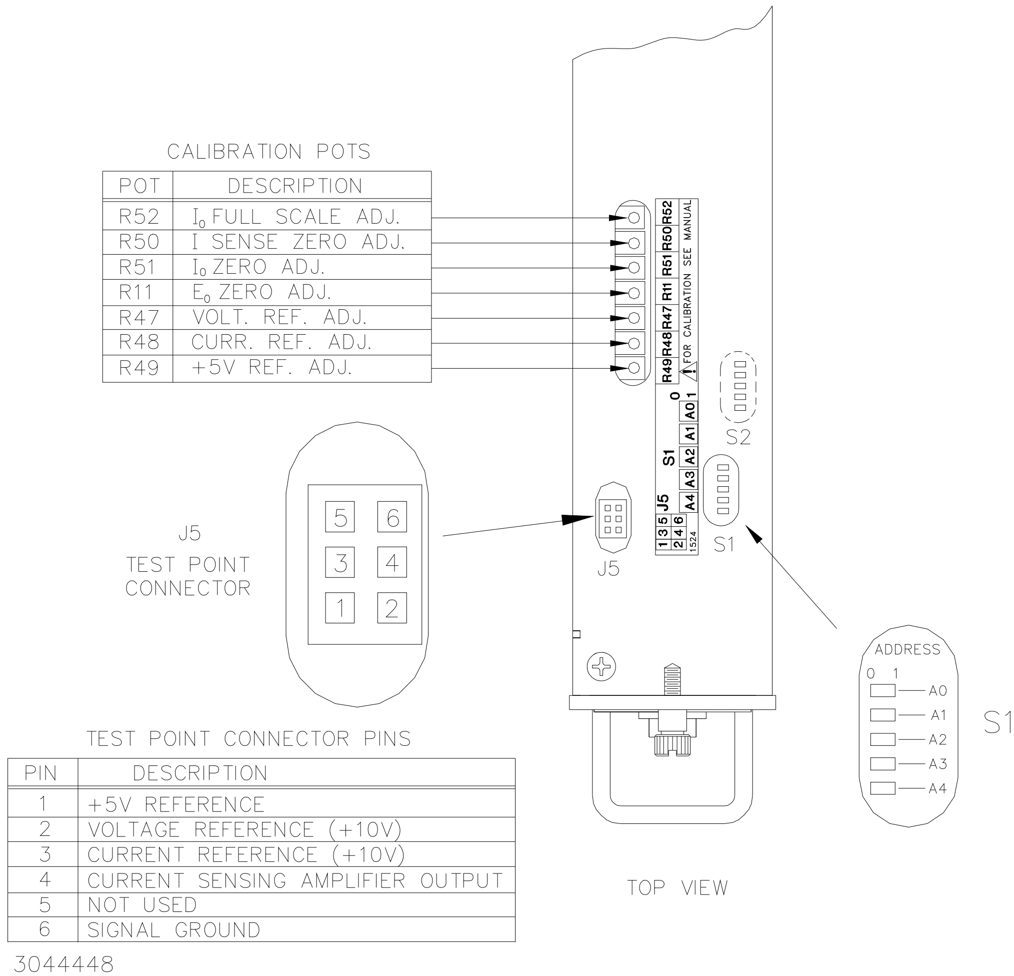
NOTES: 1. Although 31 unique addresses are provided, the maximum number of instruments which can be managed by the Kepco Controller is 27.

: 2, Secondary address 0 is not supported if the MST488-27HT controller is commanded to operate as an MST 488-27 (non-HT suffix) unit by sending SYST:SET SA0. For this case the secondary address switch value becomes the node (primary) address of the MST power module. See the MST 488-27 (non-HT suffix) Programmer manual for more details on this non-standard mode of operation.

TABLE 2-4. SECONDARY ADDRESS SELECTION

DECIMAL ADDRESS	SELECTOR SWITCH S1 SECTION (SIGNAL LINE)				
	A4	A3	A2	A1	A0
0	1	1	1	1	1
1	0	0	0	0	1
2	0	0	0	1	0
3	0	0	0	1	1
4	0	0	1	0	0
5	0	0	1	0	1
6	0	0	1	1	0
7	0	0	1	1	1
8	0	1	0	0	0
9	0	1	0	0	1
10	0	1	0	1	0
11	0	1	0	1	1
12	0	1	1	0	0
13	0	1	1	0	1
14	0	1	1	1	0
15	0	1	1	1	1
16	1	0	0	0	0
17	1	0	0	0	1
18	1	0	0	1	0
19	1	0	0	1	1
20	1	0	1	0	0
21	1	0	1	0	1
22	1	0	1	1	0
23	1	0	1	1	1
24	1	1	0	0	0
25	1	1	0	0	1
26	1	1	0	1	0
27	1	1	0	1	1

NOTE:
1. See PAR. 2.5.1for details regarding the use of secondary addressing
2. If the Power Module is already installed in a Rack Adapter and it is necessary to change the secondary bus address, the Power Module must first be removed from the Rack Adapter as described in PAR.2.5.3 below.



CALIBRATION POTS

POT	DESCRIPTION
R52	I_0 FULL SCALE ADJ.
R50	I SENSE ZERO ADJ.
R51	I_0 ZERO ADJ.
R11	E_0 ZERO ADJ.
R47	VOLT. REF. ADJ.
R48	CURR. REF. ADJ.
R49	+5V REF. ADJ.

TEST POINT CONNECTOR PINS

PIN	DESCRIPTION
1	+5V REFERENCE
2	VOLTAGE REFERENCE (+10V)
3	CURRENT REFERENCE (+10V)
4	CURRENT SENSING AMPLIFIER OUTPUT
5	NOT USED
6	SIGNAL GROUND

FIGURE 2-2. CONFIGURATION AND CALIBRATION CONTROLS AND TEST POINTS

2.5.2 INSTALLATION

To install the MST-MHT Power Module in the RA 55H Rack Adapter or CA 400H case, proceed as follows:

1. The factory setting for the control bus address is 1; if address 1 is already in use, refer to PAR. 2.5.1 to change the address setting.

NOTE: If the Power Module is already installed in a Rack Adapter and it is necessary to change the control bus address, the Power Module must first be removed from the Rack Adapter as described in PAR. 2.5.3 below.

2. To ensure full engagement of the module interconnect to the RA 55H Rack Adapter or CA 400H case, pull out the two slotted captive thumb screws (at the front of the Module) and turn counterclockwise until the threads engage.

CAUTION

When inserting a Module into a Rack Adapter under power, the Module POWER switch must be placed in the OFF position prior to insertion.

3. Align slots of the Module with the guides of the Rack Adapter and insert Module into Rack Adapter slot. Secure with the two thumb screws (maximum torque applied to thumb screws is 10 foot-lbs).

2.5.3 REMOVAL

To remove the Power Module from the RA 55H Rack Adapter or CA 400H case, proceed as follows:

CAUTION

When removing a Module from a Rack Adapter under power, the Module POWER switch must be placed in the OFF position prior to extraction.

1. Loosen the two slotted captive thumb screws that hold the Module in place in the Rack Adapter until they disengage from the Rack Adapter.

2. Extract the module from the Rack Adapter using the front panel handle.

2.6 GROUNDING

Interconnections linking a stabilized Power Module to an a-c power source and a load are critical for both performance considerations and safety requirements. For optimum performance certain rules must be observed. These rules are described in detail in the following paragraphs.

2.6.1 SAFETY GROUNDING

National and international safety standards set procedures for the grounding of a metal cover and chassis of an instrument connected to an a-c power source.

When properly installed in the RA 55H Rack Adapter, the Power Module chassis is connected to the RA 55H safety ground terminal via the GROUND pins of the AC/Control Bus connector (Figure 2-6). For operation of the MST-MHT Power Module outside the RA 55H Rack Adapter, consult Kepco Applications Engineering for assistance.

WARNING

RA 55H RACK ADAPTER MUST ALWAYS BE GROUNDED WHEN CONNECTED TO AN A-C POWER SOURCE.

2.6.2 D-C (OUTPUT) GROUNDING

D-C output connections are those between the Power Module and the load, including remote sensing connections. Despite precautions to eliminate noise such as shielding and twisted wire-pairs, output connections may pick up radiated noise of a wide frequency. To minimize such undesired effects, one side of the Power Module output/load may be grounded. Pin 4 of the DC

Output connector (or GND terminal of Adapter Kit 219-0618 if installed at the rack adapter) is connected to chassis (frame) ground. Although the d-c output is isolated from chassis or ground up to ± 500 V d-c (±400V d-c if Adapter Kit 219-0618 is installed), in certain applications the user may elect to terminate either the positive or negative terminals to chassis ground in order to optimize system performance.

Successful d-c grounding depends on careful analysis of the system operation; only general guide lines are provided here. One of the major points, however, is to avoid ground loops. Ground loops are created when two or more points of different ground potentials in the output circuit are grounded. An undesired signal (noise) is developed that is superimposed on the load (output potential). A way to avoid ground loops is to check for points of resistance to ground. Differences in ground potential can be avoided if the output circuit is completely isolated. A single point can then be selected along the Power Module output circuit and returned to ground with a single wire. This method is dependent on the specific application.

2.7 PRELIMINARY CHECK-OUT

2.7.1 REQUIRED EQUIPMENT

- Host computer w/communication cable for selected controller
- Kepco Controller (See PAR. 1.4.1).
- RA 55H or CA 400H rack adapter; alternative is to use Input Power/Communication Cable (see Table 1-3)
- Load Interface Cable or mating load connector (see Table 1-3)
- Digital Voltmeter (DVM)
- Switch (SPST) rated 32V d-c, 1A

2.7.2 INITIAL SETUP

Initial set-up is as follows (See Figure 2-3):

1. Connect the Unit under test (UUT) to the computer/controller interface (refer to the appropriate Controller Instruction Manual and to the Rack Adapter (RA 55H or CA 400H) Instruction Manual for source power connections). NOTE: An Alternative configuration using the Input Power Communication cable in place of the rack adapter may be used.

2. Install the MST-MHT Power Module into a vacant rack adapter slot (see PAR. 2.5.2).

3. Configure the Load Connector Adapter and connect DVM as shown in Figure 2-4.

CAUTION: DO NOT repeatedly toggle the power ON/OFF switch as this may cause unit to fault.

4. Apply a-c power first to the MST-MHT power module(s) by setting Power ON/OFF switch on front panel to ON., then apply a-c power to the Controller.

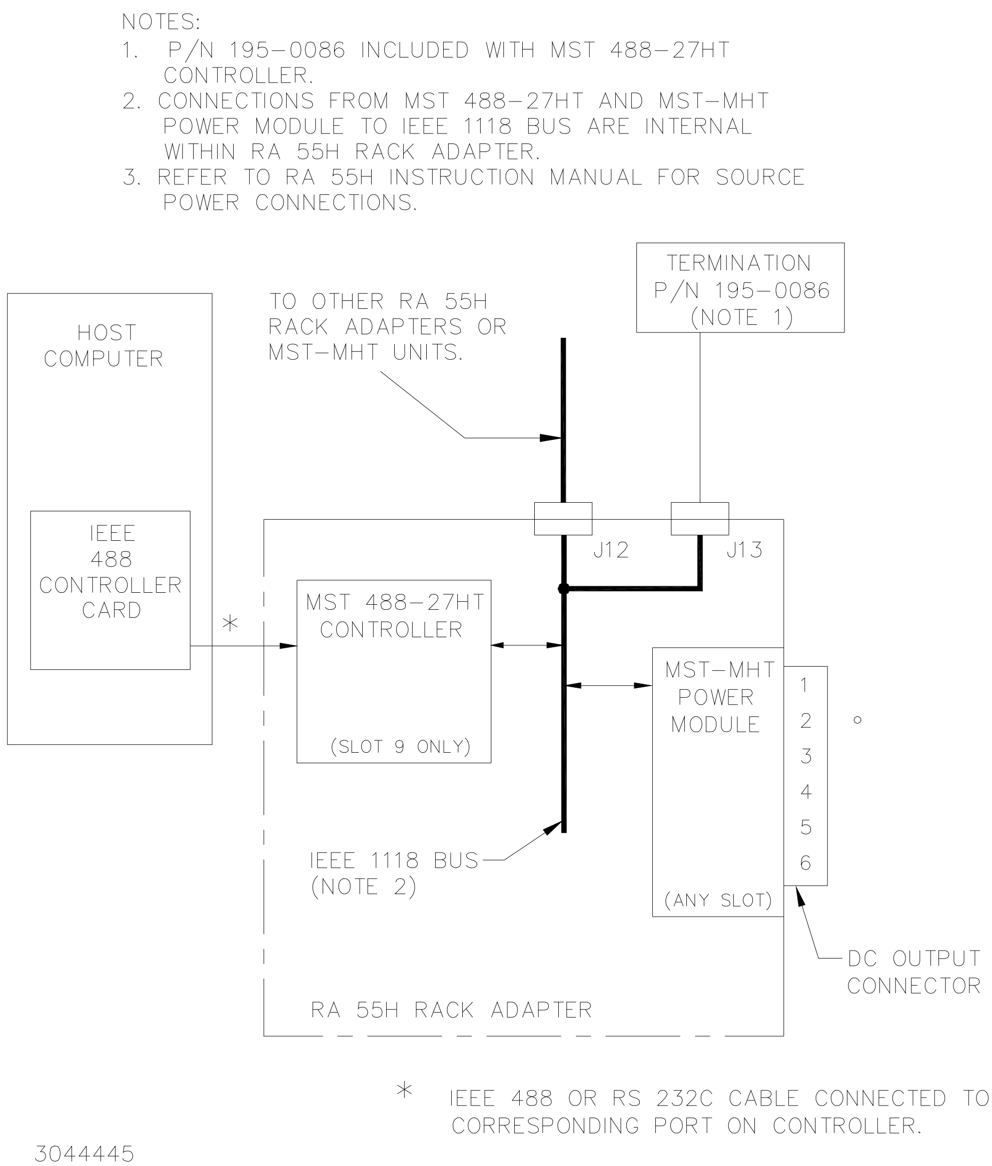


FIGURE 2-3. INITIAL CHECKOUT SETUP

5. Set switch S1 (Figure 2-4) to CLOSE SENSE position.

NOTE: If the sequence in step 4, above, is reversed (i.e., a-c power applied to the Controller first and MST-MHT power modules last), the operator must send an IEEE 488 Device Clear command via the Host Computer prior to issuing other commands.

For proper time delays between commands refer to PAR. 3.1.2. For details on the SCPI commands, refer to the Instruction Manual for the applicable controller (see PAR. 1.4.1).

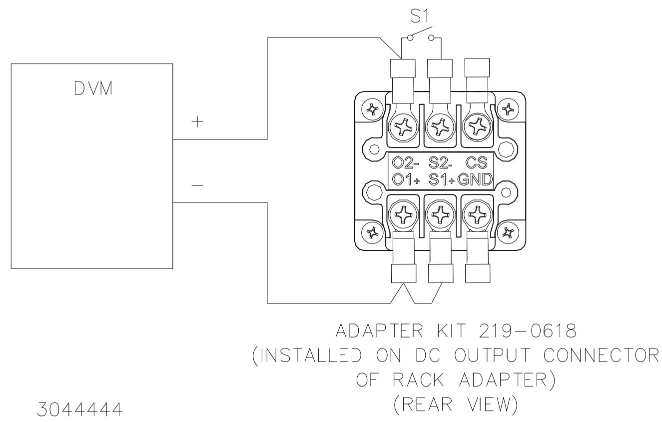


FIGURE 2-4. DC OUTPUT CONNECTOR CONFIGURATION FOR PRELIMINARY CHECKOUT

2.7.3 CHECKOUT PROCEDURE

The following checkout procedure requires commands to be issued by the host computer to the MST 488-27HT Controller in order to program the power module or read back information (voltage, current or status) from the power module; it does not include the IEEE 488 SCPI Bus Commands.

Each module must be assigned a unique GPIB address. The MST 488-27HT controller is the primary address and the MST-MHT power module is the secondary address. All commands are sent to this pair of addresses during the checkout procedure.

1. Issue command from the host computer to initialize the Power Module.
   `*RST`

2. Issue commands from the host computer to set the MST-MHT Power Module to Voltage Mode, program output voltage to $+E_{MAX}$, current limit to I_{MAX} and enable the output; e.g. for MST 36-5MHT, issue the following commands:
   `VOLT 36,:CURR 5;:OUTP ON`

NOTE: The commands used in the following steps use the MST 36-5MHT as an example; substitute the appropriate values for $\pm E_{MAX}$ for other models. E_{MAX} is the maximum output voltage of the unit listed in Table 1-1; I_{MAX} is the maximum output current of the unit as listed in Table 1-1 for 45° C.

3. Verify that VOLTAGE MODE and OUTPUT ENABLED indicators on front panel are on and VOLTS meter on front panel indicates E_{MAX}.

4. With DVM connected across terminals O1+ and O2– of the DC Output connector (Figure 2-4) verify that DVM reads $+E_{MAX}$ (e.g. for MST 36-5MHT DVM reads 36V d-c).

5. Issue command from the host computer to read back voltage.
   `MEAS:VOLT?`
   Verify that readback voltage is $+E_{MAX}$(e.g. 36V for MST 36-5MHT).

6. Set switch S1 (Figure 2-4) to OPEN SENSE position. Verify that the unit responds as described in 3.7b.

7. Set switch S1 (Figure 2-4) to CLOSE SENSE position. Set power switch to OFF, then ON, to reset the unit. Then power cycle the MST 488-27HT controller.

8. Send the following command from the host computer:
   `VOLT:PROT 10`
   Set switch S1 (Figure 2-4) to OPEN SENSE position; verify OUTPUT ENABLED indicator on front panel goes off and unit responds as described in PAR. 3.8.1.

9. Verify that DVM connected across terminals O1+ and O2– of DC Output connector reads 0V.

10. Reset the unit per PAR. 3.7.1.

11. Either a) short the load, b) select a load which will sustain current mode operation or c) connect a short across terminals O1+ and O2– of DC Output connector.

12. Issue the following commands from the host computer:
    ```
    OUTP:OFF
    FUNC :MODE CURR
    CURR 5 ; VOLT 36
    ```

13. Verify that CURRENT MODE indicator on front panel is ON and AMPS meter on front panel indicates I_{MAX} (e.g. 5A for MST 36-5MHT).

14. Issue the following command from the host computer:
    `OUTP:ON`

15. Verify that unit is in current mode: CURRENT MODE indicator on front panel is ON, AMPS meter on front panel indicates I_{MAX} (e.g. 5A for MST 36-5MHT), and the VOLTS meter indicates the voltage drop based on the load resistance, or if load is shorted, the VOLTS meter indicates the voltage drop based on the load wire resistance

16. Issue the following commands from the host computer:
    `MEAS:CURR?`

17. Verify that the read back current is I_{MAX} (e.g. 5A for MST 36-5MHT) and is about same as the current showing on front panel AMPS meter. NOTE: This is the current set by CURR command at step 12

18. Issue the following commands from the host computer:
    `MEAS:VOLT?`

19. Verify that read back voltage (voltage across sense lines) is about same as the voltage showing on the front panel VOLTS meter. This is the external measured voltage across the load regulation point (where MST sense lines are connected).

2.8 POWER MODULE TO LOAD INTERFACE

The general function of a voltage or current stabilized Power Module is to deliver rated output to the load. The load may be fixed or variable; resistive, capacitive, or inductive; and may be located close to or far away from the Power Module. The Power Module is designed for varied applications. The aim of the following paragraphs is to instruct the user in the interface of the Power Module to the load.

The perfect interface between a Power Module and load insures optimum performance. To approach this state of operation, one must be familiar with certain requirements, such as inter-connection guidelines, Ohm's Law and a-c theory.

Load Wire Selection - A stabilized d-c Power Module is not an ideal voltage or current source with zero output impedance (voltage mode) or infinite output impedance (current mode): All voltage sources have some amount of impedance which increases with frequency and all current sources have impedance which decreases with frequency (see Figure 2-5).

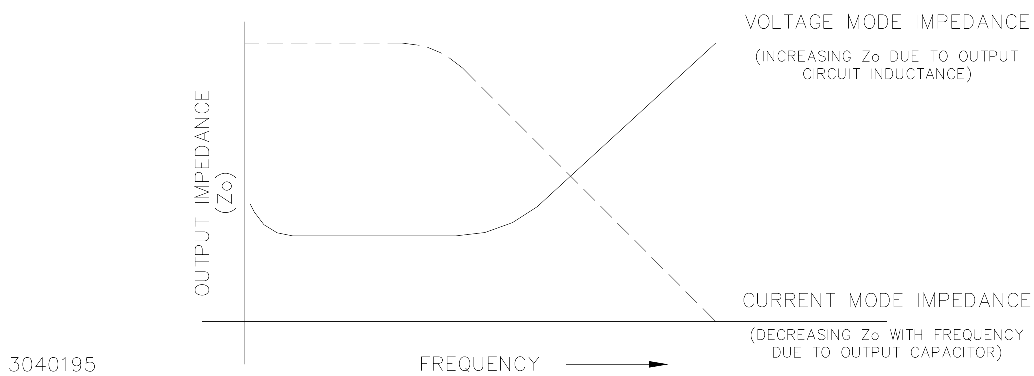


FIGURE 2-5. OUTPUT IMPEDANCE VS. FREQUENCY

A practical model for a voltage-stabilized Power Module includes a series inductance representing d-c and low frequency source impedance. Load leads should have minimum voltage drops (error sensing discussed in PAR. 2.10 below) and minimum inductance (error sensing does not compensate for this). Similarly a model for a current stabilized Power Module includes a parallel capacitor representing the d-c and low frequency source impedance. These considerations are important if:

- The load is constantly changing value.
- The load is switched “on” and “off.”
- The output of the Power Module is step programmed.
- The load is reactive.
- Dynamic output response of the Power Module is of concern.

2.9 CONNECTION, GENERAL

All input and output connections between the Power Module and RA 55H Rack Adapter are made automatically when the Power Module is fully seated in a Rack Adapter slot. Refer to the Rack Adapter Instruction Manual for instructions on connecting RA 55H output connectors to the load, a-c input power, and control signals.

The d-c output connector, labeled DC OUTPUT, is located on the back of chassis (Figure 2-6). Adapter Kit 219-0618 is must be installed on the DC Output Connector at the rear of the chassis to meet the all specifications listed in Table 1-1. For the DC Output Connector pin designations on MST-MHT units via Adapter Kit 219-0618 refer to Table 2-5 and Figure 2-6.

TABLE 2-5. DC OUTPUT CONNECTOR/ADAPTER KIT TERMINAL DESIGNATIONS

MST-MHT SIGNAL	CONNECTOR TERMINAL (See Figure 2-6)
Output Terminal 1 (+)	O1+
Output Terminal 2 (–)	O2-
Sense Terminal 1 (+)	S1+
Sense Terminal 2 (–)	S2-
Current Share Bus	CS
Module Chassis	GND
NOTE: The polarity for the terminals indicated above are for output enabled and polarity not reversed (normal).	

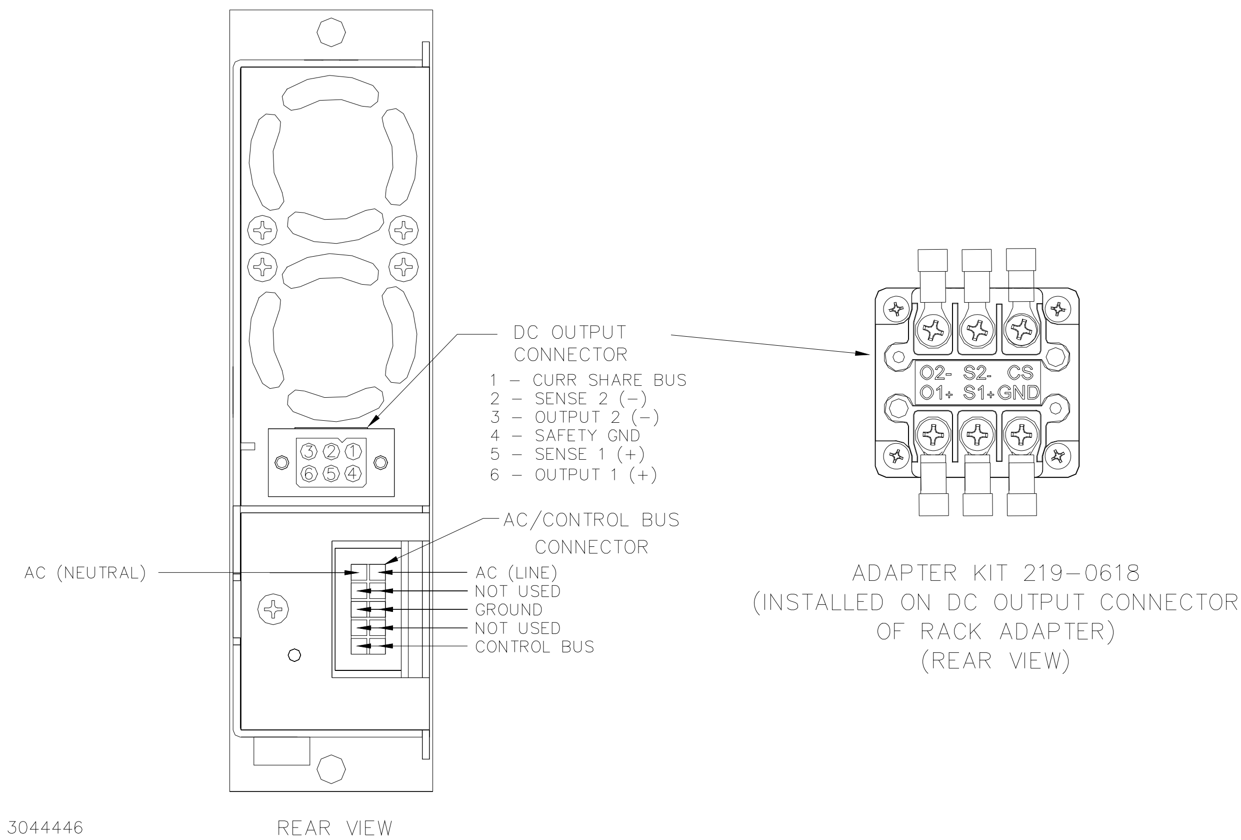
2.9.1 LOAD CONNECTION WITH LOCAL ERROR SENSING

The most basic power supply/load interface is a 2-wire connection between the power supply output terminals and the load. This connection method employs local error sensing which consists of connecting the error sense leads (terminals S1+ and S2–) directly to the power supply output (terminals O1+ and O2–). Its main virtue is simplicity: since voltage regulation is maintained at the power supply output, the regulation loop is essentially unaffected by the impedances presented by the load interconnection scheme. The main disadvantage is that it cannot compensate for losses introduced by the interconnection scheme and, therefore, regulation degrades directly as a function of distance and load current. The main applications for this method are for powering primarily resistive and relatively constant loads located close to the power supply, or for loads requiring stabilized current exclusively. The load leads should be tightly twisted to reduce pick-up.

2.9.2 LOAD CONNECTION WITH REMOTE ERROR SENSING

If the load is located at a distance from the power supply terminals, or if reactive and/or modulated loads are present, remote error sensing should be used to minimize their effect on the voltage stabilization. A twisted shielded pair of wires from the sensing terminals directly to the load will compensate for voltage drops in the load interconnection scheme (up to 0.5V maximum per wire); the termination point of the error sensing leads should be at or as close as practical to the load. Adapter Kit 219-0618 includes capacitive filtering, eliminating the typical requirement for additional filtering capacitors. If adapter Kit 219-0618 is not used, it is recommended that some amount of local decoupling capacitance be placed at the error sense termination point to minimize the risk of unwanted pick-up affecting the remote error sense function. For very long power module/load interconnecting cables and/or reactive loads, it may be necessary to add decoupling capacitors between the power and sense terminals at the power module side of the cable to suppress oscillation due to cable inductance. A general recommendation is to install a network of one (1) 10µF, 6.3V capacitor paralleled by one (1) 0.1µF ceramic capacitor across each output sense pair (pins 6 to 5 and 3 to 2, respectively).

NOTE: As electrolytic capacitors are normally polarized make sure that the positive (+) terminal of each one are respectively connected to the +V (pin 6) and -S (pin 2) pins.



NOTE: To remove Adapter Kit 219-0618, refer to Kit 219-0618 RA 55 Connector Adapter Kit Instruction Sheet (see PAR. 1.1 for download instructions).

FIGURE 2-6. CONNECTOR LOCATIONS AND PIN ASSIGNMENTS

SECTION 3 - OPERATION

3.1 INTRODUCTION TO CONTROLLING THE MST-MHT POWER MODULE OUTPUT

The MST-MHT family of Power Modules is designed for remote operation only. Operating the power supply requires a series of commands to be sent to the Power Module from a host computer, via a selected IEEE 1118 bus compatible Controller (see PAR. 1.4.1). The commands may either be pre-programmed or sent individually using a keyboard, depending upon the controller selected.

The MST-MHT Power Module responds to SCPI (Standard Commands for Programmable Instruments) commands. SCPI provides a common language conforming to IEEE 488.2 for instruments. For an explanation of SCPI commands and program syntax, refer to the applicable controller Instruction Manual (see PAR. 1.1 for download instructions).

3.1.1 STATUS FLAGS (ERROR MESSAGES)

The MST-MHT Power Module supplies information to the controller regarding its operating condition when queried via the SYST:ERR? command. A listing of the standard error messages appear sin the Instruction Manual for the MST 488-27HT Controller (see PAR.1.1). Table 3-1 lists the “catastrophic” status messages, along with the related MST-MHT Power Module condition.

TABLE 3-1. ERROR MESSAGES

STATUS MESSAGE	POWER MODULE CONDITION
POWER LOSS	OVERVOLTAGE / OVERCURRENT (See PAR. 3.7.2) SOURCE POWER LOSS (See PAR. 3.7.5)
None	Not Supported
OVERTEMPERATURE	OVERTEMPERATURE (See PAR. 3.7.4)
OVERLOAD	OPERATION IN MODE OTHER THAN PROGRAMMED MODE (See PAR’s. 3.2.1, 3.2.2)
VOLTAGE ERROR	OUTPUT NOT AT PROGRAMMED VALUE
CURRENT ERROR	OUTPUT NOT AT PROGRAMMED VALUE
RELAY ERROR	DEFECT IN ISOLATION RELAY OPERATION
RELAY ERROR	OPEN SENSE LEAD OR OPEN POWER LEAD CONDITION (See PAR. 3.7.6)

3.1.2 TIMING REQUIREMENTS FOR A VALID STATUS

After sending a command that might affect the output of the Power Modules or their relays, it is recommended that the Status command be sent. For detailed information on this command refer to the applicable controller Instruction Manual. For the Controller/MST-MHT system status command to be valid, the required time delay before sending the command is as follows:

- After an OUTP ON or OFF, wait approximately 300 milliseconds.
- After a Confidence Test command or an Internal Self Test, wait approximately 400 milliseconds.
- After a Reset command, wait approximately 300 milliseconds.

3.2 OPERATING MODES

MST-MHT power modules permit the user to select the operating mode as either Voltage Mode or Current Mode, depending upon the characteristics of the load being driven by the power module. The following paragraphs describe the characteristics and method of selecting the operating mode; note the following:

- only one operating mode may be selected at a time.
- operating mode selection affects only the operation of the fault detector and not the rectangular operating characteristic of the power module.
- the MODE indicators on the front panel indicate the real-time operating mode of the Power Module.

3.2.1 VOLTAGE MODE

In this mode, the Power Module is programmed to behave as a voltage source. The user programs an operating voltage XX with a current limit YY based on the required voltage stabilization point and the maximum anticipated load current. The Power Module is now programmed to provide a stabilized output voltage XX to a load impedance greater than or equal to XX/YY; the VOLTAGE MODE indicator LED is on for these load conditions.

Load impedances below XX/YY are considered to be overloads, and the Power Module will modulate the output voltage between zero and XX as necessary to maintain the load current at YY. Operation with load impedances below XX/YY will result in the CURRENT MODE indicator LED going on and the VOLTAGE MODE indicator going off; a status query at his point will indicate a device overload condition. Increasing the load impedance to a value greater than or equal to the critical value indicated above will result in automatic return to normal operation.

3.2.2 CURRENT MODE

In this mode, the Power Module is programmed to behave as a current source. The user programs an operating current YY with a voltage limit XX based on the required current stabilization point and the maximum anticipated load voltage. The Power Module is now programmed to provide a stabilized output current YY to a load impedance less than or equal to XX/YY; the CURRENT MODE indicator LED is on for these load conditions.

Load impedances greater than XX/YY are considered to be overloads, and the Power Module will modulate the output current between zero and YY as necessary to maintain the load voltage at XX. Operation with load impedances greater than XX/YY will result in the VOLTAGE MODE indicator LED going on and the CURRENT MODE indicator going off; a status query at his point will indicate a device overload condition. Decreasing the load impedance to a value less than or equal to the critical value indicated above will result in automatic return to normal operation.

3.3 OUTPUT POLARITY REVERSAL

NOTE: Although MST-MHT Power Modules include Polarity Reversal relays, this function is not available for modules controlled by the MST 488-27HT Controller.

MST-MHT Power Modules are designed to permit reversal of output terminal polarity via a remote command. Polarity reversal is achieved via relay switching of both power and signal lines, and can be employed in both Voltage and Current operating modes. Polarity reversal can be programmed in advance of output activation (Standby) or “on-the-fly” (Active) while the output is enabled; both methods employ a “dry-switching” scheme in order to extend relay life.

For programming polarity reversal in Standby mode, the user simply issues the polarity reversal command prior to enabling the output; the Power Module will then present reversed output polarity when enabled.

For polarity reversal while the output is enabled, the action is somewhat more complex although essentially transparent to the user. Upon receipt of a polarity reversal command, the Power Module control circuit stores the previous output settings (mode, voltage and current setpoints, etc.). The output of the Power Module is immediately programmed to zero volts and zero amps. A time-out delay of 2 seconds maximum is employed to allow for discharge of any load capacitance through the Power Module's return supply; during this time-out interval, the power supply waits for the output to reach zero volts. When zero volts is established, or at the end of the 2 second time-out, the relays are switched. The output is then reprogrammed to the stored settings and operation continues. During this sequence, error message generation is inhibited. Restoration of the output to normal polarity follows a similar path.

NOTE: The “return supply” current incorporated into MST-MHT Power Modules is limited to a maximum value which may in some cases be inadequate to fully discharge all external load capacitance. To ensure dry relay switching for all output conditions, the user must ensure that the external load capacitance can be discharged completely within the 2 second time-out interval by the available current, or dry switching will not take place. The maximum external capacitance value that can be discharged within the 2 second time-out interval is calculated as follows (see Table 3-2):

$$C \leq \frac{I \times T}{\Delta V}$$

where C = Maximum external capacitance allowed to maintain dry switching (Farads)
I = Return supply current (Amps)
V = Output voltage (Volts)
T = Time (Sec) = 2 seconds

CAUTION: FAILURE TO OBSERVE THE “DRY SWITCHING” CRITERIA NOTED ABOVE WILL CAUSE DAMAGE TO THE RELAYS AND VOID THE KEPCO WARRANTY.

In order to allow for settling time, the user should wait approximately 300 milliseconds after completion of polarity reversal before sending a status query in order to avoid erroneous fault messages.

TABLE 3-2. MAXIMUM EXTERNAL CAPACITANCE VALUES TO ENSURE DRY SWITCHING

MODEL	RETURN SUPPLY CURRENT (MILLIAMPS)	MAXIMUM EXTERNAL CAPACITANCE * (μF)
MST 6-20MMHT	400	125,000
MST 15-12MMHT	400	50,000
MST 25-8MMHT	250	20,000
MST 36-5MHT	165	8,800
MST 55-3.5MHT	110	4,000
MST 75-2.5MHT	60	1,600
MST 100-2MHT	44	880
MST 150-1.2MHT	30	400

* Values shown for worst case: T = 2 seconds and ΔV = maximum voltage.

3.4 OUTPUT ENABLE AND DISABLE

Enabling or disabling the output of an MST-MHT Power Module differs, depending upon whether it is operating as a voltage source or current source. The difference is determined by the opposite impedance characteristics of an ideal voltage vs. ideal current source. This section defines the “disable” function in terms of ideal voltage or current source characteristics, and details the exact method by which MST-MHT Power Modules provides the disable function.

For both voltage and current sources the “disable” condition is always represented by a “no-load” (zero load power) impedance. Regardless of whether the MST-MHT is operating in voltage or current mode (see PAR. 3.2), the “disable” condition must ensure that the MST-MHT provides zero power to the load, while ensuring full compliance to the load when subsequently enabled. The correct implementation of the disable function, whether for voltage mode or current mode, is automatic.

The definition of an ideal voltage source is a source which will supply stable voltage (Vo) into any load impedance within the limits of its compliance current range (RL = Vo/IMAX). For an ideal voltage source a no-load condition is then defined as infinite impedance, since this is the only load condition at which the delivered power (Vo x Io) is zero. MST-MHT Power Modules provide this function by opening all power relays, thus providing an open circuit to the load from the stabilizer output. Enabling the voltage source is accomplished by closing the appropriate relay contacts, depending upon selected output polarity, thus connecting the stabilizer output to the load.

The definition of an ideal current source is a source which will supply stable current (Io) into any load conductance within the limits of its compliance voltage range (GL = Io/VMAX). For an ideal current source a no-load condition is then defined as infinite conductance (zero impedance) since this is the only load condition at which the delivered power is zero. MST-MHT Power Modules provide this function by closing all four power relays, thus placing a short circuit (RL=0) at the output of the load stabilizer. While “disabled,” output current from the MST-MHT load regulator continues to circulate within the power module and through the shorted power relays. Enabling the current source is accomplished by opening the appropriate relays contacts, depending upon the selected output polarity, thus allowing the output current to flow through the load.

As with the output polarity reversal function described in PAR. 3.3, a “dry switching” scheme is employed during the disable and enable functions. For both voltage and current modes of operation, the CIIL command to enable the output at the load is Close (CLS), and to disable the output at the load is Open (OPN); the corresponding SCPI commands are OUTP ON and OUTP OFF, respectively.

3.5 PARALLEL OPERATION

MST-MHT Power Modules are specifically designed for operation in parallel, either for increased power or for fault redundancy. The output stabilizer incorporates an active load-sharing scheme to ensure equal distribution of load current among all paralleled modules, resulting in reduced operating stress and higher reliability. The load-share circuitry employed is a single-wire type with the positive error sense connection providing the signal return path.

To determine the number of Power Modules needed for a specific application, the user divides the total required load current (including any transient peaks) by the Power Module’s rated current, rounding the result up to the next whole number if necessary. This method determines “N”, the minimum number of power modules needed to support the load. For redundant applications this number is increased based on the desired redundancy factor (N+1, N+2, etc.). For nonredundant applications, the user can reduce overall power system operating stress by increasing the number of modules above N.

For parallel operation, all Power Modules should be same model. The module d-c outputs and error sense leads are wired in parallel to the load; the load share terminals from each DC Output connector are daisy-chained together. The user must ensure that the load and sense wiring minimizes loop inductance to prevent stray pickup from injecting noise into the load share signals. Twisted pairs (shielded, if necessary) should be used for both power and error sense leads when remote error sensing is used, with all error sensing lines terminated to the same physical location; if possible, the user should employ local error sensing.

Program each module for Voltage Mode operation at identical output voltage and current limit. The load sharing circuitry will automatically select the “load master” as the module with the highest “effective” voltage supplying power to the output bus; all other modules operate as slaves and are indicated as such by the CURRENT SHARE indicator LED on the front panel of the power module. Since MST-MHT Power Modules are enabled sequentially, the enabled modules will generate output voltage errors until the minimum number of modules (N) are turned on; the user should ignore these error flags until all modules are enabled (SCPI provides a method of masking these flags using software). The same is true if modules are disabled sequentially.

3.6 SERIES OPERATION

MST-MHT Power Modules are designed to allow series operation to achieve higher output voltage if desired. Series operation requires detailed investigation into all possible output conditions which may result from either normal or abnormal operation to ensure that the power supplies are not exposed to undue stress, especially voltage. This need is increased for MST-MHT Power Modules which, because of the sequential turn-on characteristic, may be exposed to greater risk during output enabling and disabling sequences. Users wishing to operate MST-MHT Power Modules in series are directed to contact Kepco Applications Engineering for specific guidance.

3.7 FAULT PROTECTION

In addition to providing protection against externally generated faults, MST-MHT Power Modules incorporate fault protection circuitry which protects the load in the event of an internal failure or malfunction which may result in loss of output control. The fault classifications are output overvoltage, output overcurrent, internal overtemperature, source power loss and open sense lead. A description of the fault detectors associated with these faults is provided in the following paragraphs.

The response of the Power Module to any of these faults (except for open sense/power lead) is a fault shutdown procedure consisting of the following:

a. Fault Shutdown with Flag - Any of the faults (except open sense leads)

- All output power and signal relays are immediately opened, isolating the Power Module from the load;
- Output voltage and current are programmed to zero;
- The dc-dc converter which powers the output stabilizer is latched off;

- Status bit 4 appears in the Questionable register of the MST 488-27HT controller indicating a catastrophic failure. Upon receiving status bit 4, the Controller removes that Control Bus address from the look-up table, preventing further commands from being directed to the faulty power module.

b. Fault Shutdown with Output disabled - If an open sense lead condition is detected, the fault shutdown procedure is as follows:

- All output power and signal relays are immediately opened, isolating the Power Module from the load;
- Output voltage and current are programmed to zero;
- If open sense caused the failure, status bit 10 appears in the Questionable register of the MST 488-27HT controller.

3.7.1 FAULT RECOVERY

Recovery from any fault condition (described above) requires that the user cycle source power off for a minimum of 5 seconds. After reapplication of source power, a IEEE 488 DCL (device clear) command must be sent to the controller to restore the module's Control Bus address to the look-up table. This procedure eliminates any possibility of casual reapplication of a Power Module to the system load after symptoms of a catastrophic module failure have been detected.

3.7.2 FIXED OVERVOLTAGE DETECTOR

The output stabilizer control circuitry of the MST-MHT Power Module includes a fixed overvoltage amplifier. This devices monitors the actual output voltage supplied by the Power Module and compares it to a fixed reference voltage. In the event that a parameter exceeds the fixed voltage limit by an amount equal to 10% of the Power Module's rated voltage, the circuit initiates a fault shutdown procedure as described in PAR. 3.7a. The tolerance of the fixed overvoltage hardware trigger is the minimum value listed in Table 1-1, +6%.

3.7.3 OVERCURRENT TRACKING DETECTOR

The output stabilizer control circuitry of the MST-MHT Power Module includes a separate overcurrent tracking amplifier. This device monitors the actual output current supplied by the Power Module and compares it to the programmed current value. In the event that actual current exceeds the programmed current by an amount equal to 10% of the Power Module's rated current, the circuit initiates a fault shutdown procedure as described in PAR. 3.7a The tolerance of the current fault threshold is ±3%.

3.7.4 OVERTEMPERATURE DETECTORS

Any one of a number of internal or external conditions (i.e., elevated ambient temperature, clogged vent holes, cooling fan failure, etc.) can cause elevation of internal heat sink temperatures to unsafe levels. If unattended, the resultant temperature rise of the power devices will lead to eventual destructive failure. MST-MHT Power Modules incorporate two internal thermostatic switches to detect unsafe internal operating temperatures. One is located on the heat sink related to the input preregulator and dc-dc converter, while the second monitors the heat sink related to the output stabilizer. If the temperature of either heat sink rises above a predetermined safe temperature, the related thermostat will change state, initiating a fault shutdown as described in PAR. 3.7a. The thermostat will reset upon return of the heat sink to acceptable operating temperature, however the module recovery procedure (see PAR. 3.7.1) must still be performed.

3.7.5 A-C LOSS DETECTOR

Although MST-MHT Power Modules are designed to provide a minimum of 21.5 milliseconds of output hold-up time (one full cycle of 47Hz power), loss of source power for extended periods will eventually result in complete Power Module shutdown. Additionally, certain power loss intervals can create a condition where the internal bias supply for the digital control circuitry decays partially, but not enough to force a system interrupt and reset; when this occurs, it is possible that digital communication and processing can be corrupted without warning or notice. To prevent this, MST-MHT Power Modules incorporate a power loss detector which will initiate a fault shutdown as described in PAR. 3.7a if the internal bulk d-c storage capacitor voltage falls to a level where quality of the internal bias voltages is questionable.

3.7.6 OPEN SENSE/POWER WIRE PROTECTION

In the event that the error sense leads (+S, -S) become disconnected from the power leads, the output voltage will attempt to rise uncontrollably. If the output voltage rises past the programmed overvoltage protection setting (see Table 1-1), the programmed overvoltage protection described in PAR.3.8.1 shuts down the unit. A hardware backup ensures that if the software OVP fails, the unit will shut down upon reaching the OVP hardware .trigger value (see Table 1-1), At the same time, bit 10 appears in the MST 488-27HT Controller Questionable register.

Depending on the output voltage rise time, either the programmable output protection as described in PAR .3.8.1, or the fixed overvoltage detector as described in PAR. 3.7.2, will protect the unit. Observe the front panel OUTPUT FAULT indicator to determine recovery action. If the indicator is on, refer to PAR. 3.7.1 for recovery. If the indicator is off, send `*RST` to recover.

The open sense/power wire protection circuitry can also be triggered by a power lead voltage drop in excess of the 0.5V maximum specified headroom resulting in the same situation as described above. . If the error sense lead connections appear to be correct, the user should double-check the size of the power leads to verify adequate margin. Contact Kepco Applications Engineering for assistance if necessary.

3.8 PROGRAMMABLE PROTECTION

The MST-MHT unit allows the user to set an arbitrary level for voltage protection (see PAR. 3.8.1). In addition, the MST-MHT gives users the option to shut down the unit almost immediately upon exceeding programmed current, instead of waiting until the unit exceeds programmed current by 10% (see PAR. 3.8.2).

3.8.1 PROGRAMMABLE OVERVOLTAGE PROTECTION

The `VOLT:PROT` command can be used to program the unit to shut down when actual output voltage exceeds the protection level established by `VOLT:PROT`. For this case if the actual output voltage exceeds the `VOLT:PROT` value, almost immediately upon detection, voltage and current are programmed to minimum values and the output is disabled, bit 0 (2^0) of the Questionable Condition register is set and no further commands are accepted until `*RST` is sent.

3.8.2 PROGRAMMABLE CURRENT MODE PROTECTION

If 10% Overcurrent as described in PAR. 3.7.3 is not acceptable, sending the command `CURR:PROT:STAT ON` makes it possible for overcurrent detection to be initiated as soon as the programmed current exceeds actual output current. Almost immediately upon detection, voltage and current are programmed to minimum values and the output is disabled, bit 1 (2^1) of the Questionable Condition register is set and no further commands are accepted until `*RST` is sent.

3.9 CALIBRATION

Calibration of the MST-MHT Power Module is recommended for any of the following conditions.

- Operating environment (temperature, humidity, etc.,) higher than 30°C.
- Periodic maintenance determined by user.
- Inaccurate measurements are suspected.

Perform the procedures outlined below in sequence (see Figure 2-2 for the location of calibration controls). Calibration adjustments are recommended only when the test point value exceeds the indicated tolerance on the measured value. Note that the measured value tolerance is generally an order of magnitude looser than the adjustment tolerance. This avoids unnecessary recalibration, while providing a precision adjustment if calibration is required.

NOTE: E_{MAX} is the maximum output voltage of the unit listed in Table 1-1; I_{MAX} is the maximum output current of the unit as listed in Table 1-1 for 45° C.

3.9.1 EQUIPMENT REQUIRED

Calibration of MST-MHT Series Power Modules requires the following equipment:

- Host computer
- RA 55H or CA 400H Rack Adapter, or Input Power/Communication Cable (see Table 1-3)
- Controller Module (Kepco MST 488-27HT)
- Digital Voltmeter (DVM): 6½ digit display, 10 μV resolution
- Precision Current Shunt: R_{SHUNT} < 0.02 (EMAX / IMAX)Ω

  where: E_{MAX} = rated Power Module output voltage (e.g., 36V for MST 36-5MHT)
  I_{MAX} = rated Power Module output current (e.g., 5A for MST 36-5MHT)

  NOTE: To avoid errors due to temperature drift of the shunt, a power rating of greater than 10 times actual dissipation is recommended. The above calculation results in a maximum shunt power dissipation of less than 4W, a 100W shunt is adequate for all models)

- Miscellaneous programming interface cables, load cables, etc.

Install the MST-MHT Series power module under test (UUT) in the calibration test set-up shown in Figure 3-1

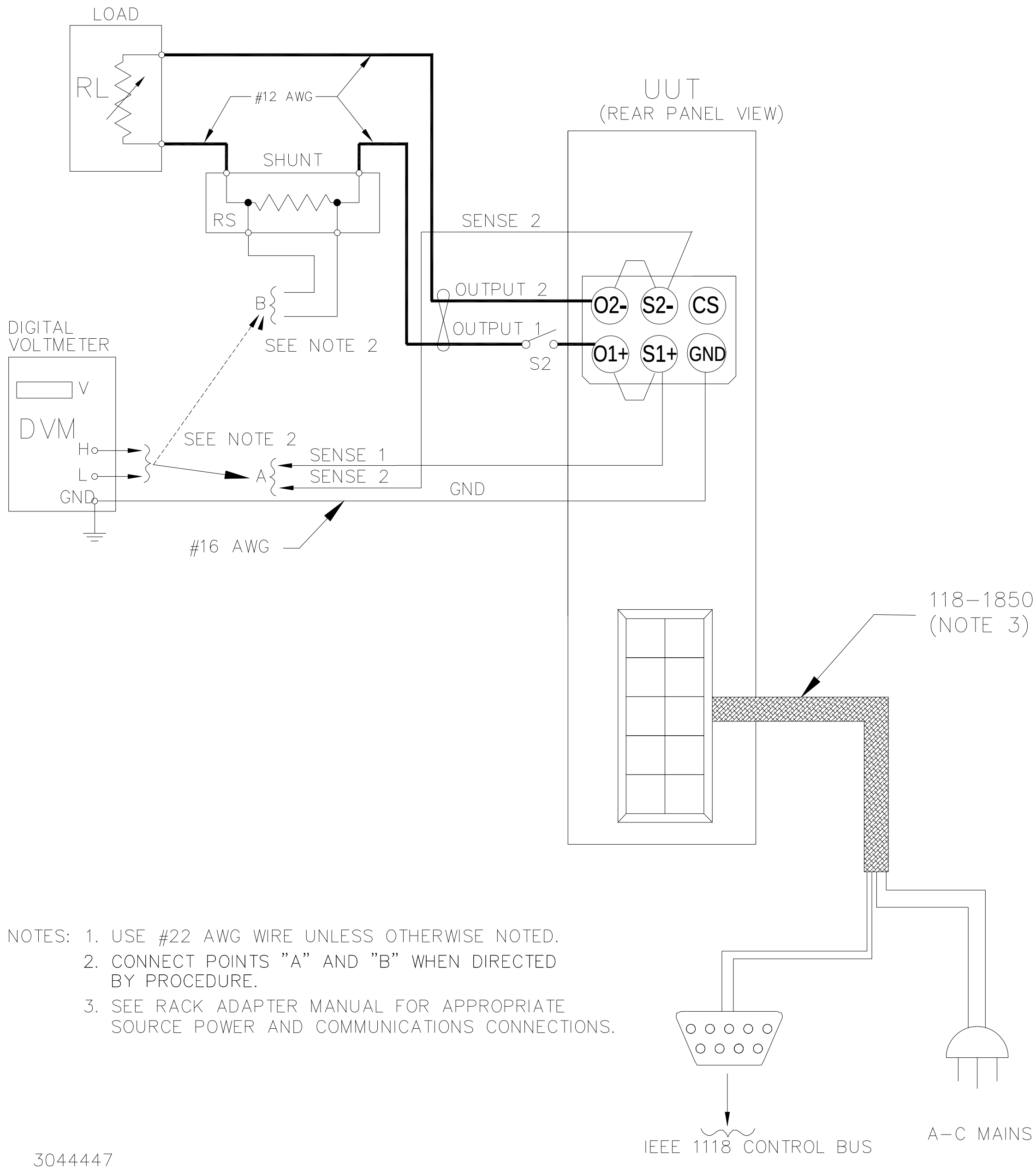


FIGURE 3-1. CALIBRATION TEST SET-UP

3.9.2 +5 VOLTS REFERENCE ADJUST (R49)

This procedure establishes the +5V reference voltage used by the analog circuits.

1. Disconnect the load and turn on the UUT. Proceed to step 3 if VOLTAGE MODE indicator is on.
2. If the CURRENT MODE indicator is on, issue a command from the host computer to set the UUT to Voltage mode. Verify that VOLTAGE MODE indicator is on.
3. Issue a command from the host computer to reset the UUT. This causes the UUT to be programmed to zero volts.
4. Connect the voltmeter to test connector J5, pins 1 (REF) and 6 (GND) (see Figure 2-2) and verify meter reads between 5.00000V ± 500µV volts. If meter reading is outside these limits, adjust potentiometer R49 for reading of +5.00000V ± 50µV.

3.9.3 OUTPUT VOLTAGE (E_O) ZERO ADJUST (R11)

This procedure adjusts the offset of the voltage comparison amplifier to be zero for a programmed output voltage of zero.

1. Configure DC OUTPUT connector as shown in Figure 3-1 and open S2.
2. With the load disconnected, issue commands from the host computer to enable the output (output relays closed), e.g. `VOLT 0;CURR 5;:OUTP ON`. Verify OUTPUT ENABLED and VOLTAGE MODE indicators are on.
3. Connect DVM to DC output connector (see Figure 2-3) pin 5, Sense 1 (+) and pin 2, Sense 2 (–) and verify that output is 0V ± 500µV.
4. If the measured output is outside these limits adjust potentiometer R11 for reading of 0.00000V ± 50µV.

3.9.4 CURRENT SENSE ZERO ADJUST (R50)

This procedure adjusts the current sensing amplifier to zero with no current flowing through the current sensing resistor.

1. Issue commands (`*RST;:OUTP ON`) from the host computer to reset the UUT.
2. Verify VOLTAGE MODE indicator is on.
3. Connect voltmeter to test connector J5, pins 4 (CSNS - Current Sense) and 6 (GND) and verify meter reads 0.00000V ± 500µV. If meter reading is outside these limits, adjust potentiometer R50 for 0.00000V ± 50µV.

3.9.5 OUTPUT CURRENT I_O ZERO ADJUST (R51)

This procedure adjusts the offset of the current comparison amplifier to be zero for a programmed output current of zero.

1. Issue commands from the host computer to set the UUT to Current Mode, program output current to 0.0A, voltage limit to E_{MAX}, enable the output and disconnect the load.

2. Verify CURRENT MODE indicator is on and OUTPUT ENABLED indicator is on with load not connected. If CURRENT MODE indicator is off, turn R51 counterclockwise until CURRENT MODE indicator is on.

3. Short the load and connect voltmeter to test connector J5, pins 4 (CSNS - Current Sense) and 6 (GND) and verify voltmeter reads 0.0000V ± 500µV. If voltmeter reading is outside these limits, adjust potentiometer R51 for 0.0000V ± 100µV.

3.9.6 VOLTAGE REFERENCE ADJUST (R47)

This procedure adjusts the internal full scale reference voltage to produce the full scale output voltage E_{MAX} when the full scale voltage is programmed.

1. Issue commands (`VOLT MAX;:CURR MAX;: OUTP ON`) from the host computer to set the UUT to Voltage Mode, program current limit to I_{MAX}, output voltage to E_{MAX} and enable the output.

2. Verify VOLTAGE MODE and OUTPUT ENABLED indicators are on.

3. Connect the voltmeter to DC output connector (see Figure 2-3) pin 5, Sense 1 (+) and pin 2, Sense 2 (–) and verify measured value is within ± 1 LSB (1/4096) of E_{MAX}. If measured value exceeds the acceptable range, adjust potentiometer R47 to E_{MAX}, within the R47 adjustment tolerance of ± 0.5 LSB (1/8192) of E_{MAX}.

3.9.7 CURRENT REFERENCE ADJUST (R48)

This procedure establishes the maximum value of the internal current reference voltage so that the readback current matches the programmed current.

1. Turn off UUT and connect precision shunt across DC Output connector pin 6, Output 1 (+), and pin 3, Output 2 (–).

2. Turn on UUT.

3. Issue commands from the host computer to set the UUT to Current Mode, program output current (I_O) to 0.99 x I_{MAX}, voltage limit to E_{MAX} and enable the output.

4. Verify that CURRENT MODE and OUTPUT ENABLED indicators are on.

5. Issue commands from the host computer to read back current.

6. Verify that the read back value (step 5) is within ± 1 LSB (4096) of the programmed value (step 3). If readback value exceeds acceptable range, adjust R48 for readback value within ±0.5 LSB (1/8192) of the programmed value.

3.9.8 CURRENT (I_O) FULL SCALE ADJUST (R52)

This procedure adjusts the gain of the current sensing amplifier so that the actual full scale output current matches the programmed output current.

1. With precision shunt across DC Output connector pin 6, Output 1 (+), and pin 3, Output 2 (–).(see PAR. 3.9.7, step 1), issue commands from the host computer to set the UUT to Current Mode, program output current (I_O) to 0.99 x I_{MAX}, voltage limit to E_{MAX} and disable the output. The unit must be operating for a minimum of 20 minutes in Current Mode with output disabled to avoid drift due to temperature fluctuations.

2. Enable the output and verify that CURRENT MODE and OUTPUT ENABLED indicators are on.

3. Record the output current as measured across the external shunt.

4. Issue commands from host computer to read back current.

5. Compare the read back current (step 4) to the measured current (step 3). Verify that measured current is equal to readback current within the acceptable range of ± 1 LSB (1/4096) of I_{MAX}. If the acceptable range is exceeded, adjust R52 until measured current is within ±0.5 LSB (1/8192) of read back current, repeating steps 1 through 5 as necessary.