OPERATOR'S MANUAL

SERIES BHK-MG

40 WATT POWER SUPPLY

1/2 RACK VOLTAGE/CURRENT-STABILIZED DC SOURCE



IMPORTANT NOTES:

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

MODEL SERIAL NO. REV. NO.

- 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.
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KEPCO®

THE POWER SUPPLIER™

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Declaration of Conformity

Application of Council directives: 73/23/EEC (LVD) 93/68/EEC (CE mark) Standard to which Conformity is declared: EN61010-1:2001 (Safety requirements for electrical equipment for measurement, control and laboratory use - Part 1) **KEPCO INC.** Manufacturer's Name and Address: 131-38 SANFORD AVENUE FLUSHING, N.Y. 11352 USA Importer's Name and Address: Type of Equipment: **Component Power Supply** Model No .: [PRODUCT MODEL NUMBER] Year of Manufacture: I, the undersigned, declare that the product specified above, when used in conjunction with the conditions of conformance set forth in the product instruction manual, complies with the requirements of the Low Voltage Directive 73/23/EEC, which forms the basis for application of the CE Mark to this product. KEPCO Inc. Place: 131-38 Sanford Ave. Flushing, N.Y.11352 USA Saul Kupferberg (Full Name) VP OF SALES Date: _____ (position)

228-1348 DC-COMP/INST 110504

Conditions of Conformance

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

- 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 Cl. 6, Cl. 7, Cl.8, Cl. 9 and EN61010-1 annex F)
- 2. This power supply is designed for stationary installation, with mains power applied via a detachable power supply cord or via direct wiring to the source power terminal block.
- 3. This power supply is considered a Class 1 (earthed) product, and as such depends upon proper connection to protective earth for safety from electric shock. (EN61010-1 Cl. 6.5.4)
- 4. This power supply 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 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 Cl. 6.5.4 and Cl.6.10.1)
- 5. This power supply has secondary output circuits that are considered hazardous, and which reach 40 VA at a potential of 300V or more.
- 6. 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.
- 7. This power supply employs a supplementary circuit protector in the form of a circuit breaker mounted on the front panel. This circuit breaker 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 Cl. 9.6.2)
- 8. 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. 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 factory set for the nominal a-c mains voltage indicated by the Voltage Range Selector switch located adjacent to the source power connection on the product's rear panel. To reconfigure the product input for other nominal mains voltages as listed herein, follow the applicable instructions shown in this manual.

NOTE: Source power must be removed from the product prior to changing the setting of the Voltage Range Selector switch.

2. Grounding

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



The PROTECTIVE EARTHING CONDUCTOR TERMINAL must 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

SECTION		PAGE
SECTIO	ON 1 - INTRODUCTION	
1.1	Scope of Manual	1-1
1.2	General Description	1-1
1.3	Specifications	1-2
1.4	Features	1-9
1.4.1	Local Control	1-9
1.4.2	Remote Control	1-9
1.4.2.1	Digital Programming	1-9
1.4.2.2	Analog Programming	1-9
1.4.3	Digital Calibration	1-9
1.4.4	Overvoltage/Overcurrent Protection	1-9
1.4.5	User-defined Voltage/Current Limits	1-10
1.4.6	Nonvolatile Storage of Programmed Sequences or Active Settings	
1.4.7	Current Measurement Scale	1-10
1.4.8	Fast Mode/Slow Mode Selection	1-10
1.4.9	Built-in Protection	1-10
1.4.10	Internal Signals Available for Customer Use	1-11
1.4.11	External Trigger Port	
1.4.12	Current Sink Capability	
1.5	Equipment Supplied	
1.6	Accessories	
1.7	Safety	
	ON 2 - INSTALLATION	
2.1	Unpacking and Inspection	
2.2	Terminations and Controls	
2.3	Source Power Requirements	
2.4	Cooling	
2.5	Preliminary Operational Check	
2.6	Installation	
2.6.1	Bench Top Use	
2.6.2	Rack Mounting	
2.7	Wiring Instructions	
2.7.1	Safety Grounding	
2.7.2	Source Power Connections	
2.7.3	D-C Output Grounding	
2.7.4	Power Supply/Load Interface	
2.7.5	Load Connection - General	
2.7.5.1	Local Sensing/Remote Sensing Select	
2.7.5.2	Fast Mode/Slow Mode Select	
2.7.5.3	Grounding Network Configuration	
2.7.5.4	Positive Output, Negative Terminal Grounded	
2.7.5.5	Negative Output, Positive Terminal Grounded	2-13
2.8	Operating Configuration	
2.9	Status Port	2-14
SECTIO	ON 3 - OPERATION	
3.1	General	3-1
3.2	Local Mode Operation	3-1
3.2.1	Front Panel Keypad and LCD	
3.2.1.1	Command Entry Status	
3.2.1.2	Data Entry Status	
3.2.1.3	Display (LCD)	
3.2.1.4	Keypad Functions	
3.2.2	Turning the Power Supply On	
3 2 3	Setting Local Mode	3_4

SECTION		PAGE
3.2.4	Adjusting LCD Contrast	3-5
3.2.5	Enabling/Disabling Audible Beeps	
3.2.6	Enabling/Disabling DC Output Power	
3.2.6.1	Disabling DC Output	
3.2.6.2	Disabling DC Output Using Remote On/Off Port	
3.2.6.3	Remote Shutdown using External Trigger Port	
3.2.6.4	Power Up DC Output Control	
3.2.7	Reset Operation	
3.2.7.1	Setting Power-Up & Reset Current	
3.2.8	Setting Output Voltage or Current	
3.2.9	Setting Overvoltage or Overcurrent Protection	
3.2.10	Changing Maximum Voltage or Current Value	
3.2.11	Storing Power Supply Output Settings	
3.2.12	Recalling Stored Output Settings	
3.2.13	Firmware Version	
3.2.14	Local Mode Programming of the Power Supply	
3.2.14.1	Creating or Modifying a Program (Program Edit Mode)	
3.2.14.1.1	Modifying Programmed Time Interval	
3.2.14.1.2	Time Interval Accuracy	
3.2.14.2	Running a Program	
3.2.14.3	Stepping Through a Program	
3.2.14.4	Cycling a Program	
3.2.14.5	Running a Program Once	
3.2.14.6	Stopping a Running Program	
3.2.14.7	Sample Program	
3.2.15	Calibration	
3.3	Remote Mode Programming Using SCPI commands via IEEE 488 (GPIB). Bus	
3.3.1	IEEE 488 (GPIB) Bus Protocol	
3.3.2	DCL Control	
3.3.3	Changing the GPIB Address	
3.3.4	External Trigger	
3.4	BHK-MG VISA Instrument driver	
3.5	RS232-C Operation	
3.5.1	Setting RS 232 Baud Rate	
3.5.2	Serial INterface	
3.5.3	RS 232 Implementation	
3.5.3.1	Echo Mode	3-17
3.5.3.2	Prompt Method	3-17
3.5.3.3	XON XOFF Method	
3.5.4	Isolating RS 232 Communication Problems	3-17
3.6	Programming Techniques to Optimize performance	
3.6.1	Example of Proper Programming	
3.6.2	Explanation of Programming Techniques	3-18
3.7	SCPI Programming	
3.7.1	SCPI Messages	3-19
3.7.2	Common Commands/Queries	3-19
3.7.3	SCPI Subsystem Command/Query Structure	3-19
3.7.3.1	ABORt Subsystem	3-19
3.7.3.2	DISPlay Subsystem	3-19
3.7.3.3	INITiate Subsystem	
3.7.3.4	LIST Subsystem	
3.7.3.5	MEASure Subsystem	3-20
3.7.3.6	OUTPut Subsystem	
3.7.3.7	Instrument Subsystem	3-20
3.7.3.8	STATus Subsystem	
3.7.3.9	System Subsystem	
3.7.3.10	TRIGger subsystem	3-20
3.7.3.11	[SOURce:]VOLTage and [SOURce:]CURRent Subsystems	3-20

SECTION		PAGE
3.7.3.12	CALibrate Subsystem	3-20
3.7.4	Program Message Structure	3-22
3.7.4.1	Keyword	3-23
3.7.4.2	Keyword Separator	3-23
3.7.4.3	Query Indicator	3-23
3.7.4.4	Data	
3.7.4.5	Data Separator	
3.7.4.6	Message Unit Separator	
3.7.4.7	Root Specifier	
3.7.4.8	Message Terminator	
3.7.5	Understanding The Command Structure	
3.7.6	Program Message Syntax Summary	
3.7.7	SCPI Program Examples	
3.8	Remote Programming Using Analog Programming Terminals	
3.8.1	Analog Programming Warnings and Cautions	
3.8.2	Programming with external resistance	
3.8.2.1	Voltage Mode	
3.8.2.2	Current Mode	
3.8.3	Programming with external voltage using a low impedance Voltage source	
3.8.3.1	Voltage Mode	
3.8.3.2	Current Mode	
3.8.4	Analog Programming with external voltage using a high impedance, low level (1V) Voltage source	
3.8.4.1	Voltage Mode	
3.8.4.2	Current Mode	
3.8.5	Analog Programming with external current source (1 mA)	
3.8.5.1	Voltage Mode	
3.8.5.2	Current Mode	
3.9	Operating Modes	
3.9.1	Slow/Fast mode of operation	
3.9.2	Series operation	
3.9.2.1		
3.9.2.1	Automatic series operation	
3.9.2.2.1	Voltage Mode Operation	
3.9.2.2.1	Current Mode Operation	
3.9.3 3.9.3.1	Parallel operation	
	· · · · · · · · · · · · · · · · · · ·	
3.9.3.2	Master-slave parallel operation	
3.9.3.2.1 3.9.3.2.2	Voltage Mode Operation Current Mode Operation	.3-62
SECTIO	DN 4 - CALIBRATION	
4.1	General	
4.2	Equipment Required	
4.3	Calibration Description	
4.4	Calibration Using Front Panel Keys	
4.4.1	Voltage Calibration	
4.4.2		
4.5	Calibration Using VISA Driver	
4.6		
4.7	Restoring Previous Calibration Values	
4.8	Restoring Factory Calibration Values	
1 Q	Calibration Storage	1_5

SECTION		PAGE
APPENI	DIX A - IEEE 488.2 COMMAND/QUERY DEFINITIONS	
A.1	Introduction	A-1
A.2	*CLS — Clear Status Command	
A.3	*ESE — Standard Event Status Enable Command	A-1
A.4	*ESE? — Standard Event Status Enable Query	
A.5	*ESR? — Event Status Register Query	
A.6	*IDN? — Identification Query	
A.7	*OPC — Operation Complete Command	A-2
A.8	*OPC? — Operation Complete Query	A-2
A.9	*RCL — Recall Command	A-2
A.10	*RST — Reset Command	A-3
A.11	* SAV — Save Command	A-3
A.12	*SRE — Service Request Enable Command	A-4
A.13	*SRE? — Service Request Enable Query	
A.14	*STB? — Status Byte Register Query	
A.15	*TRG — Trigger Command	
A.16	*TST? — Self Test Query	A-4
APPENI	DIX B - SCPI COMMAND/QUERY DEFINITIONS	
B.1	Introduction	B-1
B.2	Numerical Values.	B-2
B.3	ABORt Command	B-2
B.4	CALibrate:CURRent[:DATA] Command	B-2
B.5	CALibrate:CURRent:LEVel Command	B-2
B.6	CALibrate:SAVE Command	
B.7	CALibrate:STATus Command	B-4
B.8	CALibrate:STATe? Query	B-4
B.9	CALibrate:VOLTage[:DATA] Command	
B.10	CALibrate:VOLTage:LEVel Command	
B.11	CALibrate:ZERO Command	B-4
B.12	DISPlay:CONTrast Command	
B.13	DISPlay:CONTrast? Query	
B.14	DISPlay:MODE Command	
B.15	DISPlay:MODE? Query	
B.16	DISPlay:TEXT Command	
B.17	DISPlay:TEXT? Query	
B.18	INITiate[:IMMediate] Command	
B.19	INITiate:CONTinuous Command	
B.20	INITiate:CONTinuous Query	
B.21	INSTrument:STATe	
B.22	[SOURce:]LIST:CLEar Command	
B.23	[SOURce:]LIST:COUNt Command	
B.24	[SOURce:]LIST:COUNt? Query	
B.25	[SOURce:]LIST:COUNt:SKIP Command	
B.26	[SOURce:]LIST:COUNt:SKIP? Query	
B.27	[SOURce:]LIST:CURRent Command	
B.28	[SOURce:]LIST:CURRent? Query	
B.29	[SOURce:]LIST:CURRent:POINts? Query	
B.30	[SOURce:]LIST:DIRection Command	
B.31	[SOURce:]LIST:DIRection? Query	
B.32	[SOURce:]LIST:DWELI Command	
B.33	[SOURce:]LIST:DWELI? Query	
B.34	[SOURce:]LIST:DWELI:POINts? Query	
B.35	[SOURce:]LIST:QUERy Command	
B.36	[SOURce:]LIST:QUERy? Query	B-9

SECTION		PAGE
B.37	[SOURce:]LIST:VOLTage Command	B-9
B.38	[SOURce:]LIST:VOLTage? Query	
B.39	[SOURce:]LIST:VOLTage:POINts? Query	
B.40	MEASure[:SCALar]:CURRent[:DC]? Query	
B.41	MEASure:VOLTage[:SCALar][:DC]? Query	
B.42	OUTPut[:STATe] Command	
B.43	OUTPut[:STATe] Query	
B.44	[SOURce:]CURRent[:LEVel][:IMMediate][:AMPlitude] Command	
B.45	[SOURce:]CURRent[:LEVel][:IMMediate][:AMPlitude] Query	
B.46	[SOURce:]CURRent:[:LEVel]TRIGgered[:AMPlitude] Command	
B.47	[SOURce:]CURRent:[:LEVel]TRIGgered[:AMPlitude]? Query	
B.48	[SOURce:]CURRent:LIMit[:HIGH] Command	
B.49	[SOURce:]CURRent:LIMit[:HIGH]? Query	
B.50	[SOURce:]CURRent:PROTection[:LEVel] Command	
B.51	[SOURce:]CURRent:PROTection[:LEVel]? Query	
B.52	[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPlitude] Command	
B.53	[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPlitude]? Query	
B.54	[SOURce:]VOLTage:[:LEVel]TRIGgered[:AMPlitude] Command	
B.55	[SOURce:]VOLTage:[:LEVel]TRIGgered[:AMPlitude]? Query	
B.56	[SOURce:]VOLTage:LIMit[:HIGH] Command	
B.57	[SOURce:]VOLTage:LIMit[:HIGH]? Query	
B.58	[SOURce:]VOLTage:PROTection[:LEVel] Command	
B.59	[SOURce:]VOLTage:PROTection[:LEVel]? Query	
B.60	[SOURce:]FUNCtion:MODE? Query	
B.61	STATus:OPERation:CONDition Query	
B.62	STATus:OPEReration:ENABle Command	
B.63	STATus:OPEReration:ENABle? Query	
B.64	STATus:OPERation[:EVENt] Query	
B.65	STATus:PRESet Command	
B.66	STATus:QUEStionable[:EVENt]? Query	
B.67	STATus:QUEStionable:CONDition? Query	
B.68	STATus:QUEStionable:ENABle Command	
B.69	STATus:QUEStionable:ENABle? Query	
B.70	SYSTem:COMMunication:GPIB:ADDRess Command	
B.71	SYSTem:COMMunication:GPIB:ADDRess? Query	
B.72	SYSTem:COMMunication:SERial:BAUD Command	
B.73	SYSTem:COMMunication:SERial:BAUD? Query	
B.74	SYSTem:COMMunication:SERial:ECHO Command	
B.75	SYSTem:COMMunication:SERial:ECHO? Query	
B.76	SYSTem:COMMunication:SERial:PACE Command	
B.77	SYSTem:COMMunication:SERial:PACE? Query	
B.78	SYSTem:COMMunication:SERial:PROMpt Command	
B.79	SYSTem:COMMunication:SERial:PROMpt? Query	
B.80	SYSTem:ERRor? Query	
B.81	SYSTem:ERRor:CODE? Query	
B.82	SYSTem:ERRor:CODE:ALL? Query	
B.83	SYSTem:KLOCk Command	
B.84	SYSTem:KLOCk? Query	
B.85	SYSTem:LANGuage Command	
B.86	SYSTem:LANGuage? Query	
B.87	SYSTem:PASSword:CENable Command	
B.88	SYSTem:PASSword:DISable Command	
B.89	SYSTem:PASSword:NEW Command	
B.90	SYSTem:PASSword:STATe? Query	
B.91	SYSTem:SECurity:IMMediate Command	
B.92	SYSTem:SET Command	
B.93	SYSTem:VERSion Query	
B.94	TRIGger:SOURce Command	
		<i></i>

LIST OF FIGURES

IGURE	TITLE	PAGE
1-1	BHK-MG 40W Series Programmable Power Supply	x
1-2	BHK 40W Series Power Supply, Mechanical Outline Drawing	
1-3	RA 24 Rack Adapter with two 1/2 Rack BHK-MG 40W Units	
2-1	BHK-MG Series, Front Panel Controls, Indicators and Connectors	
2-2	BHK-MG Series, Rear Panel Controls and Connections	
2-3	LCD Power On Defaults	
2-4	Local Sensing, Slow Mode Selected, Grounding Network Connected,	2-1
2 7	Floating Output (Factory Default Configuration)	2-12
2-5	Remote Sensing, Fast Mode Selected, Positive Output Grounded	
2-6	Status Port Opto-coupler Active "LOW" Configuration	
2-7	Status Port Opto-coupler Active "HIGH" Configuration	
3-1	LCD Power On Defaults	
3-1	RS 232 Implementation	
3-3	Tree Diagram of SCPI Commands Used with BHK-MG 40W Power Supply	
3-4	Message Structure	
3- 4 3-5	Typical Example Of BHK-MG 40W Power Supply Program Using SCPI Commands	
3-6	Analog Voltage Programming, Simplified Diagram	
3-7	Analog Current Programming, Simplified Diagram	3-21
3-8	Analog Programming of Output Voltage (Voltage Mode)	2.24
0.0	or Voltage Limit (Current Mode) using Resistance	3-31
3-9	Analog Programming of Output Current (Current Mode)	0.00
0.40	or Current Limit (Voltage Mode) using Resistance	3-32
3-10	Analog Programming of Output Voltage (Voltage Mode) or Voltage Limit	0.04
0.44	(Current Mode) using Isolated (floating) Low Impedance Voltage Source (VS)	3-34
3-11	Analog Programming of Output Voltage (Voltage Mode) or Voltage	0.05
0.40	Limit (Current Mode) using Grounded Low Impedance Voltage Source (VS)	3-35
3-12	Analog Programming of Output Current (Current Mode) or Current Limit	
0.40	(Voltage Mode) using Isolated (Floating) Low Impedance Voltage Source (VS)	3-36
3-13	Analog Programming of Output Current (Current Mode) or Current	
	Limit (Voltage Mode) using Grounded Low Impedance Voltage Source (VS)	3-37
3-14	Analog Programming of Output Voltage (Voltage Mode) or Voltage	
	Limit (Current Mode) using High Impedance, Low Level (1V) Voltage Source (VS)	3-39
3-15	Analog Programming of Output Current (Current Mode) or Current	
	Limit (Voltage Mode) using High Impedance, Low Level (1V) Voltage Source (VS)	3-40
3-16	Analog Programming of Output Voltage (Voltage Mode) or Voltage	
	Limit (Current Mode) using Current Source (1mA) (CS)	3-42
3-17	Analog Programming of Output Current (Current Mode) or Current	
	Limit (Voltage Mode) using Current Source (1mA) (CS)	
3-18	Slow Mode/Fast Mode Operation	
	Series Automatic Configuration	
3-20	Series Master-Slave (Voltage Mode) Configuration	
3-21	Series Master-Slave (Current Mode) Configuration	
3-22	Parallel Automatic Configuration	
3-23	Parallel Master-Slave (Voltage Mode) Configuration	
3-24	Parallel Master-Slave (Current Mode) Configuration	
A-1	GPIB Commands	
B-1	Programming the Output	
B-2	Using Calibration Commands and Queries	
B-3	Using Display Commands	
B-4	Using LIST Commands and Queries	B-10
B-5	Programming Current	
B-6	Programming Voltage	
B-7	Using Status Commands and Queries	
B-8	Using System Commands and Queries	B-20

Vİ BHK 1/2 RACK 110504

LIST OF TABLES

TABLE	TITLE	PAGE
1-1	Model Parameters	1-2
1-2	BHK-MG 40W Specifications	1-2
1-3	Connector A2J5 Signal Descriptions	1-12
1-4	Equipment Supplied	1-12
1-5	Accessories	1-13
1-6	Safety Symbols	1-13
2-1	Controls, Indicators, and Connectors	2-2
2-2	IEEE 488 Port Connector Pin Assignments	2-4
2-3	Status and Remote oN/oFF Port Connector Pin Assignments	
2-4	RS 32C PORT Input/Output Pin Assignments	2-5
2-5	External Trigger Port Pin Assignments	2-5
2-6	Rear Output Terminal Strip A6TB1, Terminal Assignments	2-5
2-7	Voltage Programming Terminal Strip A6TB2, Terminal Assignments	2-5
2-8	Current Programming Terminal Strip A6TB3, Terminal Assignments	2-6
2-9	Internal Jumper Configuration	2-14
3-1	LCD Messages	3-2
3-2	Key Functions	3-2
3-3	Memory Location Worksheet	3-10
3-4	Sample Program (Model BHK-MG 500-80MG)	
3-5	IEEE 488 (GPIB) Bus Interface Functions	
3-6	IEEE 488 (GPIB) Bus Command Mode Messages	3-13
3-7	IEEE 488 (GPIB) Bus Data Mode Messages	3-14
3-8	Rules Governing Shortform Keywords	
3-9	Feedback Resistor and Current Sensing Resistor Values	
4-1	Factory Default Calibration Passwords	4-4
4-2	Calibration Storage	4-5
A-1	IEEE 488.2 Command/query Index	
A-2	Standard Event Status Enable Register and Standard Event Status Register Bits	
A-3	Service Request Enable and Status Byte Register Bits	
B-1	SCPI Subsystem Command/query Index	B-1
B-2	Operation Condition Register, Operation Enable Register,	
	and Operation Event Register Bits	B-16
B-3	Questionable Event Register, Questionable Condition Register	
	and Questionable Condition Enable Register Bits	
B-4	Error Messages	B-21

SERVICE SAFETY INSTRUCTIONS

Read these safety instructions, as well as the applicable installation, operating and servicing instructions contained in this manual before using the power supply.



Do not touch the output terminals. The high voltage output is dangerous. Electric shock can cause injury or death.

Do not remove the cover or disassemble the unit. There are no operator serviceable components or adjustments inside the unit. High voltage components inside the unit can cause serious injury even with input power disconnected.

CAUTION

If this power supply is used in OEM equipment, the OEM equipment manufacturer is responsible for attaching appropriate warning labels on the OEM equipment.

Operating the power supply outside the specified limits for input voltage, temperature, or other environmental conditions noted in this manual can damage the power supply and void the warranty.

Safety Messages

The BHK-MG can be controlled by digital and/or analog inputs. When the output is disabled, whether by the OUTPUT ON/OFF key, SCPI command via GPIB or RS 232 interface, or via the Status and Remote On/Off Port, an internal solid-state switch sets the voltage/current references to zero, resulting in zero output from the power supply. In the case of the OUTPUT ON/OFF key or SCPI command, if the solid state switch fails, and the output is higher than 8V, and the current is higher than two LSBs, a shutdown sequence begins: the unit beeps and flashes the message Power Down in XX sec for 10 seconds as XX counts down from 10 to 0. After 10 seconds the input circuit breaker trips OFF. If the circuit breaker does not trip OFF, BHK Failure is displayed on the LCD.

There are no operator serviceable parts inside the case. Service must be referred to authorized personnel. Using the power supply in a manner not specified by Kepco. Inc. may impair the protection provided by the power supply. Observe all safety precautions noted throughout this manual. The following table lists symbols used on the power supply or in this manual where applicable.

SAFETY SYMBOLS

SYMBOL	Meaning	SYMBOL	Meaning
4	WARNING: RISK OF ELECTRIC SHOCK.	WARNING	INDICATES THE POSSIBILITY OF BODILY INJURY OR DEATH.
\triangle	CAUTION: REFER TO REFER- ENCED PROCEDURE.	CAUTION	INDICATES THE POSSIBILITY OF EQUIPMENT DAMAGE.

BHK-MG 110504 iX

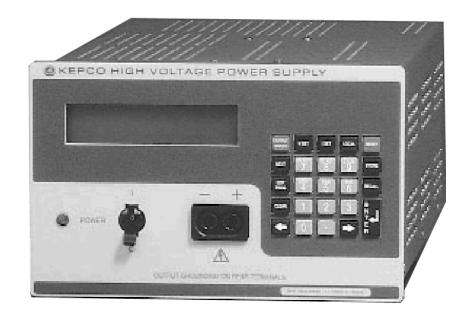


FIGURE 1-1. BHK-MG 40W SERIES PROGRAMMABLE POWER SUPPLY

X BHK-MG110504

SECTION 1 - INTRODUCTION

1.1 SCOPE OF MANUAL

This manual contains instructions for the installation, operation and service of the Half Rack BHK-MG 40W series of output power stabilized voltage or current, d-c power supplies manufactured by KEPCO, Inc., Flushing, New York, U.S.A.



DANGEROUS AND LETHAL POTENTIALS ARE PRESENT, BOTH WITHIN THIS POWER SUPPLY, AND AT THE OUTPUT!

Before proceeding to use the power supply, read this manual very carefully. Caution must be used when working with, and making connections to, this power supply. Use only wires with the proper voltage rating for high voltage connections. Use the designated plugs for the front panel output. Be extremely careful when analog programming inputs are used, especially with the negative output of the power supply grounded.

Unless otherwise specified, always connect the test and measuring equipment to the input power source using an isolating transformer having a suitable isolating voltage rating. Follow all instructions regarding the grounding of the test set-up. Refer all servicing to qualified service personnel only.

1.2 GENERAL DESCRIPTION

The BHK-MG 40W Power Supply Series (Figure 1-1) are full-range, automatic crossover, linear voltage/current stabilizers with a full rectangular output characteristic. Four single-output models are available as listed in Table1-1.

Although designed as a stand-alone bench top unit, the half-rack cross section permits mounting two units side by side in a standard 19-inch wide rack using Kepco's RA 24 Rack Adapter (see Figure 1-3). Connections can be made at both rear output terminals (recommended for rack mounted configurations) and front output terminals (recommended for bench applications). Rear connections are made from a drawer-type access panel that is pulled out for installation of connections, and then inserted and secured during operation. Sensing output terminals are available at the rear terminals only. These power supplies operate from either 115V or 230V a-c (nominal - switch selectable), 50 or 60 Hz (nominal) input source power. Since there are no internal adjustments, BHK-MG 40W Power Supplies offer excellent output voltage/current stability and easy calibration.

Output voltage and current are displayed on an alphanumeric Liquid Crystal Display (LCD). Control of the BHK-MG 40W can be either local, via the front panel keypad and display, or remote - using either analog signals (applied to Analog Programming Terminals), or digital programming via the IEEE 488.2 (GPIB) communication bus. Both digital control (either local or remote) and analog control can be used simultaneously. Digital control is done with 12 bits of resolution over the entire voltage/current range.

BHK-1/2-MG (SVC) 110504

1.3 SPECIFICATIONS

Table 1-1 lists the parameters applicable to individual models. Table 1-2 lists general specifications applicable to all models except where otherwise noted.

TABLE 1-1. MODEL PARAMETERS

	OUTPUT OUTPUT VOLTAGE CURRENT RANGE RANGE	NA A VIBALINA	OUTPUT EQUIVALENT IMPEDANCE (FAST MODE)				
MODEL NUMBER		CURRENT RANGE	OUTPUT POWER	VOLTAGE MODE (SERIES R-L)		CURRENT MODE (PARALLEL R-C)	
	(VOLTS)	(mA)	(WATTS)	R _{d-c} (Ohms)	L (mH)	R _{d-c} (MOhms)	C (μ F)
BHK 300-130MG	0 - 300	0 - 130	39	0.115	See Note	15.4	See Note
BHK 500-80MG	0 - 500	0 - 80	40	0.313	See Note	41.7	See Note
BHK 1000-40MG	0 - 1000	0 - 40	40	4.25	See Note	166.7	See Note
BHK 2000-20MG	0 - 2000	0 - 20	40	5.0	See Note	666.7	See Note
NOTE: Contact Kepco for assistance.							

TABLE 1-2. BHK-MG 40W SPECIFICATIONS

SPECIFIC	ATION	RATING/DESCRIPTION	CONDITION
INPUT CHARACTERIST	ICS		
a-c Voltage	nominal (switch select- able)	115/230V a-c	Single phase
	range (switch selectable)	105-125/210-250V a-c	
Frequency	nominal	50/60Hz	
	range	47-63Hz	
Current	115V a-c	1.1A a-c	Nominal power at output
	230V a-c	0.6A a-c	
OUTPUT CHARACTERI	STICS		
by the unit from the load		oltage is programmed to a lower	ne unit to the load). Sink current (absorbed or value. The sink current is constant, from
Type of Stabilizer		Linear with automatic cross- over	Voltage/Current
Adjustment range	Voltage	0 to 100% of rating	
(Adjustment is either continuous using analog programming, or stepped using digital programming)	Current	0-100% of rating	
Programming resolution	Voltage and Current	0.025% of rating	Current measurement requires calibrated shunt
Programming accuracy	Voltage	0.025% of rating	
	Current	0.05% of rating	Current measurement requires calibrated shunt
Data Readback	Voltage	0.05% of rating	
accuracy	Current	0.05% of rating	10-100% of rating
		0.01% of rating	<10% of rating (automatic 10X magnifier)
Source effect	Voltage	0.001% E _O max	Input voltage
	Current	0.002% I _O max	105-125/210-250V a-c

1-2 BHK-1/2-MG (SVC) 110504

TABLE 1-2. BHK-MG 40W SPECIFICATIONS (Continued)

SPECIFIC	CATION	RATING/DESCRIPTION	CONDITION	
OUTPUT CHARACTER	ISTICS (CONTINUED)			
Load effect	Voltage	0.005% E _O max	no load - full load	
	Current	0.015% I _O max	short - full load	
Temperature effect	Voltage	0.01% E _O max	Ambient temperature	
(per degree C)	Current	0.02% I _O max	0 to 50° C	
Time effect	Voltage	0.01% E _O max	0.5-8.5 hours	
	Current	0.02% I _O max	Ambient temperature: 25° C	
Ripple (rms/p-p)	Voltage:	0.004% / 0.04% E _O max	Minus output terminal connected to GND.	
	Current:	0.02% / 0.2% I _O max	Voltage: Nominal load Current: Short with calibrated shunt.	
Programming rise/fall time (fast mode)	Voltage	180μs (275μs for BHK 2000-20MG)	Load \geq E _O max/I _O max, Vout between zero and E _O max, measured between 10% and 90% of E _O max	
	Current	200μs	Load \leq E $_{\rm O}$ max/I $_{\rm O}$ max, lout between zero and I $_{\rm O}$ max, measured between 10% and 90% of I $_{\rm O}$ max	
Transient recovery to load	Voltage Fast Mode	5% E _O max/100 μsec	Vout=400 Vdc and load switched	
change (Amplitude/time constant)	Slow Mode	0.5% E _O max/1 msec	between infinity and 400/I _O max	
ŕ	Source Current Fast Mode	50% I _O max/100 μsec	lout = I _O max and load switched between 0.1 x E _O max/I _O max and ≤E _O max/I _O max	
Small signal 3-dB Bandwidth (Fast Mode)	Voltage	2.5 KHz	Load = E _O max/I _O max, Vprog out = 200V d-c (from keypad) Vv analog in = 0.2 V rms (from analog input terminal)	
	Current	2.3 KHz	Load = E _O max/I _O max, Iprog out = 200 x I _O max/E _O max (from keypad) Vc analog in = 0.2 V rms (from analog input terminal)	
Slew rate (Fast Mode)	Voltage	>1.2% E _O max (V/μs)	$\begin{aligned} \text{Load} &\geq \text{E}_{\text{O}} \text{ max/I}_{\text{O}} \text{ max}, \\ \text{Measured as the chord of the exponential} \\ \text{response to a square waveform between} \\ \text{zero and E}_{\text{O}} \text{ max and back to zero}. \end{aligned}$	
	Current	>1.1% I _O max (mA/μs)	Load = calibrated shunt Measured as the chord of the exponential response to a square waveform between zero and I _O max and back to zero.	
Overshoot		None	Turn ON/Turn OFF	
Output Impedance		See Table 1-1.		
Remote Sensing Range (default = local sensing)		0.5 V d-c per lead	Provisions for 4-terminal (Kelvin) connection to load	
D-C Isolation voltage	BHK 300-130MG, BHK 500-80MG, BHK 1000-40MG	output voltage	Between either output terminal and ground	
	BHK 2000-20MG	0.5KV d-c or a-c p-p plus max. output voltage	Between either output terminal and ground	

BHK-1/2-MG (SVC) 111704 1-3

TABLE 1-2. BHK-MG 40W SPECIFICATIONS (Continued)

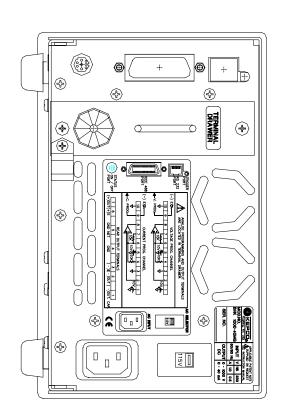
ATION	RATING/DESCRIPTION	CONDITION
STICS (CONTINUED)		
(All models)	1350V a-c/1 min	Between shorted inputs and chassis
BHK 300-130MG	1950V d-c/1 min	Between shorted outputs and chassis.
BHK 500-80MG	2250V d-c/1 min	
BHK 1000-40MG	2000\/ d a/4 min	
BHK 2000-20MG	2800V a-c/1 min	
	0.1 Ohm max.	Between ground input connection and chassis @ 30A
	25 μA rms /100 uA p-p, for 11 (chassis to EARTH-GND)	5V a-c input voltage
Local	Front panel Keypad: disable t	ooth digital and analog programming sig-
Remote	 IEEE 488 (GPIB) port RS 232 port Status & Remote On/Off port TTL signal NO relay contact NC relay contact type. Trigger port (shutdown line) 	Disables both digital and analog programming signals. Shutdown line is for disable only - removing the signal does not reenable the output.
	places for current settings (ex	for voltage settings and three decimal cept that only one decimal place is used BHK 1000-40MG and BHK 2000-20MG).
Overtemperature:		See PAR. 1.4.9a
Overvoltage/Overcurrent:	0 to 1.1 x E _O max 0 to 1.1 x I _O max	See PAR. 1.4.4
Uneven voltage in pass element:		See PAR. 1.4.9c
AC line failure:		See PAR. 1.4.9e
Interruption between sensing and power terminals:		See PAR. 1.4.9f
Overload of main or auxiliary power trans- former:		See PAR. 1.4.9g
BHK 300-130MG	6.6 μF ±10%	
BHK 500-80MG	3.0 µF ±10%	All internal output capacitors are
BHK 1000-40MG	0.94 μF±10%	non-polarized type.
BHK 2000-20MG	0.21 μF±10%	
	+10 ±-0.2V d-c -10 ±-0.2V d-c	max.10 mA d-c
		•
Туре	Output transistor (open collect	tor) from an optocoupler
7 F - 1	Ic = 8mA d-c, Vceo = 40V d-c, Pd = 150mW@25°C	
	Ic = 8mA d-c, Vceo = 40V d-c	, Pd = 150mW@25°C
Output Ratings	Ic = 8mA d-c, Vceo = 40V d-c Saturated transistor when AC	·
Output Ratings Logic	·	·
	BHK 300-130MG BHK 500-80MG BHK 1000-40MG BHK 2000-20MG Local Remote Overtemperature: Overvoltage/Overcurrent: Uneven voltage in pass element: AC line failure: Interruption between sensing and power terminals: Overload of main or auxiliary power transformer: BHK 300-130MG BHK 500-80MG BHK 1000-40MG	BHK 300-130MG BHK 500-80MG BHK 1000-40MG BHK 2000-20MG BHK 2000-20MG BHK 2000-20MG 2800V d-c/1 min 0.1 Ohm max. 25 μA rms /100 uA p-p, for 11 (chassis to EARTH-GND) Local Front panel Keypad: disable to nals. Remote - IEEE 488 (GPIB) port - RS 232 port - Status & Remote On/Off port - TTL signal - NO relay contact - NC relay contact type Trigger port (shutdown line) Two decimal places are used places for current settings (ex for setting voltage on Models Overtemperature: Overvoltage/Overcurrent: 0 to 1.1 x E _O max 0 to 1.1 x I _O max Uneven voltage in pass element: AC line failure: Interruption between sensing and power terminals: Overload of main or auxiliary power transformer: BHK 300-130MG 6.6 μF ±10% BHK 500-80MG 3.0 μF ±10% BHK 1000-40MG 0.94 μF±10% BHK 2000-20MG 0.21 μF±10% H10 ±-0.2V d-c

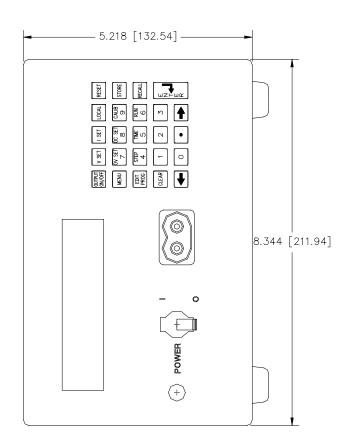
1-4 BHK-1/2-MG (SVC) 110504

TABLE 1-2. BHK-MG 40W SPECIFICATIONS (Continued)

SPECIFICAT	ΓΙΟΝ	RATING/DESCRIPTION	CONDITION
Series Connection		Automatic or Master-Slave Operation, limited by the d-c isolation limit voltage	For slave unit, use analog programming only.
Parallel Connection		Automatic or Master-Slave Operation	For slave unit, use analog programming only.
GENERAL (ENVIRONME	NTAL) CHARACTER	RISTICS	
Temperature	Operating		0° to +50° C
	Storage	-	20° to +70° C
Humidity		0 to 95% RH	Non condensing operating & storage
Shock		20g, 11msec ±50% half sine	Non operating, 3-axes, 3 shocks each axis
Vibration		5-10Hz 10mm double amplitude	Non operating, 3-axes, 1 hour each axis
Cooling		Built-in fan, exhaust to rear	
PHYSICAL CHARACTER	ISTICS		
Dimensions		See Figure 1-2.	
Weight	English	26 lbs.	Unpacked
	Metric	12 Kg	
a-c source connections	Front	Circuit Breaker, 2-pole	
_	Rear	Detachable IEC 3-wire type connector	
d-c output terminals	Rear panel	Terminal Block (11 positions),	±Output, ±Sense, Ground, Internal Capacitor (–), Grounding Network
	Front panel	Jacks (2)	±Output
Control	Local:	Digital control using front pane	el keypad(24 pads) and LCD
_	Remote:		I IEEE 488 Bus (24 pin female connector). panel terminal strips (10 positions) for
Digital display front panel		Voltage, current, mode, settings, menu, program, etc.	2 x 16 character alphanumeric LCD with LED backlight

BHK-1/2-MG (SVC) 110504 1-5





NOTES:

- 1. MATERIAL: A) CHASSIS, COVER & BACK PLATE: #16 GA. C.R.S. B) FRONT PANEL: 1/8 THICK 6061-T6 ALUMINUM.
 - B) TROW TAREE. TO THIS COOL TO ALOWING.
- 2. FINISH: A) CHASSIS & BACK PLATE: CADMIUM PLATE WITH CROMATE WASH.
 - B) COVER: CHARCOAL GRAY VINYL TEXTURE (OUTSIDE), CADMIUM PLATE (INSIDE).
 - C) FRONT PANEL: LIGHT GRAY PER FEDERAL STD. 595, COLOR #26440.
- 3. DIMENSION IN PARENTHESES ARE IN MILLIMETERS.
- 4. TOLERANCES ARE $\pm 1/32$ (0.8), EXCEPT AS NOTED.

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FIGURE 1-2. BHK 40W SERIES POWER SUPPLY, MECHANICAL OUTLINE DRAWING (SHEET 1 OF 2)

1-6 BHK-1/2-MG (SVC) 110504

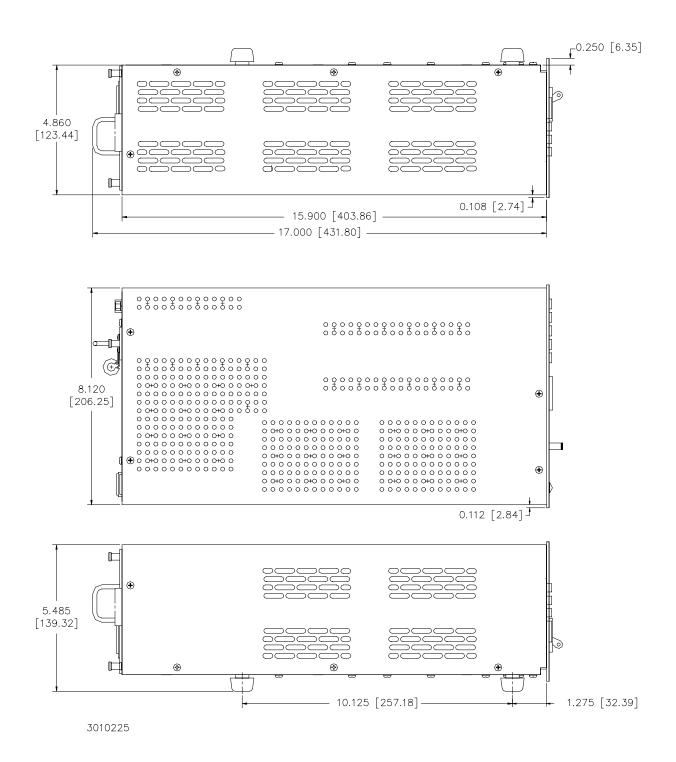


FIGURE 1-2. BHK 40W SERIES POWER SUPPLY, MECHANICAL OUTLINE DRAWING (SHEET 2 OF 2)

BHK-1/2-MG (SVC) 110504

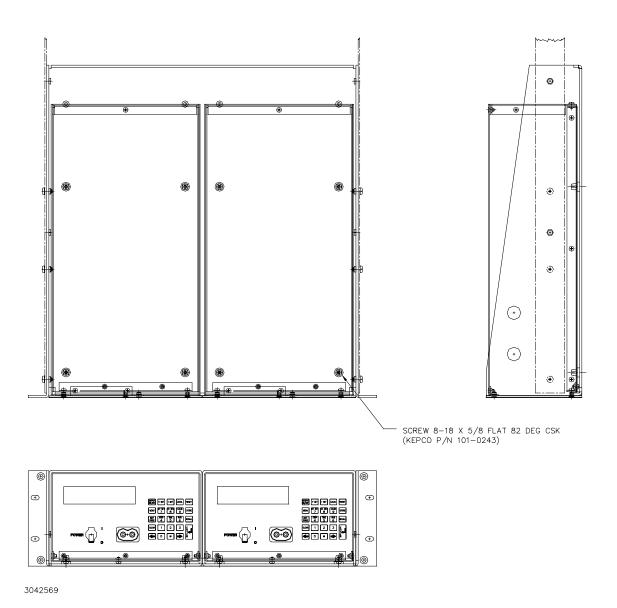


FIGURE 1-3. RA 24 RACK ADAPTER WITH TWO 1/2 RACK BHK-MG 40W UNITS

1-8 BHK-1/2-MG (SVC) 110504

1.4 FEATURES

1.4.1 LOCAL CONTROL

Front panel keypad entries and an LCD type display are utilized for setting and/or adjusting output voltage and current under local control. The keypad's keys are organized to either directly execute commands, or to introduce a program that can either be run once or cycled. Calibration of the unit is facilitated by a password -protected, menu-driven procedure from the front panel. Refer to PAR. 3.2 for more information.

1.4.2 REMOTE CONTROL

Remote control of the BHK-MG 40W Power Supply can be accomplished either through digital or analog programming.

1.4.2.1 DIGITAL PROGRAMMING

Digital control is available directly via the IEEE 488.2 (GPIB) bus using SCPI commands. Nearly all features available in local mode can be accessed in remote mode through digital programming. Refer to PAR's. 3.3 and 3.7 for more information.

1.4.2.2 ANALOG PROGRAMMING

BHK-MG Power Supplies can also be controlled remotely using analog means, such as analog voltage or current, fixed or variable resistors, or a combination of them. This great flexibility is made possible by two uncommitted amplifiers (for voltage and current) and two reference voltages (+10V d-c and -10V d-c) available at the rear panel analog programming terminals. The chosen means of control (voltage, current, resistance, or a combination) must deliver 0 to -10 Vdc at the output of the uncommitted amplifiers in order to have control over the entire range of the output voltage/current limit or output current/voltage limit. Refer to PAR. 3.8 for more information.

1.4.3 DIGITAL CALIBRATION

The BHK-MG 40W Power Supply contains no internal adjustments. Calibration is done entirely via the front panel keypad and LCD, using a calibrated DVM and a corresponding precision shunt resistor. Calibration instructions appear on the front panel LCD after a password is entered.

Calibration constants for programming and read-back activities are calculated by the microcontroller and stored in the non-volatile memory. No internal adjustments are necessary The previous calibration is saved and can be restored if desired. The original factory calibration can also be restored. Refer to Section 4 for more information.

1.4.4 OVERVOLTAGE/OVERCURRENT PROTECTION

Overvoltage and Overcurrent protection values can be individually programmed. The range for overvoltage and overcurrent values are 0 to 1.1 x E_O max, 0 to 1.1 x I_O max. If the output voltage/current is maintained at or above the overvoltage/overcurrent protection value for more than 9ms, the protection circuit cuts the pass element off, discharges the output capacitor, trips the POWER circuit breaker to OFF and sends a flag on a dedicated line (status port connector). The default values are 1.1 x E_O max for overvoltage protection, and 1.1 x I_O max for overcurrent protection. Refer to PAR. 3.2.9 for more information.

BHK-1/2-MG (SVC) 110504 1-9

1.4.5 USER-DEFINED VOLTAGE/CURRENT LIMITS

The BHK-MG 40W Power Supply can be programmed not to exceed user-defined values that can be lower than the maximum values. For example, the BHK 500-80MG, which has maximum output values of 500V d-c, 0.08A d-c, can be limited to 100V d-c, 0.04A d-c for working with circuitry that might be damaged by higher levels. Once the limits are set, the power supply becomes, in effect a 100V d-c, 0.04A d-c supply and values exceeding the limit values will not be accepted. Refer to PAR. 3.2.10 for more information.

1.4.6 NONVOLATILE STORAGE OF PROGRAMMED SEQUENCES OR ACTIVE SETTINGS

The BHK-MG 40W Power Supply contains 40 memory locations that can be used either to preprogram a sequence of output values or to store active settings. For programming sequences each memory location accommodates six parameters: output voltage, output current, overvoltage, overcurrent, time (how long the parameters are in effect) and the next address in the sequence. Values are stored in the nonvolatile memory, and are retained when the unit is turned off. Refer to PAR. 3.2.14 for more information.

The same 40 memory locations are also available to save the active programmed settings (voltage, current, overvoltage, overcurrent). The saved setting can be recalled by specifying the memory location. Refer to PAR's. 3.2.11 and 3.2.12 for more information.

1.4.7 CURRENT MEASUREMENT SCALE

Measurement of a decreasing output current of the power supply that falls below $8.98\% \pm 0.1\%$ of the rated value is automatically measured with increased resolution/accuracy by a factor of 10 until the current rises above $9.69\% \pm 0.1\%$ of rated value.

1.4.8 FAST MODE/SLOW MODE SELECTION

BHK-MG Series Power Supplies can be configured by external strapping for either slow mode operation with the internal output capacitor connected to the output, or fast mode operation with the internal output capacitor disconnected from the output. The slow mode (default state) is recommended for voltage stabilization because of its low output noise and low recovery amplitude to a dynamically changing load. The fast mode offers a faster response to step or dynamic programming of the output voltage (in voltage mode), when the power supply is used as a power amplifier. Fast mode is also recommended for current stabilization because of its fast response to a dynamically changing load. Refer to PAR. 3.9.1 for more information.

1.4.9 BUILT-IN PROTECTION

BHK-MG Series Power Supplies provide built-in protection against the following:

- a. Overtemperature of the pass element. Heatsink temperature is monitored. If an overtemperature condition is maintained for more than 2.5ms, the following actions are initiated: the pass element is cut off, the output capacitor is discharged, and the unit is turned off by tripping the circuit breaker. A flag is sent to the host computer via a dedicated line of the Status and Remote On/Off port.
- b. Overvoltage/overcurrent at the output. See PAR. 1.4.4
- c. Uneven voltage in the pass and sink elements. Voltage is monitored across different transistors of the pass and sink elements. If uneven voltage continues for more than 20ms, the pass element is cut off, the output capacitor is discharged, the POWER circuit breaker is tripped to OFF and a flag is sent to the host computer on a dedicated line (Status and Remote On/Off Port connector)

1-10 BHK-1/2-MG (SVC) 110504

- d. **Input Voltage Selector set incorrectly.** If the selector is set to 115V a-c and the input voltage is 230V a-c, the input circuit breaker will be tripped without delay. A flag is sent to the host computer on a dedicated line (Status and Remote On/Off Port).
- e. **AC line failure.** If AC line is missing for more than 50 ms, a flag is sent to the host computer on a dedicated line (Status Port connector). In addition, if the jumper at A3-JP2 is installed (default state), the pass element is cut off, the output capacitor is discharged, and the POWER circuit breaker is tripped to OFF.
- f. **Interruption between the sensing and corresponding power output terminals.** If there is an interruption between the sensing and power terminals, two diodes connected in parallel between the sensing lead and the corresponding power lead (one forward biased and one reverse biased), allow the power supply to continue to function.
- g. **Overload of the main or auxiliary power transformer.** If input current of the main transformer exceeds 1.1A a-c @ 115V a-c or 0.6A a-c @ 230V a-c, the input POWER circuit breaker is tripped to OFF, the pass element is cut off, the output capacitor is discharged, and a flag is sent to the Status Port connector. The reaction time is inversely proportional to the input overcurrent: from a minimum of 10ms for 10 times nominal current, to a maximum of 100 seconds for 25% above nominal current.

If input current of the auxiliary power transformer exceeds a predetermined value, the PTC (Positive Thermal Coefficient) thermistor (in series with the primaries of the auxiliary transformers) resistance will increase, thus reducing the voltage across the primary of the corresponding transformer. If this occurs, the pass element will be cut off. In some circumstances, depending upon which transformer is involved and whether an overcurrent condition is detected during or after power-up, the input circuit breaker may trip OFF.

h. **Current Limit.** The current through the pass and sink elements is monitored. If this current is 1.5 times larger than the nominal value for more than 20ms, the pass element is cut off, the output capacitor is discharged, and the POWER circuit breaker is tripped to OFF. A flag is sent to the host computer via the Status and Remote On/Off Port.

1.4.10 INTERNAL SIGNALS AVAILABLE FOR CUSTOMER USE

Some internal signals produced by the unit are available at connector A2J5 for either monitoring or testing purposes. Refer to Table 1-3 for a description of available signals.

1.4.11 EXTERNAL TRIGGER PORT

The External Trigger Port provides two functions: a shutdown input can be used to immediately shut down the power supply output (see PAR. 3.2.6.3) and a trigger input can be used to restore the output to previously defined settings (see PAR. 3.3.4).

1.4.12 CURRENT SINK CAPABILITY

BHK-MG 40W Series power supplies are able to sink up to 5% of the nominal current when in voltage mode and greater than 75% of the unit's maximum rated current when in current mode. The fixed current mode sink value is model dependent and has a tolerance of 10%. When the BHK-MG 40W is in sink mode, the unit displays the word "Sink" and the sink current value (negative) on the front panel display. This capability is useful in applications such as capacitor testing, where the sink capability allows the rapid discharge of the device under test, permitting subsequent tests to be started earlier, thus increasing the throughput of the testing process.

BHK-1/2-MG (SVC) 110504 1-11

The sink current in current mode is quite stable, allowing this feature to be used with the discharging process to determine the value of a capacitor under test by measuring the discharge time, using the formula $C = T \times I / V$ (the charge time, which is more accurate, can also be used in the formula), where

T = discharge or charge time

V = change in voltage from fully charged to fully discharged, or vice versa.

I = discharging or charging current (BHK-MG charging current has a tolerance of

0.05% of nominal value, discharge current has a tolerance of 10% of nominal value)

The value of the capacitor under test can be calculated directly by measuring T and either using the above formula and the appropriate tolerance for I, or by comparing T to that of a known capacitor value.

TABLE 1-3. CONNECTOR A2J5 SIGNAL DESCRIPTIONS

SIGNAL	PIN. NO.	VALUE	TYPE	
Step Down Flag	2	< -11V for steady or step-up output > +11V for step-down output, or when pro- tection circuit has functioned.	Output of open loop Op Amp (A2U2C) through 1K resistance.*	
V-C Mode Flag	3	< -11V for CV (Constant Voltage) mode > +11V for CC (Constant Current) mode	Output of open loop Op Amp (A2U2A) through 1K resistance.*	
Source-sink Flag	4	< -11V for sink > +11V for source	Output of open loop Op Amp (A2U9) through 1K resistance.*	
Power GND	5	N/A	Recommended to be used as Return for signal at pin 2.	
Current Monitor (not calibrated)	6	$0V \pm 10$ mV (for I _O = 0mA) to +10V ± 0.12 V (for I _O = Full Scale)	Output of closed loop Op Amp (A2U14B) *	
Signal GND	7	N/A	Recommended to be used as Return for signals at pins 6 and 8.	
Voltage Monitor (not calibrated)	8	$0V \pm 10$ mV (for E _O = 0V) to +10V ± 0.25V (for E _O = Full Scale)	Output of closed loop Op Amp (A2U1B) *	
* Recommended load	* Recommended load equal to or greater than 10K ohms.			

1.5 EQUIPMENT SUPPLIED

Equipment supplied with the unit is listed in Table 1-3.

TABLE 1-4. EQUIPMENT SUPPLIED

ITEM	PART NUMBER	QUANTITY
Power Cord	118-0557	1
Plug housing for front panel output jack	142-0489	1
Contact (crimp, snap-in)) for plug housing	107-0361	2
Status and Remote On/Off Port mating connector	142-0488	1
Two-terminal Link for rear panel output	172-0300	2
Three-terminal Link for rear panel output	172-0305	2
Four-terminal Link for rear panel output (installed)	172-0407	2
Five-terminal Link for rear panel output	172-0321	1
Six-terminal Link for rear panel output	172-0408	1

1-12 BHK-1/2-MG (SVC) 110504

1.6 ACCESSORIES

Accessories for the BHK Power Supply are listed in Table 1-4.

TABLE 1-5. ACCESSORIES

ITEM	FUNCTION	PART NUMBER
IEEE 488 (GPIB) Cable, 1m long	Connects BHK-MG 40W Power Supply to GPIB bus.	SNC 488-1
IEEE 488 (GPIB) Cable, 2m long	Connects BHK-MG 40W Power Supply to GPIB bus.	SNC 488-2
IEEE 488 (GPIB) Cable, 4m long	Connects BHK-MG 40W Power Supply to GPIB bus.	SNC 488-4
Rack Adapter	Allows rack mounting of two units side by side (see Figure 1-3).	RA 24
Slide (2)	Allows rack-mounted units to slide in and out.	CS-01, -02, -03 (Kepco) 110-QD-20-2, 22-2, 22-4 (Jonathan)
External Trigger Port mating connector	Allows access to external trigger function	142-0486 (Kepco) MDP-023 (Power Dynamics)
RS 232 Port Adapter Cable Kit	Contains RJ 45 Patch cord, two RS 232 adapters (one with male pins to connect to DTE equipment and one with female pins to connect to a personal computer), and an RS 232 Loop Back test Connector (to test RS 232 communication and aid in isolating RS 232 communication problems).	KIT 219-0436

1.7 SAFETY

There are no operator serviceable parts inside the case. Service must be referred to authorized personnel. Using the power supply in a manner not specified by Kepco. Inc. may impair the protection provided by the power supply. Observe all safety precautions noted throughout this manual. Table 1-6 lists symbols used on the power supply or in this manual where applicable.

TABLE 1-6. SAFETY SYMBOLS

SYMBOL	MEANING
A	CAUTION: RISK OF ELECTRIC SHOCK.
\triangle	CAUTION: REFER TO REFERENCED PROCEDURE.
WARNING	INDICATES THE POSSIBILITY OF BODILY INJURY OR DEATH.
CAUTION	INDICATES THE POSSIBILITY OF EQUIPMENT DAMAGE.

BHK-1/2-MG (SVC) 110504 1-13/(1-14 Blank)

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 2.5. If any indication of damage is found, file an immediate claim with the responsible transport service.

2.2 TERMINATIONS AND CONTROLS

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

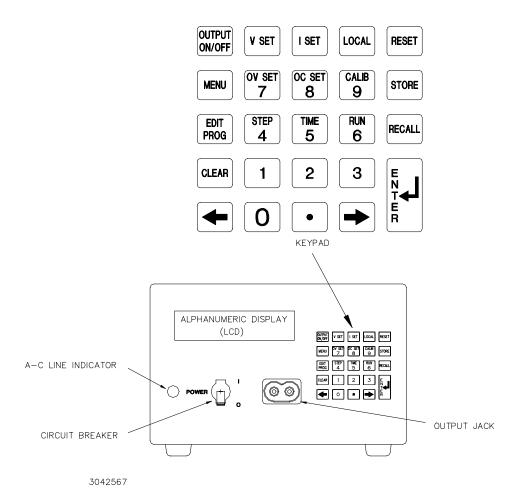


FIGURE 2-1. BHK-MG SERIES, FRONT PANEL CONTROLS, INDICATORS AND CONNECTORS

BHK-1/2-MG SERIES 110504 2-1

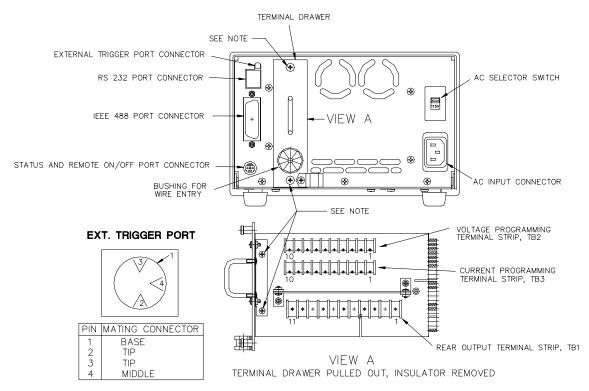
TABLE 2-1. CONTROLS, INDICATORS, AND CONNECTORS

CONTROL, INDICATOR, CONNECTOR	FUNCTION			
	FRONT PANEL (See Figure 2-1.)			
A-C line indicator	Lights to indicate unit turned on and a-c power applied.			
LCD	2 x 16 character Liquid Display with LED backlight. Shows voltage, current mode, settings, menu, program, etc.			
Keypad	24 keys used for local operation of the power supply; Refer to Table 3-2 for details.			
POWER circuit breaker	Circuit breaker used to turn unit on and off.			
Output jack	Provide front panel access to d-c output of power supply.			
	REAR PANEL (See Figure 2-2.)			
IEEE 488 PORT	24-pin GPIB connector used to connect to GPIB bus (see Table 2-2 for pin assignments).			
STATUS AND REMOTE ON/OFF PORT	Notifies host computer either that a-c input is not present or a major failure of power supply has occurred and allows remote on/off control of the unit (see Table 2-3 for pin assignments).			
RS 232 PORT	8-pin connector telephone jack type used to connect to RS 232 bus. Adapter cable kit (see Table 1-5) converts to 9-pin jack (see Table 2-4 for 9-pin assignments).			
EXTERNAL TRIGGER PORT	4-pin connector used to restore previously stored settings or to shut down the output (see Table 2-5 for pin assignments). NOTE: Mating connector is a 3-pin plug.			
OUTPUT TERMINALS barrier strip TB1 (See NOTE 1.)	Provides Power Supply output connection points. (See Table 2-6 for terminal assignments)			
V PROG terminal strip TB2 (See NOTE 1.)	Provides input/output signals for analog programming of output voltage or voltage limit. (See Table 2-7 for terminal assignments.)			
I PROG terminal strip TB3 (See NOTE 1.)	Provides input/output signals for analog programming of output current or current limit. (See Table 2-8 for terminal assignments.)			
AC SELECTOR switch	Used to select between nominal input line voltage of 115 V a-c or 230 V a-c.			
AC INPUT connector	Provides a-c source power to unit.			
Terminal Drawer Closed detector (see NOTE 2.)	Provides protection when Terminal Drawer is open by tripping the a-c circuit breaker to off.			

NOTES 1. Accessible by loosening two captive screws and pulling out terminal drawer, and removing protective insulator (see Figure 2-2).

2. The Terminal Drawer detector (located on PC board A3) and the a-c circuit beaker function as an interlock switch.

2-2 BHK-1/2-MG SERIES 110504



NOTE: REMOVE SCREWS AND PULL OUT DRAW TO ACCESS REAR OUTPUT TERMINALS AND VOLTAGE AND CURRENT PROGRAMMING TERMINALS

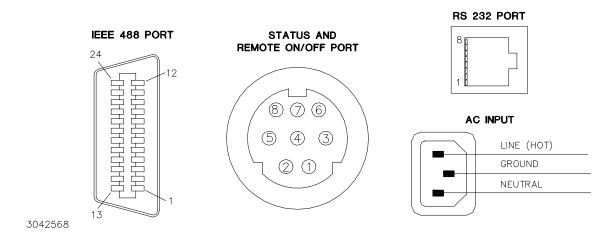


FIGURE 2-2. BHK-MG SERIES, REAR PANEL CONTROLS AND CONNECTIONS

BHK-1/2-MG SERIES 110504 2-3

TABLE 2-2. IEEE 488 PORT CONNECTOR PIN ASSIGNMENTS

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
	1	DI01	I/O Line
	2	DI02	I/O Line
	3	DI03	I/O Line
	4	DI04	I/O Line
	5	EOI	End or Identify
	6	DAV	Data Valid
	7	NRFD	Not Ready for Data
	8	NDAC	Not Data Accepted
	9	IFC	Interface Clear
	10	SRQ	Service Request
	11	ATN	Attention
IEEE 488 PORT	12	SHIELD	Shield
A1J1	13	DI05	I/O Line
	14	DI06	I/O Line
	15	DI07	I/O Line
	16	DI08	I/O Line
	17	REN	Remote Enable
	18	GND	Ground (signal common)
	19	GND	Ground (signal common)
	20	GND	Ground (signal common)
	21	GND	Ground (signal common)
	22	GND	Ground (signal common)
	23	GND	Ground (signal common)
	24	LOGIC GND	Logic Ground

TABLE 2-3. STATUS AND REMOTE ON/OFF PORT CONNECTOR PIN ASSIGNMENTS

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
	1	Armature	Relay control armature contact.
	2	N-open	Normally open relay control input: pins 1 - 2 open for output ON, pins 1 - 2 closed for output OFF (Jumper A3JP1 should be in the factory default position, between pins 1 and 2).
	3	N-closed	Normally closed relay control input: pins 1 - 3 closed for output ON, pins 1 - 3 open for output OFF (Jumper A3JP1 should be inserted between pins 2 and 3).
STATUS AND	4	5V Return	Return for TTL control
REMOTE ON/OFF	5	Not Used.	
PORT	6	TTL	TTL control input: Logic 0 for unit ON, logic 1 for unit OFF.
CONNECTOR A3J14	7	Collector	Collector of LED-transistor optocoupler. Notifies host computer of absence of a-c input or a major power supply failure, active "high" (see PAR 1.4.9), requires pin 8 to be connected to the "-" of the host computer d-c supply as described in PAR.2.9.
	8	Emitter	Emitter of LED-transistor optocoupler. Notifies host computer of absence of a-c input or a major power supply failure, active "low" (see PAR 1.4.9), requires pin 7 to be connected to the "+" of the host computer d-c supply as described in PAR. 2.9.

2-4 BHK-1/2-MG SERIES 110504

TABLE 2-4. RS 32C PORT INPUT/OUTPUT PIN ASSIGNMENTS

CONNECTOR	PIN	SIGNAL NAME	FUNCTION	Adapter Cable (P/N KIT 219-0436)	
				PIN	FUNCTION
RS 232 PORT (connector A1J5)	1	RTN	Return	1	Signal Ground
	2	Not Used	Not Used	2	Receive Data
	3	TXD	Transmit Data	3	Transmit Data
	4	RXD	Receive Data	4	Data Terminal Ready (protocol not used)
	5	RTN	Return	5	Signal Ground
	6	Not Used	Not Used	6	Data Set Ready (protocol not used)
	7	RTN	Return	7	Request To Send (protocol not used)
	8	RTN	Return	8	Clear To Send (protocol not used)
				9	Signal Ground

TABLE 2-5. EXTERNAL TRIGGER PORT PIN ASSIGNMENTS

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
TRIGGER PORT (connector A1J2)	1	Trigger- Shutdown RTN	Return for TRIGGER and SHUTDOWN signals.
	2	SHUTDOWN	Logic 0 causes BHK output to go be disabled (see PAR. 3.2.6.3).
	4	TRIGGER	Logic 0 triggers BHK to previously stored setting (see PARs. 3.3.4 and B.94.)

TABLE 2-6. REAR OUTPUT TERMINAL STRIP A6TB1, TERMINAL ASSIGNMENTS

THE E E OF THE THE TERMINATE OF THE TRANSPORT OF THE TRAN				
SIGNAL NAME	FUNCTION			
- OUT C	Connection to the internal output capacitor			
– OUT	Negative d-c output connection			
-S	Negative sense connection			
GND	Ground (chassis) connection			
GND NET	Grounding network connection			
+S	Positive sense connection			
+ OUT	Positive d-c output connection			
	SIGNAL NAME - OUT C - OUT -S GND GND NET +S			

TABLE 2-7. VOLTAGE PROGRAMMING TERMINAL STRIP A6TB2, TERMINAL ASSIGNMENTS

TERMINAL	SIGNAL NAME	FUNCTION
1	-10V	-10V d-c reference voltage
2	V(NINV)	Noninverting input of uncommitted amplifier
3	SGND	Signal common
4	V(+IN)	Programming input for positive input signal
5	+10V	+10V d-c reference voltage
6	V(INV)	Inverting input of uncommitted amplifier
7	V(FBK)	Internal feedback resistor; the other end is connected to uncommitted amplifier output
8	V(OUT)	Output of uncommitted amplifier
9	–V EXT	External analog programming voltage input: 0 to –10V programs 0 to 100% of E _O max.
10	SGND	Signal common

BHK-1/2-MG SERIES 110504 2-5

TABLE 2-8. CURRENT PROGRAMMING TERMINAL STRIP A6TB3, TERMINAL ASSIGNMENTS

TERMINAL	SIGNAL NAME	FUNCTION
1	-10V	-10V d-c reference voltage
2	C(NINV)	Noninverting input of uncommitted amplifier
3	SGND	Signal common
4	C(+IN)	Programming input for positive input signal
5	+10V	+10V d-c reference voltage
6	C(INV)	Inverting input of uncommitted amplifier
7	C(FBK)	Internal feedback resistor; the other end is connected to uncommitted amplifier output
8	C(OUT)	Output of uncommitted amplifier
9	C EXT	External analog programming voltage input: 0 to –10V programs 0 to 100% of I _O max.
10	SGND	Signal common

2.3 SOURCE POWER REQUIREMENTS



BEFORE APPLYING AC SOURCE POWER TO THE POWER SUPPLY, VERIFY THAT THE LINE VOLTAGE TO BE SUPPLIED MATCHES THE POSITION OF THE AC INPUT SELECTOR SWITCH AT THE REAR PANEL (FACTORY DEFAULT IS 115V).

This power supply operates with the installed circuit breaker from single phase AC mains power over the specified voltage and frequency ranges without adjustment or modification. The AC INPUT SELECTOR switch located on the rear panel (Figure 2-2) allows selection of either 115Vac or 230Vac source power.

The maximum AC current absorbed by the BHK-MG 40W Power Supply from the power source is 1.1A a-c @115V a-c and 0.6A a-c @230V a-c; the power source must be able to deliver the maximum current as well as surge current ten times larger than maximum.

2.4 COOLING

The power devices used within the power supply are maintained within their operating temperature range by means of internal heat sink assemblies cooled by two internal (d-c type) cooling fans.

ALL INLET AND EXHAUST OPENINGS AROUND THE POWER SUPPLY CASE MUST BE KEPT CLEAR OF OBSTRUCTION TO ENSURE PROPER AIR ENTRY AND EXHAUST.

Periodic cleaning of the power supply interior is recommended. If the power supply is rack mounted, or installed within a confined space, care must be taken that the ambient temperature, which is the temperature of the air immediately surrounding the power supply, does not rise above the specified limits (see Table 1-2).

2-6 BHK-1/2-MG SERIES 110504

2.5 PRELIMINARY OPERATIONAL CHECK

WARNING

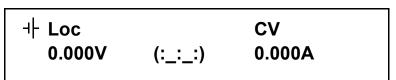
BEFORE APPLYING AC SOURCE POWER TO THE POWER SUPPLY, VERIFY THAT THE LINE VOLTAGE TO BE SUPPLIED MATCHES THE POSITION OF THE AC INPUT SELECTOR SWITCH AT THE REAR PANEL (FACTORY DEFAULT IS 115V).

A simple operational check after unpacking and before equipment installation is advisable to ascertain whether the power supply has suffered damage resulting from shipping.

Refer to Figures 2-1 and 2-2 for location of operating controls and electrical connections. Tables 2-1 and 3-2 explain the functions of operating controls/indicators and keypad keys, respectively.

- With **POWER** switch set to down (OFF) position, connect the power supply to source power.
- 2. With no load connected, set **POWER** switch to the up (ON) position. Each time the unit is turned on an internal self-test is performed and the power on indications (Figure 2-3) are visible. If these indications do not appear, the power supply will be inoperative.

The alphanumeric display (LCD) indicates the model and GPIB address. After a few seconds, the display presents the power supply default values: Local mode (Loc), Output On/Off (Off), output voltage and current (0.000V 0.000A) and command entry status (see Figure 2-3.). Overvoltage and overcurrent protection are set to the maximum values (PAR. 1.4.4), but are not displayed. To enable the output of the BHK-MG, press the OUTPUT ON/OFF key on the front panel



NOTE: (:_:_:) indicates blinking colon (:), Command Entry status (=_==) indicates blinking equal sign (=), Data Entry status

FIGURE 2-3. LCD POWER ON DEFAULTS

NOTE: Six keys with dual functions are labeled with both a command and a number. The command is referred to when the unit is in (:_:_:) command entry status; the number is referred to when the unit is in (=_=_=) data entry status.

- 3. Allow unit to warm up for at least 15 minutes.
- 4. Connect a digital voltmeter (DVM) to the output jack at the front panel.
- 5. Press **VSET** key. Verify bottom line of LCD reads **Vset** (=_=_=) **0.0 v**. Use number keys to enter nominal output voltage (e.g. for BHK 500-80MG, 500V is the nominal output voltage) and press **ENTER**. Output voltage will be displayed at bottom left of LCD. Verify the LCD reads CV (constant voltage mode).

BHK-1/2-MG SERIES 110504 2-7

NOTE: If tolerances specified in the following steps are exceeded, refer to Section 4 and recalibrate the unit.

- 6. Compare the programmed output voltage value with the voltage reading of the DVM; the difference between the two should not exceed 0.025% of the nominal voltage of the unit.
- 7. Compare the voltage reading of the LCD with that of the DVM; the difference between the two should not exceed 0.05% of the nominal voltage of the unit.
- 8. Press **VSET** key and enter different value for output voltage, then repeat steps 6 and 7 using different values for programmed voltage.
- 9. Disable the output by pressing **OUTPUT ON/OFF** key; verify LCD reads 0.0V and 0.0mA within 0.05% of the nominal voltage of the unit.
- Disconnect DVM and connect precision shunt (see PAR. 4.2) across front panel output terminals; connect DVM across shunt (sensing terminals).
- 11. Using VSET key, set output voltage to 30V.
- 12. Similarly, using **ISET** key, program output current to the nominal output current of the power supply (e.g., for BHK 500-80MG, 80mA is the nominal output current).
- 13. Press **OUTPUT ON/OFF** key to enable the output of the unit. Verify the LCD reads **CC** (constant current mode) and a small value for output voltage ($R_S \times I_{o \text{ (prog)}} \times 0.001$) in volts, where R_S = resistance of shunt in ohms and $I_{o \text{ (prog)}}$ = the actual value for current programmed in step 12 (in milliamperes).
- 14. Note DVM reading (V_{DVM}) and calculate the output current using the formula $I_O = V_{DVM} \times 1000/R_S$ in milliamperes (mA).
- 15. Compare the programmed output current value (step 12) with the value shown indirectly by DVM (calculated in step 14); the difference between the two should not exceed 0.05% I_{O} max \pm (TOL_{Rs})% I_{O} , where I_{O} is the output current and TOL_{Rs} is the tolerance of the precision shunt (step 10).
- 16. Compare the output current value shown by the LCD (step 13) with the value shown indirectly by DVM (calculated in step 14); the difference between the two should not exceed $0.05\%\ I_O max\ \pm (TOL_{Rs})\%\ I_O$.
- 17. Repeat steps 15 and 16 using different values for programmed current.
- Disable the output by pressing OUTPUT ON/OFF key, turn-off power supply and disconnect the shunt.

2.6 INSTALLATION

2.6.1 BENCH TOP USE

The unit is designed to be used as a bench top instrument. Front panel output terminals are provided for easy access. However, if the application requires remote sensing, it is necessary to use rear output terminals for sensing connections.

2-8 BHK-1/2-MG SERIES 110504

2.6.2 RACK MOUNTING

Using a Kepco RA 24 Rack Adapter, two 1/2 rack BHK-MG 40W units can be mounted in a 19-inch wide rack, after the bench-type feet are removed (see Figure 1-3). Optional slides for the rack adapter (see Table 1-5) can be used to improve access to the unit.

2.7 WIRING INSTRUCTIONS

Interconnections between an a-c power source and the power supply, and between the power supply and its load are as critical as the interface between other types of electronic equipment. If optimum performance is expected, certain rules for the interconnection of source, power supply and load must be observed by the user. These rules are described in detail in the following paragraphs.

To access to the output and analog programming terminal strips it is necessary to pull out the terminal drawer as follows:

- 1. Loosen two captive screws securing the terminal drawer to the rear panel.
- 2. Use the handle provided to pull out the terminal drawer.
- 3. Remove two screws attaching the protective insulator to the terminal strip PC board, then snap out the insulator and remove it.
- 4. Thread wires through wire-entry bushing before connecting to terminal strip.
- 5. After all connections have been completed, snap the insulator in place and secure with two screws. Then insert the terminal drawer into the rear panel (taking care that the bottom of the PC board/insulator engage the internal guides) and secure with two captive screws.

NOTE: The unit will not operate unless the terminal drawer is securely inserted in the rear panel.

2.7.1 SAFETY GROUNDING

Local, national and international safety rules dictate the grounding of the metal cover and case of any instrument connected to the a-c power source, when such grounding is an intrinsic part of the safety aspect of the instrument. The ground terminal of the source power connector (Figure 2-2) is connected to the BHK-MG chassis and the instructions below suggest wiring methods which comply with these safety requirements; however, in the event that the specific installation for the power system is different from the recommended wiring, it is the customer's responsibility to ensure that all applicable electric codes for safety grounding requirements are met.

2.7.2 SOURCE POWER CONNECTIONS

Source power is connected to the power supply via the three-wire input power cable supplied.

2.7.3 D-C OUTPUT GROUNDING

Connections between the power supply and the load and sensing connections may, despite precautions such as shielding, twisting of wire pairs, etc., be influenced by radiated noise, or "pick-up". To minimize the effects of this radiated noise the user should consider grounding one side of the power supply/load circuit. The success of d-c grounding requires careful analysis of

BHK-1/2-MG SERIES 110504 2-9

each specific application, however, and this recommendation can only serve as a general guideline.

One of the most important considerations in establishing a successful grounding scheme is to avoid GROUND LOOPS. Ground loops are created when two or more points are grounded at different physical locations along the output circuit. Due to the interconnection impedance between the separated grounding points, a difference voltage and resultant current flow is superimposed on the load. The effect of this ground loop can be anything from an undesirable increase in output noise to disruption of power supply and/or load operation. The only way to avoid ground loops is to ensure that the entire output/load circuit is fully isolated from ground, and only then establish a single point along the output/load circuit as the single-wire ground point.

The exact location of the "best" d-c ground point is entirely dependent upon the specific application, and its selection requires a combination of analysis, good judgement and some amount of empirical testing. If there is a choice in selecting either the positive or negative output of the power supply for the d-c ground point, both sides should be tried, and preference given to the ground point producing the least noise. For single, isolated loads the d-c ground point is often best located directly at one of the output terminals of the power supply; when remote error sensing is employed, d-c ground may be established at the point of sense lead attachment. In the specific case of an internally-grounded load, the d-c ground point is automatically established at the load.

The output terminals (located on both the front or rear panel) for BHK-MG Power Supplies are d-c isolated ("floating") from the chassis in order to permit the user maximum flexibility in selecting the best single point ground location. Care must be taken in measuring the ripple and noise at the power supply: measuring devices which are a-c line operated can often introduce additional ripple and noise into the circuit.

There is, unfortunately, no "best" method for interconnecting the load and power supply. Individual applications, location and nature of the load require careful analysis in each case. Grounding a single point in the output circuit can be of great importance. It is hoped that the preceding paragraphs will be of some assistance in most cases. For help in special applications or difficult problems, consult directly with Kepco's Application Engineering Department.

2.7.4 POWER SUPPLY/LOAD INTERFACE

The general function of a voltage or current stabilized power supply is to deliver the rated output quantities to the connected load. The load may have any conceivable characteristic: it may be fixed or variable, it may have predominantly resistive, capacitive or inductive parameters; it may be located very close to the power supply output terminals or it may be a considerable distance away. The perfect interface between a power supply and its load would mean that the specified performance at the output terminals would be transferred without impairment to any load, regardless of electrical characteristics or proximity to each other.

The stabilized d-c power supply is definitely not an ideal voltage or current source, and practical interfaces definitely fall short of the ideal. All voltage-stabilized power supplies have a finite source impedance which increases with frequency, and all current-stabilized power supplies have a finite shunt impedance which decreases with frequency. The method of interface between the power supply output and the load must, therefore, take into account not only the size with regard to minimum voltage drop, but the configuration with regard to minimizing the impedance introduced by practical interconnection techniques (wire, bus bars, etc.). The series inductance of the load wire must be as small as possible as compared to the source inductance of the power supply: although the error sensing connection to the load compensates for the d-c voltage drop in the power leads, it cannot compensate for the undesirable output effects of the

2-10 BHK-1/2-MG SERIES 110504

power lead inductance. These lead impedances (both power and sensing leads) are especially important if the load is a) constantly modulated or step-programmed, b) has primarily reactive characteristics, or c) where the dynamic output response of the power supply is critical to load performance.

2.7.5 LOAD CONNECTION - GENERAL

Load connections to the BHK-MG 40W Power Supply are achieved via the rear output terminal strip (TB1); (+) and (-) outputs are also available at the jack located on the front panel. Configuration of the rear output terminal strip is facilitated by five types of links supplied with the unit:

2-terminal link: (qty 2)

• 3-terminal link: (qty 2)

4-terminal link: (qty 2)

• 5-terminal link: (qty 1)

6-terminal link: (qty 1)

These links are used to configure the power supply for local or remote sensing, slow or fast mode, insertion of the grounding network, isolated (floating) output, and negative or positive grounded output. The links allow many possible configurations using various combinations of the configurable parameters noted above.

The BHK-MG 40W Power Supply is shipped from the factory configured as follows (factory default configuration): local sensing, grounding network connected, slow mode, output isolated from ground (floating). This configuration is obtained using two 4-terminal links connected as shown in Figure 2-4.

NOTE: REGARDLESS OF OUTPUT CONFIGURATION, OUTPUT SENSE LINES MUST BE CONNECTED FOR PROPER OPERATION, EITHER LOCALLY, OR AT THE LOAD (REMOTE). OBSERVE POLARITIES: THE +S TERMINAL (TB1-6) MUST BE CONNECTED TO EITHER +OUT (TB1-7) (LOCAL) OR +LOAD (REMOTE), AND THE - S TERMINAL (TB1-3) MUST BE CONNECTED TO EITHER –OUT (TB1-2) (LOCAL) OR –LOAD (REMOTE).

Figures 2-4 and 2-5 are typical load connection diagrams illustrating the configurations explained in the following paragraphs.

2.7.5.1 LOCAL SENSING/REMOTE SENSING SELECT

Local sensing (factory default configuration) is established by connecting terminals TB1-6 (+S) to TB1-7 (+OUT) and TB1-2 (-OUT) to TB1-3 (-S) (see Figure 2-4). The power supply is shipped with these connections installed for local sensing.

Remote sensing is established by removing the links between TB1-6, TB1-7 and TB1-2, TB1-3. The +S and –S lines must be connected at the load (see Figure 2-5).

2.7.5.2 FAST MODE/SLOW MODE SELECT

Fast mode is established when there is no connection between TB1-2 (-OUT) and TB1-1 (-OUT C) (see Figure 2-5). Slow mode (factory default configuration) can be established by con-

BHK-1/2-MG SERIES 110504 2-11

necting TB1-2 to TB1-1, thus connecting the internal output capacitor to the output (see Figure 2-4).

2.7.5.3 GROUNDING NETWORK CONFIGURATION

When the output is floating there is a tendency for large changes in output voltage to affect the digital programming section, possibly resulting in an erroneous output. The parallel RC grounding network is designed to be connected to ground at the output when the output is floating to ensure that the digital programming section is not adversely affected by the dynamic swing of the output. The power supply is shipped with the grounding network connected: a connection between terminals TB1-5 (GND NET) and TB1-6 (+S). To disconnect the grounding network from the output, remove the connection across TB1-5 and TB1-6 (see Figure 2-4).

2.7.5.4 POSITIVE OUTPUT, NEGATIVE TERMINAL GROUNDED

To configure the BHK-MG as a positive output power supply (referenced to ground), connect the negative output terminal to ground: connect TB1-4 (GND - CHASSIS) to TB1-3 (–S). To avoid degraded load regulation in current mode it is necessary to remove the grounding network from the circuit by removing the link between TB1-6 (+S) and TB1-5 (GND NET).

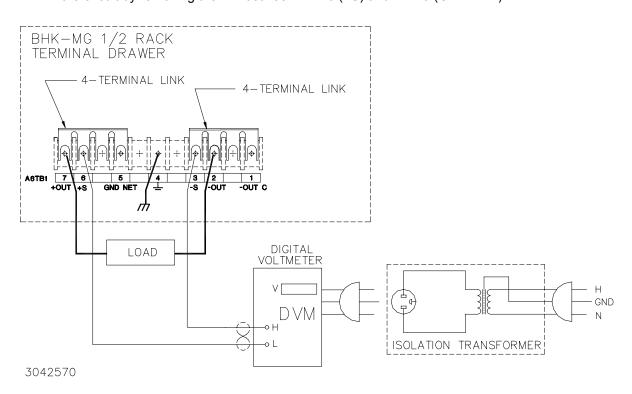


FIGURE 2-4. LOCAL SENSING, SLOW MODE SELECTED, GROUNDING NETWORK CONNECTED, FLOATING OUTPUT (FACTORY DEFAULT CONFIGURATION)

2-12 BHK-1/2-MG SERIES 110504

2.7.5.5 NEGATIVE OUTPUT, POSITIVE TERMINAL GROUNDED

To configure the BHK-MG as a negative output power supply (referenced to ground), connect the positive output terminal to ground: use a 5-terminal link to connect TB1-4 (GND - CHASSIS) to TB1-6 (+S). Note that when the positive output is grounded, the ground network (TB1-5) is inoperative (see Figure 2-5).

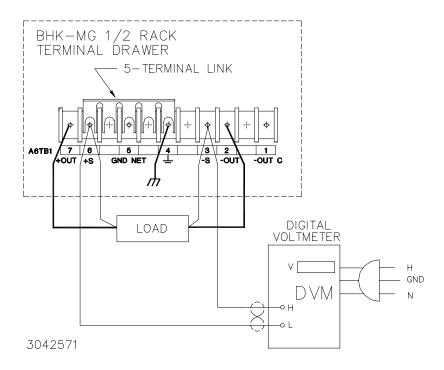


FIGURE 2-5. REMOTE SENSING, FAST MODE SELECTED, POSITIVE OUTPUT GROUNDED

2.8 OPERATING CONFIGURATION

The complete operating configuration is defined by jumper configuration of internal boards.

Table 2-9 lists the location of the internal jumpers and their function. This information is provided for reference purposes only, to indicate the configuration options available. Do not attempt to alter the jumper configuration. For assistance in changing any jumper-selected parameter contact Kepco Applications Engineering.

BHK-1/2-MG SERIES 110504 2-13

TABLE 2-9. INTERNAL JUMPER CONFIGURATION

LOCATION	JUMPER	DEFAULT STATUS	FUNCTION
A1	J6	Not Installed	For Service Personnel only. When installed (short circuit) a first time calibration will be initiated. Use this jumper only when necessary, then remove the jumper after calibration is initiated.
A2	JP1	Installed	Enables input circuit breaker to trip when arcing at the output is detected.
А3	JP1	Installed between pin 1 and 2	Jumper installed between pins 1 and 2: Prepares unit to receive a Relay N. (normally) Open Contact between pins 1 and 2 of the Status and Remote On/Off Port. When contact is open unit is turned ON; when contact is closed, unit is turned OFF. Jumper installed between pins 2 and 3: Prepares unit to receive a Relay N. (normally) Closed Contact between pins 1 and 3 of the Status and Remote On/Off Port. When contact is closed unit is turned ON; when contact is open, unit is turned OFF.
	JP2	Installed	Enables input circuit breaker to trip when input power loss is detected.

2.9 STATUS PORT

The status port opto-coupler can be configured for either active "low" (see Figure 2-6) or active "high" (see Figure 2-7).

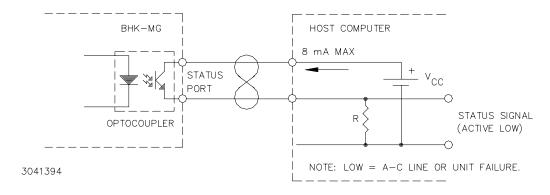


FIGURE 2-6. STATUS PORT OPTO-COUPLER ACTIVE "LOW" CONFIGURATION

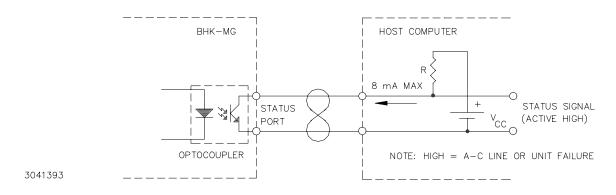


FIGURE 2-7. STATUS PORT OPTO-COUPLER ACTIVE "HIGH" CONFIGURATION

2-14 BHK-1/2-MG SERIES 110504

SECTION 3 - OPERATION

3.1 GENERAL

This section explains how to operate the BHK-MG 40W Power Supply. The power supply can be operated either in Local mode using the front panel keypad and LCD (PAR. 3.2), or in Remote mode using SCPI commands via either the GPIB bus (PARs. 3.3, 3.7) or RS 232 bus (PAR. 3.5) or using analog programming via the rear panel terminals (PAR 3.8). Remote analog programming can be combined with either local programming using the front panel keyboard or remote programming using SCPI commands via either the GPIB or RS 232 bus.

3.2 LOCAL MODE OPERATION

Local operation of the BHK-MG 40W Power Supply is accomplished via the 24 key keypad on the front panel. All indications are provided by the 2-line LCD. Local mode operation includes a description of the interaction between the LCD and the front panel keypad. Each key of the front panel is described, with a reference to a paragraph detailing the use of that key.

3.2.1 FRONT PANEL KEYPAD AND LCD. (SEE FIGURE 2-1)

The front panel keypad is comprised of 24 keys, 13 dedicated to command functions, five dedicated to data functions, and six keys that have both command and data functions. When the power supply is in command entry status the command functions are effective; when the power supply is in data entry status the data functions are effective.

3.2.1.1 COMMAND ENTRY STATUS

Indicated by blinking colon (:) on bottom line of LCD; the power supply is waiting for a command to be entered. Valid command entry is accompanied by a brief audible beep; data will not be accepted (accompanied by longer audible buzz). The LCD indicates the actual voltage and current at the output terminals. When the output is disabled (LCD bottom line reads Output OFF), the power supply is in Command entry status even though the blinking colon is not visible.

NOTE: The blinking colon is indicated by (:_:_:) in this manual.

3.2.1.2 DATA ENTRY STATUS

Indicated by blinking equal sign (=) on bottom line of LCD; the power supply is waiting for data to be entered. Valid data entry is accompanied by a brief audible beep; commands will not be accepted (accompanied by longer audible buzz). Enter new value (the \leftarrow key erases data entered). Press ENTER to accept new setting, or CLEAR to exit without changing setting.

NOTE: The blinking equal sign is indicated by (= = =) in this manual.

3.2.1.3 **DISPLAY (LCD)**

The LCD is a 2-line display with a capacity of 16 characters per line. The information is generally arranged as shown in Table 3-1 (information that does not follow this format is self-explanatory).

TABLE 3-1. LCD MESSAGES

LOCATION		MESSAGE	DESCRIPTION	
	Top left	Loc/Rem	Digital control status: either Remote or Local	
To	op middle	SINK	Shows that the unit is in sink mode and is absorbing energy either from the load or the internal output capacitor. The sink current is model-dependent and appears on the second line of the display preceded by a minus (–) sign.	
	top right OFF/CV/CC Off/Constant voltage mode/constant current mod		Off/Constant voltage mode/constant current mode	
Bottom	in command entry	n.nV	Actual output voltage	
left:	In data entry	(parameter)	e.g. OVset if OV SET key was pressed.	
	Bottom	(:_:_:)	Command entry status	
	middle:	(=_=_=)	Data entry status	
	in command entry	n.n mA	Actual output current.	
Bottom	In data entry	n.n V or n.n mA	Present programmed value of parameter, replaced by data entered.	
right:		(–)	Minus sign Indicates current absorbed either from the load or discharge of the internal output capacitor.	

3.2.1.4 KEYPAD FUNCTIONS

Keypad functions are listed in Table 3-2. Six keys have dual functions, depending on whether the power supply is in command entry status (waiting for a command to be entered), or data entry status (waiting for a number to be entered). Command entry status is indicated by a blinking colon (:_:_:) and data entry status is indicated by a blinking equal sign (=_=_=).

NOTE: Keys with dual functions are labeled with both a command and a number. The command label is referred to when the unit is in (:_:_:) command entry status; the number is referred to when the unit is in (=_=_=) data entry status.

TABLE 3-2. KEY FUNCTIONS

KEY	POWER SUPPLY STATUS ACTIVE	DESCRIPTION	REFERENCE PARAGRAPH
OUTPUT ON/OFF	Command Entry	If top line of LCD reads OFF, press to enable the output. If output is on, press to disable the output controlled.	3.2.6
V SET	V SET Command Entry Press to set output voltage. After V SET is pressed, previous setting is displayed. Data entry required to enter new value of output voltage; press ENTER to accept displayed value.		3.2.8
I SET Command Entry		Press to set output current. After I SET is pressed, previous setting is displayed. Data entry required to enter new value of output current; press ENTER to accept displayed value.	3.2.8
LOCAL Command Entry LOCAL key. Press to enable keypad. If LCD reads KEYF		If the power supply is in remote mode, keypad is disabled except for LOCAL key. Press to enable keypad. If LCD reads KEYPAD LOCKED, the LOCAL key is also disabled and can only be unlocked by remote operation.	3.2.3, B.83
RESET Command Entry		ommand Entry Press to restore the power on default values: CV mode, output voltage = 0, output current = minimum (2.5% of I _{Omax}), overvoltage and overcurrent values per Table 1-2.	

3-2 BHK-1/2-MG 110504

TABLE 3-2. KEY FUNCTIONS (CONTINUED)

KEY	POWER SUPPLY STATUS ACTIVE	DESCRIPTION	REFERENCE PARAGRAPH
MENU	Command Entry	Press to enter Menu commands: press repeatedly to scroll through Menu functions: (1) set LCD contrast, (2) GPIB address, (3) Baud Rate. (4) Loop Back Test (5) DCL control, (6) Power-Up Digital DC Output on/off, (7) speaker on/off, (8) change calibration password, (9) Go to Previous calibration, (10) Go to Factory Calibration, (11) view firmware version number, (12) set Power-up and RESET current, (13) set maximum voltage, (14) set maximum current. Press ENTER, RESET or CLEAR to exit Menu.	(1) 3.2.4, (2) 3.3.3 (3) 3.5.1, (4) 3.5.4 (5) 3.3.2, (6) 3.2.6.4 (7,)3.2.5, (8) 4.6, (9) 4.7, (10) 4.8 (11) 3.2.13 (10) 3.2.7.1 (11, 12) 3.2.10
OV SET	Command Entry	Press to set overvoltage protection value. Data entry required to enter the overvoltage protection value; press ENTER to accept displayed value.	3.2.9
7	Data Entry	Press to enter number 7.	3.2.1.2
OC SET	Command Entry	Press to set overcurrent protection value. Data entry required to enter new overcurrent protection value; press ENTER to accept displayed value.	3.2.9
8	Data Entry	Press to enter number 8.	3.2.1.2
CALIB	Command Entry	Press to enter Calibration status. Requires password entry; instructions appear on LCD.	4.3
9	Data Entry	Press to enter number 9.	3.2.1.2
STORE	Command Entry	Press to store present values of output voltage and current and overvoltage and overcurrent protection. Data entry required to select memory location where values are to be stored	3.2.11
EDIT PROG	Command Entry	Press to select the starting memory location to be edited. Then use ← or → to view or modify the parameters of a specific memory location or to create a new program.	3.2.14.1
STEP	Command Entry	Press to select starting address of program to be executed one step at a time. Address is updated each time STEP is pressed.	3.2.14.3
4	Data Entry	Press to enter number 4.	3.2.1.2
TIME Command Entry		Press to edit time value for specific memory location. Select memory location (data entry), then enter time value, 0.01 to 300 seconds (data entry).	3.2.14.1
5	Data Entry	Press to enter number 5.	3.2.1.2
RUN	Command Entry	Press to run a program. Requires data entry to select starting location. Press ENTER to accept displayed value.	3.2.14.2
6	Data Entry	Press to enter number 6.	3.2.1.2
RECALL	Command Entry	Press to recall previously stored values of output voltage and current, and overvoltage and overcurrent protection. Data entry required to select memory location containing values to be recalled; press ENTER to accept displayed value.	3.2.12
CLEAR	Data Entry	Press to exit Data Entry status; any numbers entered are lost. Restores Command Entry status	3.2.8
1	Data Entry	Press to enter number 1.	3.2.1.2
2	Data Entry	Press to enter number 2.	3.2.1.2
3	Data Entry	Press to enter number 3.	3.2.1.2
ENTER	Data Entry	Press to accept data entered and return to Command Entry status.	3.2.8

TABLE 3-2. KEY FUNCTIONS (CONTINUED)

KEY	POWER SUPPLY STATUS ACTIVE	DESCRIPTION	REFERENCE PARAGRAPH
Command Entry		 In CV (constant voltage), press to decrease output voltage by increment equal to voltage resolution (0.025% of E_Omax). In CC (constant current), press to decrease output current by increment equal to current resolution (0.025% of I_Omax). In EDIT PROG status, changes the parameter displayed on LCD for a specific memory location and decrements memory location displayed on LCD. 	3.2.8, 3.2.14.1
	Data Entry Erases number to left, or decreases value shown (e.g. Display Contrast setting).		3.2.8
0	Data Entry	Press to enter number 0.	3.2.1.2
(.)	Data Entry	Press to enter decimal point	3.2.1.2
→	Command Entry	 In CV (constant voltage), press to increase output voltage by increment equal to voltage resolution (0.025% of E_Omax). In CC (constant current), press to increase output current by increment equal to current resolution (0.025% of I_Omax). In EDIT PROG status, changes the parameter displayed on LCD for a specific memory location and increments memory location displayed on LCD 	3.2.8, 3.2.14.1
	Data Entry	Increases value shown (e.g. Display Contrast setting).	3.2.8

3.2.2 TURNING THE POWER SUPPLY ON

Setting the POWER switch to the up position turns the power supply on; setting the switch to the down position shuts the power supply off. When the power supply is turned on, the LCD briefly displays self test messages, then displays the power supply type on the top line (e.g., Kepco BHK 500) and GPIB addr. = nn on the bottom line, where BHK 500 is model BHK 500-80MG and nn is the GPIB address (factory default GPIB address = 6). After a few seconds, the bottom line of the LCD displays the voltage and current at the BHK-MG output. The top line displays either OFF or the current status of the unit as shown in Figure 3-1. The status of the unit upon power-up can be changed using the MENU key as detailed in PAR. 3.2.6.4. Power on defaults also include setting maximum values for overcurrent and overvoltage protection (PAR. 1.4.4), but are not displayed. If the unit fails a self-test, the LCD shows the last successful operation, and the unit beeps continually.



NOTE: (:_:_:) indicates blinking colon (:), Command Entry status (=_=_=) indicates blinking equal sign (=), Data Entry status

FIGURE 3-1. LCD POWER ON DEFAULTS

3.2.3 SETTING LOCAL MODE

When the power supply is turned on, it is automatically set to Local mode. If remote commands are accepted over the GPIB bus, the power supply will automatically go into Remote mode (Rem at the upper left of the LCD). Pressing the **LOCAL** key will restore Local mode. When in Remote mode, all keys except **LOCAL** are disabled.

3-4 BHK-1/2-MG 110504

The BHK-MG incorporates a "keypad lockout" command which allows the **LOCAL** key to be disabled during remote operation, preventing inadvertent setting of the power supply to Local mode. When the keypad is locked, the LCD displays **Rwl** in place of **Loc**. If the keypad is locked, it must be unlocked either by a remote command (see Appendix B, PAR. B.83), or cycling the power supply off then on.

3.2.4 ADJUSTING LCD CONTRAST

With the power supply in command entry status (:_:_:), press **MENU** key until LCD displays **CONTRAST**. Press → or ← key to increase or decrease contrast for optimum viewing. The contrast can also be set directly by entering a number from 1 to 9. Press **ENTER** or **CLEAR** to exit menu.

3.2.5 ENABLING/DISABLING AUDIBLE BEEPS

With the power supply in command entry status (:_:::), press **MENU** until LCD displays **SPEAKER**. The top line indicates if the speaker is on or off (the factory default setting is speaker on). Enter 1 to enable the speaker, or 0 to disable the speaker. Press **ENTER** or **CLEAR** to exit menu. Audible beeps associated with safety or failure messages are always enabled and can not be disabled.

3.2.6 ENABLING/DISABLING DC OUTPUT POWER

When the power supply is turned on, the output is automatically enabled, and the bottom line of the LCD gives voltage and current measurements at the output.

3.2.6.1 DISABLING DC OUTPUT

To disable the output, press the red **OUTPUT ON/OFF** key; the top line of the LCD reads: OFF and the bottom line displays output voltage and current (zero). When the output is disabled, voltage and current references are disabled; the power supply remains in Command Entry status. Pressing the **OUTPUT ON/OFF** key again enables the output: the previously programmed values of voltage and current are restored and the LCD displays the mode (CV or CC) and actual values of output voltage and current.

NOTE: After disabling the output by pressing the **OUTPUT ON/OFF** key, if the analog input is causing more than 8Vd-c to appear at the output terminals, or if current exceeds two LSBs, the unit will beep and enter a controlled shutdown for safety purposes unless the override jumper has been installed (see Table 2-9). The bottom line will flash a message showing the time remaining before shutdown (e.g POWER OFF 9 SEC). After the 10 second countdown the front panel circuit breaker will trip. (If the unit does not shut down due to a defective protection circuit or faulty circuit breaker, the LCD displays **BHK** **FAILURE ** and beeps constantly.) This feature is not available if the output is disabled via the Status and Remote On/Off Port.

3.2.6.2 DISABLING DC OUTPUT USING REMOTE ON/OFF PORT

The output can also be Enabled and Disabled by using the inputs available at the Status and Remote On/Off port at the rear panel. Output on/off control can be obtained using either a normally-open relay contact, a normally-closed relay contact, or a TTL type signal. Controlling the output through the Status and Remote On/Off Port is similar to using the **OUTPUT ON/OFF** key or the SCPI OUTPut ON and OUTPut OFF commands. Refer to Table 1-2 for characteristics of Status and Remote On/Off Port signals and to Table 2-3 for pin assignments and functional description.

3.2.6.3 REMOTE SHUTDOWN USING EXTERNAL TRIGGER PORT

A temporary short between pin 2 and pin 1 of the External Trigger port (or if pin 2 is at TTL logic 1, applying a temporary logic 0 to pin 2 referenced to pin 1) produces a shutdown signal which immediately shuts down the power supply output: output is disabled and voltage and current are set to zero (1 LSB maximum for voltage, 20 LSBs maximum for current). The DCL Control setting (see PAR. 3.3.2) determines the output settings when the output is enabled: either restored to the voltage/current settings in effect at the time shutdown was initiated, or voltage and current still programmed to zero

NOTE: Turn off power to the unit or disable the output before inserting the plug in the External Trigger port to avoid unintentionally initiating shutdown or trigger.

3.2.6.4 POWER UP DC OUTPUT CONTROL

The output of the power supply can be programmed to be either enabled or disabled upon power-up. With the power supply in command entry status (:_:_:), press the **MENU** key until LCD displays Dig off @Pwr-Up or Dig on @Pwr-Up. indicating whether the Digital DC Output will be on (enabled) or off (disabled) upon power-up. Press 1 to enable the Digital DC Output upon power up. This sets the output to zero volt and current to the Power-up and Reset current value. Press 0 to disable the output upon power up. Press CLEAR or RESET to exit menu and return to command entry status.

3.2.7 RESET OPERATION

RESET overrides all other local commands to reset the power supply to the power on defaults: output voltage set to zero, output current set to the value specified as the power-up and reset current (see PAR. 3.2.7.1), overcurrent and overvoltage protection set to the maximum values per PAR. 1.4.4. The output is either enabled or disabled, as determined by the SYST:SET command setting (see PAR. B.92) and the front panel DCL Control setting (enabled for "output = 0," disabled for "output unchanged;" see PAR. 3.3.2 for details). The default configuration is for RESET to disable the output (output OFF). The power supply remains in command entry status.

3.2.7.1 SETTING POWER-UP & RESET CURRENT

The factory setting of the power-up and reset current is 1.28% of lo max. This insures that the power supply is in voltage mode when the unit is initially turned on or a reset occurs. The user can change this value to be from 0 to 10% of the unit's rated current. To change this setting, ensure the unit is in command entry status (:_:_:) and press the **MENU** key until the top line of the display presents the message PWR-UP & RESET and the bottom line shows ISET = n.n ma, where n.n is the present value of power-up and reset current. Press **MENU** key to leave the value unchanged. Press number keys and the decimal key to enter a new value (the key erases data just entered) or **CLEAR** to exit without changing the setting.

If the value entered is higher than 10% of the rated current for the power supply, the bottom line of the LCD flashes Iset MAX = xx where xx = lomax/10 (e.g., for BHK500-80MG, xx = 8.0mA). The unit remains in data entry status (=_=_=) waiting for a value equal to or less than the 10% of rated current.

3.2.8 SETTING OUTPUT VOLTAGE OR CURRENT

V SET and **I SET** set output voltage and current limit, respectively, when the unit is in constant voltage (CV) mode and set voltage limit and output current, respectively, when the unit is in constant current (CC) mode. The mode (CV or CC) is determined by the load together with the programmed settings. As long as the voltage across the load produces a current that is less than the **I SET** value, the unit operates in CV mode (voltage programmed to **V SET** value, current

3-6 BHK-1/2-MG 110504

limited by I SET value). If the load changes to the point that current through the load reaches the I SET value, the unit automatically enters CC mode (current programmed to I SET value, voltage limited by V SET value).

With the power supply in command entry status (:_:_:), press **V SET** (voltage) or **I SET** (current) key to put the power supply in data entry status (=_=_=). The lower right side of the LCD shows the programmed setting in effect when the key is pressed. Press **ENTER** or **CLEAR** to exit without changing setting. Enter new value (the key erases data just entered) and press **ENTER** to accept new setting or **CLEAR** to exit without changing setting.

NOTE: Two decimal places are used for voltage settings and three decimal places for current settings (except that only one decimal place is used for setting voltage on Models BHK 1000-40MG and BHK 2000-20MG).

With the power supply in command entry status (:_::_), an alternative is to use \Rightarrow key (increase) or \Leftarrow key (decrease) to change the output by the minimum increment (0.025% of E_Omax for voltage, 0.025% of I_Omax for current). In CC mode, these keys control output current; in CV mode they control output voltage. When the unit switches from constant current (CC) to constant voltage (CV) mode, or from CV to CC mode the \Rightarrow and \Leftarrow keys are reassigned to the active parameter. Once the transition point is reached, each press of the \Rightarrow key increases voltage, then current, changing the mode, from CV to CC or from CC to CV. The \Rightarrow and \Leftarrow keys have no effect after the maximum (or programmed limit) has been reached.

If the value entered exceeds the maximum setting, the LCD bottom line flashes VsetMAX=n.n V or IsetMAX=n.n mA where n.n is the maximum setting (see PAR.3.2.10). Press CLEAR and enter a value that does not exceed the maximum setting.

3.2.9 SETTING OVERVOLTAGE OR OVERCURRENT PROTECTION

With the power supply in command entry status (:_::), press OV SET (overvoltage) or OC SET (overcurrent) to put the power supply in data entry status (=_=_=). The lower right side of the LCD shows the programmed setting in effect when the key is pressed. Press ENTER or CLEAR to exit without changing setting. Enter new value and press ENTER to accept new setting (the key erases data just entered), or CLEAR to exit without changing setting.

The value for overvoltage protection can be set within the range of 0 to 1.1 x E_O max; overcurrent can be set within the range of 0 to 1.1 x I_O max. The factory default values are 1.1 x E_O max for overvoltage protection and 1.1 x I_O max for overcurrent protection.

NOTE: Two decimal places are used for voltage settings and three decimal places for current settings (except that only one decimal place is used for setting voltage on Models BHK 1000-40MG and BHK 2000-20MG).

3.2.10 CHANGING MAXIMUM VOLTAGE OR CURRENT VALUE

The default maximum values of voltage and current are determined by the model, e.g., 500V and 80mA for the BHK 500-80MG. These values can be lowered by the user to prevent inadvertent damage to a specific circuit under test by establishing software limits through the use of the **MENU** key. Lowering the maximum values of the BHK 500-80MG to 100V and 40mA, effectively makes the unit a 100V/40mA power supply.

With the power supply in command entry status (:_:_:), press **MENU** key until the LCD reads **New MAXIMUM Vset** (or **Iset**) (=_=_=) **n.n** where n.n is the maximum value setting to be changed (V for voltage, mA for current). Press **ENTER** or **CLEAR** to exit menu without changing setting. Press number keys to enter new value and press **ENTER** to accept new setting (the key erases data just entered), or **CLEAR** to exit without changing setting.

NOTE: Two decimal places are used for voltage settings and three decimal places for current settings (except that only one decimal place is used for setting voltage on Models BHK 1000-40MG and BHK 2000-20MG).

If a value is entered that is higher than the rated maximum for the power supply, the bottom line of the LCD flashes vset or iset max = < som max > where <math>som max > where som max > where

Once the maximum value has been changed, if a value higher than the new maximum is attempted to be programmed, the LCD flashes vset (or iset) max = n.n where n.n is the programmed maximum (V for voltage, mA for current).

NOTE: If the programmed output value is higher than the new maximum value established with the **MENU** key, the output will be automatically limited to the new maximum value.

3.2.11 STORING POWER SUPPLY OUTPUT SETTINGS

The programmed settings of voltage, current, overvoltage protection and overcurrent protection can be stored in one of the 40 memory locations available for local programming (see PAR. 3.2.14).

With the power supply in command entry status (:_::), press **STORE** key. The LCD reads **STORE** mem (=_=_=) nn where nn is the memory location where the settings are to be stored. Press **ENTER** or **CLEAR** to exit without changing setting. Enter memory location (from 1 to 40) and press **ENTER**. The programmed voltage, current, overvoltage protection and overcurrent protection settings in effect when **ENTER** is pressed are stored in the selected memory location. To recall stored settings, see PAR. 3.2.12.

3.2.12 RECALLING STORED OUTPUT SETTINGS

With the power supply in command entry status (:_:::), press RECALL. The LCD reads RECALL mem (=_=_=) nn where nn is the memory location holding the settings to be retrieved. Press ENTER or CLEAR to exit without changing setting. Enter memory location (from 1 to 40) and press ENTER. The stored settings for voltage, current, overvoltage protection and overcurrent protection replace the current values, and the unit returns to (:_:_:) command entry status.

3.2.13 FIRMWARE VERSION

To display the firmware version of the power supply, the power supply must be in command entry status (:_:_:). Press the **MENU** key until the LCD displays **BHK XXXX,SSSSS mm-dd-YYYY,V.zz** where XXXX indicates the power supply model (e.g. XXXX = 1000 for BHK 1000-40MG), SSSSS indicates the serial number, mm-dd-yyyy indicates the factory calibration date and V.zz indicates the firmware version. Press **ENTER** or **CLEAR** to exit menu and return to command entry status.

3.2.14 LOCAL MODE PROGRAMMING OF THE POWER SUPPLY.

Local mode programming offers the user 40 memory locations that can be used to program the power supply. Each location defines values for output voltage, output current, overcurrent protection, overvoltage protection, time duration (between 0.1 and 300 seconds) for the programmed settings, and the address of the next memory location in the program.

3-8 BHK-1/2-MG 110504

3.2.14.1 CREATING OR MODIFYING A PROGRAM (PROGRAM EDIT MODE)

Creating a program and modifying an existing program are identical except that a program modification requires only selected parameters to be changed rather than all new parameter values. With the power supply in command entry status (:_:_:), press **EDIT PROG** key. The top line indicates the **STARTaddr.**(=_=_=)nn, where nn is one of 40 memory location. To select a different address, enter new value and press **ENTER**.

The top line of the LCD indicates the active memory location, e.g. ViewVAL Mem <n> where n is the memory location previously chosen. The bottom line of the LCD indicates the parameter on the left (Iset, Vset, OVset, OCset, TIMEval, NEXT STEP), the parameter's value on the right, and data entry status (=_==) in the middle. To modify time values see PAR.3.2.14.1.1.

Press ENTER to accept displayed value, or enter new value and press ENTER to accept new setting (the LCD displays the next parameter). Press CLEAR to exit Program Edit mode without changing value. Use → or ← key to scroll forward or backward to view next or previous parameter or memory location. For a program to run once, then stop, see PAR. 3.2.14.5; to cycle a program continuously, see 3.2.14.4. After all program values have been set, press CLEAR or ENTER to exit Program Edit mode. Setting up a program can be made easier by copying the Memory Location Worksheet (Table 3-3) and filling in the values before programming the power supply.

3.2.14.1.1 MODIFYING PROGRAMMED TIME INTERVAL

The **TIME** key offers a quick and easy way to change the time for any memory location. With the power supply in command entry status (:_:_:), press **TIME** key. The LCD displays **TIME@nn** (=_=_=) where nn is the current memory location of the TIME function. Press **ENTER** or **CLEAR** to exit without changing setting. Enter the new location and then press **ENTER**. The display now shows **TIMEval** = n.n s where n.n is the time value set for the selected location. The default time interval for all 40 steps is 0.01 second. Enter new value (between 0.01 and 300 seconds) and press **ENTER** to accept new value or press **CLEAR** to exit without changing value. The unit returns to command entry status (:_:_:). Refer to PAR. 3.2.14.1.2 if accuracy of time values is important.

3.2.14.1.2 TIME INTERVAL ACCURACY

The accuracy of the time interval is $\pm 2.5\%$. For setting time intervals from 0.01 to 2.50 seconds, the unit will accept times with 0.01 second resolution. (e.g., 2.49 seconds). For setting time intervals between 2.50 seconds and 50 seconds the second decimal place is ignored, providing resolution to 0.1 second (e.g., entering 2.79 is accepted as 2.70). When the time interval is greater than 50 seconds, the decimal is ignored and the time increment is in full seconds.

3.2.14.2 RUNNING A PROGRAM

With the power supply in command entry status (:_:_:_:), press **RUN** key. The LCD bottom line indicates the start address of the program. Press **ENTER** key to run the program starting with that address. To change the starting address, enter new value and press **ENTER** to run the program. Press **CLEAR** to exit without running the program.

When the program is running, the LCD displays the actual voltage and current, however if any step is programmed for less than 0.3 seconds, the LCD reads *** RUNNING PROGRAM***.

TABLE 3-3. MEMORY LOCATION WORKSHEET

MEMORY LOCATION	I SET (Current) (mA)	V SET (Voltage) (V)	OCset (Overcurrent Protection) (mA)	OV set (Overvoltage Protection) (V)	TIMEval (0. to 300) (Sec)	NEXT STEP (Next location to execute)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
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34						
35						
36						
37						
38						
39						
40						

3-10 BHK-1/2-MG 110504

3.2.14.3 STEPPING THROUGH A PROGRAM



Programmed voltage is present at the output as steps are executed.

The STEP function is useful for examining a program that has just been created or edited before running it in real-time. With the power supply in command entry status (:_:_:), press STEP key. The LCD bottom line indicates the start address of the program; press ENTER to begin stepping at that address. To change the starting address, enter new value and press ENTER to begin stepping at the new address, press CLEAR to exit without stepping through the program.

The LCD top line shows LoC to indicate local mode, aa *bb where aa is the memory location just executed, bb is the NEXT STEP location, and shows cv (constant voltage) or cc (constant current) to indicate the actual operating mode. The LCD bottom line shows the output voltage and current measurements for the location just executed, and (:_:_:) indicates command status. Press STEP to execute location bb. The LCD will again display the location just executed, voltage and current measurements, and the NEXT STEP location. Continue to press STEP to execute the program one step at a time. The OUTPUT ON/OFF key can be used to turn the output on or off when in step mode.

Press **CLEAR**, or **RESET** to exit Step function: **CLEAR** keeps the output at the values established by that step (as permitted by the load). **RESET** restores the power on defaults (Figure 3-1).

3.2.14.4 CYCLING A PROGRAM

To cycle a program, modify the program (see PAR. 3.2.14.1) and go to the last memory location to be executed and set the NEXT STEP address to the Starting address, causing the program to loop and repeat indefinitely. For example, if the last location is 14, and the starting location is 05, press **EDIT PROG**, enter **14**, then press **ENTER**. Press **+** until LCD reads **ViewVAL Mem14 NEXT STEP** (=_=_=). Enter **5** and press **ENTER**. When the program runs, it will start at location 05, continue to 14, then loop back to the location 05, and repeat indefinitely.

3.2.14.5 RUNNING A PROGRAM ONCE

To set up a program to stop after running once, modify the program (see PAR. 3.2.14.1) and go to the last memory location to be executed and set the NEXT STEP address to 0. For example, with the power supply in command entry status (:_:_:), press **EDIT PROG**. Enter the last memory location you want executed (e.g. 14), then press **ENTER**. Press ** key until LCD reads **ViewVAL Mem14 NEXT STEP** (=_=_=). Enter 0 and press **ENTER**. The program will now stop after memory location 14 is executed. When the program stops, the power supply will continue to provide the output specified by the last location (in the above example, location 14).

3.2.14.6 STOPPING A RUNNING PROGRAM

There are three ways to stop a program that is running:

Press CLEAR key: the program immediately stops at the step (location) that was being
executed when the key was pressed. The power supply output remains at the values
specified by that step.

- Press RESET key: The program stops and power on defaults are restored (see PAR. 3.2.7).
- Press OUTPUT ON/OFF key: the output is disabled (programmed to zero) and the program immediately stops at the step (location) that was being executed when the key was pressed. Pressing the OUTPUT ON/OFF key again restores the output to the values specified by the step in effect when the program was stopped.

3.2.14.7 SAMPLE PROGRAM

Table 3-4 shows a sample program designed to cycle continuously; if the NEXT STEP value for location 3 is set to 00, the program will run once and stop.

OCset OV set TIMEval **ISET** V SET **NEXT STEP MEMORY** (Overcurrent (Overvoltage (Current) (Voltage) (0.01 to 300) (Next location LOCATION Protection) Protection) to execute) (mA) (Sec) (V) (mA) (V) 420 440 2 500 40 550 1.8 03 33 3 40 250 44 300 1.0 01

TABLE 3-4. SAMPLE PROGRAM (MODEL BHK-MG 500-80MG)

3.2.15 CALIBRATION

See Section 4.

3.3 REMOTE MODE PROGRAMMING USING SCPI COMMANDS VIA IEEE 488 (GPIB). BUS

BHK-MG Power Supplies may be programmed over a control bus using SCPI (Standard Commands for Programmable Instruments). SCPI provides a common language conforming to IEEE 488.2 for instruments used in an automatic test system. The control bus used must be either the IEEE 488 standard communication bus (General Purpose Interface Bus, GPIB). or the RS 232 Serial Bus described in PAR. 3.5. Refer to Table 2-1 for input/output signal allocations.) Most power supply functions available from the keypad can be programmed via remote commands, in addition to some that are not available from the keypad (e.g. triggering, and local lockout).

This section includes a discussion of GPIB bus protocols (PAR. 3.3.1), instructions for changing the GPIB address (PAR. 3.3.3), a discussion of the VISA (Virtual Instrumentation Software Architecture) driver supplied with the unit (PAR. 3.4), followed by a detailed explanation of SCPI programming (PAR. 3.7)

3.3.1 IEEE 488 (GPIB) BUS PROTOCOL

Table 3-5 defines the interface capabilities of the BHK-MG 40W Power Supply (Talker/Listener) relative to the IEEE 488 (GPIB) bus (reference document *ANSI/IEEE Std 488: IEEE Standard Digital Interface for Programmable Instrumentation*) communicating with a Host Computer—Controller (Talker/Listener). Tables 3-6 and 3-7 define the messages sent to the BHK-MG, or received by the BHK-MG, via the IEEE 488 bus in IEEE 488 command mode and IEEE 488 data mode, respectively. These messages are enabled during the "handshake" cycle, with the BHK-MG 40W Power Supply operating as either a Talker or a Listener.

3-12 BHK-1/2-MG 110504

TABLE 3-5. IEEE 488 (GPIB) BUS INTERFACE FUNCTIONS

FUNCTION	SUBSET SYMBOL	COMMENTS
Source Handshake	SH1	Complete Capability (Interface can receive multiline messages)
Acceptor Handshake	AH1	Complete Capability (Interface can receive multiline messages)
Talker	Т6	Basic talker, serial poll, unaddress if MLA (My Listen Address) (one-byte address)
Listener	L4	Basic listener, unaddress if MTA (My Talk Address) (one-byte address).
Service Request	SR1	Complete Capability. The interface sets the SRQ line true if there is an enabled service request condition.
Remote/Local	RL1	Complete capability. Interface selects either local or remote information. In local mode the BHK-MG executes front panel commands, but can be set to remote mode via IEEE 488 bus. When in Remote mode all front panel keys are disabled except LOCAL. LOCAL key can be disabled using keypad lockout command (see Appendix B, PAR. B.83) so that only the controller or a power on condition can restore Local mode.
Parallel Poll	PP0	No Capability
Device Clear	DC1	Complete Capability. BHK-MG accepts DCL (Device Clear) and SDC (Selected Device Clear).
Device Trigger	DT1	Respond to *TRG and <get> trigger functions.</get>
Controller	C0	No Capability

TABLE 3-6. IEEE 488 (GPIB) BUS COMMAND MODE MESSAGES

MNEMONIC	MESSAGE DESCRIPTION	COMMENTS
DCL	Device Clear	Received
GET	Group Execute Trigger	Received
GTL	Go To Local	Received
IFC	Interface Clear	Received
LLO	Local Lockout	Received
MLA	My Listen Address	Received
MTA	My Talk Address	Received
ОТА	Other Talk Address	Received (Not Used)
RFD	Ready for Data	Received or Sent
SDC	Selected Device Clear	Received
SPD	Serial Poll Disable	Received
SPE	Serial Poll Enable	Received
SRQ	Service Request	Sent
UNL	Unlisten	Received
UNT	Untalk	Received

TABLE 3-7. IEEE 488 (GPIB) BUS DATA MODE MESSAGES

MNEMONIC	MESSAGE DESCRIPTION	COMMENTS
DAB	Data Byte	Received or Sent
END	End	Received or Sent
EOS	End of String	Received or Sent
RQS	Request Service	Sent
STB	Status Byte	Sent

3.3.2 DCL CONTROL

The device clear (DCL) and selected device clear can be set to operate in two modes. In the "output = 0" mode, when the device clear is received the output is disabled; when the output is enabled, the output of the power supply is set to zero volts and current is set to the power-up and reset current value (see PAR. 3.2.7.1). In the "output unchanged" mode sending DCL or selected DCL disables the output, but has no effect on output voltage and current as required by IEEE specification 488.2 so that when the output is enabled, the settings in effect when DCL was issued are restored. Note that the DCL setting also affects the operation of RESET (see PAR. 3.2.7). The factory default value is "output=0" mode.

To change the DCL mode the unit must be in command entry mode (:_::], then depress the **MENU** key until the top line of the display shows the current setting: either DCL OUTP = 0 or DCL = OUTP UNCHNG. Depress 1 for "output unchanged" mode where the output is unaffected by DCL; depress 1 again for "output = 0" mode where DCL sets the output to 0 volts and current is set to the power-up and reset current value (see PAR. 3.2.7.1).

3.3.3 CHANGING THE GPIB ADDRESS

When the power supply is in command entry status (:_:_:), press **MENU** key until the top line of the LCD displays **GPIB** addr. = nn where nn indicates the current GPIB address. Enter new value and press **ENTER** to accept new setting, or **CLEAR** to exit without changing setting. The GPIB address default value is set to 6.

3.3.4 EXTERNAL TRIGGER

The External Trigger Port can be used to restore the power supply output to settings previously defined using SCPI commands. This can be done by applying a temporary short between pin 4 and pin 1 of the External Trigger Port, (or if pin 4 is at TTL logic 1, applying a temporary logic 0 to pin 4 referenced to pin 1).

NOTE: Turn off power to the unit or disable the output before inserting the plug in the External Trigger port to avoid unintentionally initiating shutdown or trigger.

The following remote SCPI commands must be sent before the external trigger at pin 4 activated:

 The values to be set upon receiving the external trigger at pin 4 must be programmed using VOLT:TRIG (PAR B.54) and CURR:TRIG (PAR B.46) commands.

3-14 BHK-1/2-MG 110504

- Choose external trigger source by sending TRIG:SOUR EXT (PAR. B.94)
- Choose either single shot (by sending INIT:CONT OFF (PAR B.19), then arm each trigger by sending INIT:IMM (PAR B.18) prior to activating the external trigger at pin 4) or continuous action (by sending INIT:CONT ON (PAR B.19).

NOTE: The output must be enabled prior to activating the external trigger at pin 4 of the External Trigger port in order for the external trigger to work properly.

3.4 BHK-MG VISA INSTRUMENT DRIVER

The VISA instrument driver simplifies programming with a VISA compatible GPIB controller. and Includes 1) source code (C) for all VISA functions, and 2) a complete programming reference manual which can be used to program one or more BHK-MG power supplies using a virtual front panel observed on a computer monitor.

Download the latest VISA driver from the Kepco website at http://www.kepcopower.com/drivers.htm

Although the software drivers supplied by Kepco are VISA compliant, they also require the installation of the proper 16-bit VISA driver from your GPIB card supplier. Many vendors supply this software with the hardware; National Instruments (http://www.natinst.com) has the driver for their cards available on the internet at a file transfer site (ftp://ftp.natinst.com — find the folder for support and VISA drivers). The driver to be installed is the win16 driver, even if your system is running under Windows 95 or Windows NT.

3.5 RS232-C OPERATION

The BHK-MG may be operated via an RS232-C terminal, or from a PC using a terminal emulation program. The default settings are as follows:

Baud rate: 9600 (no jumper between RTS and CTS on RS 232 port)

Parity: None

Data Bits 8

• Stop Bits 1

Echo ON

XON OFF

3.5.1 SETTING RS 232 BAUD RATE

When the power supply is in local mode, command entry status:, press **MENU** key until LCD displays **BAUD RATE** =. The top line of the LCD indicates the current RS 232 baud rate (default = 19200). Use \Rightarrow and \leftarrow keys to scroll through the available baud rate settings (19200, 9600, 4800 or 2400). Press **ENTER** to accept new setting (new baud rate is effective immediately), or **CLEAR** to exit without changing setting.

3.5.2 SERIAL INTERFACE

The serial interface behaves like the GPIB interface in that the command is parsed after receiving a control character of either a Line Feed or Carriage Return. The serial interface supports three special control characters. The three special control characters are:

Backspace (08_H) Causes the last character in the input buffer to be removed from the

input buffer queue.

Carriage Return (0D_H) Causes the input buffer to be parsed by the BHK-MG.

Line Feed (0A_H) Causes the input buffer to be parsed by the BHK-MG.

3.5.3 RS 232 IMPLEMENTATION

The following paragraphs are provided to help the user understand how the RS 232 serial interface is implemented in the BHK-MG. Since the RS 232 protocol does not use a parity bit, the echo mode is the default method used to ensure reliable communication between the command originator (computer) and the BHK-MG 40W Power Supply, thus avoiding a more complex "handshake" protocol.

When the BHK-MG is in the RS 232 echo mode it returns all data sent to the host controller. The BHK-MG provides two additional options that allow handshake communication: the Prompt method and the XON XOFF method. In standard echo mode the controller must verify that each character is echoed back by the BHK-MG. As shown in Figure 3-2, there are times when the BHK-MG does not echo back the character from the controller, requiring that the controller resend the character. By using the handshake options (prompt and XON XOFF) the host controller can ensure that serial data interrupts occurring after parsing of the incoming message do not result in lost data.

Figure 3-2 illustrates the default echo mode, the prompt method and the XON XOFF method described in the following paragraphs.

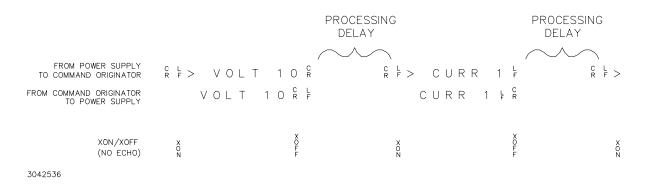


FIGURE 3-2. RS 232 IMPLEMENTATION

Only three control characters (characters between 00_H and $1F_H$) are acknowledged by the power supply:

- Carriage Return (CR, 0D_H)
- Line Feed (LF, 0A_H)
- Back Space (BS, 08_H)

BS deletes the last character entered, with the exception of CR or LF characters. Either the CR or LF character acts as the line terminator, initiating parsing of the ASCII data sent to the BHK-MG by the command originator. When the line is parsed, the BHK-MG sends the line terminator sequence CR LF to the command originator.

3-16 BHK-1/2-MG 110504

All non-control characters are sent via the serial port of the command originator. The control character BS is echoed as BS Space BS. Only the first control character is returned in response to either a CR LF or LF CR character sequence (see Figure 3-2).

3.5.3.1 ECHO MODE

Echo mode is the default method of ensuring data is transferred without errors. Each byte (character) is echoed back to the sender where it is verified as the same character that was just sent. If the character is incorrect or missing, the sender sends the character again until the correct character is verified as having been received.

All non-control characters are sent via the serial port of the command originator. The control character BS is echoed as BS Space BS. Only the first control character is returned in response to either a CR LF or LF CR character sequence (see Figure 3-2).

3.5.3.2 PROMPT METHOD

The command originator sends a message line (command) to the BHK-MG and waits until the prompt sequence CR LF > $(3E_H,\,62_{10})$ is received. The BHK-MG sends the prompt sequence CR LF > to the command originator indicating the power supply is ready to receive the next command and data will not be lost. The prompt method is similar to the echo method described above, except that the command originator does not have to compare each character and repeat any characters dropped while the IEEE 1118 bus (BITBUS) is active. The operation of the BHK-MG is identical for echo mode and prompt mode; implementation of prompt mode is at the command originator.

3.5.3.3 XON XOFF METHOD

The XON XOFF method allows the BHK-MG to control when the command originator is allowed to send data. The command originator can only send data after the XON (transmission on) character (011 $_{\rm H}$) has been received; the command originator stops sending data after receiving the XOFF (transmission off) character (013 $_{\rm H}$), and waits until the XON character is received before sending additional data.

Control characters, either CR or LF, are returned as XOFF CR if echo mode is on, and as XOFF if echo mode is off. XOFF stops data from the command originator and the BHK-MG returns the normal sequence of CR LF (if echo mode is enabled).

3.5.4 ISOLATING RS 232 COMMUNICATION PROBLEMS

A Loop Back test can be run from the front panel to aid in isolating RS 232 communication problems. The unit is designed to pass the test only with the Loop Back test connector (part of Kit 219-0436, see Table 1-5) installed.

- 1. With the power supply in local mode, command entry status :, press **MENU** key until LCD reads LOOP BACK TEST UNTESTED 1=RUN.
- 2. Press the 1 key to run the test with the Loop Back Test connector NOT installed and verify the LCD reads FAILED. If the LCD reads PASSED, the power supply is defective and requires repair.
- 3. Install the loop back test connector into RS 232 port and press the 1 key to rerun the test. If the LCD reads PASSED, the power supply is operating properly. If the LCD reads FAILED, the unit requires repair.

4. To test the integrity of the cable assembly connecting the power supply RS 232 port to the computer, remove the Loop Back test connector from the power supply RS 232 port and connect the cable in its place. With the DB9 adapter installed on the opposite end of the cable, connect a short jumper wire between pins 2 and 3 of the adapter connector and repeat the test of (3) above. If the LCD display reads FAILED, the cord is either the improper type (not null modem) or is defective. If the LCD display reads PASSED, the cable is correct; remove the jumper and reconnect the cable to the computer.

If each of the above steps is completed successfully, the problem lies in the computer hardware and/or software. Refer to the Product Support area of the Kepco website for additional information regarding RS 232 communications problems: www.kepcopower.com/support.

3.6 PROGRAMMING TECHNIQUES TO OPTIMIZE PERFORMANCE

Proper programming techniques can offer significant response time improvement and reduce undesirable transients at the output. The key to performance optimization is to minimize mode changes (voltage mode/current limit to current mode/voltage limit or vice versa). Mode changes should be limited to changes in load conditions (to which the power supply will respond automatically), or by programming the limit parameter when required by the user application.

The proper way to program the supply is to initially program the operating parameter to zero and the complementary limit parameter to the desired maximum value. Subsequent commands should change only the operating parameter. (The operating parameter is the parameter that controls the output, e.g., voltage controls the output in voltage mode, current in current mode.) The complementary limit parameter should be programmed only when there is a need to change it.

3.6.1 EXAMPLE OF PROPER PROGRAMMING

Assume the power supply is intended to operate in a test application that requires a set of specific output voltages. The initial set of commands should program output voltage and current limit. If the same current limit applies to the rest of the test, all subsequent commands should only program output voltage.

3.6.2 EXPLANATION OF PROGRAMMING TECHNIQUES

Kepco's auto-crossover digital supplies can operate in either voltage mode with current limit, or current mode with voltage limit. The operating mode is determined by the voltage and current commands received, as well as the load.

Each time voltage and current commands are received, the unit must evaluate the commands and the load conditions to determine the proper operating mode. Reducing the number of times this evaluation must be made is desirable because Kepco's digital auto-crossover supplies employ two separate feedback loops. Each time there is a potential mode change, there is always an uncontrolled period of a few milliseconds while the two feedback loops compete for control of the output. In addition to increasing the time before the output reflects the programmed command, undesirable transients may also be present at the output during this period.

By sending only the operating command, there is no doubt as to what the operating mode will be, so the unit is never uncontrolled, response is quick and no transients are possible.

3-18 BHK-1/2-MG 110504

3.7 SCPI PROGRAMMING

SCPI (Standard Commands for Programmable Instruments) is a programming language conforming to the protocols and standards established by IEEE 488.2 (reference document ANSI/IEEE Std 488.2, IEEE Standard Codes, Formats, Protocols, and Common Commands). SCPI commands are sent to the BHK-MG 40W Power Supply as ASCII output strings within the selected programming language (PASCAL, BASIC, etc.) in accordance with the manufacturer's requirements for the particular GPIB controller card used.

Different programming languages (e.g., BASIC, C, PASCAL, etc.) have different ways of representing data that is to be put on the IEEE 488 bus. It is up to the programmer to determine how to output the character sequence required for the programming language used. Address information (GPIB address) must be included before the command sequence. (See PAR.3.3.3 to establish the BHK-MG 40W Power Supply GPIB address.)

3.7.1 SCPI MESSAGES

There are two kinds of SCPI messages: program messages from controller to power supply, and response messages from the power supply to the controller. Program messages consist of one or more properly formatted commands/queries and instruct the power supply to perform an action; the controller may send a program message at any time. Response messages consist of formatted data; the data can contain information regarding operating parameters, power supply state, status, or error conditions.

3.7.2 COMMON COMMANDS/QUERIES

Common commands and queries are defined by the IEEE 488.2 standard to perform overall power supply functions (such as identification, status, or synchronization) unrelated to specific power supply operation (such as setting voltage/current). Common commands and queries are preceded by an asterisk (*) and are defined and explained in Appendix A (see Table 4-4). Refer also to syntax considerations (PARs 3.7.3 through 3.7.6).

3.7.3 SCPI SUBSYSTEM COMMAND/QUERY STRUCTURE

Subsystem commands/queries are related to specific power supply functions (such as setting output voltage, current limit, etc.) Figure 3-3 is a tree diagram illustrating the structure of SCPI subsystem commands used in the BHK-MG 40W Power Supply with the "root" at the left side, and specific commands forming the branches. The following paragraphs introduce the subsystems; subsystem commands are defined and explained in Appendix B.

3.7.3.1 ABORT SUBSYSTEM

This subsystem allows pending trigger levels to be cancelled.

3.7.3.2 DISPLAY SUBSYSTEM

This subsystem controls the second line of the LCD. The first line will always display the LOCal or REMote operation status and the constant Voltage (CV) or constant Current functioning mode (CC).

3.7.3.3 INITIATE SUBSYSTEM

This subsystem enables the trigger system. When a trigger is enabled, the triggering action will occur upon receipt of a GPIB <GET>, *TRG or TRIGger command. If a trigger circuit is not enabled, all trigger commands are ignored.

3.7.3.4 LIST SUBSYSTEM

The LIST subsystem is represented by 250 memory locations (groups of settings) which are stored in the volatile memory. Each setting contains values for: Current, Voltage, and Time. The range for the first two values is the maximum available range for the specific power supply. The Time setting is between 0.01 and 655.35 seconds.

3.7.3.5 MEASURE SUBSYSTEM

This query subsystem returns the voltage and current measured at the power supply's output terminals.

3.7.3.6 OUTPUT SUBSYSTEM

This subsystem controls the power supply's voltage and current outputs

3.7.3.7 INSTRUMENT SUBSYSTEM

This subsystem controls the power supply's voltage and current outputs and allows compatibility with other vendor's products

3.7.3.8 STATUS SUBSYSTEM

This subsystem programs the power supply status register. The power supply has two groups of status registers: Operation and Questionable. Each group consists of three registers: Condition, Enable, and Event.

3.7.3.9 SYSTEM SUBSYSTEM

This subsystem controls the RS 232 port, as well as system errors, passwords, security, language, beep, version and keyboard lockout

3.7.3.10 TRIGGER SUBSYSTEM

This subsystem controls the remote triggering of the power supply.

3.7.3.11 [SOURCE:]VOLTAGE AND [SOURCE:]CURRENT SUBSYSTEMS

These subsystems program the output voltage and current of the power supply.

3.7.3.12 CALIBRATE SUBSYSTEM

The BHK-MG series of power supplies support software calibration. A full calibration consist of a voltage calibration and a current calibration. Both voltage and current calibrations consist of a zero and a full scale calibration. There are two ways to perform the calibration: locally using the front panel keys, or remotely sending commands through the GPIB bus. These two ways cannot be combined.

3-20 BHK-1/2-MG 110504

ROOT: (colon)		
	— ABORt subsystem	─ [SOURce:] subsystem	STATus subsystem
	ABORt	[SOURce:]	STATus
		VOLTage	:OPERation
	 INITiate subsystem 	[:LEVel]	:CONDition?
	INITiate	[:IMMediate]	:ENABle val
	[:IMMediate]	[:AMPLitude] val	:ENABle?
	:CONTinuous bool	[:AMPLitude]? MIN, MAX	[:EVENt]? :PRESet
	:CONTinuous?	:TRIGgered	:QUEStionable
		[:AMPLitude] val	:CONDition?
	— CALibrate subsystem	[:AMPLitude]? MIN, MAX	:ENABle val
	CALibrate	:PROTection	:ENABle?
	:STATe <boolean> ,password</boolean>	:TRIPped? :CLEar	[:EVENt]?
	:STATe?	:CLEAI :LIMit	:VOLTage
	:VOLTage	[:HIGH] val	:CONDition?
	:LEVel (MIN MAX PROT)	[:HIGH]? MIN, MAX	:ENABle val
	[:DATA] val	CURRent	:ENABle?
	GAIN (UP DOWN) :CURRent	[:LEVel]	:[:EVENt]?
	:LEVel (MIN MAX MAG PROT)	[:IMMediate]	:CURRent
	[:DATA] val	[:AMPLitude] val	:CONDition?
	GAIN (UP DOWN)	[:AMPLitude]? MIN, MAX	:ENABle val
	:MEAS val	:TRIGgered	:ENABle?
	:MEAS?	[:AMPLitude] val	:[:EVENt]?
	:ZERO	[:AMPLitude]? MIN, MAX	0)/07
	:SAVE	:PROTection	 SYSTem subsystem
		:TRIPped?	SYSTem
	— DISPlay subsystem	:CLEar	COMM:SER
	DISPlay	:LIMit	:BAUD val
	:CONTrast 0 to 0.9	[:HIGH] val	:BAUD?
	:CONTrast?	[:HIGH]? MIN, MAX FUNCtion	:ECHO :ECHO? ON, OFF
	[:WINDow]:TEXT[:DATA] ""	:MODE VOLTage CURRent	:PACE
	[:WINDow]:TEXT[:DATA]?	:MODE VOLTAGE CONNENT	:PACE? NONE, XON
	[:WINDow]:STATe (0 1)		:PROMpt
	[:WINDow]:STATe?	— LIST subsystem	:PROMpt? ON, OFF
		LIST	:GPIB:ADDR val
		:CURRent	:GPIB:ADDR?
		[:LEVel] val	:ERRor
	— MEASure subsystem	[:LEVel]?	[:NEXT]?
	MEASure	:PROTection val	:CODE?
	[:SCALar]:CURRent[:DC]?	:PROTection?	[:NEXT]?
	[:SCALar]:[VOLTage][:DC]?	:VOLTage	:ALL?
		[:LEVel] val	:GPIB:ADDR val
	─ OUTPut subsystem	[:LEVel]?	:GPIB:ADDR?
	OUTPut	:PROTection val	:PASSword
	[:STATe] ON or OFF	:PROTection?	[:CENAble] (code)
	[:STATe]?	:INDex val	:STATe?
		:INDex?	:CDISenable (code)
		:SEQuence	:NEW (OLD NEW)
		:STARt val	:SECUrity :IMMediate
		:STARt ? :NEXT val	:LANGuage(SCPI COMPatibili
		:NEXT Val :NEXT?	:BEEP
		:DWELI val	:VERSion?
		:DWELI?	:KLOCk <boolean></boolean>
		.DWLLI:	:KLOCk?
		─ TRIGGER subsystem	
		TRIGger	INSTRument subsystem
		:SOURce	INSTrument
			:STATe?

FIGURE 3-3. TREE DIAGRAM OF SCPI COMMANDS USED WITH BHK-MG 40W POWER SUPPLY

:STATe (ON | OFF)

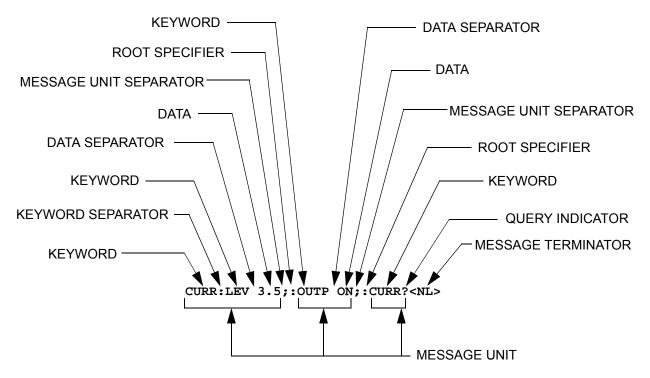


FIGURE 3-4. MESSAGE STRUCTURE

In order to enter the calibration mode the correct calibration access code (password) must be entered. If the password has been forgotten call the factory and a secret password (which has been assigned to your power supply) will be provided. During the calibration, new calibration data is computed which is then stored in the non volatile memory.

The equipment required for calibration is specified in PAR. 4.2.

Because the voltage measured will be used as reference for calibration, the DVM itself must be calibrated accurately. During voltage calibration, the voltage, overvoltage and voltage readback are calibrated and during current calibration the current, overcurrent, current readback and 10 percent scale current readback are calibrated. The normal procedure is to calibrate voltage first and then current. However, you do not have to do a complete calibration each time. If required, you may calibrate only the voltage or the current and then proceed to saving the calibration results. For voltage calibration all loads must be disconnected and the sense terminals connected to the corresponding output terminals. The digital voltmeter will be connected to the output of the power supply. For current calibration after disconnecting all loads an appropriate shunt resistor will be connected across output terminals and the digital voltmeter will be connected across the sense terminals of the shunt resistor.

3.7.4 PROGRAM MESSAGE STRUCTURE

SCPI program messages (commands from controller to power supply) consist of one or more *message units* ending in a *message terminator* (required by Kepco power modules). The message terminator is not part of the syntax; it is defined by the way your programming language indicates the end of a line ("newline" character). The message unit is a keyword consisting of a single command or query word followed by a message terminator (e.g., CURR?<newline> or TRIG<end-of-line>). The message unit may include a data parameter after the keyword separated by a space; the parameter is usually numeric (e.g., CURR 5<newline>), but may also be a string (e.g., OUTP ON<newline>). Figure 3-4 illustrates the message structure, showing how

3-22 BHK-1/2-MG 110504

message units are combined. The following subparagraphs explain each component of the message structure.

NOTE: An alternative to using the message structure for multiple messages defined in the following paragraphs is to send each command as a separate line. In this case each command must use the full syntax shown in Appendix B.

3.7.4.1 KEYWORD

Keywords are instructions recognized by a decoder within the BHK-MG, referred to as a "parser." Each keyword describes a command function; all keywords used by the BHK-MG are listed in Figure 3-3.

Each keyword has a long form and a short form. For the long form the word is spelled out completely (e.g. STATUS, OUTPUT, VOLTAGE, and TRIGGER are long form keywords). For the short form only the first three or four letters of the long form are used (e.g., STAT, VOLT, OUTP, and TRIG). The rules governing short form keywords are presented in Table 3-8.

TABLE 3-8. RULES GOVERNING SHORTFORM KEYWORDS

IF NUMBER OF LETTERS IN LONGFORM KEYWORD IS:	AND FOURTH LETTER IS A VOWEL?	THEN SHORT FORM CONSISTS OF:	EXAMPLES
4 OR FEWER	(DOES NOT MATTER)	ALL LONG FORM LETTERS	MODE
5 OR MORE	NO	THE FIRST FOUR LONG FORM LETTERS	MEASure, OUTPut, EVENt
3 OR MORE	YES	THE FIRST THREE LONG FORM LETTERS	LEVel, IMMediate, ERRor

You must use the rules above when using keywords. Using an arbitrary short form such as ENABL for ENAB (ENABLE) or IMME for IMM (IMMEDIATE) will result in an error. Regardless of which form chosen, you must include all the letters required by that form.

To identify the short form and long form in this manual, keywords are written in upper case letters to represent the short form, followed by lower case letters indicating the long form (e.g., IMMediate, EVENt, and OUTPut). The parser, however, is not sensitive to case (e.g., outp, OutP, OUTPut, ouTPut, or OUTp are all valid).

3.7.4.2 KEYWORD SEPARATOR

If a command has two or more keywords, adjacent keywords must be separated by a colon (:) which acts as the keyword separator (e.g., CURR:LEV:TRIG). The colon can also act as a root specifier (paragraph 3.4.4.7).

3.7.4.3 QUERY INDICATOR

The question mark (?) following a keyword is a query indicator. This changes the command into a query. If there is more than one keyword in the command, the query indicator follows the last keyword. (e.g., VOLT? and MEAS:CURR?).

3.7.4.4 DATA

Some commands require data to accompany the keyword either in the form of a numeric value or character string. Data always follows the last keyword of a command or query (e.g., VOLT:LEV:TRIG 14 or SOUR:VOLT? MAX

3.7.4.5 DATA SEPARATOR

Data must be separated from the last keyword by a space (e.g., VOLT:LEV:TRIG 14 or SOUR:VOLT? MAX

3.7.4.6 MESSAGE UNIT SEPARATOR

When two or more message units are combined in a program message, they must be separated by a semicolon (;) (e.g., VOLT 15;MEAS:VOLT? and CURR 12; CURR:TRIG 12.5).

3.7.4.7 ROOT SPECIFIER

The root specifier is a colon (:) that precedes the first keyword of a program message. This places the parser at the root (top left, Figure 3-3) of the command tree. Note the difference between using the colon as a keyword separator and a root specifier in the following examples:

VOLT:LEV:IMM 16 Both colons are keyword separators.

:CURR:LEV:IMM 4 The first colon is the root specifier, the other two are keyword separators.

VOLT:LEV 6;:CURR:LEV 15 The second colon is the root specifier, the first and third are keyword separators

:INIT ON;:TRIG;:MEAS:CURR?;VOLT? The first three colons are root specifiers.

3.7.4.8 MESSAGE TERMINATOR

The message terminator defines the end of a message. One message terminator is permitted:

new line (<NL>), ASCII 10 (decimal) or 0A (hex)

NOTE: Kepco power supplies *require* a message terminator at the end of each program message. The examples shown in this manual assume a message terminator will be added at the end of each message. Where a message terminator is shown it is represented as <NL> regardless of the actual terminator character.

3.7.5 UNDERSTANDING THE COMMAND STRUCTURE

Understanding the command structure requires an understanding of the subsystem command tree illustrated in Figure 3-3. The "root" is located at the top left corner of the diagram. The parser goes to the root if:

- a message terminator is recognized by the parser
- a root specifier is recognized by the parser

Optional keywords are enclosed in brackets [] for identification; optional keywords can be omitted and the power supply will respond as if they were included in the message. The root level keyword [SOURce] is an optional keyword. Starting at the root, there are various branches or paths corresponding to the subsystems. The root keywords for the BHK-MG 40W Power Supply are :ABORt, :CALibrate, :DISPlay, :INITiate, :LIST, :MEASure, :OUTPut, [:SOURce], :STATus, :SYSTem and :TRIGger. Because the [SOURce] keyword is optional, the parser moves the path to the next level, so that VOLTage, CURRent, and FUNCtion commands are at the root level.

3-24 BHK-1/2-MG 110504

Each time the parser encounters a keyword separator, the parser moves to the next indented level of the tree diagram. As an example, the STATus branch is a root level branch that has three sub-branches: OPERation, PRESet, and QUEStionable. The following illustrates how SCPI code is interpreted by the parser:

STAT:PRES<NL>

The parser returns to the root due to the message terminator.

STAT:OPER?:PRES<NL>

The parser moves one level in from STAT. The next command is expected at the level defined by the colon in front of OPER?. Thus you can combine the following message units STAT:OPER? and STAT:PRES;

STAT:OPER:COND?;ENAB 16<NL>

After the OPER:COND? message unit, the parser moves in one level from OPER, allowing the abbreviated notation for STAT:OPER:ENAB.

3.7.6 PROGRAM MESSAGE SYNTAX SUMMARY

- Common commands begin with an asterisk (*).
- Queries end with a question mark (?).
 - Program messages consist of a root keyword and, in some cases, one or more message units separated by a colon (:) followed by a message terminator. Several message units of a program message may be separated by a semicolon (;) without repeating the root keyword.
 - If a program message has more than one message unit, then a colon (:) must precede the next keyword in order to set the parser back to the root (otherwise the next keyword will be taken as a subunit of the previous message unit).
 - e.g., the command meas:volt?;curr? will read output voltage and output current since both volt? and curr? are interpreted as subunits of the meas command.
 - Several commands may be sent as one message; a line feed terminates the message.
 Commands sent together are separated by a semicolon (;). The first command in a message starts at the root, therefor a colon (:) at the beginning is not mandatory.
 - e.g., the command meas:volt?;:curr? will read output voltage and programmed current since the colon preceding curr? indicates that curr? is not part of the meas command and starts at the root.
 - UPPER case letters in mnemonics are mandatory (short form). Lower case letters may
 either be omitted, or must be specified completely (long form)
 e.g., INSTrument (long form) has the same effect as INST (short form).
 - Commands/queries may be given in upper/lower case (long form) e.g., **SoUrCe** is allowed.
 - Text shown between brackets [] is optional.
 e.g., :[SOUR]VOLT:[LEV] TRIG has the same effect as :VOLT TRIG

3.7.7 SCPI PROGRAM EXAMPLES

Refer to Appendix B, Figures B-1 through B-8 for examples illustrating the use of SCPI commands.

Figure 3-5 is an example of a program using SCPI commands to program the BHK-MG 40W Power Supply. The program illustrated is for a configuration using an IBM PC or compatible with a National Instruments GPIB interface card. (It will be necessary to consult the manufacturer's data to achieve comparable functions with an interface card from a different manufacturer.) This program sets output voltage (Voltage mode) or voltage limit (Current mode) to 5V, and current limit (Voltage mode) or output current (Current mode) to 1A, then reads the measured (actual) voltage and current, then prints the measurements.

```
Sample Program For KEPCO power supply, using National Instruments
   GPIB interface card and IBM PC or compatible computer
#include <stdio.h>
#include "decl.h"
char rd_str[80];
                        // Input buffer
char dat_str[80];
                        // Output buffer
int bd,adr;
 main() {
  ibsre(bd,1);
                         // Set remote line true
  strcpy(dat_str,"VOLT 5;CURR 1"); // Define a set command
  strcat(dat_str,"\r\n");
                        // Append delimiter
  ibwrt(adr,dat_str,strlen(dat_str)); // Send string to power supply
  strcpy(dat_str,"MEAS:VOLT?;CURR?"); // Define a measure command
  strcat(dat_str,"\r\n");
                         // Append delimiter
  ibwrt(adr,dat_str,strlen(dat_str)); // Send string to power supply
  // Read result of measure
  }
```

FIGURE 3-5. TYPICAL EXAMPLE OF BHK-MG 40W POWER SUPPLY PROGRAM USING SCPI COMMANDS

3.8 REMOTE PROGRAMMING USING ANALOG PROGRAMMING TERMINALS

The BHK-MG 40W Power Supply is designed with separate, but similar, circuits for analog voltage programming (Figure 3-6) and analog current programming (Figure 3-7). The voltage programming circuit is used for programming output voltage if the unit is in voltage mode, or voltage limit if the unit is in current mode. Similarly, the current programming circuit programs output current in current mode, and current limit in voltage mode.

3-26 BHK-1/2-MG 110504

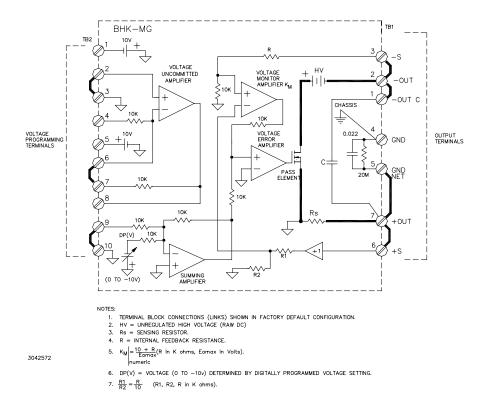
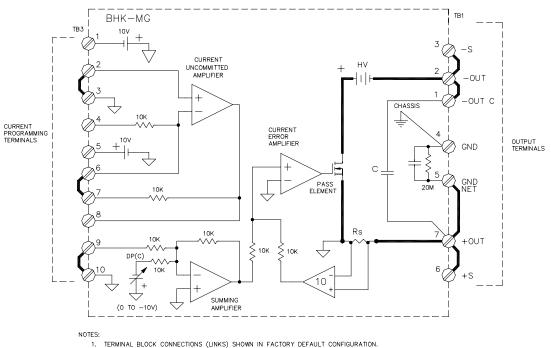


FIGURE 3-6. ANALOG VOLTAGE PROGRAMMING, SIMPLIFIED DIAGRAM



HV = UNREGULATED HIGH VOLTAGE (RAW DC)
Rs = SENSING RESISTOR

4. DP(C) = VOLTAGE (0 TO -10V) DETERMINED BY DIGITALLY PROGRAMMED CURRENT SETTING. 3042573

FIGURE 3-7. ANALOG CURRENT PROGRAMMING, SIMPLIFIED DIAGRAM

3-27 BHK-1/2-MG 110504

For each circuit, the digital programming section provides a voltage (DP (V) for voltage, DP (C) for current), between zero and -10V d-c, applied to the input of a summing amplifier. This amplifier drives, in turn, the voltage error amplifier and the pass element to produce the output. Each circuit also includes an uncommitted amplifier which can be configured to be summed with the output of the digital programming section at the input of the summing amplifier. Configuration of the uncommitted amplifiers is accomplished at the ANALOG PROGRAMMING TERMINALS at the rear panel: VOLTAGE PROG. terminal strip TB2 for voltage, CURRENT PROG. terminal strip TB3 for current.

If digital programming is at zero, analog programming requires a voltage between zero and – 10V d-c to be applied to terminal 9 (TB2 for voltage, TB3 for current). If digital programming is combined with analog programming, the voltage range for the signal applied to terminal 9 is:

Voltage programming: TB2-9: 0 to $-\left(10 - \text{Eout}_{dp} \times \frac{10}{\text{Eomax}}\right) V$

Current programming: TB3-9: 0 to $-\left(10 - Iout_{dp} \times \frac{10}{Iomax}\right)V$

where:

Eout_{dp} = digitally programmed output voltage/voltage limit lout_{dp} = digitally programmed output current/current limit

The uncommitted amplifiers can be configured to produce the required voltage from a number of analog sources. Some basic analog configurations are presented in the following paragraphs:

- · External resistance
- · Low impedance voltage source
- Grounded voltage source
- · High impedance voltage source
- · Current source

Different analog sources can be used simultaneously; e.g., resistance can be sued to control voltage programming while a grounded voltage source controls current programming. Analog programming can also be combined with digital programming (either locally via the keypad or remotely via the GPIB bus) since the two programming methods are summed together. For example, for the BHK 500-80MG Power Supply, if the output is programmed digitally to 200V, and an analog signal which would produce a 100V output is applied to the uncommitted amplified, the output would go to 300V (assuming the value of the load and the programmed value of output current allow the power supply to remain in voltage mode).

NOTE: It is important to remember that **BOTH** voltage and current channels must be programmed (e.g., if analog programming of voltage mode is used, the current limit **must** be programmed by either analog or digital programming).

The availability of the two uncommitted amplifiers, ±10V d-c reference voltages and the two summing amplifiers, means that many configurations are possible for analog control of the power supply.

3-28 BHK-1/2-MG 110504

3.8.1 ANALOG PROGRAMMING WARNINGS AND CAUTIONS



THE POWER SUPPLY PRODUCES DANGEROUS VOLTAGES WHICH CAN BE LETHAL. ALWAYS OBSERVE THE FOLLOWING PRECAUTIONS.

a. Always connect the chassis of the power supply to a good AC ground (earth) connected to OUTPUT TERMINALS terminal strip TB1, terminal 4.

NOTE: All connections must be tight, whether at the terminal strips of the power supply or at external equipment.

- b. Use high voltage rated cables (at least 3kV) for all connections, even for programming connections. Where required use twisted pair cable or shielded single or pair cable (shield to chassis), rated for high voltage.
- c. Even though the BHK-MG 40W Power Supply will discharge the output capacitor at turn-off, verify that the output is safe before making any attempt to connect or disconnect the load.
- d. Verify that the input circuit breaker is off and remove the line cord before connecting or disconnecting the load or other external components to analog programming terminals.
- e. If possible, connect one side of the output to ground (either side may be grounded). The power supply can also operate with the output "floating" with respect to ground.



The following warnings and cautions apply to the output terminals:

- If the external equipment (e.g., Digital Voltmeter) has floating inputs and the power supply is operating with +OUT terminal connected to ground, connect the LOW input of the external equipment to +OUT terminal of the power supply.
- If the external equipment (e.g., Digital Voltmeter) has floating inputs and the power supply is working with –OUT terminal connected to ground, connect the LOW input of the external equipment to –OUT terminal of the power supply.
- If the power supply outputs should stay isolated from ground, any external equipment connected to the output terminal should be connected to a-c source power using an isolating transformer, or should have floating inputs.

NOTE: Any isolating transformer used for connecting test equipment to a-c source power should have the isolation rated to a value higher than the maximum output voltage of the power supply.

WARNING

The following warnings and cautions apply to the analog programming terminals because the analog control circuitry operates at the +OUTPUT potential and the common of the analog control circuitry is connected to the +OUT terminal (TB1) through the sensing resistor (Rs) of the power supply.

- If the power supply is operating with +OUT terminal connected to ground, do not connect
 grounded inputs or outputs of any external equipment to power supply analog programming terminals. If this situation is unavoidable, connect the external equipment to a-c
 source power using an isolating transformer. For external equipment with grounded output only, use the uncommitted amplifier of the power supply in differential configuration.
- If the power supply is operating with –OUT terminal connected to ground, the external programming source must be isolated up to the maximum output voltage plus 1KV. The programming source must be either battery powered or powered through an isolation transformer and feature "fully insulated controls and chassis."
- If the power supply must operate isolated from ground (floating), any external equipment connected to the ANALOG PROGRAMING TERMINALS must also be isolated (battery operated or connected to a-c source power using an isolating transformer).

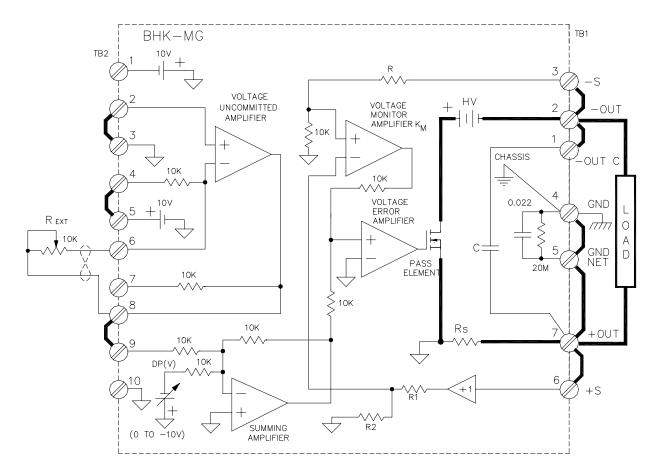
Safety Message

When the output is disabled, whether by the OUTPUT ON/OFF key, SCPI command via GPIB or RS 232 interface, or via the Status and Remote On/Off Port, an internal solid-state switch sets the voltage/current references to zero, resulting in zero output from the power supply. In the case of the OUTPUT ON/OFF key or SCPI command, if the solid state switch fails, and the output is higher than 8V, and the current is higher than 1mA, a shutdown sequence begins: the unit beeps and flashes the message Power Down in XX sec for 10 seconds as XX counts down from 10 to 0. After 10 seconds the input circuit breaker trips OFF. If the circuit breaker does not trip OFF, BHK Failure is displayed on the LCD.

3.8.2 PROGRAMMING WITH EXTERNAL RESISTANCE

Figures 3-8 and 3-9 are simplified diagrams of the BHK-MG showing the jumper configuration and external connections required for analog programming using an external resistance. Figures 3-8 shows programming of either output voltage when the unit is in voltage mode, or voltage limit when the unit is in current mode. Figure 3-9 is a similar diagram for programming either output current when the unit is in current mode, or current limit when the unit is in voltage mode.

3-30 BHK-1/2-MG 110504



NOTE: UNIT SHOWN IN SLOW MODE, +OUT TERMINAL GROUNDED, LOCAL SENSING.

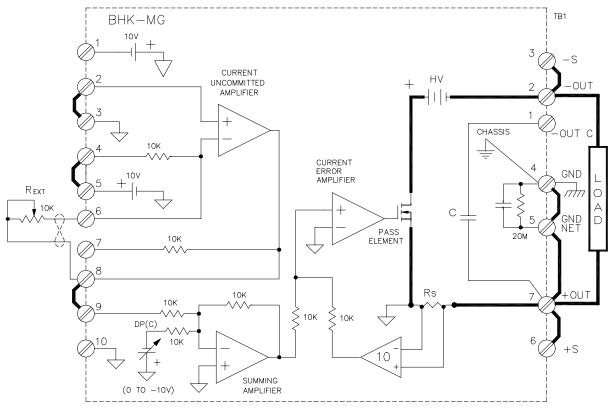
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FIGURE 3-8. ANALOG PROGRAMMING OF OUTPUT VOLTAGE (VOLTAGE MODE) OR VOLTAGE LIMIT (CURRENT MODE) USING RESISTANCE

For either voltage programming or current programming, the external resistor R_{EXT} connected across terminals 6 and 8 of VOLTAGE PROG terminal strip TB2 or CURRENT PROG. terminal strip TB3 functions as a feedback resistor for the internal uncommitted amplifier dedicated to voltage or current programming. This uncommitted amplifier is configured to amplify and invert the +10V reference applied via terminals 4 and 6 of TB2 or TB3. The output of the uncommitted amplifier is applied via terminals 8 and 9 of TB2 or TB3 to a summing network at the input of the summing amplifier. For voltage programming, the other input to the summing amplifier, DP (V), is from the voltage portion of the digital programming circuitry (either from the keypad or the GPIB bus). For current programming, the other input to the summing amplifier, DP (C), is from the current portion of the digital programming circuitry (either from the keypad or the GPIB bus).

TABLE 3-9. FEEDBACK RESISTOR AND CURRENT SENSING RESISTOR VALUES

RESISTOR	BHK 300-130MG	BHK 500-80MG	BHK 1000-40MG	BHK 2000-0.02MB
Voltage Feedback Resistor R (Ohms)	300K*	500K*	1000K*	2000K*
Current Sensing Resistor Rs (Ohms)	0.008K*	0.0125K*	0.025K*	0.050K*
* All resistors are 1% tolerance.				



NOTE: UNIT SHOWN IN FAST MODE, +OUT TERMINAL GROUNDED, LOCAL SENSING.

FIGURE 3-9. ANALOG PROGRAMMING OF OUTPUT CURRENT (CURRENT MODE)
OR CURRENT LIMIT (VOLTAGE MODE) USING RESISTANCE

3.8.2.1 VOLTAGE MODE

With the power supply in voltage mode (see Figure 3-8) and the digitally programmed output voltage at zero, varying the external resistor from 0 to 10K causes the output voltage of the power supply to vary linearly from 0 to Eomax with a slope of (0.0001 x Eomax) volts per ohm. The following equation gives the output voltage as determined by external resistance R_{EXT} .

Eo = $(-1) (10V) \times (R_{EXT}/10K) \times (-1) (10K/10K) \times (-1) (R/10K)$

 $= (-1) (0.1 \times R) \times R_{EXT}$

 $= -0.1R \times R_{EXT} (V d-c)$

where

R_{EXT}= External resistance (K-ohms), variable from 0 to 10K ohms. This resistance can take the form of a rheostat, a fixed resistor, or a group of resistors which are step-switched by mechanical, electrical or electronic means (step-switching must be "make before break"). Use only high quality resistor(s) having a temperature coefficient of 20 parts per million or better and a wattage rating of 0.5W minimum.

R = Internal feedback resistance (K-ohms), determined by Model (see Table 3-9).

NOTE: Output voltage is referenced to +OUT and output current is negative leaving +OUT terminal. This convention applies to voltage and current programming calculations of PAR. 3.8

3-32 BHK-1/2-MG 110504

3.8.2.2 CURRENT MODE

With the power supply in current mode (see Figure 3-9) and the digitally programmed output voltage at zero, varying the external resistor from 0 to 10K causes the output current of the power supply to vary linearly from 0 to lomax with a slope of (0.0001 x lomax) mA per ohm. The following equation gives the output current as determined by external resistance R_{EXT} .

```
lo = [(-1) (10V) \times (R_{EXT}/10K) \times (-1) (10K/10K) \times (-1/10) (10K/10K)]/Rs

= (-1) (0.1/Rs) \times R_{EXT}

= (-0.1/Rs) \times R_{EXT} (mA d-c)
```

where

Rs = Internal shunt resistance (K-ohms), determined by Model (see Table 3-9). (See above for definition of R_{EXT} .)

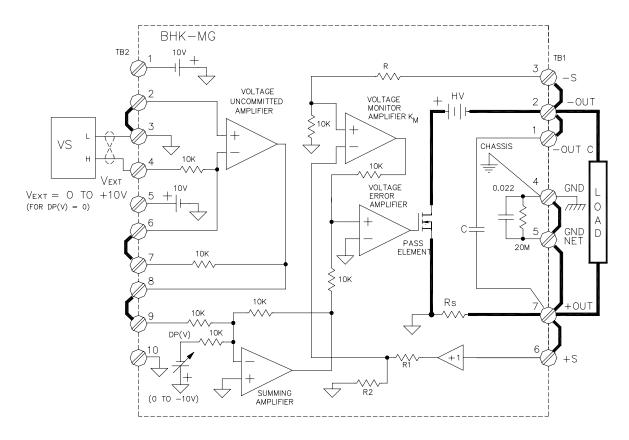
3.8.3 PROGRAMMING WITH EXTERNAL VOLTAGE USING A LOW IMPEDANCE VOLTAGE SOURCE

Figures 3-10 through 3-13 are simplified diagrams of the BHK-MG showing the jumper configuration and external connections required for analog programming using a low impedance voltage source. Figure 3-10 shows an isolated voltage source, Figure 3-11 shows a grounded voltage source for programming of either output voltage when the unit is in voltage mode, or voltage limit when the unit is in current mode. Figures 3-12 (isolated voltage source) and 3-13 (grounded voltage source) are similar diagrams for programming either output current when the unit is in current mode, or current limit when the unit is in voltage mode.

The external voltage source is applied to the input of the uncommitted amplifier which is configured either as an inverting repeater (Figures 3-10 and 3-12) for isolated voltage sources or a differential amplifier having a gain of -1 (Figures 3-11 and 3-13) for grounded voltage sources. The positive voltage is applied to the inverting input of the uncommitted amplifier referenced to internal signal ground. The voltage source impedance should be low compared to the 10K input impedance into the programming terminals of the power supply.

CAUTION

Observe the following to avoid damage to the power supply. For isolated voltage sources (Figures 3-10 and 3-12), the external voltage source output must be isolated from ground (floating output), or be powered from an a-c source that is isolated from ground to avoid short-circuiting the internal sensing resistor,. If neither of these options are practical, use the grounded voltage source configurations shown in Figures 3-11 and 3-13.



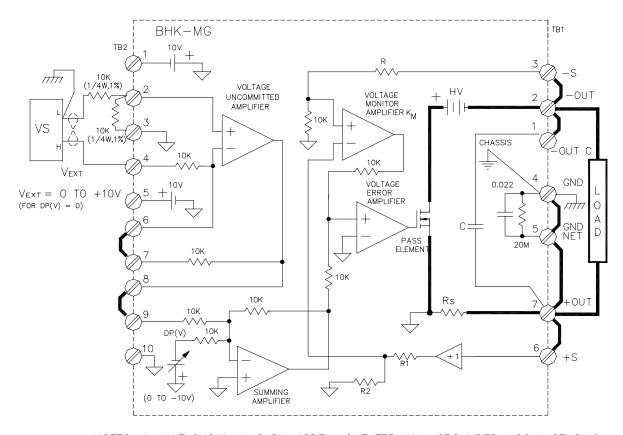
NOTES: 1. UNIT SHOWN IN SLOW MODE, +OUT TERMINAL GROUNDED, LOCAL SENSING.

- 2. VOLTAGE SOURCE (VS) MUST BE FLOATING WITH RESPECT TO CHASSIS GROUND, EITHER A LOW IMPEDANCE D-C SUPPLY OR A LOW IMPEDANCE FUNCTION GENERATOR.
- 3. WITH VOLTAGE SOURCE (VS) GENERATING A SYMETRICAL WAVEFORM, USE DIGITAL PROGRAMMING TO PROGRAM PROPER BIAS.

3042576

FIGURE 3-10. ANALOG PROGRAMMING OF OUTPUT VOLTAGE (VOLTAGE MODE) OR VOLTAGE LIMIT (CURRENT MODE) USING ISOLATED (FLOATING) LOW IMPEDANCE VOLTAGE SOURCE (VS)

3-34 BHK-1/2-MG 110504

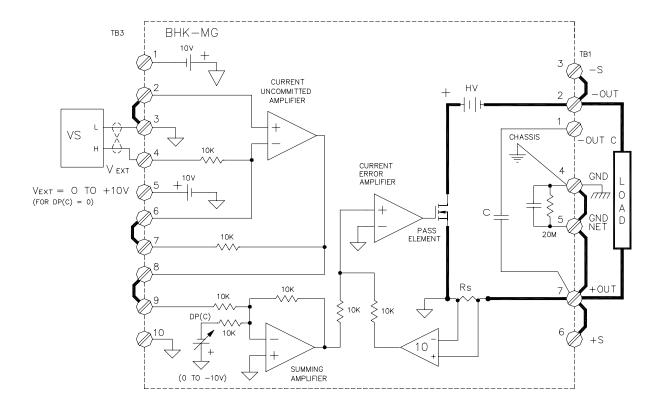


NOTES: 1. UNIT SHOWN IN SLOW MODE, +OUT TERMINAL GROUNDED, LOCAL SENSING.

- 2. VOLTAGE SOURCE (VS) CAN BE GROUNDED D-C SUPPLY OR GROUNDED FUNCTION GENERATOR.
- 3. WITH VOLTAGE SOURCE (VS) GENERATING A SYMETRICAL WAVEFORM, USE DIGITAL PROGRAMMING TO PROGRAM PROPER BIAS.

3042577

FIGURE 3-11. ANALOG PROGRAMMING OF OUTPUT VOLTAGE (VOLTAGE MODE) OR VOLTAGE LIMIT (CURRENT MODE) USING GROUNDED LOW IMPEDANCE VOLTAGE SOURCE (VS)



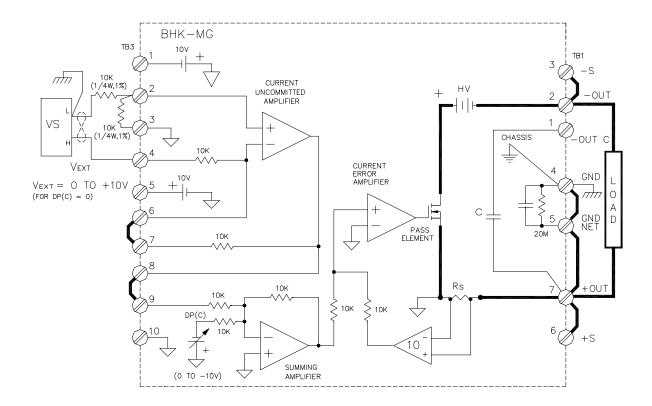
NOTES: 1. UNIT SHOWN IN FAST MODE, +OUT TERMINAL GROUNDED, LOCAL SENSING.

- 2. VOLTAGE SOURCE (VS) MUST BE FLOATING WITH RESPECT TO CHASSIS GROUND, EITHER A LOW IMPEDANCE D—C SUPPLY OR A LOW IMPEDANCE FUNCTION GENERATOR.
- 3. WITH VOLTAGE SOURCE (VS) GENERATING A SYMETRICAL WAVEFORM, USE DIGITAL PROGRAMMING TO PROGRAM PROPER BIAS.

3042578

FIGURE 3-12. ANALOG PROGRAMMING OF OUTPUT CURRENT (CURRENT MODE) OR CURRENT LIMIT (VOLTAGE MODE) USING ISOLATED (FLOATING) LOW IMPEDANCE VOLTAGE SOURCE (VS)

3-36 BHK-1/2-MG 110504



NOTES: 1. UNIT SHOWN IN FAST MODE, +OUT TERMINAL GROUNDED, LOCAL SENSING.

- 2. VOLTAGE SOURCE (VS) CAN BE GROUNDED D—C SUPPLY OR GROUNDED FUNCTION GENERATOR.
- 3. WITH VOLTAGE SOURCE (VS) GENERATING A SYMETRICAL WAVEFORM, USE DIGITAL PROGRAMMING TO PROGRAM PROPER BIAS.

3042579

FIGURE 3-13. ANALOG PROGRAMMING OF OUTPUT CURRENT (CURRENT MODE) OR CURRENT LIMIT (VOLTAGE MODE) USING GROUNDED LOW IMPEDANCE VOLTAGE SOURCE (VS)

3.8.3.1 VOLTAGE MODE

With the power supply in voltage mode (see Figure 3-10 or 3-11) and the digitally programmed output voltage at zero, varying the low impedance voltage source from 0 to +10V causes the output voltage of the power supply to vary linearly from 0 to Eomax with a slope of (0.1 x Eomax) volts per volt. The following equations give the output voltage as determined by a low impedance voltage source V_{FXT} .

ANALOG PROGRAMMING, DIGITAL PROGRAMMING = 0:

Eo = $(-1) (V_{EXT}) x (10K/10K) x (-1) (10K/10K) x (-1) (R/10K)$

 $= (-1) (0.1 \times R) \times V_{EXT}$

= $-0.1R \times V_{FXT} (V d-c)$

where

R = Internal feedback resistance (K-ohms), determined by Model (see Table 3-9).

V_{EXT} = External low impedance voltage source. This source can be either a d-c source delivering a positive output voltage, or a function generator with an internal positive bias. If the

bias is not available from the function generator, use the digital programming feature of the BHK-MG to provide proper bias to avoid clipping the waveform at the output of the power supply.

ANALOG PROGRAMMING COMBINED WITH DIGITAL PROGRAMMING:

$$Eo = -(0.1 \times R \times V_{EXT}) - Eout_{DP} (V d-c)$$

where

 $Eout_{DP}$ = Output voltage programmed digitally (from either local keypad or remote GPIB bus) (See above for definitions of R and V_{EXT} .)

3.8.3.2 CURRENT MODE

With the power supply in current mode (see Figure 3-12 or 3-13) and the digitally programmed output voltage at zero, varying the low impedance voltage source from 0 to +10V causes the output current of the power supply to vary linearly from 0 to lomax with a slope of (0.1 x lomax) mA per volt. The following equations give the output current as determined by the low impedance voltage source V_{EXT} .

ANALOG PROGRAMMING, DIGITAL PROGRAMMING = 0:

```
Io = [(-1) (V_{EXT}) \times (10K/10K) \times (-1) (10K/10K) \times (-1/10) (10K/10K)]/Rs

= (-1) (0.1/Rs) \times V_{EXT} (mA d-c)

= -(0.1/Rs) \times V_{EXT} (mA d-c)
```

where

Rs =Internal shunt resistance (K-ohms), determined by Model (see Table 3-9). (See above for definition of V_{EXT} .)

ANALOG PROGRAMMING COMBINED WITH DIGITAL PROGRAMMING:

$$Io = -(0.1/Rs) \times V_{EXT} - Iout_{DP} (mA d-c)$$

where

 $lout_{DP}$ = Output current programmed digitally (from either local keypad or remote GPIB bus) (See above for definitions of Rs and V_{EXT} .)

3.8.4 ANALOG PROGRAMMING WITH EXTERNAL VOLTAGE USING A HIGH IMPEDANCE, LOW LEVEL (1V) VOLTAGE SOURCE

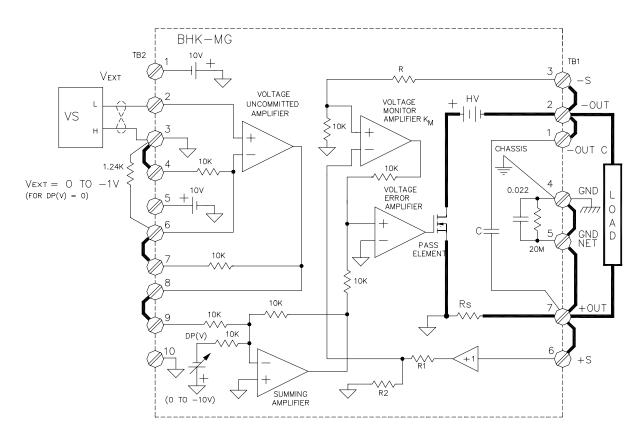
Figures 3-14 and 3-15 are simplified diagrams of the BHK-MG showing the jumper configuration and external connections required for analog programming using a high impedance, low level (1V), voltage source. Figure 3-14 shows the configuration for programming of either output voltage when the unit is in voltage mode, or voltage limit when the unit is in current mode. Figure 3-15 is a similar diagrams for programming either output current when the unit is in current mode, or current limit when the unit is in voltage mode

CAUTION

Observe the following to avoid damage to the power supply. The external voltage source output must be isolated from ground (floating output), or be powered from an a-c source that is isolated from ground to avoid short-circuiting the internal sensing resistor.

3-38 BHK-1/2-MG 110504

The external voltage source is applied to the input of the uncommitted amplifier which is configured as a noninverting amplifier having a gain of 10.

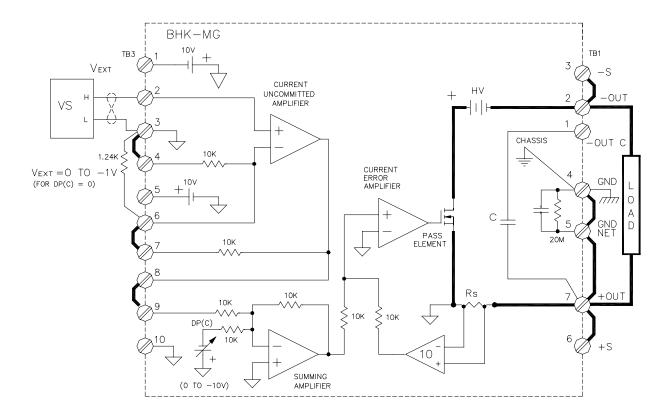


NOTES: 1. UNIT SHOWN IN SLOW MODE, +OUT TERMINAL GROUNDED, LOCAL SENSING.

- 2. VOLTAGE SOURCE (VS) MUST BE FLOATING WITH RESPECT TO CHASSIS GROUND, EITHER A HIGH IMPEDANCE D-C SUPPLY OR A HIGH IMPEDANCE FUNCTION GENERATOR.
- 3. WITH VOLTAGE SOURCE (VS) GENERATING A SYMETRICAL WAVEFORM, USE DIGITAL PROGRAMMING TO PROGRAM PROPER BIAS.

3042580

FIGURE 3-14. ANALOG PROGRAMMING OF OUTPUT VOLTAGE (VOLTAGE MODE) OR VOLTAGE LIMIT (CURRENT MODE) USING HIGH IMPEDANCE, LOW LEVEL (1V) VOLTAGE SOURCE (VS)



NOTES: 1. UNIT SHOWN IN FAST MODE, +OUT TERMINAL GROUNDED, LOCAL SENSING.

- 2. VOLTAGE SOURCE (VS) MUST BE FLOATING WITH RESPECT TO CHASSIS GROUND, EITHER A HIGH IMPEDANCE D-C SUPPLY OR A HIGH IMPEDANCE FUNCTION GENERATOR.
- 3. WITH VOLTAGE SOURCE (VS) GENERATING A SYMETRICAL WAVEFORM, USE DIGITAL PROGRAMMING TO PROGRAM PROPER BIAS.

3042581

FIGURE 3-15. ANALOG PROGRAMMING OF OUTPUT CURRENT (CURRENT MODE) OR CURRENT LIMIT (VOLTAGE MODE) USING HIGH IMPEDANCE, LOW LEVEL (1V) VOLTAGE SOURCE (VS)

3-40 BHK-1/2-MG 110504

3.8.4.1 VOLTAGE MODE

With the power supply in voltage mode (see Figure 3-14) and the digitally programmed output voltage at zero, varying the high impedance voltage source from 0 to -1V causes the output voltage of the power supply to vary linearly from 0 to Eomax with a slope of (Eomax) volts per volt. The following equations give the output voltage as determined by a high impedance voltage source V_{EXT} .

ANALOG PROGRAMMING, DIGITAL PROGRAMMING = 0:

```
Eo = (V_{EXT}) \times (11.1K/1.1K) \times (-1) (10K/10K) \times (-1) (R/10K)
= -(R) \times |V_{EXT}| (V d-c)
```

where

R = Internal feedback resistance (K-ohms), determined by Model (see Table 3-9).

V_{EXT} = External low impedance voltage source (Volts). This source can be either a d-c source delivering a negative output voltage, or a function generator with an internal negative bias. If the bias is not available from the function generator, use the digital programming feature of the BHK-MG to provide proper bias to avoid clipping the waveform at the output of the power supply.

ANALOG PROGRAMMING COMBINED WITH DIGITAL PROGRAMMING:

$$Eo = -(R \times |V_{FXT}|) - Eout_{DP} (V d-c)$$

where

 $Eout_{DP}$ = Output voltage programmed digitally (from either local keypad or remote GPIB bus) (See above for definitions of R and V_{EXT} .)

3.8.4.2 CURRENT MODE

With the power supply in current mode (see Figure 3-15) and the digitally programmed output voltage at zero, varying the high impedance voltage source from 0 to -1V causes the output current of the power supply to vary linearly from 0 to lomax with a slope of (lomax) mA per volt. The following equations give the output current as determined by the low impedance voltage source V_{EXT} .

ANALOG PROGRAMMING, DIGITAL PROGRAMMING = 0:

```
lo = [(V_{EXT}) \times (11.1 \text{K}/1.1 \text{K}) \times (-1) (10 \text{K}/10 \text{K}) \times (-1/10) (10 \text{K}/10 \text{K})]/\text{Rs}
= -(1/\text{Rs}) \times |V_{EXT}| (\text{mA d-c})
```

where

Rs =Internal shunt resistance (kOhms), determined by Model (see Table 3-9). (See above for definition of V_{EXT} .)

ANALOG PROGRAMMING COMBINED WITH DIGITAL PROGRAMMING:

$$Io = -(1/Rs) x |V_{EXT}| - Iout_{DP} (mA d-c)$$

where

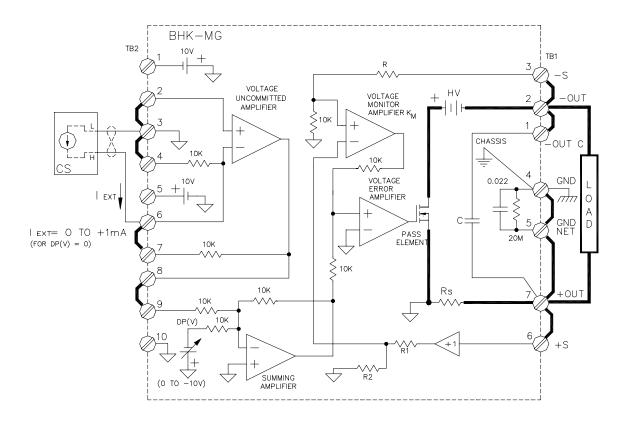
 $lout_{DP}$ = Output current programmed digitally (from either local keypad or remote GPIB bus) (See above for definitions of Rs and V_{EXT} .)

3.8.5 ANALOG PROGRAMMING WITH EXTERNAL CURRENT SOURCE (1 mA)

Figures 3-16 and 3-17 are simplified diagrams of the BHK-MG showing the jumper configuration and external connections required for analog programming using a current source (1mA). Figure 3-16 shows the configuration for programming of either output voltage when the unit is in voltage mode, or voltage limit when the unit is in current mode. Figure 3-17 is a similar diagrams for programming either output current when the unit is in current mode, or current limit when the unit is in voltage mode

CAUTION

Observe the following to avoid damage to the power supply. The external current source output must be isolated from ground (floating output), or be powered from an a-c source that is isolated from ground to avoid short-circuiting the internal sensing resistor.



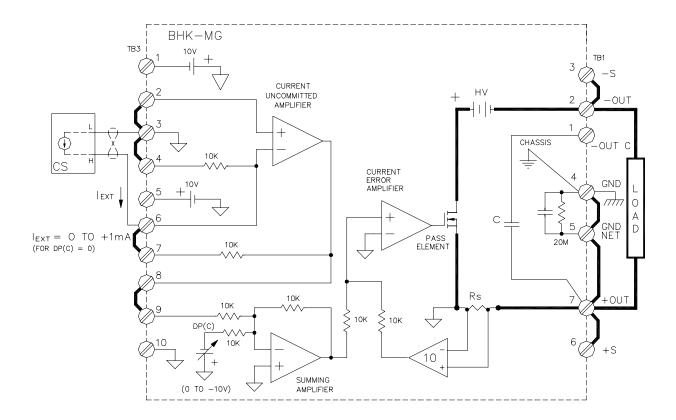
NOTES: 1. UNIT SHOWN IN SLOW MODE, +OUT TERMINAL GROUNDED, LOCAL SENSING.

- 2. CURRENT SOURCE (CS) MUST BE FLOATING WITH RESPECT TO CHASSIS GROUND, EITHER A CONSTANT CURRENT D—C SUPPLY OR A CONSTANT CURRENT FUNCTION GENERATOR.
- 3. WITH CURRENT SOURCE (CS) GENERATING A SYMETRICAL WAVEFORM, USE DIGITAL PROGRAMMING TO PROGRAM PROPER BIAS.

3042582

FIGURE 3-16. ANALOG PROGRAMMING OF OUTPUT VOLTAGE (VOLTAGE MODE) OR VOLTAGE LIMIT (CURRENT MODE) USING CURRENT SOURCE (1mA) (CS)

3-42 BHK-1/2-MG 110504



- NOTES: 1. UNIT SHOWN IN FAST MODE, +OUT TERMINAL GROUNDED, LOCAL SENSING.
 - 2. CURRENT SOURCE (CS) CAN BE FLOATING WITH RESPECT TO CHASSIS GROUND, EITHER A CONSTANT CURRENT D—C SUPPLY OR A CONSTANT CURRENT FUNCTION GENERATOR.
 - 3. WITH CURRENT SOURCE (CS) GENERATING A SYMETRICAL WAVEFORM, USE DIGITAL PROGRAMMING TO PROGRAM PROPER BIAS.

3042583

FIGURE 3-17. ANALOG PROGRAMMING OF OUTPUT CURRENT (CURRENT MODE) OR CURRENT LIMIT (VOLTAGE MODE) USING CURRENT SOURCE (1mA) (CS)

The external current source is applied to the inverting input of the uncommitted amplifier which is configured as a current-voltage converter.

CAUTION

Observe the following to avoid damage to the power supply. The external current source output must be isolated from ground (floating output), or be powered from an a-c source that is isolated from ground to avoid short-circuiting the internal sensing resistor.

3.8.5.1 VOLTAGE MODE

With the power supply in voltage mode (see Figure 3-16) and the digitally programmed output voltage at zero, varying the external current source from 0 to 1mA causes the output voltage of the power supply to vary linearly from 0 to Eomax with a slope of (Eomax) volts per mA. The following equations give the output voltage as determined by the external current source I_{EXT}.

ANALOG PROGRAMMING, DIGITAL PROGRAMMING = 0:

```
Eo = (-1)I_{EXT} \times (10K) \times (-1) (10K/10K) \times (-1) (R/10K)
= -(R) \times |I_{EXT}| (V d-c)
```

where

- R = Internal feedback resistance equal to correction resistance (K-ohms), determined by Model (see Table 3-9).
- I_{EXT} = External current source (mA). This source can be either a d-c source or a function generator with an internal bias delivering a constant current. If the bias is not available from the function generator, use the digital programming feature of the BHK-MG to provide proper bias to avoid clipping waveform at the output of the power supply.

ANALOG PROGRAMMING COMBINED WITH DIGITAL PROGRAMMING:

$$Eo = -(R \times |I_{EXT}|) - Eout_{DP} (V d-c)$$

where

 $Eout_{DP}$ = Output voltage programmed digitally (from either local keypad or remote GPIB bus) (See above for definitions of R and V_{EXT} .)

3.8.5.2 CURRENT MODE

With the power supply in current mode (see Figure 3-17) and the digitally programmed output voltage at zero, varying the external current source from 0 to 1mA causes the output current of the power supply to vary linearly from 0 to lomax with a slope of (lomax) mA per mA. The following equations give the output current as determined by the external current source I_{EXT} .

ANALOG PROGRAMMING, DIGITAL PROGRAMMING = 0:

```
lo = [(-1) I_{EXT} x (10K) x (-1) (10K/10K) x (-1/10) (10K/10K)]/Rs
= -(1/Rs) x | I_{EXT} | (mA d-c)
```

where

Rs =Internal shunt resistance (K-ohms), determined by Model (see Table 3-9). (See above for definition of I_{FXT} .)

ANALOG PROGRAMMING COMBINED WITH DIGITAL PROGRAMMING:

$$Io = -(1/Rs) x | I_{EXT}| - Iout_{DP} (mA d-c)$$

where

 $lout_{DP}$ = Output current programmed digitally (from either local keypad or remote GPIB bus) (See above for definitions of Rs and l_{EXT} .)

3-44 BHK-1/2-MG 110504

3.9 OPERATING MODES

This section describes the following operating modes for the BHK-MG 40W Power Supply

- Slow/Fast Mode
- Series Operation
- Automatic Series Operation
- Master-Slave Series Operation
- · Parallel Operation
- Automatic Parallel Operation
- Master-Slave Parallel Operation

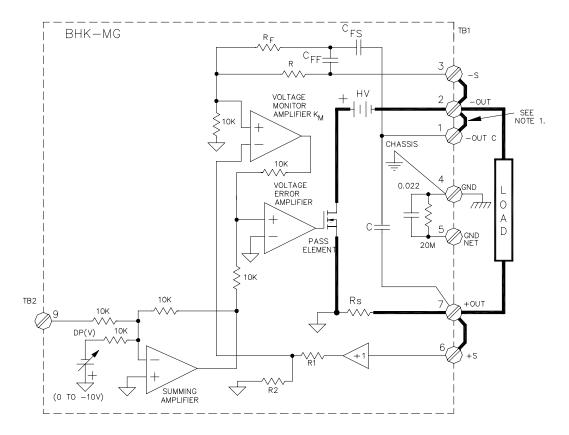
3.9.1 SLOW/FAST MODE OF OPERATION

In slow mode of operation the internal output capacitor C_{OUT} is connected across the sensing terminals via TB1, terminal 1 (-OUT.C) and terminal 2 (-OUT). This effectively increases the main feedback capacitance by adding the internal feedback capacitor for slow mode C_{FS} . to the fast mode capacitor C_{FF} (see Figure 3-18). When internal output capacitor C_{OUT} is across the output, output noise is reduced, and, in voltage mode, the amplitude of transients caused by dynamic load changes is also reduced. The disadvantage of slow mode is that programming time is increased. Therefore, slow mode is recommended for voltage mode applications where low noise and low amplitude recovery transients due to dynamic load changes are important.

In fast mode of operation the internal output capacitor is disconnected from the sensing terminals, by removing the link between TB1, terminal 1 (-OUT.C) and terminal 2 (-OUT). This also effectively reduces the main feedback capacitance by removing the internal capacitor for slow mode, C_{FS} from the circuit. This configuration reduces the programming time in voltage mode and, in current mode, reduces the duration of transients caused by dynamic load changes; the disadvantage is that output noise is increased. Therefore, the fast mode of operation is recommended for voltage mode applications when a quick response to programming is important (e.g., when the power supply is effectively operating as a power amplifier), and for current mode applications when quick recovery time at load changes is desired.

If desired, an external output capacitor can also to be used; the following instructions apply when using an external output capacitor:

a. Use a capacitor rated to more than the maximum output voltage of the power supply. If a series combination of polarized type capacitors is used, potential equalizer resistors in parallel with each capacitor should be installed and attention should be paid to the polarity of the capacitors: the "plus" terminal of each capacitor is connected to the "minus" terminal of the next capacitor, if present, or to +OUT terminal of the power supply (see Figure 3-18).



NOTES: 1. UNIT SHOWN IN SLOW MODE, LOCAL SENSING. REMOVE LINK BETWEEN TERMINAL 1 AND 2 FOR FAST MODE.

- 2. $C_{OUT} = INTERNAL OUTPUT CAPACITOR$
- 3. $C_{FF} = INTERNAL FEEDBACK CAPACITOR FAST MODE$ 4. $C_{FS} = INTERNAL FEEDBACK CAPACITOR SLOW MODE$
- 5. BOTH CFF AND CFS ARE ACTIVE IN SLOW MODE.

3042584

FIGURE 3-18. SLOW MODE/FAST MODE OPERATION

- b. If precise control of the voltage across the external capacitor is desired, use remote sensing: connect the sensing leads and power leads across the external output capacitor and connect the load to the external capacitor.
- If the external capacitor has a value much smaller than internal output capacitor C_{OUT} (see Table 1-2), then it is not necessary to connect the internal capacitor at the output using the link between terminals TB1-1 and TB1-2. If the external capacitor is comparable or larger than the internal C_{OLIT} , it is advisable to connect the internal C_{OLIT} across the output by installing the link between terminals TB1-1 and TB1-2, in order to increase the main feedback capacitance.

CAUTION

Isolate all external circuitry connected to the ungrounded ("live") output terminal of the power supply; isolation should be rated to more than maximum output voltage.

3-46 BHK-1/2-MG 110504

3.9.2 SERIES OPERATION

Kepco BHK-MG power supplies can be series-connected to increase output voltage if the precautions outlined below are followed. Two basic series-connection methods are generally used: automatic (PAR. 3.9.2.1) and master-slave (PAR. 3.9.2.2).



HANDLING HIGH VOLTAGE, LOW IMPEDANCE EQUIPMENT IS DANGEROUS, AND POTENTIALLY LETHAL. OBSERVE ALL PRECAUTIONS LISTED IN PAR. 3.8.1., AS WELL AS THE PRECAUTIONS LISTED BELOW.

- a. Do not exceed the specified isolation voltage limit (see Table 1-2). If the isolation voltage might be exceeded, limit the excursion of one power supply output: e.g., if two BHK 2000-20MG models are to be series-connected, the output of one must be restricted to 0.5 kV (limiting the series combination to a maximum of 2.5kV), because the isolation voltage for this model is 2kV + 0.5kV (see Table 1-2).
- b. Connect the chassis ground terminal, TB1-4, of all series-connected power supplies to a good a-c ground (earth ground).
- c. If necessary, the grounding network can be used for each one of the series-connected power supplies within the limits of the maximum isolation voltage (see Table 1-2) of the Model BHK-MG Series (refer to PAR. 2.7.5.3 for additional information regarding use of the grounding network).
- d. The series combination of BHK-MG power supplies can operate either isolated from ground (floating) or with either of the two output terminals of the series combination grounded. When analog programming is used, however, it is recommended that the positive output terminal of the series combination be grounded to avoid potentially hazardous conditions requiring the use of fully insulated external equipment (see precautions of PAR. 3.8.1).

If the negative output terminal is grounded, special precautions are required when using external programming sources: THE PROGRAMMING SOURCE MUST BE ISOLATED AND INSULATED for the sum of the voltages of the series combination. The programming source must be either battery powered or powered through an isolation transformer and have "fully insulated controls and chassis" features (see also PAR. 3.8.1).

NOTE: The simplified schematic diagrams (Figures 3-19 through 3-21) illustrating the associated interconnections show the power supplies configured in either slow mode for units operating in voltage mode or fast mode for units operating in current mode, however other combinations are also possible. Due to the low current involved, the units are shown using local sensing since the drop across the power leads is usually negligible compared to the output voltage. However, when very precise control of output voltage applied to the load is desired, remote sensing should be used. Contact Kepco Applications Engineering when special configurations are indicated.

3.9.2.1 AUTOMATIC SERIES OPERATION

This operating configuration (see Figure 3-19) is characterized by the fact that each power supply is independent and must be controlled (programmed) individually, either remotely—via

either the GPIB bus or by analog means—or locally via the keypad. Practical considerations suggest that the units operate in voltage mode - current limit, controlled from the local keypad. The output voltage and current of the series combination are given by the following equations:

$$Eo = Eo_A + Eo_B$$

where

Eo, lo are output values of the series combination (in Volts and milliamperes, respectively) Eo_A, Eo_B are the individual output voltages for two series-connected power supplies (in Volts)

R_{LOAD} is the load value (in K-ohms).

The maximum current delivered by the series combination is dictated by the power supply with the lowest nominal current and correspondingly, the highest nominal output voltage. For the current limit to operate properly, set the desired value of current limit (for the series combination) at the power supply with the highest nominal output voltage; set the current limit of the other power supply to a larger value (1% larger or more).

RECOMMENDED PROCEDURE. The following steps are recommended to ensure the combination of power supplies configured for automatic series operation (power assembly) is properly connected and set up properly.

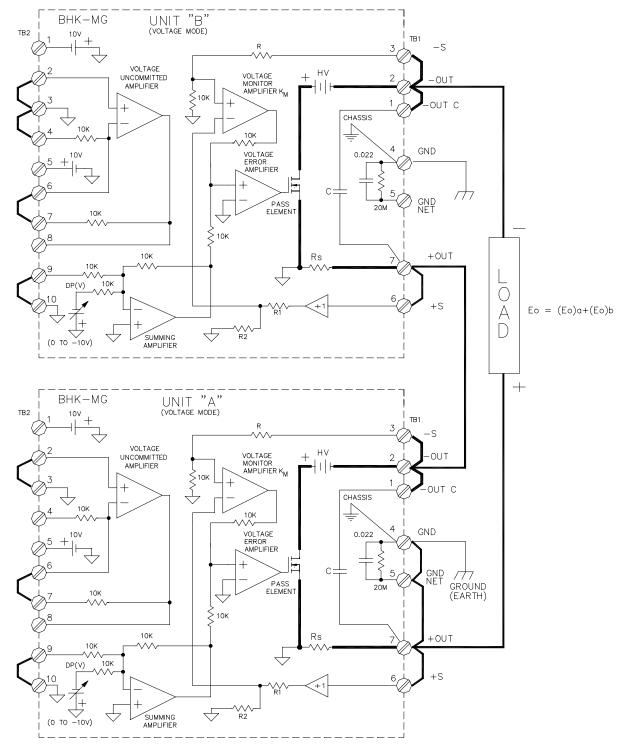
- 1. With the units turned off, perform all external wiring (see Figure 3-19). If possible, use a properly rated switch between the power supply and the load.
- 2. Apply power to the units:
 - a. If a load switch is used, open the switch. Set POWER switch of both units to up position to turn power on.
 - b. If load switch is not used, set POWER switch of both units to up position to turn power on, then press OUTPUT ON/OFF key once on each unit to disable the output.
- 3. Program Unit A as follows:

NOTE: If using two different BHK models, e.g., 500-80MG and 1000-40MG, unit A must be the one with the lower current capacity: 1000-40MG

- a. Program IsetA to the current limit for the power assembly.
- b. Program VsetA to: $V_{set} = E_0 \frac{E_0 max A}{(E_0 max A + E_0 max B)}$ (to nearest volt) where:
 - Eo is the output voltage of the power assembly,
 - EomaxA is the rated maximum output voltage for unit A (e.g. 500 for the BHK 500-80MG),
 - EomaxB is the rated maximum output voltage for unit B.
- c. Program overcurrent value of unit A (locsetA) to 1.1 x current limit for power assembly (step 3a).

3-48 BHK-1/2-MG 110504

- d. Program overvoltage value of unit A (VovsetA) to 1.1 x VsetA (step 3b).
- 4. Program unit B as follows:.
 - a. Program IsetB to approximately 1.01 to 1.02 x IsetA (step 3a). This maximum current limit is never used except in the unlikely event that the current limit of Unit A is not working.
 - b. Program VsetB to (Eo VsetA) (VsetA is set in step 3b).
 - c. Program overcurrent value of unit B (locsetB) to 1.1 x lsetB (step 4a).
 - d. Program overvoltage value of unit B (VovsetB) to 1.1 x VsetB (step 4b).
- 5. To apply power to the load:
 - a. If load switch used, close the switch.
 - b. If load switch not used, press POWER ON/OFF key (once) on unit B, then unit A.
- 6. To disable power to the load:
 - a. If load switch used, open the switch.
 - b. If load switch not used, press POWER ON/OFF key once: first on unit A, then on unit B.
 - c. Alternative: Turn both units off by setting POWER switch to off (down) position, first on unit A, then on unit B.



NOTES:

- 1) THE SERIES COMBINATION IS SHOWN USING LOCAL SENSING, SLOW MODE, OPERATING IN VOLTAGE MODE WITH "+OUTPUT" TERMINAL GROUNDED.
- 2) UNITS "A" AND "B" ARE CONTROLLED INDEPENDENTLY, USING DIGITAL PROGRAMMING (DP(V)), EITHER LOCAL OR REMOTE; ANALOG PROGRAMMING CAN ALSO BE USED.

FIGURE 3-19. SERIES AUTOMATIC CONFIGURATION

3-50 BHK-1/2-MG 110504

3.9.2.2 MASTER-SLAVE SERIES OPERATION (AUTOMATIC TRACKING)

This configuration is characterized by the fact that only the master power supply is programmed (controlled), while the slave power supply follows the command of the master in a ratio which may be predetermined by the user. This method is, therefore, often termed automatic tracking.

A master-slave series combination with a single slave is shown in Figure 3-20 configured to operate in voltage mode, and in Figure 3-21 to operate in current mode. The master can be controlled either remotely—via either the GPIB bus or by analog means—or locally via the keypad. The slave can only be programmed by analog programming using external resistance (see also PAR. 3.8.2). The external resistor (R_{EXT}) becomes the input resistor of the uncommitted amplifier (slave) which is configured as an inverting amplifier.

3.9.2.2.1 VOLTAGE MODE OPERATION

When the series combination (Figure 3-20) is operating in voltage mode, both units are in voltage mode: the master receives voltage programming commands and the slave tracks the output voltage of the master.

The output voltage of the series combination in voltage mode is given by the equation,

```
Eo = Eo_M + Eo_S

= Eo_M + [Eo_M \times (10/R_{EXT}) \times (Eomax_S/10)]

= Eo_M + [Eo_M \times (Eomax_S/R_{EXT})]
```

(eq1)

where

 Eo_M , Eo_S are the output voltages of the master and slave unit, respectively, in Volts $\mathsf{Eomax}_\mathsf{S}$ is the maximum output voltage of the slave unit, in Volts R_FXT is the external programming resistor of the slave unit, in K-ohms.

When R_{EXT} (K-ohms) = $Eomax_M$ (Volts), then $Eo = Eo_M + Eo_M x Eomax_S/Eomax_M$, with the maximum value of $Eomax_M + Eomax_S$.

When R_{EXT} (K-ohms) = $Eomax_S$ (Volts), then $Eo = 2 \times Eo_M$, having the maximum value $Eomax = 2 \times Eomax_M$.

When the value of R_{EXT} (in K-ohms) equals Eomax_{M} (in Volts), as the master is programmed, the slave will automatically follow proportionally, so the when the master is at maximum output voltage, the slave will also be at its own maximum output voltage. This combination is practical when connecting different BHK-MG models in series.

The output of the series combination will be double the output voltage of the master if the value of R_{EXT} (in K-ohms) equals Eomax_S (in Volts).

When the maximum master and slave output voltages are different, the value of R_{EXT} (in Kohms) must always be equal to, or greater than Eomax_{M} (in Volts), otherwise the slave supply will be programmed to a voltage higher than Eomax_{S} , resulting in an overvoltage condition.

The maximum current delivered by the series combination is dictated by the power supply with the lowest nominal current and correspondingly, the highest nominal output voltage. For the current limit to operate properly, set the desired value of current limit (for the series combination) at the power supply with the highest nominal output voltage; set the current limit of the other power supply to a larger value (1% larger or more).

The load current is given by the equation,

$$Io = Eo/R_{IOAD}$$

RECOMMENDED PROCEDURE. The following steps are recommended to ensure the combination of power supplies (power assembly) configured for master-slave series (automatic tracking) operation is connected and set up properly for voltage mode operation.

1. With the units turned off, perform all external wiring (see Figure 3-20). If possible, use a properly rated switch between the power supply and the load. Use $R_{\text{EXT}} = \text{Eomax}_{\text{M}}$ (see PAR. 3.9.2.2.1).

2. Apply power to the units:

- a. If a load switch is used, open the switch. Set POWER switch of both units to up position to turn power on.
- b. If load switch is not used, Set POWER switch of both units to up position to turn power on, then press OUTPUT ON/OFF key once on each unit to disable the output.

3. Program slave unit as follows:

- a. Program Iset_S to approximately 1.01 to 1.02 x current limit for power assembly. This maximum current limit is never used except in the unlikely event that the current limit of master unit is not working.
- b. Program Vset_S to 0.
- c. Program overcurrent value of slave unit (locset_S) to 1.1 x lset_S (step 3a).
- d. Program overvoltage value of slave unit (Vovset_S) to

1.1 x
$$\frac{(\text{Eo})(\text{Eomax}_S)}{(\text{Eomax}_M) + (\text{Eomax}_S)}$$

where Eo is the output voltage desired for the assembly.

4. Program master unit as follows:

a. $Program\ Iset_M$ to the current limit of the power assembly.

$$\text{b. Program Vset}_{M} \text{ to } \quad \frac{(\texttt{Eo})(\texttt{Eomax}_{M})}{(\texttt{Eomax}_{M}) + (\texttt{Eomax}_{S})} \quad .$$

- c. Program overcurrent value of master unit (locset_M) to 1.1 x lset_M (step 4a).
- d. Program overvoltage value of master unit (Vovset_M) to 1.1 x Vset_M (step 4b).

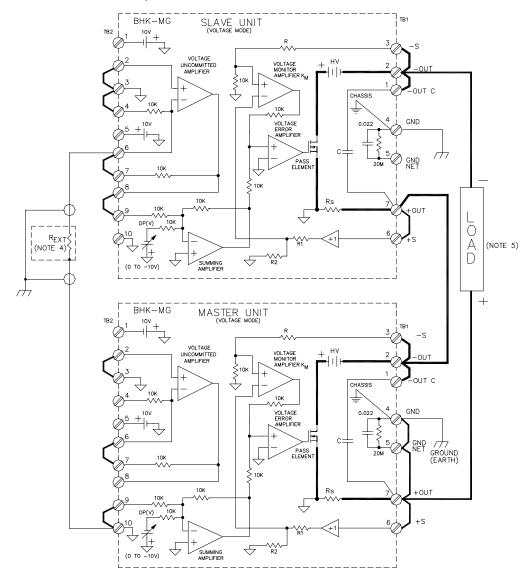
5. To apply power to the load:

- a. If load switch used, close the switch.
- If load switch not used, press POWER ON/OFF key (once) on master unit, then slave unit.

3-52 BHK-1/2-MG 110504

6. To disable power to the load:

- a. If load switch used, open the switch.
- b. If load switch not used, press POWER ON/OFF key: once on the master unit, then once on the slave unit.
- c. Alternative: Turn both units off by setting POWER switch to off (down) position, first on master unit, then on slave unit.



NOTES:

- 1) THE SERIES COMBINATION IS SHOWN USING LOCAL SENSING, SLOW MODE, OPERATING IN VOLTAGE MODE WITH "+OUTPUT" TERMINAL GROUNDED.
- 2) CONTROL OF THE MASTER UNIT IS DONE BY DIGITAL PROGRAMMING (DP(V)), EITHER LOCAL OR REMOTE; ANALOG PROGRAMMING CAN ALSO BE USED.
- 3) CONTROL OF THE SLAVE UNIT CAN BE DONE ONLY BY ANALOG PROGRAMMING (DP (V) = OV), AS SHOWN.
- 4) R_{EXT} (K-ohms) = $Eomax_M$ (Volts)

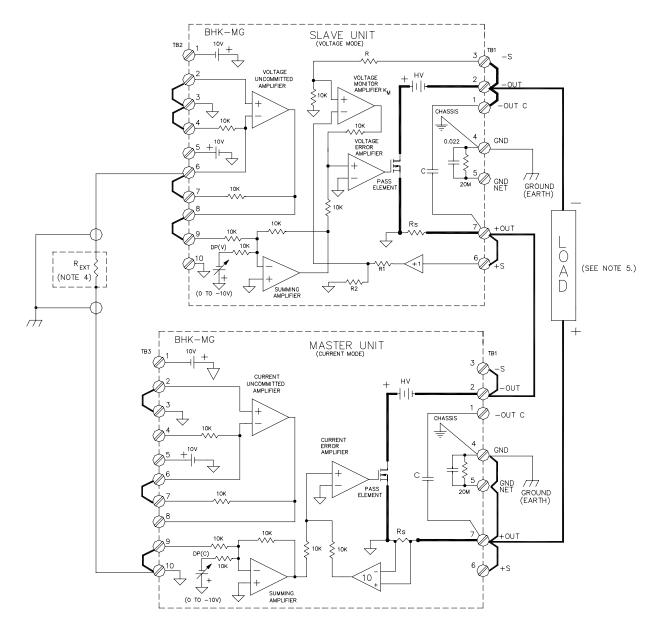
5) Eo = Eo_M + Eo_M $\frac{\text{Eomax}_S}{\text{Eomax}_M}$ 3042586

FIGURE 3-20. SERIES MASTER-SLAVE (VOLTAGE MODE) CONFIGURATION

3-53 BHK-1/2-MG 110504

3.9.2.2.2 CURRENT MODE OPERATION

When the series combination is operating in current mode (see Figure 3-21), the master is in current mode and receives current programming commands while output voltage is determined by the current through the load; the slave is in voltage mode and tracks the master output voltage.



NOTES:

5) $lo = lo_M$

- 1) THE SERIES COMBINATION IS SHOWN IN FAST MODE, OPERATING IN CURRENT MODE WITH '+OUTPUT" TERMINAL GROUNDED.
- 2) CONTROL OF THE MASTER UNIT IS DONE BY DIGITAL PROGRAMMING (DP (V)), EITHER LOCAL OR REMOTE; ANALOG PROGRAMMING CAN ALSO BE USED.
- 3) CONTROL OF THE SLAVE UNIT CAN BE DONE ONLY BY ANALOG PROGRAMMING (DP (V) = 0V), AS SHOWN.
- 4) R_{EXT} (K-ohms) = $Eomax_M$ (Volts)

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FIGURE 3-21. SERIES MASTER-SLAVE (CURRENT MODE) CONFIGURATION

3-54 BHK-1/2-MG 110504 The output current of the series combination operating in current mode is determined by the output current of the master:

 $Io = Io_M$, where Io_M is the output current of the master, in mA.

The load voltage is Eo = $lo_M \times R_{LOAD}$ where Eo is the output voltage of the series combination.

The split of voltage between the master and slave is the same as for voltage mode (see eq1 above); when R_{EXT} (in K-ohms) = $Eomax_S$ (in Volts), the slave and master output voltage are the same: $Eo_S = Eo_M = Eo / 2$.

RECOMMENDED PROCEDURE. The following steps are recommended to ensure the combination of power supplies (power assembly) configured for master-slave series (tracking) operation is connected and set up properly for current mode operation.

- 1. With the units turned off, perform all external wiring (see Figure 3-21). Use $R_{\text{EXT}} = \text{Eomax}_{\text{M}}$ (see PAR. 3.9.2.2.1) If possible, use a properly rated switch between the power supply and the load.
- 2. Apply power to the units:
 - a. If a load switch is used, close the switch. Set POWER switch of both units to up position to turn power on.
 - b. If load switch is not used, Set POWER switch of both units to up position to turn power on, then press OUTPUT ON/OFF key once on each unit to disable the output.
- 3. Program slave unit as follows:
 - a. Program $lset_S$ to approximately 1.01 to 1.02 x nominal output current lo for power assembly. This maximum current limit is never used except in the unlikely event that the current limit of master unit is not working.
 - b. Program Vset_S to 0.
 - c. Program overcurrent value of slave unit (locset_S) to 1.1 x lset_S (step 3a).
 - d. Program overvoltage value of slave unit (Vovset_S) to $\frac{(1.1)(E_{LIM})(Eomax_S)}{Eomax_M + Eomax_S}$
 - E_{LIM} is the voltage limit of the power assembly.
 - Eomax_M is the nominal maximum voltage of the master unit (e.g. for BHK 1000-0.2MG = 1000 volts).
 - Eomax_S is the nominal maximum voltage of the slave unit.
- 4. Program master unit as follows:
 - a. Program $lset_M$ to the desired output current, l_O of the power assembly.
 - b. Program $Vset_M$ to $\frac{(E_{LIM})(EomaxM)}{(EomaxM + EomaxS)}$.
 - c. Program overcurrent value of master unit (locset_M) to 1.1 x lset_M (step 4a).

- d. Program overvoltage value of master unit (Vovset_M) to 1.1 x Vset_M (step 4b).
- 5. To apply power to the load:
 - a. If load switch used, open the switch.
 - If load switch not used, press POWER ON/OFF key once on slave unit, then once on master unit.
- 6. To disable power to the load:
 - a. If load switch used, close the switch.
 - b. If load switch not used, press POWER ON/OFF key once on master unit, then once on slave unit.
 - c. Alternative: Turn both units off by setting POWER switch to off (down) position, first on master unit, then on slave unit.

3.9.3 PARALLEL OPERATION

Kepco BHK-MG power supplies can be parallel-connected for increased output current, if the precautions outlined below are followed. Two basic parallel-connection methods are generally used: automatic (PAR. 3.9.2.1) and master-slave (PAR. 3.9.2.2).:



HANDLING HIGH VOLTAGE, LOW IMPEDANCE EQUIPMENT IS DANGEROUS, AND POTENTIALLY LETHAL. OBSERVE ALL PRECAUTIONS LISTED IN PAR. 3.8.1., AS WELL AS THE PRECAUTIONS LISTED BELOW.

- a. Connect the chassis ground terminal, TB1-4, of all parallel-connected power supplies to a good a-c ground (earth ground).
- b. If necessary, the grounding network can be used for each one of the parallel-connected power supplies (refer to PAR. 2.7.5.3 for additional information regarding use of the grounding network).
- c. The parallel combination of BHK-MG power supplies can operate either isolated from ground (floating) or with either of the two output terminals of the parallel combination grounded. When analog programming is used, however, it is recommended that the positive output terminal of the parallel combination be grounded to avoid potentially hazardous conditions requiring the use of fully insulated external equipment (see precautions of PAR. 3.8.1).

If the negative output terminal is grounded, special precautions are required when using external programming sources: THE PROGRAMMING SOURCE MUST BE ISOLATED AND INSULATED for the maximum output voltage of the parallel combination. The programming source must be either battery powered or powered through an isolation transformer

3-56 BHK-1/2-MG 110504

and have "fully insulated controls and chassis" features (see also PAR's. 3.8.2 through 3.8.5).

NOTE: The simplified schematic diagrams (Figures 3-22 through 3-24), illustrating the associated interconnections, show the power supplies configured in either slow mode for units operating in voltage mode, or fast mode for units operating in current mode, however other combinations are also possible. Due to the low current involved, the units are shown using local sensing since the drop across the power leads is usually negligible compared to the output voltage. However, when very precise control of output voltage applied to the load is desired, remote sensing should be used. Contact Kepco Applications Engineering when special configurations are indicated.

3.9.3.1 AUTOMATIC PARALLEL OPERATION

This operating configuration (see Figure 3-22) is characterized by the fact that each power supply is independent and must be controlled (programmed) individually, either remotely—via either the GPIB bus or by analog means—or locally via the keypad. Practical considerations suggest that identical units be configured to operate in voltage mode - current limit, controlled from the local keypad.

For most cases, when the output current is less than the maximum current of a single supply, only the supply with the highest actual output voltage will control the output; the other supply will be inactive. When the current limit of the working unit is reached, it will go from voltage mode to current mode and the other unit will begin to operate in voltage mode, controlling the output voltage and delivering the difference in current between what the load demands and the current limit of the first unit. This is especially true when the power supplies are working with remote sensing and there is a minimum difference (one least significant bit:1 LSB) between the actual output voltages of the two power supplies.

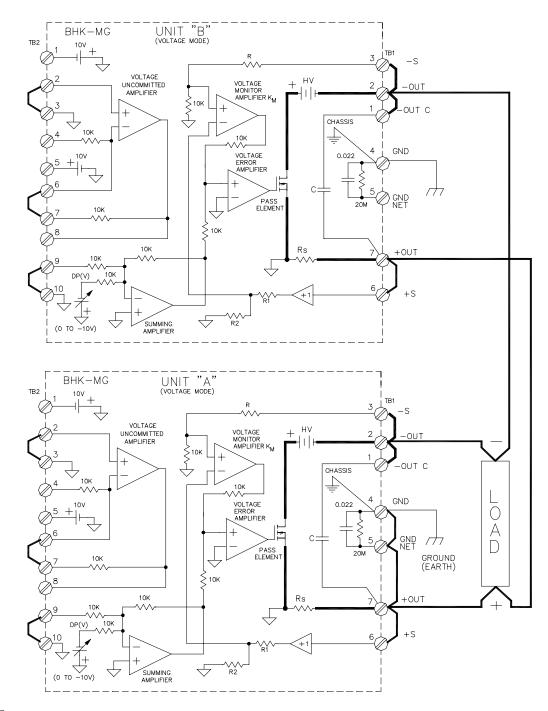
When using local sensing, it is possible for both power supplies to deliver current to the load at the same time. This will occur if the power supplies are delivering precisely the same output voltage, and the lead losses are balanced. It can also occur if the power supplies deliver nearly the same voltage, but the lead losses compensate to make the output voltages identical.

The maximum current that can be delivered by the parallel combination is the sum of the maximum output current for each individual power supply.

RECOMMENDED PROCEDURE. The following steps are recommended to ensure the combination of power supplies (power assembly) is connected and set up properly for automatic parallel operation. Identical models are recommended for parallel operation.

- 1. With the units turned off, perform all external wiring (see Figure 3-22). If possible, use a properly rated switch between the power supply and the load.
- 2. Apply power to the units:
 - a. If a load switch is used, open the switch. Set POWER switch of both units to up position to turn power on.
 - b. If load switch is not used, Set POWER switch of both units to up position to turn power on, then press OUTPUT ON/OFF key once on each unit to disable the output.
- 3. Program Unit A as follows:
 - a. Program IsetA to 1/2 the expected load current: I_{I OAD}/2.

b. Program VsetA to: $E_0 + \frac{EomaxA}{2500}$ where:



NOTES:

- 1) THE SERIES COMBINATION IS SHOWN USING LOCAL SENSING, SLOW MODE, OPERATING IN VOLTAGE MODE WITH "+OUTPUT" TERMINAL GROUNDED.
- 2) UNITS "A" AND "B" ARE CONTROLLED INDEPENDENTLY, USING DIGITAL PROGRAMMING (DP(V)), EITHER LOCAL OR REMOTE; ANALOG PROGRAMMING CAN ALSO BE USED.
- 3) OUTPUT VOLTAGE OF UNITS "A" AND "B" MUST BE SET TO THE SAME VALUE.

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FIGURE 3-22. PARALLEL AUTOMATIC CONFIGURATION

3-58 BHK-1/2-MG 110504

- · Eo is the output voltage of the power assembly.
- EomaxA is the rated maximum output voltage for unit A (e.g. 500 for the BHK 500-80MG).
- c. Program overcurrent value of unit A (locsetA) to 1.1 x lsetA (see step 3a).
- d. Program overvoltage value of unit A (VovsetA) to 1.1 x Eo.

4. Program unit B as follows:

- a. Program IsetB to the rated maximum current of unit B (IomaxB), e.g., 80 (mA) for BHK 500-80MG.
- b. Program VsetB to Eo.
- c. Program overcurrent value of unit B (locsetB) to 1.1 x the rated maximum current for unit B (lomaxB), e.g., 1.1 x 80 = 88 mA for BHK 500-80MG.
- d. Program overvoltage value of unit B (VovsetB) to 1.1 x Eo.

5. To apply power to the load:

- a. If load switch used, close the switch.
- b. If load switch not used, press POWER ON/OFF key once on unit A, then once on unit B.

6. To disable power to the load:

- a. If load switch used, open the switch.
- b. If load switch not used, press POWER ON/OFF key once: first on unit B, then on unit A.
- c. Alternative: Turn both units off by setting POWER switch to off (down) position, first on unit B, then on unit A.

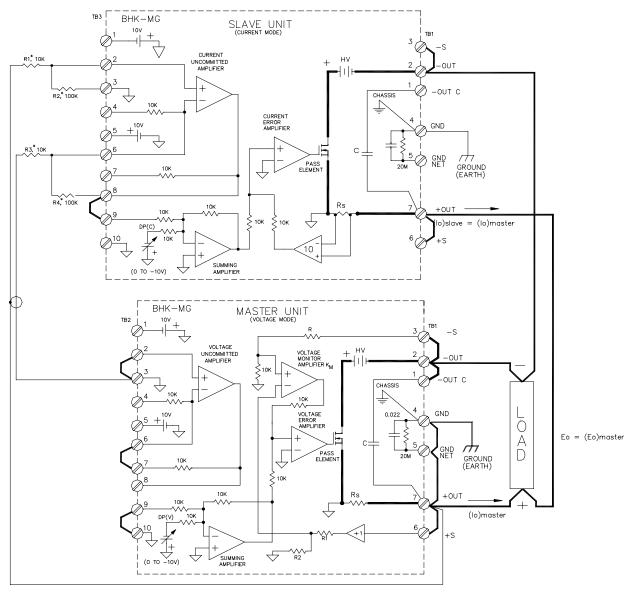
3.9.3.2 MASTER-SLAVE PARALLEL OPERATION

This configuration is characterized by the fact that only the master power supply is programmed (controlled), while the slave power supply stays in current mode, providing the same output current as the master.

A master-slave parallel combination with a single slave is shown in Figure 3-23 configured to operate in voltage mode, and in Figure 3-24 to operate in current mode. The master can be controlled either remotely—via either the GPIB bus or by analog means—or locally via the keypad. The slave can only be programmed by analog programming using four external resistors connected to the uncommitted amplifier in a differential configuration which amplifies the voltage across the master sensing resistor by a factor of ten.

3.9.3.2.1 VOLTAGE MODE OPERATION

When the parallel combination is configured to operate in voltage mode (see Figure 3-23), the master operates in voltage mode, receiving voltage programming commands, and the slave tracks the output current of the master.



NOTES:

- 1) THE PARALLEL COMBINATION IS SHOWN USING LOCAL SENSING, IN SLOW MODE, OPERATING IN VOLTAGE MODE WITH "+OUTPUT" TERMINAL GROUNDED.
- 2) CONTROL OF THE MASTER UNIT IS DONE BY DIGITAL PROGRAMMING (DP(V)), EITHER LOCAL OR REMOTE;
- ANALOG PROGRAMMING CAN ALSO BE USED.

 3) CONTROL OF THE SLAVE UNIT CAN BE DONE ONLY BY ANALOG PROGRAMMING (DP (C) = OV), AS SHOWN.
- $*\frac{R2}{R1} = \frac{R}{R}$

FIGURE 3-23. PARALLEL MASTER-SLAVE (VOLTAGE MODE) CONFIGURATION

The output voltage of the parallel combination in voltage mode is given by the equation,

3-60 BHK-1/2-MG 110504

Eo = Eo_M where Eo_M is the output voltage of the master unit, in Volts.

The load current is given by the equation,

$$Io = Eo / R_{IOAD}$$
.

The individual currents of the master and slave supplies are,

$$lo_{M} = lo_{S} = lo / 2$$
.

RECOMMENDED PROCEDURE. The following steps are recommended to ensure the combination of power supplies (power assembly) configured for parallel master-slave operation is connected and set up properly for voltage mode operation.

- 1. With the units turned off, perform all external wiring (see Figure 3-23). If possible, use a properly rated switch between the power supply and the load. Identical models are recommended for parallel operation.
- 2. Apply power to the units:
 - a. If a load switch is used, open the switch. Set POWER switch of both units to up position to turn power on.
 - b. If load switch is not used, Set POWER switch of both units to up position to turn power on, then press OUTPUT ON/OFF key once on each unit to disable the output.
- 3. Program slave unit as follows:
 - a. Program output current of slave unit (Iset_S) to 0.
 - b. Program $Vset_S$ to the rated maximum voltage of the slave unit (e.g., for BHK1000-40MG set $Vset_S$ = 1000).
 - c. Program overcurrent value of slave unit (locset_S) to 1.1 x rated maximum current of slave unit (e.g., for BHK 1000-40MG, program locset_S = 44 (mA)).
 - d. Program overvoltage value of slave unit ($Vovset_S$) to 1.1 x output voltage of power assembly (Eo).
- 4. Program master unit as follows:
 - a. Program $lset_M$ to 1/2 the desired current limit, l_{LIM} of the power assembly.
 - b. Program Vset_M to the output voltage of the power assembly, Eo.
 - c. Program overcurrent value of master unit (locset_M) to 1.1 x lset_M (step 4a).
 - d. Program overvoltage value of master unit (Vovset_M) to 1.1 x Vset_M (step 4b).
- 5. To apply power to the load:
 - a. If load switch used, close the switch.

- b. If load switch not used, press POWER ON/OFF key once on slave unit, then once on master unit.
- 6. To disable power to the load:
 - a. If load switch used, open the switch.
 - b. If load switch not used, press POWER ON/OFF key once on master unit, then once on slave unit.
 - c. Alternative: Turn both units off by setting POWER switch to off (down) position, first on master unit, then on slave unit.

3.9.3.2.2 CURRENT MODE OPERATION

When the parallel combination is configured to operate in current mode (see Figure 3-24), the master is in current mode, receiving current programming commands, and the slave tracks the output current of the master.

The output current of the assembly in current mode is given by the equation,

 $Io = 2 \times Io_M$, where Io_M is the output current of the master, in mA.

The load voltage is given by

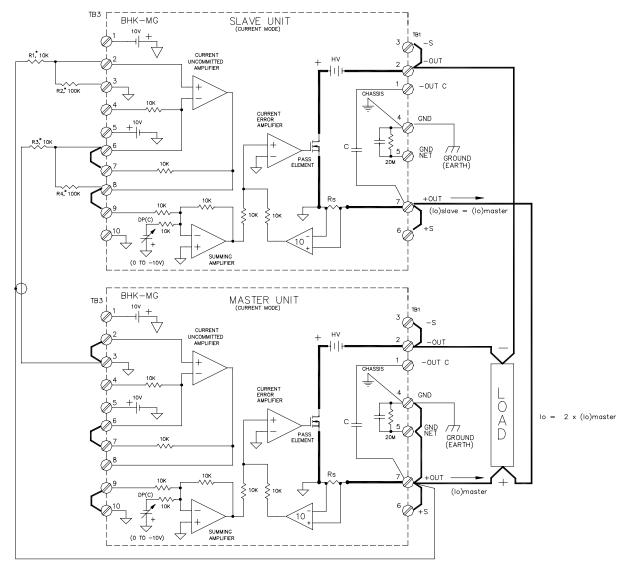
Eo =
$$2 \times Io_M \times R_{IOAD}$$
.

- NOTES: 1. The uncommitted amplifier of the slave unit uses 0.0091 mA (maximum) of the output current, reducing the accuracy of the generated current. This can be avoided by using the uncommitted amplifier of the master unit, configured as a non-inverting repeater, between the signal coming from the master sensing resistor signal (terminal 2) and the input to R1 shown in Figure 3-24.
 - 2. The current of the slave unit will be slightly larger than the current of the master unit (approximately 1% for BHK 500-80MG) due to the voltage drop on the wire connecting the internal sensing resistor to the externally accessible terminal TB1-7 (see Figure 3-24).

RECOMMENDED PROCEDURE. The following steps are recommended to ensure the combination of power supplies (power assembly) configured for parallel master-slave operation is connected and set up properly for current mode operation. Identical models are recommended for parallel operation.

- 1. With the units turned off, perform all external wiring (see Figure 3-24). If possible, use a properly rated switch between the power supply and the load.
- 2. Apply power to the units:
 - a. If a load switch is used, close the switch. Set POWER switch of both units to up position to turn power on.
 - b. If load switch is not used, Set POWER switch of both units to up position to turn power on, then press OUTPUT ON/OFF key once on each unit to disable the output.

3-62 BHK-1/2-MG 110504



- 1) THE PARALLEL COMBINATION IS SHOWN USING LOCAL SENSING, IN FAST MODE, OPERATING IN CURRENT MODE WITH "+OUTPUT" TERMINAL GROUNDED.

 2) CONTROL OF THE MASTER UNIT IS DONE BY DIGITAL PROGRAMMING (DP(C)), EITHER LOCAL OR REMOTE; ANALOG PROGRAMMING CAN ALSO BE USED.
- 3) CONTROL OF THE SLAVE UNIT CAN BE DONE ONLY BY ANALOG PROGRAMMING (DP (C) = 0V), AS SHOWN.

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 $* \frac{R2}{R1} = \frac{R4}{R3}$

FIGURE 3-24. PARALLEL MASTER-SLAVE (CURRENT MODE) CONFIGURATION

3-63 BHK-1/2-MG 110504

3. Program slave unit as follows:

- a. Program output current of slave unit (Iset_S) to 0.
- b. Program $Vset_S$ to the rated maximum voltage of the slave unit, Eomax_S (e.g., for BHK1000-40MG set $Vset_S = 1000$).
- c. Program overcurrent value of slave unit (locset_S) to 1.1 x rated maximum current of slave unit, lomax_S (e.g., for BHK 1000-40MG, program locset_S = 44 (mA)).
- d. Program overvoltage value of slave unit (Vovset_S) to 1.1 x voltage limit E_{LIM} desired for power assembly.

4. Program master unit as follows:

- a. Program Iset_M to 1/2 the desired output current, Io, of the power assembly.
- b. $Program Vset_M$ to the voltage limit, E_{LIM} desired for power assembly.
- c. Program overcurrent value of master unit (locset_M) to 1.1 x lset_M (step 4a).
- d. Program overvoltage value of master unit (Vovset_M) to 1.1 x Vset_M (step 4b).

5. To apply power to the load:

- a. If load switch used, open the switch.
- b. If load switch not used, press POWER ON/OFF key once on slave unit, then once on master unit.

6. To disable power to the load:

- a. If load switch used, close the switch.
- b. If load switch not used, press POWER ON/OFF key once on master unit, then once on slave unit.
- c. Alternative: Turn both units off by setting POWER switch to off (down) position, first on master unit, then on slave unit.

3-64 BHK-1/2-MG 110504

SECTION 4 - CALIBRATION

4.1 GENERAL

This section contains the calibration instructions for the Power Supply. It is recommended that the user be familiar with Local Mode operation (PAR.3.2) before calibrating the unit.

A full calibration consists of a voltage calibration and a current calibration. Voltage calibration consists of a zero and a full scale calibration, current calibration consists of a zero, full scale and 10% of full scale calibration. (Refer to PAR. 4.3 for more information.)

There are three ways to perform the calibration: 1) locally using the front panel keys (PAR. 4.4), 2) remotely sending commands through the GPIB bus, or 3) remotely using the graphical interface supplied with the instrument driver available at www.kepcopower.com/drivers.htm (PAR. 4.5). This VISA compliant driver works with many GPIB cards from suppliers like National Instruments and Hewlett-Packard. These three calibration methods cannot be combined.

In order to enter the calibration mode the correct calibration access code (password) must be entered. If the password has been forgotten, call the factory. During the calibration, new calibration data is computed which is then stored in the nonvolatile memory.

4.2 EQUIPMENT REQUIRED

The following equipment is required to calibrate the BHK-MG 40W Power Supply.

- Digital Voltmeter (DVM) with 6 digits resolution an at least 0.002% accuracy for d-c measurements.
- Precision Shunt Resistor (with a tolerance of 0.01%, power rating of at least 10 times larger than the maximum stress, and a temperature coefficient equal to or better than 20 ppm per degree C). During the calibration procedure the LCD displays the minimum requirements for the shunt resistor. However, to avoid problems due to drift caused by heat dissipation, Kepco recommends the following:

BHK 300-130MG: 7.69 Ohms, 0.01%, 25W
 BHK 500-80MG: 12.5 Ohm, 0.01%, 10W
 BHK 1000-40MG: 25 Ohm, 0.01%, 10W
 BHK 2000-20MG: 50 Ohm, 0.01%, 5W

NOTE:

- Because the voltage measured will be used as reference for calibration, the DVM used must be accurately calibrated prior to calibrating the BHK-MG 40W Power Supply.
- Proper cooling of the external precision shunt resistor ensures the accuracy of the calibration.

4.3 CALIBRATION DESCRIPTION

During voltage calibration, the voltage, overvoltage and voltage readback are calibrated and during current calibration the current, overcurrent and current readback are calibrated. The normal procedure is to calibrate voltage first and then current. However, you do not have to do a complete calibration each time. If required, you may calibrate only the voltage or the current and

then proceed to saving the calibration results. For either voltage or current calibration, BOTH zero AND full scale calibrations must be performed.

For both current and voltage calibration all loads must be disconnected from the power supply output; the sense terminals must be connected to the corresponding output terminals. For voltage calibration the digital voltmeter will be connected to the output of the power supply. For current calibration after disconnecting all loads an appropriate shunt resistor will be connected across output terminals and the digital voltmeter will be connected across the sense terminals of the shunt resistor.

4.4 CALIBRATION USING FRONT PANEL KEYS

NOTES: Keys with dual functions are labeled with both a command and a number. The command label is referred to when the unit is in (:_:_:) command entry status; the number is referred to when the unit is in (= = =) data entry status.

- 1. With the power supply in command entry status (:_:_:), press **CALIB** key. Power supply enters Calibration mode and data entry status (=_=_=) waiting for the password to be entered.
- Enter password (4 digits) and press ENTER. If password is incorrect, **wrong PASS-WORD** flashes, then LCD returns to command status. See PAR. 4.6 to change the password. (Press RESET or CLEAR to exit calibration without changing password.)
- 3. If password is correct, LCD reads **VOLTAGE CALIB**. Enter **1** for voltage calibration (see PAR. 4.4.1), enter **0** to proceed to current calibration. (Press **RESET** or **CLEAR** to exit without saving calibration values.)
- 4. LCD reads CURRENT CAL. Enter 1 for current calibration (see PAR. 4.4.2), enter 0 to proceed to next step. (Press RESET or CLEAR to exit calibration without saving values.)
- 5. Disconnect the external shunt when instructed by the message displayed on the LCD.
- 6. LDS reads **DATE:** --/---. Enter date in MM/DD/YYYY format where MM = month, DD = day, YYYY = year.
- 7. Press **ENTER** to save calibration values.

4.4.1 VOLTAGE CALIBRATION

CAUTION: Power supply output must be disconnected from any load and isolated from ground before proceeding.

- 1. With LCD reading VOLTAGE CALIB. Connect DVM., connect DVM (+) input to output (+) terminal and DVM (-) input to output (-) terminal of power supply. then press ENTER.
- 2. With LCD reading Vout ZERO adj., monitor DVM and use → or ← keys to increase or decrease output voltage as necessary to get DVM reading the minimum *positive* value. Press ENTER when complete.
- 3. LCD will flash Vout F.s.adj. **WAIT** then Vout F.s. adj < >. Monitor DVM and use → or ← keys for fine adjustment and 3 or 1 keys for coarse adjustment to increase or decrease output voltage as necessary to get DVM reading as close as possible to full scale

4-2 BHK-MG 110504

value. E.g., for BHK 500-80MG, adjust for DVM reading as close to +500.00V as possible. Press **ENTER** when complete and proceed to PAR. 4.3, step 4.

NOTE: The message Can't Adj. Full scale is displayed if either a load less than nominal or a shunt resistor is connected to the output terminals during voltage calibration. If this occurs, it is necessary to press ENTER followed by RESET to restore proper operation. Disconnect load or shunt and refer to PAR. 4.4, step 1 to restart calibration.

4.4.2 CURRENT CALIBRATION

- LCD reads CONNECT SHUNT <nn OHM >zz A (nn and zz values are determined by BHK-MG model being calibrated.; e.g., for BHK 500-80MG, LCD reads <10 OHM >2 A). (Refer to PAR. 4.2 for shunt requirements.) Connect Precision Shunt across output terminals and press ENTER.
- 2. LCD reads CONNECT DVM TO SHUNT. Connect DVM (+) input to sense terminal of shunt connected to output (+), DVM (-) to sense terminal of shunt connected to output (-). Press ENTER when connections are complete.
- 3. With LCD reading I ZERO adj., monitor DVM and use → or ← keys to increase or decrease output current as necessary for minimum *positive* DVM reading. Press ENTER when complete.
- 4. LCD will flash I F.S.adj. **WAIT** then I F.S. adj < >. Monitor DVM and use → or ← keys for fine adjustment and 3 or 1 keys for coarse adjustment to increase or decrease output voltage as necessary to get V_{DVM} reading as close as possible to value listed below. Press ENTER when complete.

$$V_{DVM} = Rs \times Io_{MAX} (mV)$$

where

Io_{MAX} (mA) is the maximum value of output current:

BHK 300-130MG: 130mA BHK 500-80MG: 80mA BHK 1000-40MG: 40mA BHK 2000-20MG: 20mA

Rs (Ohms) is the actual value of the external shunt resistor.

NOTE: The message Can't Adj. Full Scale is displayed if either the shunt resistor is not connected to the output terminals during current calibration or if the shunt resistance is too high. If this occurs, it is necessary to press ENTER followed by RESET to restore proper operation. Refer to PAR. 4.3, step 1 to restart calibration.

5. LCD will show Current C10X adj. Value = -.--mA. Monitor DVM and convert V_{DVM} to mA as follows, then note the value of C10X (milliAmps).

$$Io_{C10X}$$
 (mA) = V_{DVM} (mV)/Rs

where

lo_{C10X} (milliAmps) is the enhanced value of output current in the first 10% of the range.

Rs (Ohms) is the actual value of the external shunt resistor (the same shunt resistor can be used for Low scale, High scale and C10X current calibration).

6. Use the keypad to enter the value of lo_{C10X} (milliAmps) noted in step 5 and press ENTER. If the value is out of range, (more than 10% of output current nominal value), the message displays 10% of the maximum output current for that model, e.g. Imax=8.0000mA for BHK 500-80MG. Press CLEAR twice to return to step 5.

4.5 CALIBRATION USING VISA DRIVER

Refer to the installation instructions supplied with the VISA driver (download from Kepco's web site at www.kepcopower.com/drivers.htm) to install the "soft panel" demonstration program. The program guides you through each step of the calibration process.

NOTE: The left and right single arrow buttons on the VISA panel are equivalent to the front panel left and right arrow keys. The left double arrow button on the VISA panel is equivalent to the 1 key on the front panel keypad; the right double arrow button is equivalent to the 3 key.

4.6 CHANGING THE CALIBRATION PASSWORD

The 4-digit password is required to enter calibration mode. The factory default passwords are listed in Table 4-1.

MODEL	PASSWORD
BHK 300-0.13MG	0300
BHK 500-0.08MG	0500
BHK 1000-0.04MG	1000
BHK 2000-0.02MG	2000

TABLE 4-1. FACTORY DEFAULT CALIBRATION PASSWORDS

- 1. With the power supply in command entry status (:_:_:), press **MENU** key until LCD reads Change Passw. OldPass(=_=_=).
- 2. Enter the old password and press **ENTER**. (To exit without changing the password, press **CLEAR**.) Then enter the new 4-digit Password and press **ENTER** The password must have four digits; the default passwords are listed in Table 4-1.
- The new password is accepted and the LCD shows the next MENU screen GoTo Previous CALIB? 1(=_=_)Yes.
- 4. Press **CLEAR** to exit the Menu, press **1** to restore the previous calibration values (see PAR. 4.9), or **MENU** for additional menu screens.

4.7 RESTORING PREVIOUS CALIBRATION VALUES

Each time the unit is calibrated, the previous calibration values are retained in non-volatile memory. If it is determined that a new calibration is erroneous, the previous calibration values can be restored.

- 1. If the unit is not in command entry status :, press **CLEAR** or **RESET** to put the unit in command entry status.
- 2. Press MENU until LCD reads Goto Previous CALIB? 1=.

4-4 BHK-MG 110504

- 3. Press 1, then ENTER. LCD reads Calibration ! PassWord=.
- 4. Enter 4-digit password and press **ENTER**. Previous calibration values are restored.

4.8 RESTORING FACTORY CALIBRATION VALUES

The original factory calibration values can be restored.

- 1. If the unit is not in command entry status :, press CLEAR or RESET to put the unit in command entry status.
- 2. Press **MENU** until LCD reads **Goto Factory CALIB?** 1 =.
- 3. Press 1, then ENTER. LCD reads Calibration ! PassWord=.
- 4. Enter 4-digit password and press ENTER. Factory calibration values are restored.

4.9 CALIBRATION STORAGE

After a unit has been repaired, is operating correctly, and has been calibrated, the new calibration values should be saved. This can only be accomplished via the GPIB interface. The unit maintains the calibration tables in Flash Memory. There are three calibration areas maintained in Flash Memory: Working, Previous and Factory.

In order to store the calibration the calibration password must be enabled, and the calibration must first be dumped (a dump provides an ASCII copy of the calibration for the user) using the CAL:DMP (source) command, where (source) = FACTory, WORKing or PRIor. After the calibration is dumped, it can be copied to another area using the CAL:COPY command. The syntax is as follows: CAL:COPY (source) (destination) where (source) and (destination) refer to the areas of Flash memory where calibration data is stored, designated as: WORKing, PRIor, FACTory.

The Factory calibration should never be overwritten. The Working calibration is the active calibration. Each time a CAL:SAV is executed, the values are saved in the Working (active) area. At the same time, the values previously stored in Working are moved to Previous, and the values previously stored in Previous are no longer available. Table 4-2 illustrates calibration storage and the use of the CAL:SAV command.

TABLE 4-2. CALIBRATION STORAGE

COMMAND	WORKing	PREvious	FACTory
1. CAL:SAVE	Cal 1 values		factory cal.
2. CAL:SAVE	Cal 2 values	Cal 1 values	No Change
3. CAL:SAVE	Cal 3 values	Cal 2 values	No Change
4. CAL:SAVE	Cal 4 values	Cal 3 values	No Change

внк-мg 110504 4-5/(4-6 Blank)

APPENDIX A - IEEE 488.2 COMMAND/QUERY DEFINITIONS

A.1 INTRODUCTION

This appendix defines the IEEE 488.2 commands and queries used with the BHK-MG 40W Power Supply These commands and queries are preceded by an asterisk (*) and are defined and explained in Figures A-1 through A-14, arranged in alphabetical order. Table A-1 provides a guick reference of all IEEE 488.2 commands and queries supported in the BHK-MG 40W Power Supply.

TABLE A-1. IEEE 488.2 COMMAND/QUERY INDEX

COMMAND	PAR.	COMMAND	PAR.
*CLS	A.2	*RST	A.10
*ESE, ?	A.3, A.4	*SAV	A.11
*ESR?	A.5	*SRE, ?	A.12, A.13
*IDN?	A.6	*STB?	A.14
*OPC, ?	A.7, A.8	*TRG	A.15
*RCL	A.9	*TST?	A.16

*CLS — CLEAR STATUS COMMAND A.2

Syntax: *CLS

Description: Clears status data. Clears the following registers without affecting the corresponding Enable Regis-

ters: Standard Event Status Register (ESR), Operation Status Event Register, Questionable Status Event Register, and Status Byte Register (STB). Also clears the Error Queue. Related commands:

*OPC, *OPC?. (See example, Figure A-1.)

A.3 *ESE — STANDARD EVENT STATUS ENABLE COMMAND

*ESE

*ESE <integer> where <integer> = positive whole number: 0 to 255 per Table A-2. Syntax:

Default Value: 0

Description: This command programs the standard Event Status Enable register bits. The contents function as a mask to determine which events of the Event Status Register (ESR) are allowed to set the ESB (Event Summary Bit) of the Status Byte Register. Enables the Standard events to be summarized in the Status Byte register (1 = set = enable function, 0 = reset = disable function). All of the enabled events of the standard Event Status Enable register are logically ORed to cause ESB (bit 5) of the Status Byte Register to be set (1 = set = enable, 0 = reset = disable). (See example, Figure A-1.)

TABLE A-2. STANDARD EVENT STATUS ENABLE REGISTER AND STANDARD EVENT STATUS REGISTER BITS PON NU

CONDITION	PON	NU	CME	EXE	DDE	QUE	NU	OPC
BIT	7	6	5	4	3	2	1	0
VALUE	128	64	32	16	8	4	2	1

Power On (Not Used) Command Error **Execution Error** Device Dependent

Query Error

CME

EXE

DDE Error

*ESE? — STANDARD EVENT STATUS ENABLE QUERY **A.4**

Syntax: *ESE? Return value: Integer> value per Table A-2.

Description: Returns the mask stored in the Standard Event Status Enable Register. Contents of Standard Event Status Enable register (*ESE) determine which bits of Standard Event Status register (*ESR)

A-1 BHK-MG 110504

are enabled, allowing them to be summarized in the Status Byte register (*STB). All of the enabled events of the Standard Event Status Enable Register are logically ORed to cause ESB (bit 5) of the Status Byte Register to be set (1 = set = enable function, 0 = reset = disable function). (See example, Figure A-1.)

A.5 *ESR? — EVENT STATUS REGISTER QUERY

*ESR?

Syntax: *ESR?

Return value: <integer> (Value = contents of Event Status register as defined in Table A-2.)

Description: Reads the Standard Event Status register, clearing the register at the same time. The Standard

Event Status register bit configuration is defined in Table A-2(1 = set, 0 = reset). The error bits listed in Table A-2 are also related to error codes produced during parsing of messages and to errors in the power supply (see PAR. B.81). Related Commands: *CLS, *ESE, *OPC. (See example, Figure A-1.)

A.6 *IDN? — IDENTIFICATION QUERY

*IDN?

Syntax: *IDN?

Return value: Character string

Description: **Identifies the instrument.** This query requests identification. The power supply returns a string which contains the manufacturer name, the model, the serial number and the firmware level. The

which contains the manufacturer name, the model, the serial number and the firmware level. The character string contains the following fields: <Manufacturer>, <Model>-<Voltage>-<Current> <Calibration Date>,<Serial number>,<Firmware revision> where: <Manufacturer> = KEPCO, <Model> = BHK, <Voltage> is Eo_{MAX}, <Current> is Io_{MAX}) <Calibration Date> is 12 characters entered during calibration (recommended is month, day year: MM-DD-YYYY), <Serial number> E123456 is typical, <Firmware revision>=Vn.m (n.m revision, e.g. 7.0) (See example, Figure A-1.)

A.7 *OPC — OPERATION COMPLETE COMMAND

*OPC

Syntax: *OPC

Description: Causes power supply to set status bit 0 (Operation Complete) when pending operations are

complete This command sets Standard Event Status Register bit 0 (see Table A-2) to "1" when all previous commands have been executed and changes in output level have been completed. This command does not prevent processing of subsequent commands, but bit 0 will not be set until all pending operations are completed. (1 = set = enable function, 0 = reset = disable function). (See example, Figure A-1.) As an example, the controller sends command(s), then sends *OPC. If controller then sends *ESR?, the power supply responds with either a "0" (if the power supply is busy executing the programmed commands), or a "1" (if the previously programmed commands are complete). (See example, Figure A-1.)

A.8 *OPC? — OPERATION COMPLETE QUERY

*OPC?

Syntax: *OPC?

Return value: <1> (ASCII) placed in output queue when power supply has completed operation.

Description: Indicates when pending operations have been completed. When all pending operations are com-

plete (all previous commands have been executed and changes in output level have been completed) a "1" is placed in the Output Queue. Subsequent commands are inhibited until the pending operations are completed. *OPC? is intended to be used at the end of a command line so that the application program can monitor the bus for data until it receives the "1" from the power supply Output Queue. (See

example, Figure A-1.)

A.9 *RCL — RECALL COMMAND

*RCL

Syntax: *RCL <integer> (1 to 40)

Description: Restores power supply to previously defined levels of output voltage, output current, overvolt-

age protection, and overcurrent protection. This command selects one of the 40 power supply memory locations, each of which stores values for output current, output voltage, overvoltage protection, and overcurrent protection. The following parameters are affected by *RCL: CURR[:LEV][:IMM] VOLT[:LEV][:IMM] CURR:PROT[:LEV] VOLT:PROT[:LEV]. (See example, Figure A-1.)

A-2 BHK-MG 110504

*CLS Power supply clears status data.

*ESE 60 Power supply enables bits 5, 4, 3 and 2, allowing command error, execution

error, device dependent error and query error to set the Event Status

Summary bit when an STB command is executed.

*ESE? Returns 60, (value of the mask) verifying that bits 5, 4, 3 and 2 are enabled.

*ES Unknown command will set command error (Bit 5).

*ESR? Returns 32 (bit 5 set), indicating Command Error has occurred since the last

time the register was read.

*IDN? Power supply returns: KEPCO, BHK-1000-.04 04-20-2004,E123456, V7.0.

*OPC Allows status bit 0 to be set when pending operations complete

VOLT 250; CURR 3E-2 Sets output voltage to 250V, output current to 30mA

*SAV 33 The present state of the power supply is stored in memory location 33.

*ESR? Returns 1 (event status register cleared by prior *ESR?)
VOLT 215;CURR 15E-3 Sets output voltage to 215V, output current to 15mA,
OUTP ON Programmed voltage appears at output terminals.

*OPC? Puts "1" on output bus when command operations are complete.

*RCL 33 Values in memory location 33 recalled (250V, 30mA).

*RST Power supply reset to power on default state.

*SRE 40 When ESB or QUES bits are set (Table A-3), the Request for Service

bit will be set.

*SRE? Returns the value of the mask (40).

*STB? For example, the Power supply responds with 96 (64 + 32) if MSS and the

Event Status Byte (Table A-3) summary bit have been set. The power supply

returns 00 if no bits have been set.

VOLT 220 Power supply voltage commanded to 220V.
OUTP ON Programmed voltage appears at output terminals.

VOLT:TRIG 212 Programs power supply voltage to 212V when *TRG received.

INIT Trigger event is initialized.

*TRG Power supply reverts to commanded output voltage of 212V.

*TST? Power supply executes self test and responds with 0 if test completed

successfully, with 1 if test failed.

FIGURE A-1. GPIB COMMANDS

A.10 *RST — RESET COMMAND

*RST

Syntax: *RST

Description: Resets power supply to the power on default state (see PAR. 3.3.2). The power supply is pro-

grammed to the power on values of the following parameters: CURR[:LEV][:IMM] = 0, VOLT[:LEV][:IMM] = 0, CURR:PROT[:LEV] = max overcurrent value (see Table 1-2, VOLT:PROT[:LEV] = (maximum overvoltage value (see Table 1-2), <math>OUTP[:STAT] = ON. (See examination)

ple, Figure A-1.)

A.11 * SAV — SAVE COMMAND

*SAV

Syntax: *SAV <integer> (1 to 40)

Description: Saves the present state of output voltage, output current, overvoltage and overcurrent to the

specified memory location. This command stores the present state of the power supply to one of 40 memory locations. The following parameters are stored by *SAV: CURR[:LEV][:IMM], VOLT[:LEV][:IMM], CURR:PROT[:LEV], VOLT:PROT[:LEV], OUTP[:STAT] and SYST:LANG. The

stored values can be restored by the *RCL command. (See example, Figure A-1.)

A.12 *SRE — SERVICE REQUEST ENABLE COMMAND

*SRE

Syntax: *SRE<integer> where <integer> = value from 0 - 255 per Table A-3, except bit 6 cannot be pro-

grammed.

Description: Sets the condition of the Service Request Enable register. The Service Request Enable regis-

ter determines which events of the Status Byte Register are summed into the MSS (Master Status Summary) and RQS (Request for Service) bits. RQS is the service request bit that is cleared by a serial poll, while MSS is not cleared when read. A "1" (1 = set = enable, 0 = reset = disable) in any Service Request Enable register bit position enables the corresponding Status Byte bit to set the RQS and MSS bits. All the enabled Service Request Enable register bits then are logically ORed to cause Bit 6 of the Status Byte Register (MSS/RQS)

to be set. Related Commands: *SRE?, *STB?. (See example, Figure A-1.)

TABLE A-3. SERVICE REQUEST ENABLE AND STATUS BYTE REGISTER BITS

CONDITION	OPER	MSS RQS	ESB	MAV	QUES	ERR QUE	NU	NU
BIT	7	6	5	4	3	2	1	0
VALUE	128	64	32	16	8	4	2	1

OPER **Operation Status Summary** Master Status Summary MSS Request for Service RQS Event Status Byte summary **FSB** MAV Message available QUEStionable Status Summary **QUES ERR QUE** 1 or more errors occurred (see PAR. B.80) NU (Not Used)

*SRE?

A.13 *SRE? — SERVICE REQUEST ENABLE QUERY

Syntax: *SRE? Response: <integer> = value from 0 - 255 per Table A-3.

Description: **Reads the Service Enable Register.** Used to determine which events of the Status Byte Register are programmed to cause the power supply to generate a service request (1 = set = function enabled, 0 =

reset = function disabled). Related Commands: *SRE, *STB? (See example, Figure A-1.)

A.14 *STB? — STATUS BYTE REGISTER QUERY

*STB?

Syntax: *STB? Response: <integer> value from 0 to 255 per Table A-3.

Description: **Reads Status Byte Register without clearing it.** This Query reads the Status Byte Register (bit 6 = MSS) without clearing it (1 = set = function enabled, 0 = reset = function disabled). The register is cleared only when subsequent action clears all set bits. MSS is set when the power supply has one ore more reasons for requesting service. (A serial poll also reads the Status Byte Register, except that

cleared only when subsequent action clears all set bits. MSS is set when the power supply has one ore more reasons for requesting service. (A serial poll also reads the Status Byte Register, except that bit 6 = RQS, not MSS; and RQS will be reset.) Related Commands: *SRE, *SRE?. (See example, Fig-

ure A-1.)

A.15 *TRG — TRIGGER COMMAND

*TRG

Syntax: *TRG

Description: Triggers the power supply to be commanded to preprogrammed values of output current and

voltage. When the trigger is armed (checked by examining WTG bit in Status Operational Condition register) *TRG generates a trigger signal. The trigger will change the output of the power supply to the output voltage and current levels specified by VOLT:TRIG and CURR:TRIG commands and clear the WTG bit in the Status Operation Condition register. If INIT:CONT has been issued, the trigger subsystem is immediately rearmed for subsequent triggers, and the WTG bit is again set to 1. *TRG or GET are both addressed commands (only devices selected as listeners will execute the command).Related Commands: ABOR, INIT, TRIG, CURR:TRIG, VOLT:TRIG. (See

example, Figure A-1.)

A.16 *TST? — SELF TEST QUERY

*TST?

Syntax: *TST? Returned value: 0 or 1 (0 = pass test, 1 = fail test)

Description: Power Supply test. This query causes the power supply to do a self test and provide the controller

with pass/fail results. A cyclic redundancy check (CRC) is performed on non-volatile RAM. A "1" is

returned if there is an error.

APPENDIX B - SCPI COMMAND/QUERY DEFINITIONS

B.1 INTRODUCTION

This appendix defines the SCPI subsystem commands and queries used with the BHK-MG 40W Power Supply. Subsystem commands are defined in PAR. B.3 through B.93, arranged Alphabetically in groups as they appear in the tree diagram, Figure 3-3. Table B-1 provides a quick reference of all SCPI subsystem commands and queries used in the Interface Card.

TABLE B-1. SCPI SUBSYSTEM COMMAND/QUERY INDEX

COMMAND	PAR.	COMMAND	PAR.
ABORt	B.3	[SOUR:]CURR:LIM[:HIGH], ?	B.48, B.49
CAL:CURR[:DATA]	B.4	[SOUR:]CURR:PROT[:LEV], ?	B.50, B.51
CAL:CURR:LEV	B.5	[SOUR:]VOLT[:LEV][:IMM][:AMP], ?	B.52, B.53
CAL:SAVE	B.6	[SOUR:]VOLT[:LEV]:TRIG[:AMP]?	B.54, B.55
CAL:STAT, ? B.7, B.8		[SOUR:]VOLT:LIM[:HIGH], ?	B.56, B.57
CAL:VOLT[:DATA]	CAL:VOLT[:DATA] B.9		B.58, B.59
CAL:VOLT:LEV	B.10	[SOUR:]FUNC:MODE?	B.60
CAL:ZERO	B.11	STAT:OPER:COND?	B.61
DISP:CONT, ?	B.12, B.13	STAT:OPER:ENAB, ?	B.62, B.63
DISP:MODE, ?	B.14 , B.15	STAT:OPER[:EVENT]?	B.64
DISP:TEXT, ?	B.16, B.17	STAT:PRES	B.65
INIT[:IMM]	B.18	STAT:QUES[:EVENT]?	B.66
INIT:CONT, ?	B.19, B.20	STAT:QUES:COND?	B.67
INST:STAT	B.21	STAT:QUES:ENAB, ?	B.68, B.69
[SOUR:]LIST:CLE	B.22	SYST:COMM:GPIB:ADDR, ?	B.70, B.71
[SOUR:]LIST:COUN, ?	B.23, B.24	SYST:COMM:SER:BAUD, ?	B.72, B.73
[SOUR:]LIST:COUN:SKIP, ?	B.25, B.26	SYST:COMM:SER:ECHO,?	B.74, B.75
[SOUR:]LIST:CURR, ?	B.27, B.28	SYST:COMM:SER:PACE, ?	B.76, B.77
[SOUR:]LIST:CURR:POIN?	B.29	SYST:COMM:SER:PROM, ?	B.78, B.79
[SOUR:]LIST:DIR, ?	B.30, B.31	SYST:ERR?	B.80
[SOUR:]LIST:DWEL, ?	B.32, B.33	SYST:ERR:CODE?	B.81, B.82
[SOUR:]LIST:DWEL:POIN?	B.34	SYST:KLOCK, ?	B.83, B.84
[SOUR:]LIST:QUER, ?	B.35, B.36	SYST:LANG, ?	B.85, B.86
[SOUR:]LIST:VOLT, ?	B.37, B.38	SYST:PASS	B.87, B.88, B.89
[SOUR:]LIST:VOLT:POIN?	B.39	SYST:PASS:STAT	B.90
MEAS:CURR?	B.40	SYST:SEC	B.91
MEAS:VOLT?	B.41	SYST:SEt	B.92
OUTP[:STAT], ?	B.42, B.43	SYST:VERS?	B.93
[SOUR:]CURR[:LEV][:IMM][:AMP], ?	B.44, B.45	TRIG:SOUR	B.94
[SOUR:]CURR[:LEV]:TRIG[:AMP], ?	B.46, B.47		

B.2 NUMERICAL VALUES

The SCPI data parser of the BHK supports a maximum of 8 digits after the decimal point and a maximum integer of 4 x 10⁸. Any values greater than these are not processed by the device and no error is generated. The largest string that can be received or transmitted by the BHK is 253 characters.

All numerical data is returned in scientific notation, digits with decimal point and Exponent, e.g., 2.71E1 for 27.1 after calibration constants have been applied. Thus, for example, VOLT 14; VOLT? may return 1.39997E1 which indicates that the unit has been calibrated to provide 13.9997V for a programmed value of 14V, within the calculation accuracy of the BHK. Error "-120" results from syntactical errors, e.g., the exponent exceeds 8, a letter is identified, etc. Error "-222" is produced if the value exceeds the range of acceptable values for the parameter.

ABOR ABORT COMMAND B.3

Syntax: Short Form: ABOR Long Form: ABORt

Description: Cancels previously stored trigger levels, resets WTG. The ABORt command cancels any pending trigger levels previously stored by the CURR:TRIG or VOLT:TRIG commands. The pending level is set equal to the corresponding immediate value. ABORt also resets the WTG (Wait TriGger) bit in the Operation Condition status register. If INIT:CONT ON has been programmed, the trigger system rearms itself immediately after ABORt, thereby setting WTG. WTG is bit 5 in the STATUS OPERATION CONDITION register. The ABORt is executed each time power is turned on. Related Commands:

INIT, *RST, *TRG. (See example, Figure B-1.)

CALibrate: CURRent[:DATA] COMMAND **B.4**

CAL:CURR

Short Form: CAL:CURR[:DATA] {0 | 1 | 2 | 3} Long Form: CALibrate:CURRent[:DATA] {0 | 1 | 2 | 3} Syntax:

Description: Increases or decreases output current during calibration only. CAL:CURR[:DATA] 0 decreases output current. CAL:CURR[:DATA] 1 increases output current. CAL:CURR[:DATA] 2 decreases output current (coarse adjustment equivalent to the 1 key on the keypad). CAL:CURR[:DATA] 3 increases output current coarse adjustment equivalent to the 3 key on the keypad). These commands are used during current calibration to adjust the output current for current zero calibration as well as full scale current calibration. Output current is monitored on a calibrated digital multimeter (reading voltage at the sense terminals of the shunt resistor) and increased or decreased as required using this command. This command is only effective if Calibration status and either Current Zero or Current Full Scale calibration are active. This command is equivalent to the left and right arrow keys on the front panel. Related Commands: CAL:STAT, CAL:PASS, CAL:VOLT, CAL:CURR, CAL:ZERO, CAL:SAVE. (See example, Figure B-2.)

B.5 CALibrate: CURRent: LEVel COMMAND

CAL:CURR:LEV

Syntax: Short Form: CAL:CURR:LEV {MIN | MAX | MAG | PROT}

Long Form: CALibrate:CURRent:LEVel {MIN | MAX | MAG | PROT}

Description: Selects Current calibration, only effective with power supply in Calibrate status.

CAL:CURR:LEV MIN sets output current to zero for calibration. CAL:CURR:LEV MAX selects output current to full scale for calibration. CAL:CURR:LEV MAG selects the current magnification calibration. CAL:CURR:LEV PROT selects the overcurrent protection calibration. Normally Current Min Calibration is done first, then Current Max, then Current Magnification, then last Overcurrent Protection. Related Commands: CAL:STAT, CAL:PASS, CAL:VOLT, CAL:CURR, CAL:ZERO, CAL:SAVE. (See

example, Figure B-2.)

B-2 BHK-MG 110504 NOTES: 1. Power supply assumed to be operating in constant voltage mode.

2. Examples below are intended only to illustrate command functions. Refer to PAR. 3.6 for programming techniques to optimize performance.

OUTP ON Output enabled.

OUTP? Power supply returns "1" (output enabled).

VOLT 221; CURR 1.5E-2 Power supply output programmed to go to 221V, current limit 15mA

INIT:CONT ON Continuous triggers enabled. INIT:CONT? Power supply returns "1."

VOLT:TRIG 215;CURR:TRIG 3e-2 Power supply output programmed to return to 215V, current limit 30mA

upon receipt of trigger.

*TRG Power supply output returns to 215V,current limit 30mA.

VOLT 221; CURR 4e-2 Power supply output programmed to go to 221V, current limit 40mA

MEAS:VOLT? If actual value of output voltage is 220.9V, power supply

returns 2.209E+2.

MEAS:CURR? If actual value of output current is 0.0283A, power supply

returns 2.83E-2.

FUNC:MODE? Returns VOLT if power supply operating in constant voltage

mode, CURR for constant current mode.

CURR:TRIG? Returns 3E-2 (current value established by CURR:TRIG. VOLT:TRIG? Returns 215 (voltage value established by VOLT:TRIG.

ABOR Pending trigger levels changed to 221V, 40mA (immediate values)

VOLT 277; CURR 2.5E-2 Power supply output programmed to go to 277V, 25mA *TRG Power supply output returns to 221V, current limit 40mA.

INIT:CONT 0 Triggers disabled.
INIT:CONT? Power supply returns "0."

OUTP OFF Output disabled.

OUTP? Returns 0 (output disabled).
MEAS:VOLT? Returns 0. (measured output voltage).

VOLT? Returns 221.(programmed output voltage)
CURR? Returns 4E-2 (programmed current 40mA)

CURR? MAX Returns 4E-2 (assuming maximum allowable current for power

supply being addressed is 40mA, i.e. BHK 1000-40MG).

CURR? MIN Returns 0 (minimum allowable current).

CURR:PROT 3.8E-2 Current protection set to 38mA.

CURR? Returns 4E-2 (programmed current 40mA)

CURR:PROT? Returns 3.8E-2, indicating programmed overcurrent protection

current value = 38mA.

CURR:PROT?MAX For BHK 1000-40MG, returns 4.4E-2 (44mA, see Table 1-2).

SYST:VERS? Returns 2002.0.

FIGURE B-1. PROGRAMMING THE OUTPUT

B.6 CALibrate:SAVE COMMAND

CAL:SAVE

Syntax: Short Form: CAL:SAVE Long Form: CALibrate:SAVE

Short Form: CAL:SAVE DATE <string> Long Form: CALibrate:SAVE DATE <string>

where DATE is optional allowing <string> of up to 12 contiguous characters identifying calibrations

date to be saved. Active DATE <string > is returned by *IDN? query.

Description: Saves computed calibration values in non-volatile memory. This command saves only the cali-

bration values computed after entering Calibration status. If, for example, only Voltage calibration was performed, these are the only values saved. Previous values are not lost, and can be restored This command should be the last command before exiting Calibrate status. **Related Commands:**

CAL:STAT, CAL:DPOT, CAL:VOLT, CAL:CURR, CAL:ZERO. (See example, Figure B-2.)

B.7 CALibrate:STATus COMMAND

Syntax: Short Form: CAL:STAT <boolean>

Long Form: CALibrate:STATus <boolean> where boolean = 0 or OFF, 1 or ON

Description: Sets the power supply to Calibrate status. <boolean> 1 or ON causes power supply to enter Cali-

brate status. <boolean> 0 or OFF causes power supply to exit Calibrate status. If password is not enabled (see SYST:PASS:CEN, PAR. B.87), then error 211, Protected Setting, is added to error queue. Related Commands: SYST:PASS:CEN, CAL:VOLT, CAL:CURR, CAL:ZERO, CAL:SAVE. (See

example, Figure B-2.)

B.8 CALibrate:STATe? QUERY

Syntax:

Short Form: CAL:STAT? Long Form: CALibrate:STATe?

Return Value: <boolean> (boolean = 0 or OFF, 1 or ON)

Description: Identifies whether the power supply is in Calibrate status. 1 indicates power supply is in Calibrate

state. 0 indicates power supply is not in Calibrate state. (See example, Figure B-2.)

B.9 CALibrate:VOLTage[:DATA] COMMAND

CAL:VOLT

CAL:STAT?

CAL:STAT

Syntax: Short Form: CAL:VOLT[:DATA] {0 | 1 | 2 | 3} Long Form: CALibrate:VOLTage[:DATA] {0 | 1 | 2 | 3}

Description: Increases or decreases output voltage during calibration only.

CAL:VOLT[:DATA] 0 decreases output voltage. CAL:VOLT[:DATA] 1 increases output voltage. CAL:VOLT[:DATA] 2 decreases output voltage (coarse adjustment equivalent to the 1 key on the keypad). CAL:VOLT[:DATA] 3 increases output voltage (coarse adjustment equivalent to the 3 key on the keypad). These commands are used during voltage calibration to adjust the output voltage for voltage zero calibration as well as full scale voltage calibration. Output voltage is monitored on a calibrated digital multimeter and increased or decreased as required using this command. This command is only effective if Calibration status and either Voltage Zero or Voltage Full Scale calibration are active. This command is equivalent to the left and right arrow keys on the front panel. Related Commands: CAL:STAT, CAL:PASS, CAL:VOLT, CAL:CURR, CAL:ZERO, CAL:SAVE. (See example, Figure B-2.)

B.10 CALibrate: VOLTage: LEVel COMMAND

CAL:VOLT:LEV

Syntax: Short Form: CAL:VOLT:LEV {MIN | MAX | PROT}

Long Form: CALibrate: VOLTage: LEVel {MIN | MAX | PROT}

Description: Selects Voltage calibration, only effective with power supply in Calibrate status.

CAL:VOLT:LEV MIN selects Voltage Zero Calibration. CAL:VOLT:LEV MAX selects Voltage Full Scale Calibration. CAL:VOLT:LEV PROT selects Overvoltage Calibration. Normally Voltage Zero is done first, then Voltage Full Scale Calibration, then Overvoltage Calibration. Related Commands: CAL:STAT, CAL:PASS, CAL:VOLT, CAL:CURR, CAL:ZERO, CAL:SAVE. (See example, Figure B-2.)

B.11 CALibrate:ZERO COMMAND

CAL:ZERO

Syntax: Short Form: CAL:ZERO Long Form: CALibrate:ZERO

Description: Sets output to zero while calibration equipment connections are changed. This command is used when

changing from Voltage to Current calibration or vice-versa. CAL:ZERO sets output voltage and current to zero and causes the message "CONNECT INSTRUMENT" to be displayed on the front panel LCD. The user then connects or disconnects the shunt resistor or the digital voltmeter from the output terminals of the power supply as required for the subsequent Voltage or Current calibration. The next command should select the new parameter to be calibrated. Related Commands: CAL:STAT, CAL:VOLT,

CAL:CURR, CAL:SAVE. (See example, Figure B-2.)

B-4 BHK-MG 110504

NOTE: Examples below are intended only to illustrate command functions. Refer to PAR. 3.6 for program-

ming techniques to optimize performance.

SYST:PASS:CEN 1234 Password entered.

CAL:STAT ON Power supply enters Calibrate status.

CAL:STAT? Returns 00 indicating power supply in Calibrate status.

SYST:PASS:NEW 1234,6789 Password changed from 1234 to 6789. CAL:VOLT:LEV MIN Voltage Zero Calibration selected.

CAL:VOLT 1 Output voltage increased

--- Execute CAL:VOLT 1 and CAL:VOLT 0 as required to achieve calibration (see PAR. 4.4.1)

CAL:VOLT:LEV MAX Voltage Full Scale Calibration selected.

CAL:VOLT 0 Output voltage decreased.

--- Execute CAL:VOLT 1 and CAL:VOLT 0 as required to achieve calibration (see PAR. 4.4.1)

CAL:ZERO Output voltage and current set to zero.

* User disconnects shunt and connects DVM to output.

CAL:CURR:LEV MIN Current Zero Calibration selected.

CAL:CURR 0 Output current decreased.

--- Execute CAL:CURR 1 and CAL:CURR 0 as required to achieve calibration (see PAR. 4.4.2)

CAL:CURR:LEV MAX Current Full Scale Calibration selected. (See NOTE below.)

CAL:CURR 0 Output current decreased.

--- Execute CAL:CURR 1 and CAL:CURR 0 as required to achieve calibration (see PAR. 4.4.2)

CAL:CURR:LEV MAX Current Full Scale Calibration selected. (See NOTE below.)

CAL:CURR:LEV MAG
CAL:CURR:VAL .0079
Current 10X Magnification Calibration selected.
Sets readback current for 1/10 scale to 7.9mA.

CAL:CURR:LEV PROT
CAL:SAVE 01-02-2003
CAL:STAT 0

Overcurrent Calibration selected.
Calibration values and date saved.
Power supply exits Calibrate mode.

CAL:STAT? Returns 0 indicating power supply not in Calibrate status

FIGURE B-2. USING CALIBRATION COMMANDS AND QUERIES

B.12 DISPlay:CONTrast COMMAND

DISP:CONT

Syntax: Short Form: DISP:CONT < num value > (0.1 to 0.9)

Long Form: DISPlay:CONTrast < num value > (0.1 to 0.9)

Description: Sets the contrast of the front panel LCD. The contrast value from (0.1 to 0.9) is stored in the non-

volatile memory and is retained when the power supply is turned off. A contrast value of 0.1 is best when looking up at the display, 0.9 is best when looking down at the display. Values in between provide adjustment for optimum viewing. Related Commands: DISP:CONT?. (See example, Figure B-3.)

DISP:CONT 0.9 Sets LCD contrast value to 0.9.

DISP:CONT? Returns 0.9.

DISP:MODE NORM Changes LCD to Normal metering mode.

DISP:MODE? Returns NORMAL.

DISP:MODE TEXT Changes LCD to Text mode.

DISP:TEXT **BHK-MG IS IN USE"Second line of display reads **BHK-MG IS IN USE.

DISP:MODE? Returns "TEXT"

DISP:TEXT? Returns "**BHK-MG IS IN USE"

FIGURE B-3. USING DISPLAY COMMANDS

B.13 DISPlay: CONTrast? QUERY

Syntax: Short Form: DISP:CONT? Long Form: DISPlay:CONTrast?

Return Value: Numerical value from 0.1 to 0.9 indicating contrast setting.

Description: Identifies LCD contrast setting. When the display set to TEXT mode, returns the character string

entered by DISP:TEXT. If the display set to NORMAL mode, returns information displayed on second line of display. (This can be used to see the monitored values presently being displayed on he second

line of the LCD.) Related Commands: DISP:CONT. (See example, Figure B-3.)

B.14 DISPlay: MODE COMMAND

Syntax:

Short Form: DISP:MODE NORM or DISP:MODE TEXT

Long Form: DISPlay:MODE NORMal or DISPlay:MODE TEXT

Description: Switches the LCD display between Normal and Text mode. Switches the display between its nor-

mal metering mode and a mode in which it displays text sent by the user on the second line. The default status at power up or after *RST is NORMal. In order to display text on the second line the display mode has to be changed to TEXT. Related Commands: DISP:MODE?, DISP:TEXT,

DISP:TEXT?, *RST. (See example, Figure B-3.)

B.15 DISPlay: MODE? QUERY

Syntax: Short Form: DISP:MODE? Long Form: DISPlay:MODE?

Return Value: NORMAL or TEXT.

Description: Identifies the LCD mode. Returns NORMAL when the display is in normal mode, TEXT when the dis-

play is in text mode. Related Commands: DISP:MODE, DISP:TEXT, *RST. (See example, Figure B-3.)

B.16 DISPlay:TEXT COMMAND

DISP:TEXT

DISP:MODE?

DISP:CONT?

DISP:MODE

Syntax: Short Form: DISP:TEXT[:DATA] <char string> Long Form: DISPlay:TEXT [:DATA] <char string>

Description: Allows entry of character string to be viewed when LCD display is set to Text mode. Allows for

character strings of maximum 16 characters to be displayed (on the second line of the LCD) when the display mode is TEXT, e.g., DO NOT TOUCH or BHK-MG IS IN USE, etc. The LCD has the following character set: A to Z, 0 to 9 and special characters as <>+-/=:... If the message exceeds the display capacity only the first 16 characters will be displayed and no error message will be generated. Upon executing *RST, character string set to 16 spaces:"

". Related Commands:

DISP:TEXT?, DISP:MODE, DISP:MODE?, *RST. (See example, Figure B-3.)

B.17 DISPlay:TEXT? QUERY

DISP:TEXT?

Syntax: Short Form: DISP:TEXT? Long Form: DISPlay:TEXT]?

Return Value: Character string displayed on second line of LCD display.

Description: Returns the text displayed on second line of LCD in TEXT mode. When the display set to TEXT

mode, returns the character string entered by DISP:TEXT. If the display set to NORMAL mode, returns information displayed on second line of display. (This can be used to see the monitored values presently being displayed on the second line of the LCD.) Related Commands: DISP:MODE,

DISP:TEXT, *RST. (See example, Figure B-3.)

B.18 INITiate[:IMMediate] COMMAND

INIT[:IMM]

Syntax: Short Form: INIT[:IMM] Long Form: INITiate[:IMMediate]

Description: Enables a single trigger. If INIT:CONT is OFF, then INIT[:IMM] arms the trigger system for a single

trigger. If INIT:CONT is ON, then the trigger system is continuously armed and INIT[:IMM] is redundant. This command enables a single trigger. A GPIB <GET>, *TRG command completes the sequence. Upon receipt of the <GET>, *TRG command, the power supply will return to the programmed values of voltage and current established by the VOLT:TRIG and CURR:TRIG commands. After a GPIB <GET>, *TRG command has been received, subsequent GPIB <GET>, *TRG commands have no effect unless preceded by INIT or INIT:CONT ON. Related Commands: <GET>, *RST,

*TRG. (See example, Figure B-1.)

B-6 BHK-MG 110504

B.19 INITiate: CONTinuous COMMAND

INIT:CONT

Syntax: Short Form: INIT:CONT $\{ON \mid OFF\}$ or $\{1 \mid 0\}$ (1 = on, 0 = off)

Long Form: INITiate:CONTinuous {ON | OFF} or {1 | 0} (1 = on, 0 = off)

Description: INIT:CONT ON enables continuous triggers.; INIT:CONT OFF disables continuous triggers. If

INIT:CONT is OFF, then INIT[:IMM] arms the trigger system for a single trigger. If INIT:CONT is ON, then the trigger system is continuously armed and INIT[:IMM] is redundant. Executing *RST command to the trigger system is continuously armed and INIT[:IMM] is redundant.

sets INIT:CONT to OFF. Related Commands: TRIG:SOUR (See example, Figure B-1.)

B.20 INITiate: CONTinuous QUERY

INIT:CONT?

Syntax: Short Form: INIT:CONT? Long Form: INITiate:CONTinuous?

Return Value: 1 or 0

Description: Determines whether continuous triggers are enabled or disabled. Power supply returns value of

INIT:CONT flag: "1" = continuous triggers are enabled (INIT:CONT ON); "0" = continuous triggers dis-

abled (INIT:CONT OFF). (See example, Figure B-1.)

B.21 INSTrument:STATe

INST:STAT

Syntax: Short Form: INST:STAT <val> Long Form: INSTrument:STATe <val>

Description: Operation is identical to OUTPut:STATe command (PAR. B.42) and is provided for compatibility with

other vendors products.

B.22 [SOURce:]LIST:CLEar COMMAND

LIST:CLE

Syntax: Short Form: LIST:CLE Long Form: LIST:CLEar>

Description: Clears all list entries by setting all pointers to 0. Also sets LIST:DIR to UP, LIST:GEN to DSEQ,

Related Commands: All LIST commands (See example, Figure B-4.)

B.23 [SOURce:]LIST:COUNt COMMAND

LIST:COUN

Syntax: Short Form: LIST:COUN<int_value 0 to 65535> Long Form: LIST:COUNt> <int_value 0 to 65535>

Description: Establishes how many times the list is executed. Allows user to establish how many times the list

is executed. The order (beginning to end or end to beginning) is determined by LIST:DIR. For LIST:COUN 0, the unit will execute the sequence indefinitely until a VOLT:MODE FIXED command is

received. Related Commands: LIST:DIR. (See example, Figure B-4.)

B.24 [SOURce:]LIST:COUNt? QUERY

LIST: COUN?

Syntax: Short Form: LIST:COUNT? Long Form: LIST:COUNt?

Return Value: <int_value>

Description: Identifies how many times the list will be executed. Returns value set by LIST:COUN command.

(See example, Figure B-4.)

B.25 [SOURce:]LIST:COUNt:SKIP COMMAND

LIST:COUN:SKIP

Syntax: Short Form: LIST:COUN:SKIP nn Long Form: LIST:COUNt:SKIP nn

nn = <int value 0 to 65535>

Description: Allows beginning steps of list-generated waveform to be run once, then ignored.

When a list is to be repeated using LIST:COUNT, this command allows the user to skip the first nn steps once the full set has been executed. After the first iteration (which executes all steps), the first nn steps are skipped. The LIST:COUN:SKIP command allows the user to precondition a list-generated waveform by setting unique conditions at the beginning that are not repeated for the rest of the repetitions. LIST:CLEar sets nn to 0. Only works in LIST:DIR UP mode, if LIST:DIR DOWN is issued, this command has no effect. Related Commands: LIST:COUN, LIST:COUN:SKIP?, LIST:DIR,

LIST:CLE. (See example, Figure B-4.)

B.26 [SOURce:]LIST:COUNt:SKIP? QUERY

LIST:COUN:SKIP?

Syntax: Short Form: LIST:COUN:SKIP? Long Form: LIST:COUNt:SKIP?

Return Value: <int value>

Description: Identifies how many steps will skipped the first time the list is executed. Returns value set by

LIST:COUN:SKIP command. (See example, Figure B-4.)

B.27 [SOURce:]LIST:CURRent COMMAND

LIST:CURR

Syntax: Short Form: LIST:CURR <exp_value>, <exp_value>, . . . (to max of 250 data points)

Long Form: LIST:CURRent <exp_value>, <exp_value>, . . . (to max of 250 data points)

<exp value> = digits with decimal point and Exponent, e.g., 2.71E1 for 27.1

Description: Adds the current value (in Amps) to list. This command sequentially adds LIST:CURRent values to the main channel List Data Table. Starting location is indicated by LIST:CURR:POIN? The maximum

number of entries is 250. Since the input buffer of the BHK has a limit of 253 characters, multiple commands are necessary to complete the full 250 entries of the list. If LIST:VOLT has any entries, an error message: -221,"Settings conflict" is posted in the error queue. Related Commands:

LIST:CURR:POIN?. (See example, Figure B-4.)

B.28 [SOURce:]LIST:CURRent? QUERY

LIST:CURR?

Syntax: Short Form: LIST:CURR? Long Form: LIST:CURRent?

Return Value: <value1>, <value2>, . . . to <value16>

Description: Identifies the parameters (main channel) entered for the list. Starting at location established by

LIST:QUERy, returns comma-separated list of up to 16 values indicating the main channel parameters entered. i.e., the contents of main channel List Data Table. Related Commands: LIST: CURR, LIST:QUERy. If LIST:VOLT has any entries, an error message: -221, "Settings conflict" is posted in the

error queue. (See example, Figure B-4.)

B.29 [SOURce:]LIST:CURRent:POINts? QUERY

LIST:CURR:POIN?

Syntax: Short Form: LIST:CURR:POIN? Long Form: LIST:CURRent:POINts?

Return Value: <value> (0 to 250)

Description: Identifies the total number of points in a list and the next location to be filled by LIST:CURR

command. The LIST:CURR pointer is initially at 0 via LIST:CLE. For each data point entered by a LIST:CURR command the list pointer is incremented If LIST:CURR:POIN? returns 5, the LIST:CURR pointer is at 5 indicating there are 6 data points comprising the list. If LIST:VOLT has any entries, an error message: -221,"Settings conflict" is posted in the error queue.Related Commands: LIST:CURR.

(See example, Figure B-4.)

B.30 [SOURce:]LIST:DIRection COMMAND

LIST:DIR

Syntax: Short Form: LIST:DIR (UP|DOWN) Long Form: LIST:DIRection (UP|DOWN)

Description: Allows the list to be executed from beginning to end (UP) or from end to the beginning (DOWN). *RST or LIST:CLEar sets the list to the UP direction (beginning to end). Related Commands:

LIST:DWEL?. (See example, Figure B-4.)

B.31 [SOURce:]LIST:DIRection? QUERY

LIST:DIR?

Syntax: Short Form: LIST:DIR? Long Form: LIST:DIRection?

Return Value: <value> (UP or DOWN)

Description: Identifies the for executing the list established by LIST: DIR. Related Commands: LIST: DIR. (See

example, Figure B-4.)

B.32 [SOURce:]LIST:DWELI COMMAND

LIST:DWEL

Syntax: Short Form: LIST:DWEL <value> (0.010 to 655.35), <value>, <value>, . . . to maximum of 250 values

Long Form: LIST:DWELI <value> (0.010 to 655.35), <value>, <value>, . . . to maximum of 250 values

Description: **Determines how long the main channel parameters will be active.** Sets time value (from 0.010 to 655.35) in seconds for List:Dwell locations of the List Data Table. The main channel (either voltage or

current) is determined by the load. If LIST:DWEL is entered for only location 0, that time duration will apply to all steps when either VOLT:MODE LIST or CURR:MODE LIST is executed. Related Com-

mands: VOLT:MODE, LIST:CURR, LIST:VOLT, LIST:DWEL? (See example, Figure B-4.)

B-8 BHK-MG 110504

B.33 [SOURce:]LIST:DWELI? QUERY

LIST: DWEL?

Syntax: Short Form: LIST:DWEL? Long Form: LIST:DWELI?

Return Value: <value>

Description: Identifies the dwell times entered for the list. Starting at location established by LIST:QUERy,

returns comma-separated list of up to 16 values indicating the dwell time parameters entered. i.e., the contents of LIST:DWEL locations of the List Data Table. Related Commands: LIST: DWEL,

LIST:QUERy. (See example, Figure B-4.)

B.34 [SOURce:]LIST:DWELI:POINts? QUERY

LIST:DWEL:POIN?

Syntax: Short Form: LIST:DWEL:POIN? Long Form: LIST:DWELI:POINts?

Return Value: <value> (0 to 250)

Description:Identifies the number of locations for which time values have been entered and the next loca-

tion to be filled by a LIST:DWEL command. If LIST:DWEL:POIN? returns 6, dwell times have been entered for locations 0 through 5 and location 6 is the next to be filled by a LIST:DWEL command.

LIST:DWEL, LIST:DWEL:POIN. (See example, Figure B-4.)

B.35 [SOURce:]LIST:QUERy COMMAND

Syntax: Short Form: LIST:QUER <int_value>

Long Form: LIST:QUERy <int value>

int value = 0 to 250

Description: Determines first location to be gueried by LIST:SEQ? guery. Related Commands: LIST:QUER?.

(See example, Figure B-4.)

B.36 [SOURce:]LIST:QUERy? QUERY

Syntax: Short Form: LIST:SEQ? Long Form: LIST:SEQuence?

Return Value: <int value>

Description: Identifies first location to be queried by LIST:SEQ?, LIST:VOLT?, LIST:CURR?, LIST:DWEL?

queries. Related Commands: LIST:QUER, LIST:SEQ. (See example, Figure B-4.)

B.37 [SOURce:]LIST:VOLTage COMMAND

LIST: VOLT

LIST:VOLT?

LIST: VOLT: POIN?

LIST: QUER

LIST:QUER?

Short Form: LIST:VOLT[:LEV] <exp_value>, <exp_value>, . . . (to max of 250 data points)

Long Form: LIST:VOLTage[:LEVel] <exp value>, <exp value>, . . . (to max of 250 data points)

<exp_value> = digits with decimal point and Exponent, e.g., 2.71E1 for 27.1

Description: Adds the voltage value (in Volts) to list. This command sequentially adds LIST:VOLTage values to the main channel List Data Table locations. LIST:CLE sets starting location to 0. Next location indicated by LIST:VOLT:POIN? The maximum number of entries is 250. Since the input buffer of the BHK has a limit of 253 characters, multiple commands are necessary to complete the full 250 entries of the

list. If LIST:CURR has any entries, an error message: -221,"Settings conflict" is posted in the error queue. Related Commands: LIST:VOLT:POIN?, LIST:CLE, *RST. (See example, Figure B-4.)

B.38 [SOURce:]LIST:VOLTage? QUERY

Syntax: Short Form: LIST: VOLT? Long Form: LIST: VOLTage?

Return Value: <value1>, <value2>, . . . to <value16>

Description: **Identifies the parameters (main channel) entered for the list.** Starting at location established by LIST:QUERy, returns comma-separated list of up to 16 values indicating the main channel parameters

entered. i.e., the contents of the main channel List Data Table. Related Commands: LIST: VOLT, LIST:QUERy. If LIST:CURR has any entries, an error message: -221,"Settings conflict" is posted in the error queue. (See example, Figure B-4.)

B.39 [SOURce:]LIST:VOLTage:POINts? QUERY

Syntax: Short Form: LIST:VOLT:POIN? Long Form: LIST:VOLTage:POINts?

Return Value: <value> (0 to 250)

Description: Identifies the total number of points in a list and the next location to be filled by LIST:VOLT

command. The LIST:VOLT pointer is initially at 0 via *RST or LIST:CLE. For each data point entered by a LIST:VOLT command the list pointer is incremented If LIST:VOLT:POIN? returns 5, the LIST:VOLT pointer is at 5 indicating there are 5 data points comprising the list (locations 0 though 4) and location 5 is the next to be filled. If LIST:CURR has any entries, an error message: -221,"Settings conflict" is posted in the error queue. Related Commands: LIST:VOLT. (See example, Figure B-4.)

NOTE: Examples below are intended only to illustrate command functions. Refer to PAR. 4.1.1 for pro-

gramming techniques to optimize performance.

LIST:CLEAR Initializes the list processor to add entries, clears main channel

(LIST:CURR or LIST:VOLT) and LIST:DWEL data tables.

LIST:dwell .010 Sets the time duration for location 0 to be 0.010 second (Since dwell times

for the rest of the locations in the list are not entered before running the list,

the dwell time will be 0.010 second for all locations.

LIST:VOLT 0,2,4,6,8,10,12,14,16,18,20

Starting at location 0 (0), up to location 10 (20), fills the list with 11 data

ooints.

LIST: VOLT: POIN? Returns 11. Indicates that 11 data points have been entered, and location

11 is the next location to be filled (for the 12th data point.

NOTE: See PAR. B.2 for format and accuracy of all numerical data returned.

LIST:QUERY? Returns 0 (pointer cleared by LIST:CLE).

LIST:VOLT? Returns -20,-18,-16,-14,-12,-10,-8,-6,-4,-2,0 (the contents of locations 0

through 10). (See PAR. B.2 for format and accuracy of numerical data.)

list:volt 18,16,14,12,10,8,6,4,2,0

Adds 10 points to the list (location 11 through 20). List now has 21 points.

LIST:VOLT:POIN? Returns 21 (the next location to be filled by LIST:VOLT).

LIST:VOLT? Returns 0,2,4,6,8,10,12,14,16,18,20,18,16,14,12,10,8,6,4,2,0 (the contents

of locations 0 through 15).

LIST:QUERY 16 Start LIST queries from location 16. LIST:QUERY 32 Start LIST queries from location 32.

LIST:COUNT 100 Specifies that when VOLT:MODE LIST is issued, the user-determined

sequence will be executed 100 times. (44 steps in the list will be executed

00 times)

LIST:COUN:SKIP 4 Specifies that the first 4 steps of the sequence will only be executed the first

time through the list. For the subsequent 99 iterations established by

LIST:COUNT 100, location 0 (0V) will last 10 milliseconds.

CURR .001;VOLT 20 initializes the BHK output

OUTPUT ON Turns the output on (BHK now provides 0 volts)

LIST:CURR .001 Established current level for list.

VOLT:MODE LIST Executes the list. For 40 milliseconds the BHK outputs 0V, then outputs a

staircase triangle wave from 0V to +20V and back down to 0V. This staircase will have a uniform spacing between voltage changes of 10 millisec-

onds and will repeat 100 times.

VOLT? Returns 0 (the last step in the list set the unit to 0V.

LIST:COUN:SKIP? Returns 4. Skip first 4 steps after the first time through count.

LIST:COUN:SKIP 0 Specifies no steps to be skipped after the first time through the count.

LIST:COUNT? Returns 100.

LIST:COUNT 10 Determines that the list will be repeated 10 times when executed.

LIST:COUNT? Returns 10.

VOLT:MODE LIST Initiates execution of the list. The unit outputs a sawtooth waveform that

increases from 0V to +20V and repeats 10 times.

VOLT? Returns 0, (the last step in the list set the unit to 0V. LIST:VOLT:POIN? Returns 21 (the next location to be filled by LIST:VOLT).

LIST: VOLT 10,0,-10 Add 3 points to the list (location 21 through 23).

LIST:COUN? Returns 10 indicating that the list will be repeated 10 times when executed.

LIST:DIR? Returns UP (the default.)
LIST:DIR DOWN Reverses the sequence order.

VOLT:MODE LIST The list (24 steps) is executed. The output starts at -10V, goes to 0V, to 10V

to 0V then increases to 20V in 2V steps and repeats 10 times. The saw-tooth is similar to the previous sawtooth, except the waveform is inverted.

FIGURE B-4. USING LIST COMMANDS AND QUERIES (SHEET 1 OF 2)

В-10

LIST:QUERy 0 Sets query pointer to zero.

LIST:DWEL:POIN? Returns 1 indicating the next dwell time will be entered in location 1.

LIST:DWELL .01,.01,.01,.01,.01,.01,.01,.01

Enters dwell time of 0.01 seconds in locations 1 through 9.

Enters dwell time of 1 second in location 10. LIST: DWELL 1

VOLT:MODE LIST the list is not executed, the unit returns error -221, Settings Error indicating

the lists are not balanced.

LIST:DWELL:POINTS? Returns 11 to indicate the dwell list has 11 entries Returns 24 to indicate the voltage list has 24 entries. LIST:VOLT:POINTS?

Dwell times are entered in locations 11 through 23.

Returns 24 indicating there are now 24 step dwell times on the list. DWELL:POINTS?

LIST:QUER? Returns 0 indicating list queries will start from location 0

Causes list gueries to start at location 18 LIST: QUER 18

LIST:DWEL? Returns 01,.01,.01,.1,.1,.1 (the dwell times for locations 18 through 23.

LIST:VOLT? Returns 4,2,0,10,0,10. LIST COUNT 0 List will repeat indefinitely.

VOLT: MODE LIST The list is executed. Stair case wave now consists of 24 steps of .01 sec-

onds except for the 0V step (location 10) which outputs 0V for 1 second.

The end of the staircase has three steps of 0.1 second.

VOLT: MODE FIX Stops execution of the list

Returns 0 (the last step in the list set the unit to -20V. VOLT?

VOLT: 4 Programs output to 4V.

FIGURE B-4. USING LIST COMMANDS AND QUERIES (SHEET 2 OF 2)

B.40 MEASure[:SCALar]:CURRent[:DC]? QUERY

MEAS:CURR?

Long Form: MEASure[:SCALar]:CURRent[:DC]? Syntax: Short Form: MEAS[:SCAL]:CURR[:DC]?

Return Value: <num_value> (digits with decimal point and Exponent)

Description: Measures actual current. This query returns the actual value of output current (measured at the output terminals) as determined by the programmed value of voltage and current and load conditions. (See example, Figure B-1.) NOTE: The SCPI convention for this command allows the controller to establish the range and accuracy of the measurement if nn,nn is added after the question mark; the BHK-MG accepts this format but sets the command warning bit (13) in the status questionable register and ignores the extra characters.

B.41 MEASure: VOLTage[:SCALar][:DC]? QUERY

MEAS:VOLT?

Short Form: MEAS[:SCAL]:VOLT[:DC]? Long Form: MEASure[:SCALar]:VOLTage[:DC]? Syntax:

Description: Measures actual voltage. This guery returns the actual value of output voltage (measured at the output terminals) as determined by the programmed value of voltage and current and load conditions. (See example, Figure B-1.) NOTE: The SCPI convention for this command allows the controller to establish the range and accuracy of the measurement if nn,nn is added after the question mark; the BHK-MG accepts this format but sets the command warning bit (13) in the status questionable register and ignores the extra characters.

B.42 OUTPut[:STATe] COMMAND

OUTP

Syntax: Short Form: OUTP[:STAT] <boolean> Long Form: OUTPut[:STATe] <boolean>

<boolean>=(0 or OFF, 1 or ON)

Description: Enables or disables the power supply output (see PAR.3.2.6.2 for disabling if analog programming used). Upon power up the output is enabled (OUTP ON). When OUTP OFF is executed, the digitally programmed values of voltage and current are saved, then voltage and current are programmed to 0; analog programming is not affected. When OUTP ON is executed, the power supply output is restored to the previously saved programmed values. The saved values of voltage and current can be viewed by VOLT? and CURR? queries. Related Commands: OUTP?. (See example, Figure B-1.)

B-11 BHK-MG 110504

B.43 OUTPut[:STATe] QUERY

OUTP?

Syntax: Short Form: OUTP[:STAT]? Long Form: OUTPut[:STATe]?

Return Value: <int_value> (0 or 1)

Description: Indicates whether power supply output is enabled or disabled. Returns 0 if output disabled,

returns 1 if output enabled. Related Commands: OUTP. (See example, Figure B-1.)

B.44 [SOURce:]CURRent[:LEVel][:IMMediate][:AMPlitude] COMMAND

CURR

Syntax: Short Form: [SOUR:]CURR[:LEV][:IMM][:AMP] <exp value>

Long Form: [SOURce:]CURRent[:LEVel][:IMMediate][:AMPlitude] <exp_value> <exp_value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Sets programmed current level at power supply output. This command programs output current

to a specific value; actual output current will depend on load conditions. If the value exceeds the maximum for the model being programmed, error message -222,"Data out of range" is posted in output queue. If value programmed exceeds the CURR:LIM[:HIGH] value, a value corresponding to the current limit will be programmed. Related Commands: *RCL, *SAV, CURR:LIM[:HIGH]. (See example,

Figure B-1.)

B.45 [SOURce:]CURRent[:LEVel][:IMMediate][:AMPlitude] QUERY

CURR?

Syntax: Short Form: [SOUR:]CURR[:LEV][:IMM][:AMP]? MIN, MAX

Long Form: [SOURce:]CURRent[:LEVel][:IMMediate][:AMPlitude]? MIN, MAX

Return Value:<exp_value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Returns either the programmed value, maximum value, or minimum value of current. The

CURR? query returns the programmed value of current. Actual output current will depend on load conditions. The CURR?MAX query returns the maximum current allowed for a particular model. CURR? Returns programmed current value. CURR? MAX returns maximum current allowed for power supply. CURR? MIN returns minimum current allowed for power supply (always 0). Related

Commands: CURR. (See example, Figure B-1.)

B.46 [SOURce:]CURRent:[:LEVel]TRIGgered[:AMPlitude] COMMAND

CURR:TRIG

Syntax: Short Form: [SOUR:]CURR[:LEV]:TRIG[:AMP] <exp_value>

Long Form: [SOURce:]CURRent[:LEVel]:TRIGgered[:AMPlitude] <exp_value> <exp_value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Programs current value to be transferred to output by *TRG commands. Actual output current

will depend on load conditions. If the value exceeds the maximum for the model being programmed, error message -222,"Data out of range" is posted in output queue. If value exceeds CURR:LIM[:HIGH] value, a value corresponding to the current limit will be programmed. Related Commands: CURR.

(See example, Figure B-1.)

B.47 [SOURce:]CURRent:[:LEVel]TRIGgered[:AMPlitude]? QUERY CURR:TRIG?

Syntax: Short Form: [SOUR:]CURR[:LEV]:TRIG[:AMP]?

Long Form: [SOURce:]CURRent[:LEVel]:TRIGgered[:AMPlitude]?

Return Value: <exp_value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Returns the current value established by CURR:TRIG command. (See example, Figure B-1.)

B.48 [SOURce:]CURRent:LIMit[:HIGH] COMMAND

CURR:LIM[:HIGH]

Syntax: Short Form: [SOUR:]CURR:LIM[:HIGH] <exp_value>

Long Form: [SOURce:]CURRent:LIMit[:HIGH] <exp value>

<exp_value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Sets limit for maximum power supply output current. If the value is out of the acceptable current

range for the power supply model, error message -222,"Data out of range" is posted in the output queue. If the user tries to set an output current value larger than the CURR:LIM[:HIGH] setting, a value corresponding to the current limit will be programmed and error message -301,"Value bigger than limit" is posted in the output queue. NOTE: If the current limit is changed, any previously established trigger levels higher than the new limit must be reprogrammed to be lower than the new limit; otherwise triggers will cause the output to exceed the new limit. Once the limit is established, the unit

B-12 BHK-MG 110504

will not accept trigger values higher than the programmed limit. Related Commands: CURR. (See example, Figure B-5.)

B.49 [SOURce:]CURRent:LIMit[:HIGH]? QUERY

CURR:LIM[:HIGH]?

Syntax: Short Form: [SOUR:]CURR:LIM[:HIGH]? Long Form: [SOURce:]CURRent:LIMit[:HIGH]?

Return Value: <exp value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Returns value representing current limit set by CURR:LIM[:HIGH] command. Related Com-

mands: CURR:LIM[:HIGH], CURR. (See example, Figure B-5.)

B.50 [SOURce:]CURRent:PROTection[:LEVel] COMMAND

CURR:PROT

Syntax: Short Form: [SOUR:]CURR:PROT[:LEV] <exp_value>

Long Form: [SOURce:]CURRent:PROTection[:LEVel] <exp value>

<exp value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Sets overcurrent protection level for power supply. If the value is out of the acceptable overcur-

rent range for the power supply model, error message -222,"Data out of range" is posted in the output queue. If the power supply output exceeds the current protection level programmed, then the power supply output is disabled (programmed to 0) and the OV bit in the Questionable Condition status reg-

ister is set. (See example, Figure B-5.)

B.51 [SOURce:]CURRent:PROTection[:LEVel]? QUERY

CURR:PROT?

Syntax: Short Form: [SOUR:]CURR:PROT[:LEV]? {MIN | MAX}

Long Form: [SOURce:]CURRent:PROTection[:LEVel]? {MIN | MAX}

Return Value: <exp_value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Returns value representing current protection level. CURR:PROT? returns value set by CURR:PROT. CURR:PROT?MAX returns maximum current protection value (see Table 1-2). This

value is determined at the factory and cannot be changed by the user. CURR:PROT?MIN returns the

minimum current protection value (always 0). (See example, Figure B-5.)

NOTES: 1. The power supply is assumed to be operating in constant voltage (CV) mode.

2 Examples below are intended only to illustrate command functions. Refer to PAR. 3.6 for programming techniques to optimize performance.

VOLT 421; CURR 1.1e-2 Power supply programmed to voltage limit 421V, 0.011A.

CURR? Returns 1.1E-2.

CURR:LIM[:HIGH] 3.3e-2 Current limit set to 0.033A.

CURR:LIM[:HIGH]? Returns 3.3e-2

CURR 4.2e-1 Power supply output current programmed to 0.033A, error message

-301 posted.

CURR? Returns 1.1e-2

CURR 1.0e-2 Power supply output current programmed to 0.01A

CURR? Returns 1.0e-2 0.01A).

CURR:PROT 2.5e-2 Unit shuts down if current exceeds 25 mA.

FIGURE B-5. PROGRAMMING CURRENT

B.52 [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPlitude] COMMAND

VOLT

Syntax: Short Form: [SOUR:]VOLT[:LEV][:IMM][:AMP] <exp value>

Long Form: [SOURce:]VOLTage[:LEVe][:IMMediate][:AMPlitude] <exp_value> <exp_value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Sets programmed voltage level at power supply output. This command programs output voltage

to a specific value; actual output voltage will depend on load conditions. If the value exceeds the maximum for the model being programmed, error message -222,"Data out of range" is posted in output queue. If value programmed exceeds the VOLT:LIM[:HIGH] value, a value corresponding to the volt-

age limit will be programmed. Related Commands: *RCL, *SAV, VOLT:LIM[:HIGH]. (See example, Figure B-1.

B.53 [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPlitude]? QUERY

VOLT?

Syntax: Short Form: [SOUR:]VOLT[:LEV][:IMM][:AMP]? {MIN | MAX}

Long Form: [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPlitude]? {MIN | MAX}

Description: Identifies programmed voltage, maximum allowable voltage, or minimum voltage (always 0).

The VOLT? query returns the programmed value of voltage. Actual output voltage will depend on load conditions. The VOLT?MAX query returns the maximum voltage allowed for a particular model (e.g., 500V for BHK 500-80MG). VOLT? MIN returns minimum voltage allowed for power supply (always 0).

Related Commands: VOLT. (See example, Figure B-6.)

B.54 [SOURce:]VOLTage:[:LEVel]TRIGgered[:AMPlitude] COMMAND

VOLT:TRIG

Syntax: Short Form: [SOUR:]VOLT[:LEV]:TRIG[:AMP] <exp_value>

Long Form: [SOURce:]VOLTage[:LEVel]:TRIGgered[:AMPlitude] <exp_value> <exp_value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Programs voltage value to be transferred to output by *TRG commands. Actual output voltage

will depend on load conditions. If the value exceeds the maximum for the model being programmed, error message -222,"Data out of range" is posted in output queue. If value exceeds VOLT:LIM[:HIGH] value, a value corresponding to the voltage limit will be programmed. (See example, Figure B-1.)

B.55 [SOURce:]VOLTage:[:LEVel]TRIGgered[:AMPlitude]? QUERY

VOLT:TRIG?

Syntax: Short Form: [SOUR:]VOLT[:LEV]:TRIG[:AMP]?

Long Form: [SOURce:]VOLTage[:LEVel]:TRIGgered[:AMPlitude]?

Return Value: <exp_value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Returns value representing voltage value to be programmed by *TRG command established by

VOLT:TRIG command). (See example, Figure B-1.)

B.56 [SOURce:]VOLTage:LIMit[:HIGH] COMMAND

VOLT:LIM[:HIGH]

Syntax: Short Form: [SOUR:]VOLT:LIM[:HIGH] <exp value>

Long Form: [SOURce:]VOLTage:LIMit[:HIGH] <exp_value>

<exp value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Sets voltage limit for power supply output. If the value is out of the acceptable voltage range for

the power supply model, error message -222,"Data out of range" is posted in the output queue. If the user tries to set an output voltage level larger than the VOLT:LIM[:HIGH] setting, a value corresponding to the voltage limit will be programmed and error message -301,"Value bigger than limit" is posted in the output queue. NOTE: If the voltage limit is changed, any previously established trigger levels higher than the new limit must be reprogrammed to be lower than the new limit; otherwise triggers will cause the output to exceed the new limit. Once the limit is established, the unit will not accept trigger values higher than the programmed limit. Related Commands: VOLT. (See example, Figure B-6.)

B.57 [SOURce:]VOLTage:LIMit[:HIGH]? QUERY

VOLT:LIM[:HIGH]?

Syntax: Short Form: [SOUR:]VOLT:LIM[:HIGH]? Long Form: [SOURce:]VOLTage:LIMit[:HIGH]?

Return Value: <exp_value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Returns value representing voltage limit set by VOLT:LIM[:HIGH] command. Related Com-

mands: VOLT:LIM[:HIGH], VOLT. (See example, Figure B-6.)

B.58 [SOURce:]VOLTage:PROTection[:LEVel] COMMAND

VOLT: PROT

Syntax: Short Form: [SOUR:]VOLT:PROT[:LEV] <exp value>

Long Form: [SOURce:]VOLTage:PROTection[:LEVel] <exp value>

<exp value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Sets overvoltage protection level for power supply. If the value is out of the acceptable overvoltage

range for the power supply model, error message -222,"Data out of range" is posted in the output

B-14 BHK-MG 110504

queue. If the power supply output exceeds the voltage protection level programmed, then the power supply output is disabled (programmed to 0) and the OV bit in the Questionable Condition status register is set. (See example, Figure B-6.)

B.59 [SOURce:]VOLTage:PROTection[:LEVel]? QUERY

VOLT:PROT?

FUNC:MODE?

Syntax: Short Form: [SOUR:]VOLT:PROT[:LEV] MIN, MAX

Long Form: [SOURce:]VOLTage:PROTection[:LEVel] MIN, MAX

Return Value: <exp value> = digits with decimal point and Exponent, e.g., 2.71E+1 for 27.1

Description: Identifies overvoltage protection setting, maximum allowable overvoltage protection, or mini-

mum overvoltage protection. VOLT:PROT? returns value set by VOLT:PROT. VOLT:PROT? MAX returns maximum voltage protection value (see Table 1-2); this value is determined at the factory and cannot be changed by the user. VOLT:PROT? MIN returns the minimum voltage protection value

(always 0). (See example, Figure B-6.)

B.60 [SOURce:]FUNCtion:MODE? QUERY

Syntax: Short Form: FUNC:MODE? Long Form: [SOURce:]FUNCtion:MODE?

Return Value: VOLT or CURR

Description: Identifies the operating mode of the power supply. VOLT = Constant Voltage mode (CV).

CURR = Constant Current mode (CC). (See example, Figure B-1.)

NOTES: 1. The power supply is assumed to be operating in constant voltage (CV) mode.

2 Examples below are typical (using BHK 1000-40MG), intended only to illustrate command functions. Refer to PAR. 3.6 for programming techniques to optimize performance.

VOLT 218; CURR 1.1e-2 Power supply programmed to 218V, 0.011A. VOLT 2.157E2 Power supply programmed to go to 215.7V.

VOLT? Returns 2.157E2, indicating programmed voltage = 215.7V.

VOLT? MAX For BHK 1000-40MG, returns 1000 (1000V). VOLT? MIN Returns 0 (minimum allowable voltage).

VOLT:PROT 2.365E+2 Voltage protection set to 236.5V.

VOLT? Returns 2.157E+2, indicating programmed voltage value = 215.7V. VOLT:PROT? Returns 2.365E+2, (programmed overvoltage protection = 236.5V

VOLT:PROT?MAX For BHK 1000-40MG, returns 1.1e+2 (1100V). VOLT 221; CURR 1.1E-2 Power supply programmed to go to 221V, 0.011A.

VOLT? Returns 221.

VOLT:LIM[:HIGH] 300 Voltage limit set to 300V.

VOLT:LIM[:HIGH]? Returns 300.

VOLT 333 Power supply not programmed to 333V., error message -301 posted.

VOLT? Returns 2.21e2.

FIGURE B-6. PROGRAMMING VOLTAGE

B.61 STATus:OPERation:CONDition QUERY

STAT:OPER:COND?

Syntax: Short Form: STAT:OPER:COND? Long Form: STATus:OPERation:CONDition?

Return Value: <int_value> 0 to 1313 (1 + 32 + 256 + 1024).

Description: Returns the value of the Operation Condition Register (see Table B-2). The Operation Condition

Register contains unlatched real-time information about the operating conditions of the power supply. Bit set to 1 = function enabled (active, true); bit reset to 0 = function disabled (inactive, false). (See

example, Figure B-7.)

TABLE B-2. OPERATION CONDITION REGISTER, OPERATION ENABLE REGISTER, AND OPERATION EVENT REGISTER BITS

CONDITION	NU	CC	NU	CV	NU	WTG	NU	CAL
BIT	15-11	10	9	8	7 - 6	5	4 - 1	0
VALUE	32,768 - 2048	1024	512	256	128 - 64	32	16 -2	1

CAL - INTERFACE COMPUTING NEW CALIBRATION CONSTANTS

CC - POWER SUPPLY IN CONSTANT CURRENT MODE
CV - POWER SUPPLY IN CONSTANT VOLTAGE MODE

NU - NOT USED

WTG WAIT FOR TRIGGER (SET BY INIT SUBSYSTEM)

B.62 STATus: OPEReration: ENABle COMMAND

STAT:OPER:ENAB

Syntax: Short Form: STAT:OPER:ENAB <int_value> 0 to 1313 (1 + 32 + 256 + 1024)

Long Form: STATus:OPERation:ENABle <int value> 0 to 1313 (1 + 32 + 256 + 1024)

Description: **Sets Operation Enable Register.** The Operation Enable Register is a mask for enabling specific bits in the Operation Event Register which will cause the operation summary bit (bit 7) of the Status Byte register to be set Bit set to 1 = function enabled (active, true); bit reset to 0 = function disabled (inactive, false). The operation summary bit is the logical OR of all the enabled bits in the Operation Event

register. (See example, Figure B-7.)

NOTE: The power supply is assumed to be operating in cV (constant voltage) mode.

STAT:OPER:ENAB 1056Mask enabled for CC, WTG and bits.

STAT:OPER:ENAB? Returns 1056 (32 + 1024) (CC, WTG bits set).

STAT:QUES:ENAB 3 Mask enabled for OV and OC bits (1 + 2).

STAT:QUES:ENAB? Returns 3 (1 + 2) indicating OV and OC bits are enabled.

STAT:PRES Operation Condition and Questionable Condition registers are

reset.

INIT:CONT ON Continuous triggers enabled.

STAT:OPER:COND? Power supply returns 288 (256 + 32) to indicate that power

supply is constant voltage mode and Wait For Trigger is true.

--- OUTPUT MOMENTARILY SHORTED.

STAT:OPER? Returns 1057, e.g., indicating that since the last reading of the

Operation Event Register the power supply has entered

Constant Current mode, the Wait Trigger was set.

STAT:OPER? Returns 0 indicating no changes since previous reading of the

Operation Event register.

STAT:QUES? Returns 0 (no questionable conditions occurred since previous

reading

--- OVERTEMPERATURE CONDITION OCCURS.

STAT:QUES? Returns 8 (overtemperature condition tripped since the last

STAT:QUES? query).

STAT:QUES:COND? Returns 8, (Power supply still in overtemperature condition).

STAT:QUES? Returns 0, (Power supply no longer in overtemperature

condition).

STAT:QUES:COND? Returns 2, (Power supply still in overcurrent protection state).

SYST:ERR? Power supply returns 0, "No error" message.

FIGURE B-7. USING STATUS COMMANDS AND QUERIES

B.63 STATus: OPEReration: ENABle? QUERY

STAT:OPER:ENAB?

Syntax: Short Form: STAT:OPER:ENAB? Long Form: STATus:OPERation:ENABle?

Return Value: <int_value> 0 to 1313 (1 + 32 + 256 + 1024).

B-16 BHK-MG 110504

Description: Reads Operation Enable Register (see Table B-2). Returns value of Operation Enable Register

bits. Bit set to 1 = function enabled (active, true); bit reset to 0 = function disabled (inactive, false).

(See example, Figure B-7.)

B.64 STATus:OPERation[:EVENt] QUERY

STAT: OPER?

Syntax: Short Form: STAT:OPER[:EVEN]? Long Form: STATus:OPERation[:EVENt]?

Return Value: <int_value> 0 to 1313 (1 + 32 + 256 + 1024).

Description: Indicates changes in conditions monitored by Operational Event Register. Returns the value of

the Operation Event register. The Operation Event register is a read-only register which holds (latches) all events that occur. Reading the Operation Event register clears it.. (See example, Figure

B-7.)

B.65 STATus:PRESet COMMAND

STAT: PRES

Syntax: Short Form: STAT:PRES Long Form: STATus:PRESet

Description: Disables reporting of all status events. This command sets all bits of the Operation Condition

(Table B-2) and Questionable Condition Registers to 0, preventing all status events from being

reported. (See example, Figure B-7.)

B.66 STATus:QUEStionable[:EVENt]? QUERY

STAT: QUES?

Syntax: Short Form: STAT:QUES[EVEN]? Long Form: STATus:QUEStionable[EVENT]?

Return Value: <int_value> actual register value

Description: Indicates questionable events that occurred since previous STAT:QUES? query. Returns the

value of the Questionable Event register (see Table B-3). The Questionable Event register is a read-only register which holds (latches) all events. Reading the Questionable Event register clears it.

(See example, Figure B-7.)

TABLE B-3. QUESTIONABLE EVENT REGISTER, QUESTIONABLE CONDITION REGISTER AND QUESTIONABLE CONDITION ENABLE REGISTER BITS

CONDITION	NU	ОТ	NU
BIT	BIT 15 - 4		2 - 0
VALUE	32,768 - 16	8	4 - 1

OT - OVERTEMPERATURECONDITION NU - NOT USED

B.67 STATus: QUEStionable: CONDition? QUERY

STAT: QUES: COND?

Syntax: Short Form: STAT:QUES:COND? Long Form: STATus:QUEStionable:CONDition?

Return Value: <int_value> actual register value

Description: Returns the value of the Questionable Condition Register (see Table B-3). The Questionable

Condition Register contains unlatched real-time information about questionable conditions of the power supply. Bit set to 1 = condition (active, true); bit reset to 0 = condition (inactive, false). (See

example, Figure B-7.)

B.68 STATus: QUEStionable: ENABle Command

STAT: QUES: ENAB

Syntax: Short Form: STAT:QUES:ENAB <int value> Long Form: STATus:QUESionable:ENABle <int value>

Function: Programs Questionable Condition Enable Register.

Description: Programs Questionable Condition Enable Register (see Table B-3). The Questionable Condition

Enable Register determines which conditions are allowed to set the Questionable Condition Register; it is a mask for enabling specific bits in the Questionable Event register that can cause the questionable summary bit (bit 3) of the Status Byte register to be set. The questionable summary bit is the logical OR of all the enabled bits in the Questionable Event register. Bit set to 1 = function enabled

(active, true); bit reset to 0 = function disabled (inactive, false). (See example, Figure B-7.)

B.69 STATus: QUEStionable: ENABle? QUERY

STAT:QUES:ENAB?

Syntax: Short Form: STAT:QUES:ENAB? Long Form: STATus:QUESionable:ENABle?

Return Value: <int value> actual register value

Description: Reads Questionable Condition Enable Register (see Table B-3). Power supply returns value of

Questionable Condition Enable Register, indicating which conditions are being monitored. Bit set to 1 = function enabled (active, true); bit reset to 0 = function disabled (inactive, false). Related Com-

mands: STAT:QUES?. (See example, Figure B-7.)

B.70 SYSTem:COMMunication:GPIB:ADDRess COMMAND SYST:COMM:GPIB:ADDR

Syntax: Short Form: SYST:COMM:GPIB:ADDR<INT VAL> 1 to 30

Long Form: SYSTem:COMMunication:GPIB:ADDRess<INT VAL> 1 to 30

Description: Sets selected power supply GPIB address.

B.71 SYSTem:COMMunication:GPIB:ADDRess? QUERY SYST:COMM:GPIB:ADDR?

Syntax: Short Form: SYST:COMM:GPIB:ADDR?

Long Form: SYSTem:COMMunication:GPIB:ADDRess?

Return Value: <int value> 1 to 31

Description: Sets selected power supply GPIB address.

B.72 SYSTem:COMMunication:SERial:BAUD COMMAND SYST:COMM:SER:BAUD

Syntax: Short Form: SYST:COMM:SER:BAUD {19200 | 9600 | 4800 | 2400}

Long Form: SYSTem:COMMunication:SERial:BAUD {19200 | 9600 | 4800 | 2400}

Description: Sets the unit to operate at the specified baud rate.

B.73 SYSTem:COMMunication:SERial:BAUD? QUERY SYST:COMM:SER:BAUD?

Syntax: Short Form: SYST:COMM:SER:BAUD?

Long Form: SYSTem:COMMunication:SERial:BAUD? Return Value: <int value> {19200 | 9600 | 4800 | 2400}

Description: Returns operating baud rate.

B.74 SYSTem:COMMunication:SERial:ECHO COMMAND SYST:COMM:SER:ECHO

Syntax: Short Form: SYST:COMM:SER:ECHO (ON | OFF)

Long Form: SYSTem:COMMunication:SERial:ECHO {ON | OFF}

Description: Enables (ON) or disables (OFF) echo mode (see PAR. 3.5.3.1) Sending ON causes all subsequent

characters to be echoed back. Sending OFF turns off the character echo after the nest line terminator

character. The *RST command has no effect on echo status

B.75 SYSTem:COMMunication:SERial:ECHO? QUERY SYST:COMM:SER:ECHO?

Syntax: Short Form: SYST:COMM:SER:ECHO?

Long Form: SYSTem:COMMunication:SERial:ECHO?

Return Value: {ON | OFF}

Description: Identifies whether echo mode is active (ON) or disabled (OFF) (see PAR. 3.5.3.1).

B.76 SYSTem:COMMunication:SERial:PACE COMMAND SYST:COMM:SER:PACE

Syntax: Short Form: SYST:COMM:SER:PACE {NONE | XON}

Long Form: SYSTem:COMMunication:SERial:PACE {NONE | XON}

Description: Enables (XON) or disables (NONE) data flow control via the serial interface (see PAR. 3.5.3.3)

B.77 SYSTem:COMMunication:SERial:PACE? QUERY SYST:COMM:SER:PACE?

Syntax: Short Form: SYST:COMM:SER:PACE {NONE | XON}

Long Form: SYSTem:COMMunication:SERial:PACE {NONE | XON}

Return Value: {XON | NONE}

B-18 BHK-MG 110504

Description: Identifies whether data flow control via the serial interface is enabled (XON) or disabled

(NONE) (see PAR. 3.5.3.3).

B.78 SYSTem:COMMunication:SERial:PROMpt COMMAND SYST:COMM:SER:PROM

Syntax: Short Form: SYST:COMM:SER:PROM (ON | OFF)

Long Form: SYSTem:COMMunication:SERial:PROMpt {ON | OFF}

Description: Enables (ON) or disables (OFF) prompt (see PAR. 3.5.3.2). Sending ON causes the unit to return >

character after the command is parsed.

B.79 SYSTem:COMMunication:SERial:PROMpt? QUERY SYST:COMM:SER:PROM?

Syntax: Short Form: SYST:COMM:SER:PROM {ON | OFF}

Long Form: SYSTem:COMMunication:SERial:PROMpt {ON | OFF}

Return Value: {ON | OFF}

Description: Identifies whether prompt is enabled (ON) or disabled (OFF) prompt (see PAR. 3.5.3.2).

B.80 SYSTem:ERRor? QUERY

SYST:ERR?

Syntax: Short Form: SYST:ERR? Long Form: SYSTem:ERRor?

Return Value: <int_value,string>

Description: Posts error messages to the output queue. Returns the next error number followed by its corre-

sponding error message string from the instrument error queue. The error queue is a FIFO (first in first out) buffer that stores errors as they occur. As it is read, each error is removed from the queue and the next error message is made available. When all errors have been read, the query returns 0,"No error". If more than 15 errors are accumulated, it will overflow. The oldest errors stay in the queue but the most recent errors are discarded. The last error in the queue will be -350,"Too many errors." Error

messages are defined in Table B-4.

B.81 SYSTem:ERRor:CODE? QUERY

SYST:ERR:CODE?

Syntax: Short Form: SYST:ERR:CODE?] Long Form: SYSTem:ERRor:CODE?

Description: Returns the three character error code without the ASCII definition string. The error codes are defined

in table B-4 (See example, Figure B-1.)

B.82 SYSTem:ERRor:CODE:ALL? QUERY

SYST:ERR:CODE:ALL?

Syntax: Short Form: SYST:ERR:CODE:ALL?] Long Form: SYSTem:ERRor:CODE:ALL?

Return Value:

Description: Returns a comma-separated list of all error codes. A maximum of 15 codes will be returned; if the

queue is empty, the power supply returns 0.

B.83 SYSTem:KLOCk COMMAND

SYST:KLOC

Syntax: Short Form: SYST:KLOC <boolean> Long Form: SYSTem:KLOCk <boolean>

<boolean> (0 or OFF, 1 or ON)

Description: Locks (ON or 1) or unlocks (OFF or 0) the keypad. With the keypad unlocked the power supply

enters Remote mode as soon as a command or query is received. Once in Remote mode (with keypad unlocked) the front panel keys are disabled with the exception of the LOCAL key, which is used to

return to Local mode.

After sending a SYST:KLOC ON (keypad lock) command, all front panel keys, including LOCAL, are disabled. The power supply is now in the "local lockout" state and the LCD changes from Loc to Rwl. Local lockout can also be entered by sending the GPIB <LLO> code (hex 11) to the power supply. The power supply remains in "local lockout" until a SYST:KLOC OFF command is received. Related Com-

mands: SYST:KLOCK?. (See example, Figure B-8.)

B.84 SYSTem:KLOCk? QUERY

SYST: KLOC?

Syntax: Short Form: SYST:KLOC? Long Form: SYSTem:KLOCk?

Return Value: <int value> 0 or 1

Description: Identifies whether keypad is locked or unlocked. 0 = keypad unlocked, local operation possible by

pressing LOCAL key. 1 = keypad locked, LOCAL key disabled, only remote operation possible.

Related Commands: SYST:KLOCK. (See example, Figure B-8.)

SYST:VERS? Returns 2002.0.

SYST:KLOC ON keypad locked, only remote control possible.

SYST:KLOC? Returns 1 indicating keypad locked.

SYST:KLOC OFF keypad unlocked, pressing LOCAL key allows Local mode

operation.

SYST:KLOC? Returns 0 indicating keypad unlocked.

FIGURE B-8. USING SYSTEM COMMANDS AND QUERIES

B.85 SYSTem:LANGuage COMMAND

SYST:LANG

Syntax: Short Form: SYST:LANG {COMP | SCPI} Long Form: SYSTem:LANGuage {COMP | SCPI}

Description: Determines whether unit responds to older command formats. Sending SYST:LANG COMP causes the unit to respond to older formats such as LIST:TIME for compatible operation with software written for BHK-MG power supplies up to Revision 2.9. SYST:LANG COMP has been selected at the factory to permit the VISA demonstration program (which uses older command formats) to operate. SYST:LANG SCPI disables responses to older command formats.

B.86 SYSTem:LANGuage? QUERY

SYST:LANG?

Syntax: Short Form: SYST:LANG? Long Form: SYSTem:LANGuage?

Return Value: <string> SCPI or COMP

Description: Identifies whether unit responds to older command formats. SCPI means the unit will not

respond to older formats such as LIST:TIME. COMP means the unit will respond to older formats such as LIST:TIME for compatible operation with software written for BHK-MG power supplies. up to Revi-

sion 1

B.87 SYSTem:PASSword:CENable COMMAND

SYST:PASS:CEN

Syntax: Short Form: SYST:PASS:CEN <val> Long Form: SYSTem:PASSword:CENable <val>

Description: Sets the password enable state if the value matches the current password. This command allows

other commands such as *SAV 41 to operate.

B.88 SYSTem:PASSword:DISable COMMAND

SYST:PASS:DIS

Syntax: Short Form: SYST:PASS:DIS <val> Long Form: SYSTem:PASSword:DISable <val>

Description: Clears the password enable state if the value matches the current password.

B.89 SYSTem:PASSword:NEW COMMAND

SYST:PASS:NEW

Syntax: Short Form: SYST:PASS:NEW <old password>,<new password>

Long Form: SYSTem:PASSword:NEW <old password>,<new password>

Description: Establishes new password. The old (current) password is checked, then the replaced by the new

password. (See example, Figure B-2.)

B.90 SYSTem:PASSword:STATe? QUERY

SYST:PASS:STAT?

Syntax: Short Form: SYST:PASS:STAT? Long Form: SYSTem:PASSword:STATe?

Return Value: <int value> 0 or 1

B-20 BHK-MG 110504

Description: Returns a 1 if the password state is enabled or a 0 if it is disabled.

B.91 SYSTem:SECurity:IMMediate COMMAND

SYST:SEC:IMM

Syntax: Short Form: SYST:SEC:IMM Long Form: SYSTem:SECurity:IMMediate

Description: Initializes all NVRAM variable to factory defaults. This includes all memory steps to be set to 0 volts,

1.28% of full scale current, overvoltage and overcurrent to be set to lomax+10%, time value to be set to 0, and next step equal to 0. It also initializes the power -up state to have DC Output Control off (see

PAR 3.2.6.4). The calibration password is reset per Table 4-1.

B.92 SYSTem:SET COMMAND

SYST:SET

Syntax: Short Form: SYSTem:SET {CM0 | CM1} Long Form: SYSTem:SET {CM0 | CM1}

Description: Sending SYST:SET CM1 sets the BHK to operate in compatible mode and have all GPIB functions

compatible with earlier full rack BHK-MG models. Sending SYST:SET CM0 sets the unit to be fully

SCPI 1987 compliant.

B.93 SYSTem:VERSion QUERY

SYST:VERS?

Syntax: Short Form: SYST:VERS? Long Form: SYSTem:VERSion?

Return Value: <int value>.<int value> (YYYY.V)

Description: Identifies SCPI Version implemented. Returns SCPI Version number:

YYYY = year, V = Revision number for specified year. (See example, Figure B-8.

B.94 TRIGger:SOURce COMMAND

TRIG:SOUR

Syntax: Short Form: TRIG:SOUR {EXT | BUS} Long Form: TRIGger:SOURce {EXT | BUS}

Description: Sending TRIG:SOUR activates either internal (BUS) or external (EXT) trigger. When the external trig-

ger (ground) is applied to J2 pin 3, output voltage and current are set to previously stored values for

VOLT:TRIG and CURR:TRIG.

NOTE: If INIT:CONT 1 was sent prior to sending TRIG:SOUR EXT, continuous mode is disabled and

unit will wait for INIT:IMM

TABLE B-4. ERROR MESSAGES

ERROR MESSAGE	ESR ERROR BIT SET (SEE PAR. A.5)	EXPLANATION
O,"No error"	None	No error
-100, "Command error"	Command Error bit 5	Command and data understood, but more information included which is not recognized.
-102,"Syntax error"	Command Error bit 5	First 4 characters recognized, subsequent characters not recognized.
-103,"Invalid separator"	Command Error bit 5	For example, VOLT.PROT received instead of VOLT:PROT
-108,"Parameter Not Allowed Error"	Command Error bit 5	Volt12 sequence, channel number is invalid
-109,"Missing parameter"	Command Error bit 5	For example, VOLT instead of VOLT 21.
-111,"Header separator error"	Command Error bit 5	Missing space between volt and value or ; missing
-113,"Undefined header"	Command Error bit 5	First 4 characters could not be identified as legal command.For example, command VLT instead of VOLT
-120,"Numeric data error"	Command Error bit 5	Expected number but other characters were detected

TABLE B-4. ERROR MESSAGES (CONTINUED)

ERROR MESSAGE	ESR ERROR BIT SET (SEE PAR. A.5)	EXPLANATION
-121,"Invalid character in number"	Command Error bit 5	Volt 1,500 (comma not allowed)
-123,"Exponent too large"	Command Error bit 5	Exponent E+3 or greater is invalid.
-141,"Invalid character data"	Command Error bit 5	For example OUTP OFD or OUTP STOP instead of OUTP OFF
-150,"String data error"	Command Error bit 5	Invalid characters were detected in numeric entry.For example E.1 instead of E+1 or 4d3 instead of 4.3.
-203,"Command protected"	Execution error bit 4	Command only valid in password Cenable state
-221,"Settings Conflict"	Execution error bit 4	Invalid password from syst:pass:cen command
-222, "Data out of range"	Execution error bit 4	Value exceeds power supply rating
-223,"Data format error"	Execution error bit 4	Multiple decimals in digit, Multiple E, etc.
-224, "Illegal parameter value"	Execution error bit 4	For example, OUTP 2 instead of OUTP 1
-226,"Lists not Same Length"	Execution error bit 4	Dwell list does not match voltage or current list, or no points found for voltage or current list.
-241,"Hardware missing"	Execution error bit 4	Requesting device 2 status (INST:NSEL 2)
-282,"Illegal program name"	Execution error bit 4	Executing prog:run without LIST:SEQ command
-301,"Value bigger than limit"	Device Error bit 3 (1)	Requesting a time of 301 which is bigger than limit
-311,"Memory error"	Device Error bit 3 (1)	Power-up NV RAM error
-314,"Save/recall memory error"	Device Error bit 3 (1)	Using cell other than 1 - 41 for SAV and RCL
-341,"Non Volatile Mem. CRC error"	Device Error bit 3 (1)	Power supply constants may be corrupted; recalibration may be necessary.
-350,Queue overflow	Device Error bit 3 (1)	More than 15 errors are in queue.
-410,"Query interrupted	Query Error bit 2	New command sent before data from previous query read. Previous query data lost.
-430,Query Deadlocked	Query Error bit 2	Over 255 characters received in single input string.

⁽¹⁾ The Device error bit may be set when the status monitoring functions of the power supply detect an overvoltage/undervoltage condition.

B-22