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OPERATOR'S MANUAL

BHK-MG FULL RACK SERIES

POWER SUPPLY

VOLTAGE/CURRENT-STABILIZED DC SOURCE

KEPCO INC.
An ISO 9001 Company.

MODELS

BHK 300-0.6MG
BHK 500-0.4MG
BHK 1000-0.2MG
BHK 2000-0.1MG

IMPORTANT NOTES:

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

MODEL	SERIAL NO.	REV. NO.

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

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THE POWER SUPPLIER™

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

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.



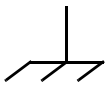
The PROTECTIVE EARTHING CONDUCTOR TERMINAL must properly connected prior to application of source power to the product (see instructions on installation herein) in order to ensure safety from electric shock.



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

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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.

WARNING

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 OUTPUT is set to off from the keypad or the GPIB, an analog input will still produce an output from the BHK-MG which will be indicated on the LCD. If the output is greater than 8 Volts and the current is higher than 2 LSB's, a shutdown sequence begins: the unit will beep, the LCD will flash DIGITAL IS OFF and SET ANALOG OFF, and the unit will shut down within 25 seconds unless the analog input is turned off. The beeping and controlled shutdown function can be overridden by a jumper option (see Table 2-9.)

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

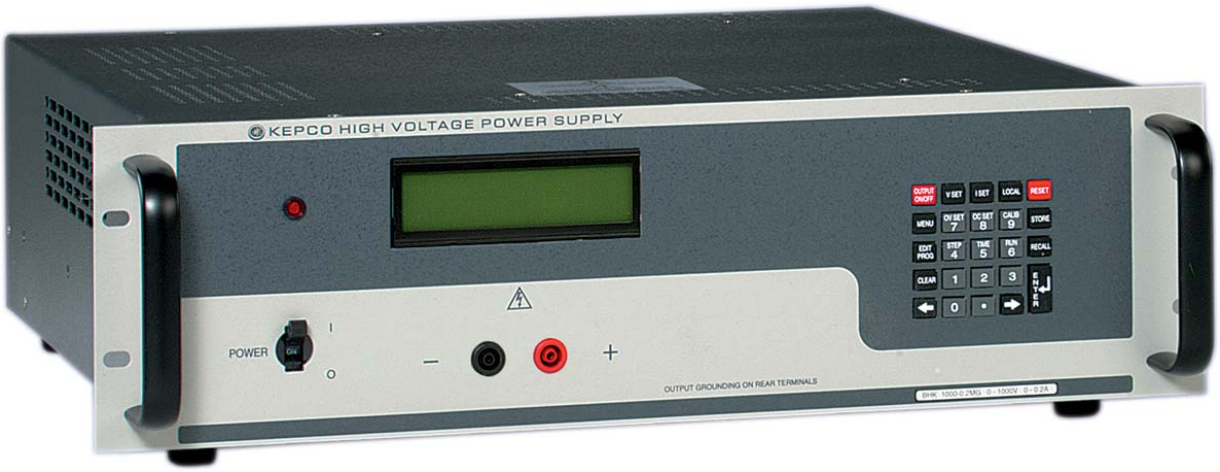


FIGURE 1-1. BHK-MG SERIES PROGRAMMABLE POWER SUPPLY

SECTION 1 - INTRODUCTION

1.1 SCOPE OF MANUAL

This manual contains instructions for the installation and operation of the BHK-MG series of 200W output power stabilized voltage or current, d-c power supplies manufactured by KEPCO, Inc., Flushing, New York, U.S.A.

WARNING

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 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, each of which have two output current ranges as listed in Table1-1.

Although designed as a stand-alone bench top unit, the full-rack cross section permits mounting in a standard 19-inch wide rack (see Table1-5). Connections can be made at both rear output terminals (recommended for rack mounted configurations) and front output terminals (recommended for bench applications). 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 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 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 either the IEEE 488.2 (GPIB) or RS 232 communication bus using SCPI commands. 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.

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

MODEL NUMBER	OUTPUT VOLTAGE RANGE 0 - E_OMax (VOLTS	OUTPUT CURRENT RANGE		MAXIMUM OUTPUT POWER (WATTS)		OUTPUT EQUIVALENT IMPEDANCE (FAST MODE)					
						VOLTAGE MODE (SERIES R–L)		CURRENT MODE (PARALLEL R–C)			
		High Scale 0 - $I_O max_H$ (mA)	Low Scale 0 - $I_O max_L$ (mA)	High Scale	Low Scale	R_{d-c} (Ohms)	L (mH)	R_{d-c} (MOhms)		C (μF)	
								High Scale	Low Scale	High Scale	Low Scale
BHK 300-0.6MG	0 - 300	0 - 600	0 - 60	180	18	0.025	2.0	3.33	33.3	0.013	0.008
BHK 500-0.4MG	0 - 500	0 - 400	0 - 40	200	20	0.0625	3.6	8.3	83	0.012	0.007
BHK 1000-0.2MG	0 - 1000	0 - 200	0 - 20	200	20	0.25	6.0	33	333	0.005	0.003
BHK 2000-0.1MG	0 - 2000	0 - 100	0 - 10	200	20	1.0	35	133	1333	0.002	0.001

TABLE 1-2. BHK-MG 200W SPECIFICATIONS

SPECIFICATION		RATING/DESCRIPTION	CONDITION
INPUT CHARACTERISTICS			
a-c Voltage	nominal (switch selectable)	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	4.0A a-c	200W at output
	230V a-c	2.1A a-c	
OUTPUT CHARACTERISTICS			
NOTE: Current specifications contained in this table refer to source current (delivered by the unit to the load). Sink current (absorbed by the unit from the load) occurs when the output voltage is programmed to a lower value. The sink current is constant, from 45% to 55% of High Current scale rating; it flows until the output reaches the lower voltage.			
Type of Stabilizer		Linear with automatic crossover	Voltage/Current
Adjustment range (Adjustment is either continuous using analog programming, or stepped using digital programming)	Voltage	0 to 100% of E_O max	See PAR. 1.4.2.2 and 1.4.2.3 for details about analog programming and readback. Use Menu program to change current scale (See PAR 3.2.10)
	Current (high scale) Current (low scale):	0-100% of I_O max_H 0-100% of I_O max_L	
Digital Programming resolution	Voltage Current	0.025% of E_O max 0.025% of I_O $max_{(H, L)}$	Current measurement requires calibrated shunt (see PAR. 4.2)
Digital Programming accuracy	Voltage	0.025% of E_O max	
	Current	0.05% of I_O $max_{(H, L)}$	
Digital Data Readback accuracy	Voltage	0.05% of E_O max	
	Current	0.05% of I_O $max_{(H, L)}$	For I_O of 9% (1) to 100% of I_O max
		0.02% of I_O $max_{(H, L)}$	For I_O of 0 to <9% (1) of I_O max (automatic 10X magnifier)
Source effect	Voltage	0.001% E_O max	Input voltage 105-125/210-250V a-c
	Current	0.002% I_O $max_{(H, L)}$	
Load effect	Voltage	0.005% E_O max	no load - full load
	Current	0.015% I_O $max_{(H, L)}$	short - full load
(1) 9% is actually between 8.98% and 9.69% of I_O max (see PAR. 1.4.7 for details).			

TABLE 1-2. BHK-MG 200W SPECIFICATIONS (Continued)

SPECIFICATION			RATING/DESCRIPTION	CONDITION
OUTPUT CHARACTERISTICS (CONTINUED)				
Temperature effect (per degree C)		Voltage	0.01% E_O max	Ambient temperature 0 to 50° C
		Current	0.02% I_O $max_{(H, L)}$	
Time effect		Voltage	0.01% E_O max	0.5-8.5 hours Ambient temperature: 25° C
		Current	0.02% I_O $max_{(H, L)}$	
Ripple (rms/p-p)	Voltage:	Fast Mode	0.002% / 0.02% E_O max	Minus output terminal connected to GND. Voltage: Nominal load Current: Short with calibrated shunt.
		Slow Mode	0.001% / 0.01% E_O max	
Fast Mode = internal output capacitor not connected. Slow Mode (default) = internal output capacitor connected	Current:	Fast Mode	0.02% / 0.2% I_O $max_{(H, L)}$	
		Slow Mode	0.01% / 0.1% I_O $max_{(H, L)}$	
Programming rise time (R)/fall time (F)	Voltage:	Fast Mode	180µs (R)/180µs (F)	Load ≥ E_O max/I_O max, Vout between zero and E_O max, measured between 10% and 90% of E_O max
		Slow Mode	90ms (R)/175ms (F)	
	Current:	Fast Mode	200µs (R)/200µs (F)	Load ≤E_O max/I_O max, Iout between zero and I_O $max_{(H, L)}$, measured between 10% and 90% of I_O $max_{(H, L)}$
		Slow Mode	90ms (R)/175ms (F)	
Transient recovery to load change (Amplitude/time constant)	Voltage	Fast Mode	5% E_O max/100 µsec	Vout=400 Vdc and load switched between infinity and 400/I_O max
		Slow Mode	0.5% E_O max/1 msec	
	Current	Fast Mode	50% I_O max/100 µsec	Iout = 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 $max_{(H, L)}$, 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)	Load ≥ E_O max/I_O max, Measured as the chord of the exponential response to a square waveform between zero and E_O max and back to zero.
		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 $max_{(H, L)}$ and back to zero.
Overshoot			None	Turn ON/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 300-0.6MG, BHK 500-0.4MG, BHK 1000-0.2MG	1KV d-c or p-p plus max. output voltage	Between either output terminal and ground
		BHK 2000-0.1MG	0.5KV d-c or p-p plus max. output voltage	Between either output terminal and ground

TABLE 1-2. BHK-MG 200W SPECIFICATIONS (Continued)

SPECIFICATION		RATING/DESCRIPTION	CONDITION
OUTPUT CHARACTERISTICS (CONTINUED)			
Withstand voltage	(All models)	1350V a-c/1 min	Between shorted inputs and chassis
	BHK 300-0.6MG	1950V d-c/1 min	Between shorted outputs and chassis.
	BHK 500-0.4MG	2250V d-c/1 min	
	BHK 1000-0.2MG	2800V d-c/1 min	
	BHK 2000-0.1MG		
Chassis connection to ground resistance		100 mohms max.	Between ground input connection and chassis @ 30A
Leakage Current		25 µA rms /100 uA p-p, for 115V a-c input voltage (chassis to EARTH-GND)	
Enable/Disable Output Power	Local	Front panel Keypad	Enables/disables digital programming signals only. Shutdown line is for disable only - removing the signal does not reenable the output (See PAR. 3.2.7.3).
	Remote	- IEEE 488 (GPIB) port - RS 232 port - Trigger port (shutdown line)	
Output Display		Output voltage is displayed with two decimals for BHK 300-0.6MG and BHK 500-0.4MG and one decimal for BHK 1000-0.2MG and BHK 2000-0.1MG.Output current for all models is displayed with two decimals when current range is set to High, and three decimals when current range is set to Low.	
Protection	Overtemperature:		See PAR. 1.4.10a
	Overvoltage/Overcurrent:	0 to 1.1 x $E_O max$ 0 to 1.1 x $I_O max_{(H, L)}$ (except BHK 300-0.6MG) 0 to 1.08 x $I_O max_{(H, L)}$ (BHK 300-0.6MG only)	See PAR. 1.4.4
	Uneven voltage/current in pass element:		See PAR. 1.4.10c
	Fan failure:		See PAR. 1.4.10d
	AC line failure:		See PAR. 1.4.10e
	Interruption between sensing and power terminals:		See PAR. 1.4.10f
	Overload of main or auxiliary power transformer:		See PAR. 1.4.10g
Internal Output Capacitor (Default state = internal output capacitor connected.)	BHK 300-0.6MG	20 µF ±6%	All internal output capacitors are non-polarized type.
	BHK 500-0.4MG	10 µF ±6%	
	BHK 1000-0.2MG	4 µF±10%	
	BHK 2000-0.1MG	2 µF±10%	
Reference Voltages for analog programming:		+10 ±-0.2V d-c –10 ±-0.2V d-c	max.10 mA d-c
Status port	Type	Output transistor (open collector) from an optocoupler	
	Output Ratings	Ic = 8mA d-c, Vceo = 40V d-c, Pd = 150mW@25° C	
	Logic	Saturated transistor when AC line is present	
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.

TABLE 1-2. BHK-MG 200W SPECIFICATIONS (Continued)

SPECIFICATION		RATING/DESCRIPTION	CONDITION
GENERAL (ENVIRONMENTAL) CHARACTERISTICS			
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 air to rear	
PHYSICAL CHARACTERISTICS			
Dimensions		See Figure 1-2.	
Weight	English	45 lbs.	Unpacked
	Metric	20 Kg	
a-c source connections	Front	Circuit Breaker, 2-pole	
	Rear	Detachable IEC 3-wire type connector Interlock switch, 1-pole	Interlock switch monitors plastic cover over rear panel terminals.
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 panel keypad(24 pads) and LCD	
	Remote:	Digital control using rear panel IEEE 488 Bus (24 pin female connector). Analog control using two rear panel terminal strips (10 positions) for voltage and current	
Digital display front panel		Voltage, current, mode, settings, menu, program, etc.	2 x 16 character alphanumeric LCD with LED backlight

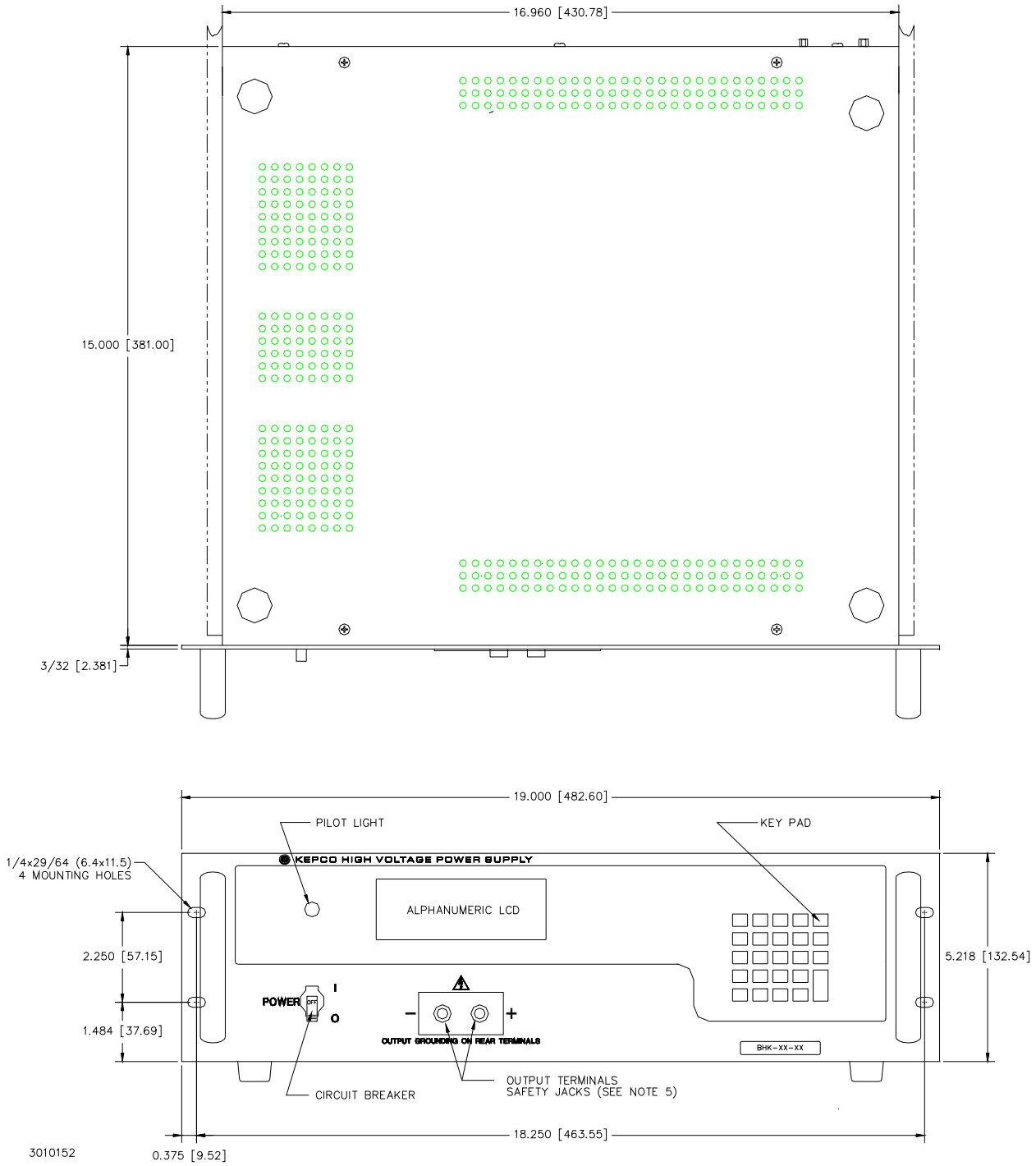
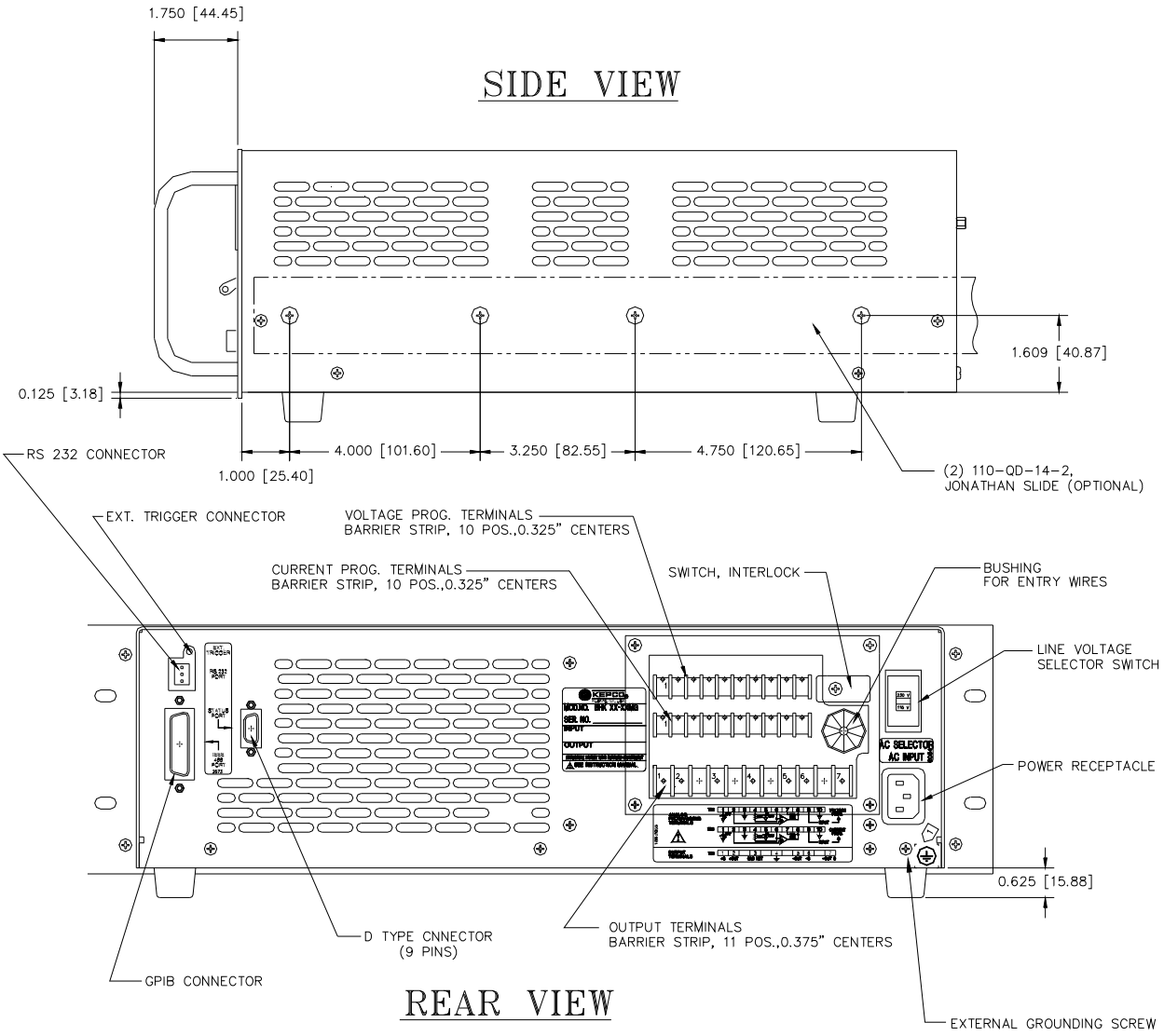


FIGURE 1-2. BHK SERIES POWER SUPPLY, MECHANICAL OUTLINE DRAWING (SHEET 1 OF 2)



NOTES:

1. MATERIAL: A) CHASSIS: #14 GA. C.R.S.
   B) FRONT PANEL: 3/32 THICK 6061-T6 ALUMINUM.
   C) COVER & BACK PLATE: #16 GA. C.R.S.
2. FINISH: A) CHASSIS & BACK PLATE: CADMIUM PLATE WITH CHROMATE WASH.
   B) COVER: CHARCOAL GRAY VINYL TEXTURE
   C) FRONT PANEL: LIGHT GRAY PER FEDERAL STD. 595, COLOR #26440.
3. DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS.
4. TOLERANCES: A. BETWEEN MOUNTING HOLES: ±1/64 (0.4)
   B. ALL OTHER DIMENSIONS ±1/32 (0.8), EXCEPT AS NOTED.
5. MATING PLUGS ARE SUPPLIED BY KEPCO

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

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 Power Supply can be accomplished either through digital or analog programming.

1.4.2.1 DIGITAL PROGRAMMING

Digital control is available directly via either the IEEE 488.2 (GPIB) or RS 232 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 3.5 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 –10V d-c 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. The analog programming port is not calibrated, however the zero point is accurate to less than 0.1%. The full scale tolerance is 2% maximum when using the preamplifier with external matched-pair resistors. Refer to PAR. 3.6 for more information about remote programming using the analog programming terminals.

1.4.2.3 ANALOG READBACK

The output voltage and current analog readback signals (uncalibrated), as well as some flag signals, are available for testing and customer usage via an internal connector (A2J5). Refer to Table 1-3 for details about A2J5 signals; refer to Table 1-5 to obtain the A2J5 mating connector. See Figure 1-3 for connector A2J5 location. Wires (with isolation rated for at least the nominal output voltage of the unit) can be routed through the wire entry bushing at the rear panel (see Figure 2-2).

1.4.3 DIGITAL CALIBRATION

The BHK-MG 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.

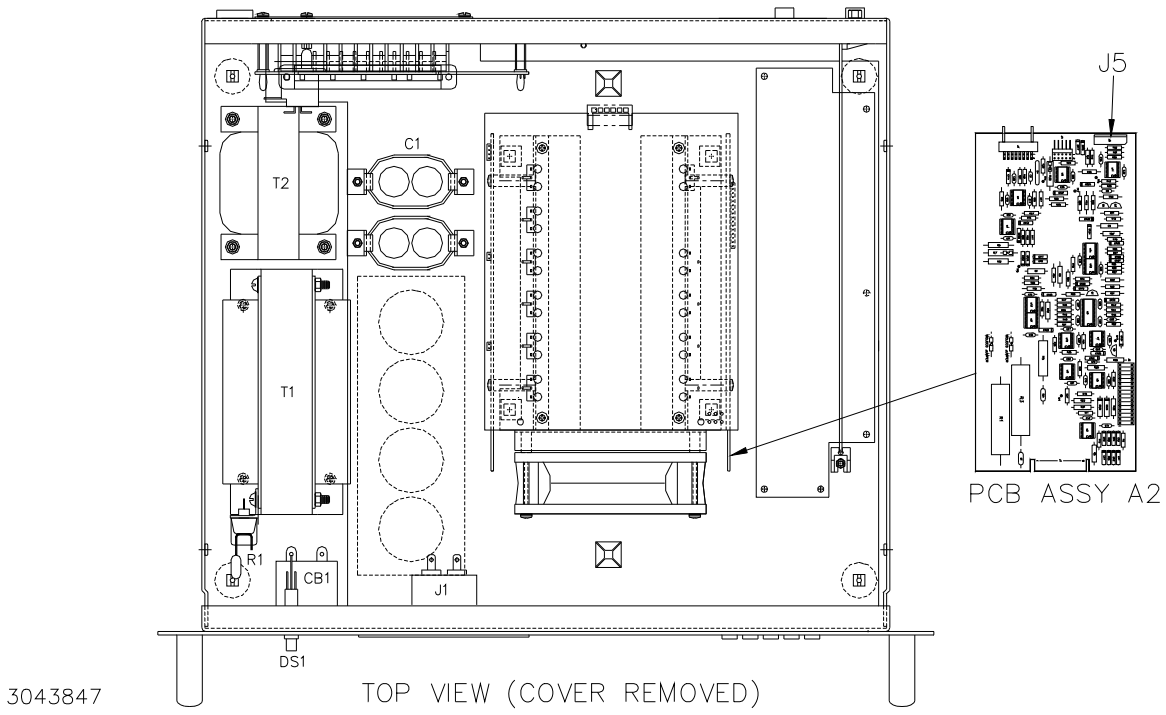


FIGURE 1-3. CONNECTOR A2J5 LOCATION

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 latches 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. 3.2.11 for more information.

1.4.5 USER-DEFINED VOLTAGE/CURRENT LIMITS

The BHK-MG Power Supply can be programmed not to exceed user-defined values that can be lower than the maximum values. For example, the BHK 500-0.4MG, which has maximum output values of 500V d-c, 0.4A d-c, can be limited to 100V d-c, 0.1A 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, 0.1A d-c supply and values exceeding the limit values will not be accepted. Refer to PAR. 3.2.12 for more information.

1.4.6 NONVOLATILE STORAGE OF PROGRAMMED SEQUENCES OR ACTIVE SETTINGS

The BHK-MG Power Supply contains 40 memory locations for each current range 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. 3.2.16 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. 3.2.13 and 3.2.14 for more information.

1.4.7 CURRENT SCALE

Output current of the power supply can be scaled down by a factor of 10, while at the same time increasing the current resolution by a factor of 10. For example the BHK 500-0.4MG has maximum output values of 500V d-c, 0.4A d-c and a current resolution of 0.1mA d-c; scaling down the output current results in a power supply with maximum values of 500V d-c, 0.04A d-c with a current resolution of 0.01mA d-c. Current scaling is easily accomplished using the Menu. Refer to PAR. 3.2.10 for more information.

Measurement of a decreasing output current of the power supply that falls below 8.98% ±0.01% of the rated value is automatically measured with increased resolution/accuracy by a factor of 10 until the current rises above 9.69% ±0.01% of rated value.

The factory setting is for the high current range, shown on the top line of the LCD in command entry status by the message "**Ihigh**." The current scale setting is retained, and displayed upon turn-on as either **Ihigh** or **Ilow.**

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. 3.7.1 for more information.

1.4.9 EXTERNAL TRIGGER PORT

The external trigger port provides two functions: a trigger input can be used to restore the output to previously defined settings using SCPI commands (see PAR. 3.3.4) and a shutdown input can be used to immediately shut down the power supply output (see PAR. 3.2.7.3).

1.4.10 BUILT-IN PROTECTION

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

a. **Overtemperature of the pass elemen**t. Heatsink temperature is monitored. If an overtemperature condition is maintained for more than 0.5ms, the following actions are initiated: the pass element is cut off and latched off, the output capacitor is discharged, the LCD displays the error message “BHK FAILURE“ and an error message is sent on the IEEE 488 Bus.

b. **Overvoltage/overcurrent at the output.** See PAR. 1.4.4

c. **Uneven voltage/current in the pass element.** Voltage is monitored across different transistors of the pass element while current is monitored through the different branches. If uneven voltage/current continues for more than 11ms, the pass element is latched 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 Port connector)

d. **Fan failure.** If fan current drops below predetermined value continuously for more than 16ms, the pass element is latched off, the output capacitor is discharged, the LCD displays the error message “BHK FAILURE” and an error message is sent on IEEE 488 Bus.

e. **AC line failure.** If AC line is missing for more than 8 ms, a flag is sent to the host computer on a dedicated line (Status Port connector). In addition, if the jumper at A7-J12 is installed (default state), the pass element is latched 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 7A a-c @ 115V a-c or 3.5A a-c @ 230V a-c, the input POWER circuit breaker is tripped to OFF, the pass element is latched 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 overcurrent, to a maximum of 100 seconds for 25% above nominal current.

   If input current of the auxiliary power transformer exceeds a predetermined value, in most cases the input POWER circuit breaker is tripped to OFF (if jumper A7J12 is installed), the pass element is latched off, the output capacitor is discharged, and a flag is sent to the Status Port connector. If the cause of the overload is a problem in the protection circuit, the input POWER circuit breaker may not trip off: the pass element will be latched off and the output capacitor will discharge more slowly, and a flag is sent to the status port. The reaction time in this case is determined by PTC (positive temperature coefficient) thermistor A5R1 between 30 and 100 seconds.

h. **Current Limit.** The current through the main branch of the pass element is monitored. If this current is maintained between 1.8 to 2.2 times larger than the nominal value for more than 11ms, the pass element is latched off, the output capacitor is discharged, and the POWER circuit breaker is tripped to OFF.

1.4.11 CURRENT SINK CAPABILITY

BHK-MG 200W Series power supplies are able to sink up to 5% of the nominal current when in voltage mode and 50% 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%. Since negative current is not displayed on the front panel meter, it is transparent to the user when the unit enters sink mode.

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.

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 x 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.

Once the capacitor under test completely discharges, current from the power supply's internal current generator will flow through the output protection diode (or, in some models, multiple diodes), resulting in a slight reverse voltage at the output which will be clamped to the value of the voltage drop across the diode(s).

1.4.12 ANALOG READBACK AND FLAG 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

TABLE 1-3. CONNECTOR A2J5 SIGNAL DESCRIPTIONS

SIGNAL	PIN. NO.	VALUE	TYPE
Current Scale Flag	1	≈ 0V for HIGH current scale > +13V for LOW current scale	Collector of PNP transistor (A2Q3) through 1K resistance.*
Step Down Flag	2	< -11V for steady or step-up output > +11V for step-down output, or when protection circuit has functioned and "BHK FAILURE" error message is displayed	Output of open loop Op Amp (A2U4B) through 1K resistance.*
Power GND	3	N/A	Recommended to be used as Return for signals at pins 1, 2, and 4.*
V-C Mode Flag	4	< -11V for CV (Constant Voltage) mode > +11V for CC (Constant Current) mode	Output of open loop Op Amp (A2U4A) through 1K resistance.*
Signal GND	5, 7	N/A	Recommended to be used as Return for signals at pins 6 and 8.*
Current Monitor (not calibrated)	6	0V ± 10mV (for I_O = 0mA) to +10V ± 0.12V (for I_O = Full Scale)	Output of closed loop Op Amp (A2U7) *
Voltage Monitor (not calibrated)	8	0V ± 10mV (for E_O = 0V to) +10V ± 0.25V (for E_O = Full Scale)	Output of closed loop Op Amp (A2U1) *
* Recommended load equal to or greater than 10K ohms.			

1.5 EQUIPMENT SUPPLIED

Equipment supplied with the unit is listed in Table 1-4.

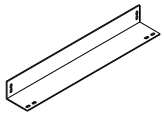
TABLE 1-4. EQUIPMENT SUPPLIED

ITEM	PART NUMBER	QUANTITY
Power Cord	118-0557	1
Plug, 2-contact for ± front panel output jacks	142-0489	1
Contact, pin type (used on plug 142-0489)	107-0361	2
Status Port mating connector	143-0296	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

1.6 ACCESSORIES

Accessories for the BHK Power Supply are listed in Table 1-5.

TABLE 1-5. ACCESSORIES

ITEM	FUNCTION	PART NUMBER
IEEE 488 (GPIB) Cable, 1m long	Connect BHK-MG Power Supply to GPIB bus.	SNC 488-1
IEEE 488 (GPIB) Cable, 2m long	Connect BHK-MG Power Supply to GPIB bus.	SNC 488-2
IEEE 488 (GPIB) Cable, 4m long	Connect BHK-MG Power Supply to GPIB bus.	SNC 488-4
Slide (2)	Allows rack-mounted units to slide in and out.	CS-01, -02, -03 (Kepco) 110-QD-14-2 (Jonathan)
Side Support “L” Bracket	L bracket mounts to vertical rails to provide additional side support for rack-mounted models.19.6 in. long x 2.3 in. high x 3.5 in. wide. Two (2) required per unit. 	128-1775
External Trigger Port mating connector	Allows access to external trigger function.	142-0527 (Kepco) SP-2501 (CUI)
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
Mating connector for A2J5 (Analog Readback and Flags)	Allow user access to analog readback and flag signal; see Table 1-3 for details.	143-0359

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

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.

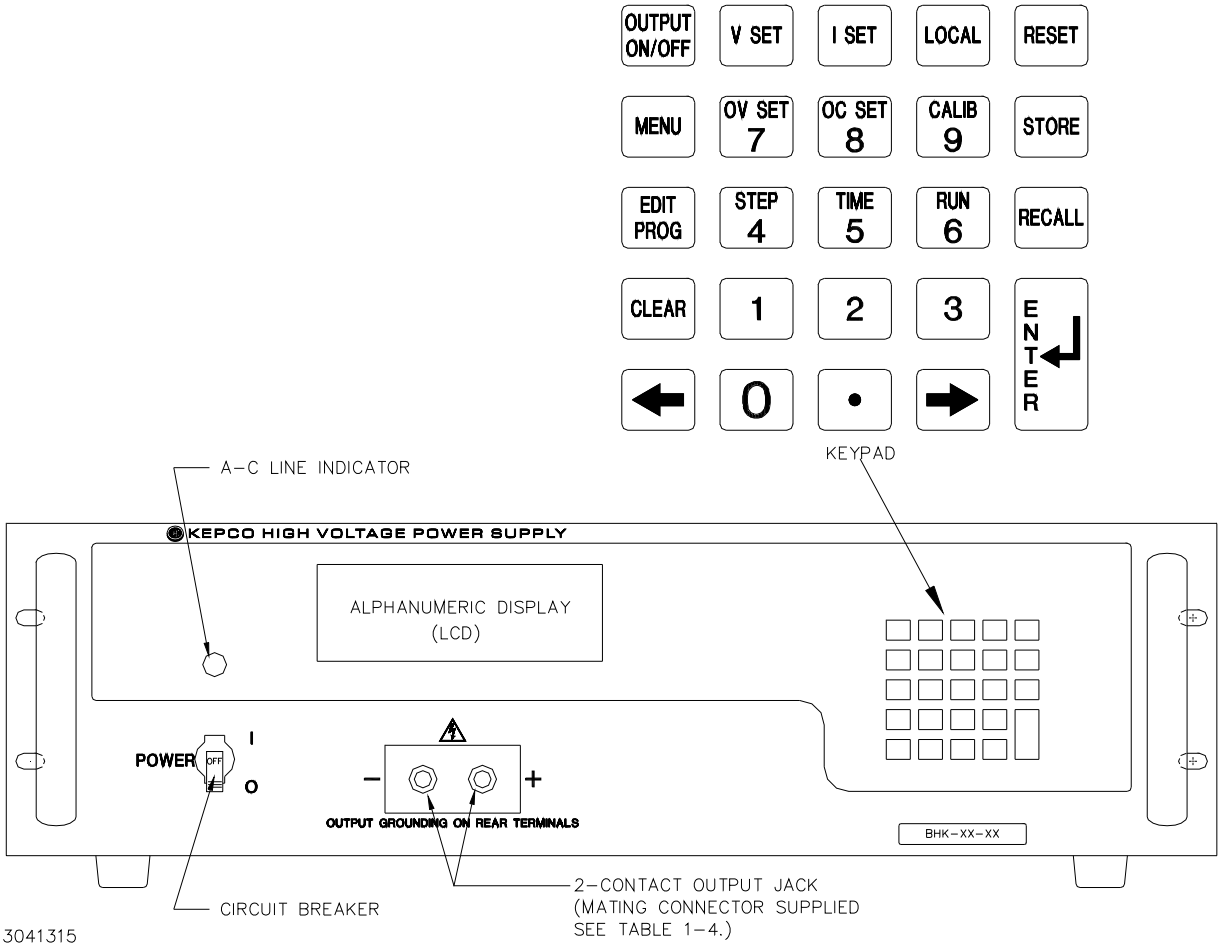


FIGURE 2-1. BHK-MG SERIES, FRONT PANEL CONTROLS, INDICATORS AND CONNECTORS

TABLE 2-1. CONTROLS, INDICATORS, AND CONNECTORS

CONTROL, INDICATOR, CONNECTOR	FUNCTION
FRONT PANEL	
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.
(+) and (–) output jacks	Provide front panel access to d-c output of power supply.
REAR PANEL	
IEEE 488 PORT	24-pin GPIB connector used to connect to GPIB bus (see Table 2-5 for pin assignments).
RS 232 PORT	8-pin telephone jack type connector used to connect to RS 232 bus (see Table 2-3 for pin assignments).
STATUS PORT	Notifies host computer either that a-c input is not present or a major failure of power supply has occurred (see Table 2-4 for pin assignments).
EXTERNAL TRIGGER PORT	4-pin connector used to restore unit to pre-established setting or to shut down the output. (see Table 2-2 for pin assignments). NOTE: Mating connector is a 3-pin plug.
OUTPUT TERMINALS barrier strip TB1	Provides Power Supply output connection points. (See Table 2-6 for terminal assignments)
V PROG terminal strip TB2	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	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.
Interlock switch	Provides protection when terminal strip cover is removed by interrupting a-c power to the unit.

TABLE 2-2. 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. 3.2.7.3).
	4	TRIGGER	Logic 0 triggers BHK to previously stored setting (see PARs. 3.3.4 and B.92.)

TABLE 2-3. RS232C 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

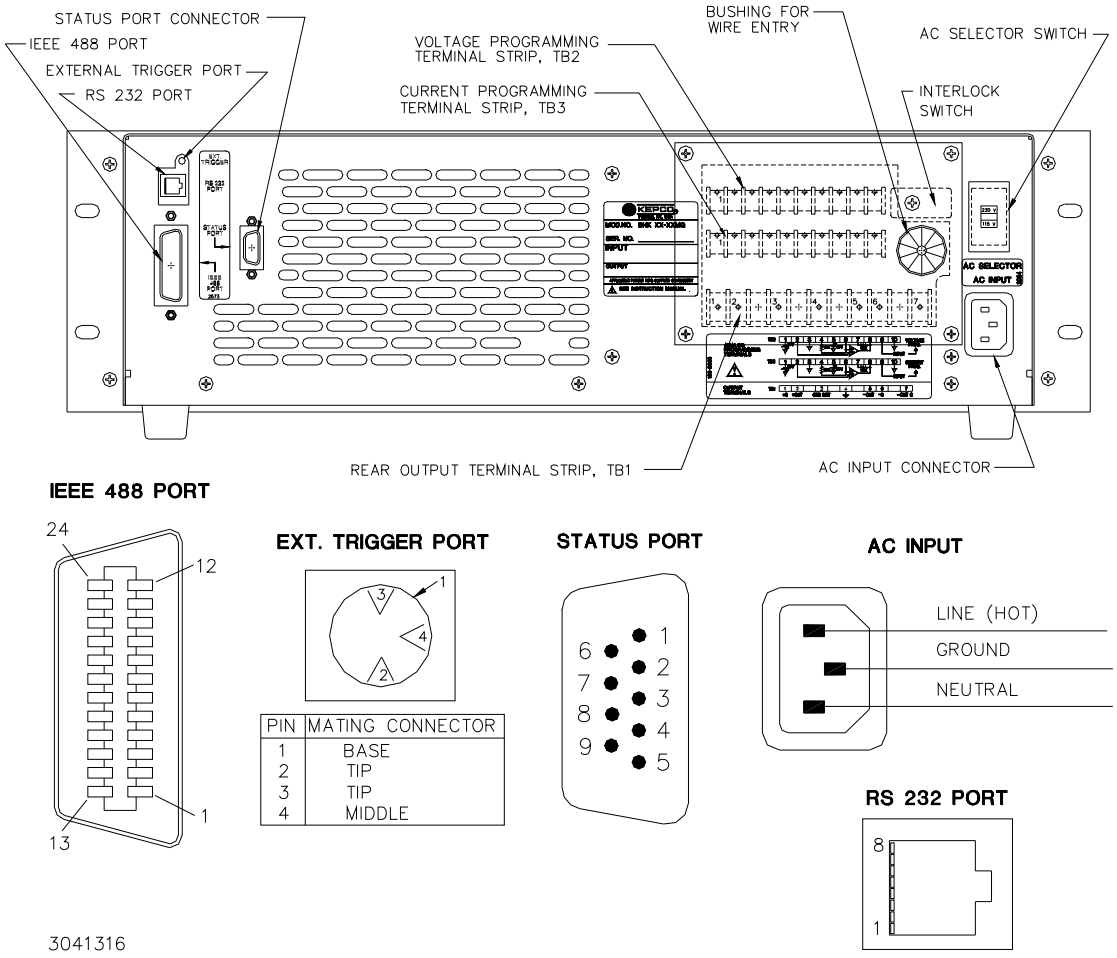


FIGURE 2-2. BHK-MG SERIES, REAR PANEL CONTROLS AND CONNECTIONS

TABLE 2-4. STATUS PORT CONNECTOR PIN ASSIGNMENTS

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
STATUS PORT CONNECTOR A5J4	1	Not Used.	
	2	Not Used.	
	3	Not Used.	
	4	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 1.4.10), requires pin 7 to be connected to the “+“ of the host computer d-c supply as described in PAR. 2.9.
	5	Not Used.	
	6	Not Used.	
	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 1.4.10), requires pin 4 to be connected to the “–“ of the host computer d-c supply as described in PAR.2.9.
	8	Not Used.	
	9	Not Used.	

TABLE 2-5. IEEE 488 PORT CONNECTOR PIN ASSIGNMENTS

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
IEEE 488 PORT A1J1	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
	12	SHIELD	Shield
	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 2-6. REAR OUTPUT TERMINAL STRIP TB1 TERMINAL ASSIGNMENTS

TERMINAL	SIGNAL NAME	FUNCTION
1	+S	Positive sense connection
2	+ OUT	Positive d-c output connection
3	GND NET	Grounding network connection
4	GND	Ground (chassis) connection
5	– OUT	Negative d-c output connection
6	–S	Negative sense connection
7	– OUT C	Connection to internal output capacitor

TABLE 2-7. VOLTAGE PROGRAMMING TERMINAL STRIP TB2, 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

TABLE 2-8. CURRENT PROGRAMMING TERMINAL STRIP TB3, 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. Usually connected to output of uncommitted amplifier.
10	SGND	Signal common

2.3 SOURCE POWER REQUIREMENTS

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).

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 nominal AC current absorbed by the BHK-MG Power Supply from the power source is 3.7A a-c @115V a-c and 1.9A a-c @230V a-c; the power source must be able to deliver the nominal current as well as surge current ten times larger than nominal.

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 an internal (d-c type) cooling fan.

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).

2.5 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.

1. 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**), Current Scale High (**Ihigh**), Constant Voltage (**CV**) mode, 0.0V, 0.0A 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. When shipped from the factory, the digital control is set to off. 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 (+) and (-) jacks 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 500-0.4MG, 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).

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.

10. 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 500-0.4MG, 400mA 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 x $I_{o\ (prog)}$ x 0.001) in volts, where R_S = resistance of shunt in ohms and $I_{o\ (prog)}$ = 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 $I_O = V_{DVM}$ x $1000/R_S$ 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 ±(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 ±(TOL_{Rs})% I_O.

17. Repeat steps 15 and 16 using different values for programmed current.

18. 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.

2.6.2 RACK MOUNTING

The unit can be mounted directly in a 19-inch wide rack, after the bench-type feet are removed. Optional slides (see Table 1-5) can be used. Installation of slides can improve access to the unit (see Figure 1-2).

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.

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 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. Output ripple specifications as measured at the output are equally valid for either side grounded. 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 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.

2.7.4.1 CABLE RECOMMENDATIONS

For power cables (positive and negative) No. 20 or 22 AWG stranded wire is recommended for each (these sizes fit the plugs supplied for the front panel output connections). The wire insulation must be rated for nominal voltage of the power supply (e.g., 500V for BHK 500-0.4MG). If a float voltage is used, the wire insulation must be rated for the nominal voltage of the power supply plus the float voltage; the DC Isolation Voltage (see Table 1-2, under Output Characteristics) defines the maximum float voltage allowed. For noisy environments, tied pair (adjacent wires secured with cable ties) or twisted pair cables are recommended. It is recommended that cable length not exceed 50 feet; for longer cable lengths, contact Kepco.

Remote sensing is used to accurately control voltage at the load rather than at the output terminals of the power supply (local sensing) by compensating for voltage drop (0.5 V d-c per lead) in the power cables. For sense cables (positive and negative) No. 22 AWG stranded wire is recommended for each. For noisy environments, tied pair or twisted pair cables are recommended. It is recommended that cable length not exceed 50 feet; for longer cable lengths, contact Kepco.

2.7.5 LOAD CONNECTION - GENERAL

Load connections to the BHK-MG power supply are achieved via the rear output terminal strip (TB1); (+) and (-) outputs are also available at jacks 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 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 (TB1-1) MUST BE CONNECTED TO EITHER +OUT (TB1-2) (LOCAL) OR +LOAD (REMOTE), AND THE - S TERMINAL (TB1-6) MUST BE CONNECTED TO EITHER –OUT (TB1-5) (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 TB1-1 (+S) to TB1-2 (+OUT) and TB1-5 (–OUT) to TB1-6 (–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 TB1-1, TB1-2 and TB1-6, TB1-7. 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 TB1-6 (–S) and TB1-7 (–OUT C) (see Figure 2-5). Slow mode (factory default configuration) can be established by connecting TB1-6 to TB1-7, 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 TB1-3 (GND NET) and TB1-2 (+OUT). To disconnect the grounding network from the output, remove the connection across TB1-3 and TB1-2 (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 TB1-5 (–OUT). To avoid degraded load regulation in current mode it is necessary to remove the grounding network from the circuit by removing the link between TB1-2 (+OUT) and TB1-3 (GND NET).

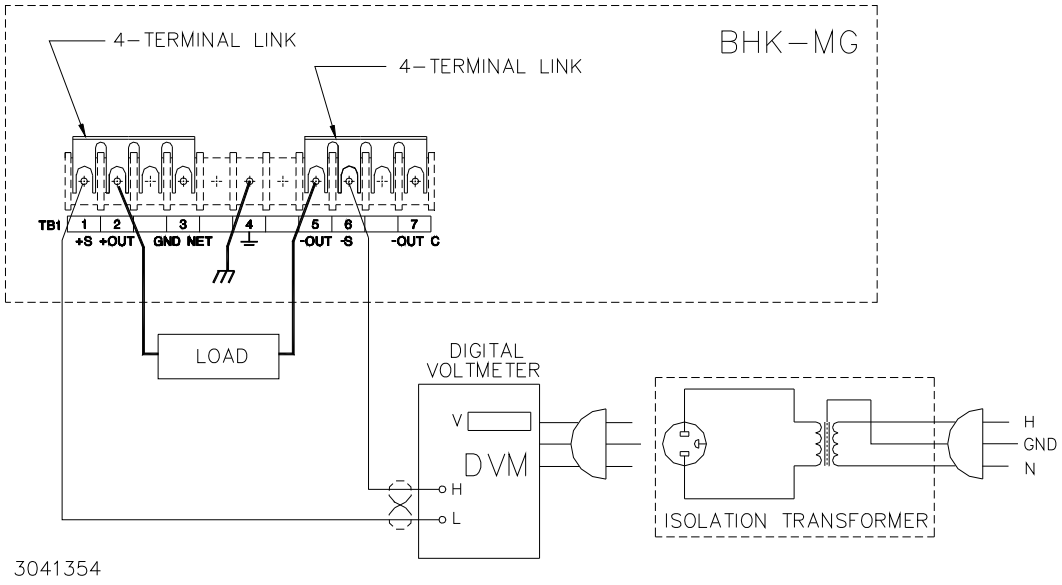


FIGURE 2-4. LOCAL SENSING, SLOW MODE SELECTED, GROUNDING NETWORK CONNECTED, FLOATING OUTPUT (FACTORY DEFAULT CONFIGURATION)

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 TB1-2 (+OUT). Note that when the positive output is grounded, the ground network (TB1-3) is inoperative (see Figure 2-5).

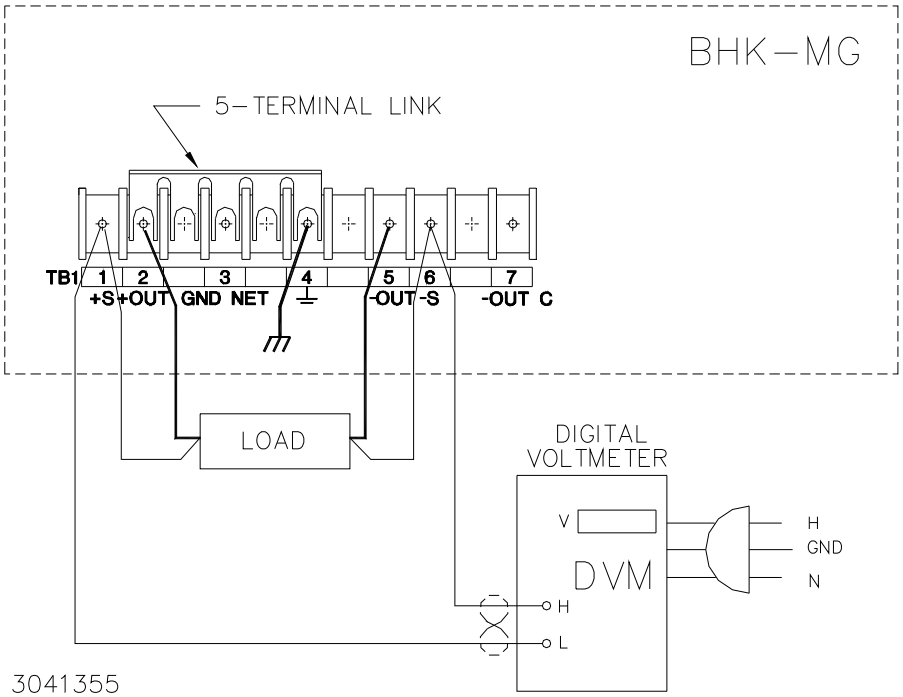


FIGURE 2-5. REMOTE SENSING, FAST MODE SELECTED, POSITIVE OUTPUT GROUNDED

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.

TABLE 2-9. INTERNAL JUMPER CONFIGURATION

LOCATION	JUMPER	DEFAULT STATUS	FUNCTION
A1	J6	Not Installed	May be installed temporarily to force the unit to enter First Time Calibration during power-up sequence. This requires the operator to enter the model and perform a full calibration of the unit.
A7	J12	Installed	Enables input circuit breaker to trip when input power loss detected.
	J13	Installed	Enables protection circuit to cut off pass element and to send a flag to digital control.
	J14	Installed	Enables “share circuit” to act on protection circuit. The share circuit detects uneven voltage or current across the pass element.

2.9 STATUS PORT

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

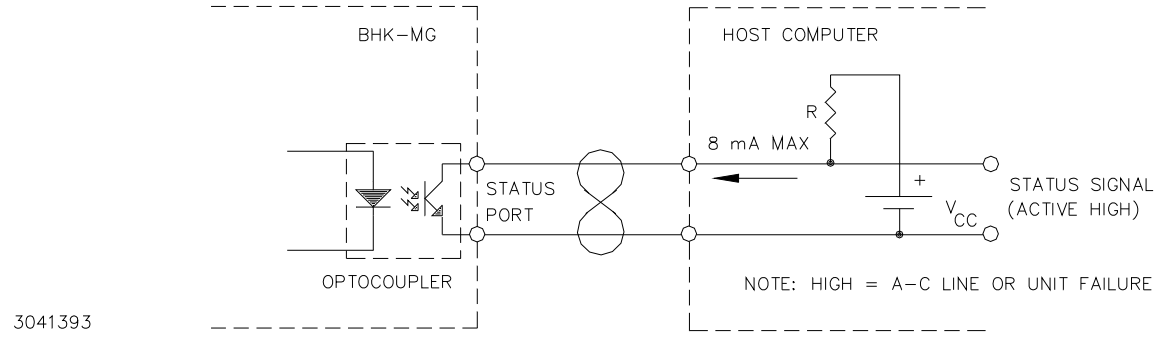


FIGURE 2-6. STATUS PORT OPTO-COUPLER ACTIVE “HIGH” CONFIGURATION

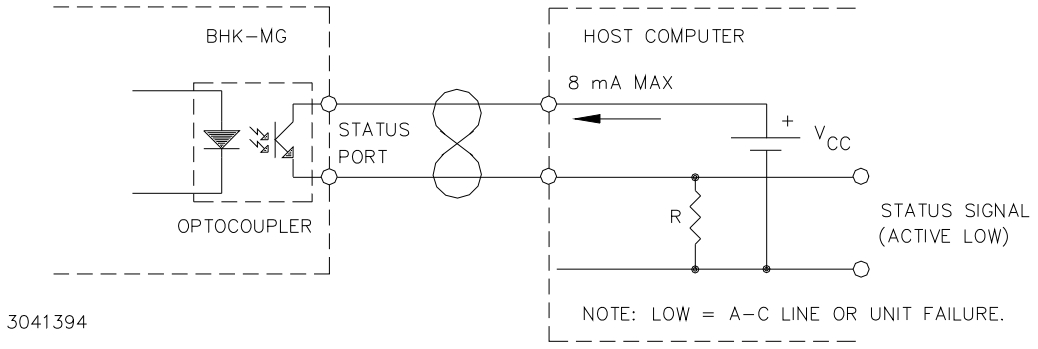


FIGURE 2-7. STATUS PORT OPTO-COUPLER ACTIVE “LOW” CONFIGURATION

SECTION 3 - OPERATION

3.1 GENERAL

This section explains how to operate the BHK-MG 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 either SCPI commands via the GPIB bus (PARs. 3.3, 3.5) or analog programming via the rear panel terminals (PAR 3.6). Remote analog programming can be combined with either local programming using the front panel keyboard or remote programming using SCPI commands via the GPIB bus.

3.2 LOCAL MODE OPERATION

Local operation of the BHK-MG 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 (=); 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 ← 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
top right		CV/CC	Constant voltage mode/constant current mode
Bottom left:	in command entry	n.nV	Actual output voltage
	In data entry	(parameter)	e.g. OVset if OV SET key was pressed.
Bottom middle:		**(: _ : _ :)**	Command entry status
Top or Bottom middle:		**(=_=_=)**	Data entry status
Bottom right:	in command entry	n.n mA	Actual output current.
	In data entry	n.n V or n.n mA	Present programmed value of parameter, replaced by data entered.

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 Digital is OFF, press to enable the output. If output is on, press to disable the output controlled by digital means (keypad or GPIB setting). If analog control used, analog input must be turned off separately to disable the output.	3.2.7
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.	3.2.9
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.	3.2.9
LOCAL	**Command Entry**	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.	3.2.4, B.84
RESET	**Command Entry**	Press to restore the power on default values: CV mode, output voltage = 0, output current value chosen from the POWER-UP OR RESET CURRENT submenu, overvoltage and overcurrent values per Table 1-2.	3.2.8

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) restore previous calibration values, (10) restore factory calibration values, (11) view firmware version number, (12) set Power-up and RESET current, (13) set maximum voltage, (14) set maximum current, (15) current scale. Press ENTER, RESET or CLEAR to exit Menu.	(1) 3.2.5, (2) 3.3.3, (3) 3.4.1 (4) 3.4.4 (5) 3.3.2 (6) 3.2.7.4 (7,)3.2.6, (8) 4.5, (9) 4.6, (10) 4.7 (11) 3.2.15 (12) 3.2.8.1 (13, 14) 3.2.12, (15) 3.2.10
OV SET 7	**Command Entry**	Press to set overvoltage protection value. Data entry required to enter the overvoltage protection value; press ENTER to accept displayed value.	3.2.11
	Data Entry	Press to enter number 7.	3.2.1.2
OC SET 8	**Command Entry**	Press to set overcurrent protection value. Data entry required to enter new overcurrent protection value; press ENTER to accept displayed value.	3.2.11
	Data Entry	Press to enter number 8.	3.2.1.2
CALIB 9	**Command Entry**	Press to enter Calibration status. Requires password entry; instructions appear on LCD.	4.3
	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	3.2.13
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.	3.2.16.1
STEP 4	**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.	3.2.16.3
	Data Entry	Press to enter number 4.	3.2.1.2
TIME 5	**Command Entry**	Press to edit time value for specific memory location. Select memory location (data entry), then enter time value, 0.01 to 655.35 seconds (data entry).	3.2.16.1.1
	Data Entry	Press to enter number 5.	3.2.1.2
RUN 6	**Command Entry**	Press to run a program. Requires data entry to select starting location. Press ENTER to accept displayed value.	3.2.16.2
	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. The previously stored output state (enabled or disabled) will also be recalled. Data entry required to select memory location containing values to be recalled; press ENTER to accept displayed value.	3.2.14
CLEAR	**Data Entry**	Press to exit Data Entry status; any numbers entered are lost. Restores Command Entry status	3.2.9
1	**Data Entry**	Press to enter number 1.	3.2.1.2

TABLE 3-2. KEY FUNCTIONS (CONTINUED)

KEY	POWER SUPPLY STATUS ACTIVE	DESCRIPTION	REFERENCE PARAGRAPH
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.	3.2.9
←	**Command Entry**	— In CV (constant voltage), press to decrease output voltage by increment equal to voltage resolution (0.025% of $E_O$max). — In CC (constant current), press to decrease output current by increment equal to current resolution (0.025% of $I_O$max). — In EDIT PROG status, changes the parameter displayed on LCD for a specific memory location and decrements memory location displayed on LCD.	3.2.9, 3.2.16.1
	Data Entry	Erases number to left, or decreases value shown (e.g. Display Contrast setting).	3.2.9
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 $E_O$max). — In CC (constant current), press to increase output current by increment equal to current resolution (0.025% of $I_O$max). — In EDIT PROG status, changes the parameter displayed on LCD for a specific memory location and increments memory location displayed on LCD	3.2.9, 3.2.16.1
	Data Entry	Increase value shown.	3.2.5

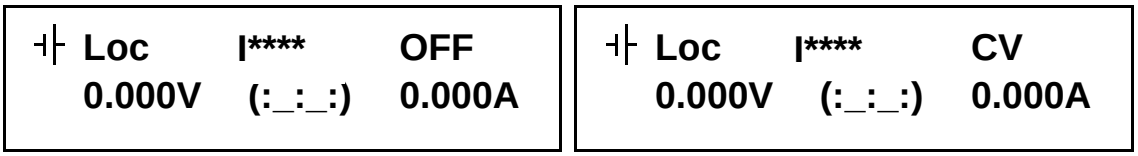
3.2.2 TURNING THE POWER SUPPLY ON

CAUTION: DO NOT REPEATEDLY TOGGLE THE CIRCUIT BREAKER/SWITCH AS THIS MAY CAUSE UNIT TO FAULT. ALLOW THE UNIT TO BE OFF FOR AT LEAST THREE (3) SECONDS BEFORE TURNING THE UNIT BACK ON TO GIVE THE POWER LOSS CIRCUIT TIME TO RESET.

Set Power ON/OFF circuit breaker/switch on front panel to the up position to turn the power supply on. If actuator does not lock when released, wait a few seconds before trying again. The circuit breaker is “trip-free” design; if overload exists or the protection is activated, contacts cannot be held closed by actuator. Setting the circuity breaker/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 500-0.4MG 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. 3.2.7.4. 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.

If the unit fails self-test during power-up, error messages are shown on the LCD. The failure will usually cause the test to be repeated, and if the unit passes the second test, power-up continues and the error message disappears. Refer to PAR. 3.2.3 for details.



(a) Default Display State for OUT OFF @ Pwr-Up Selection (PAR. 3.2.7.4)

(b) Default Display State for OUT ON at Pwr-Up Selection (PAR. 3.2.7.4)

NOTE: **(: _ : _ :)** indicates blinking colon (:), Command Entry status
(= _ = _ =) indicates blinking equal sign (=), Data Entry status
**** indicates previously set current scale. High indicates high range, Low indicates low range.

FIGURE 3-1. LCD POWER ON DEFAULTS

3.2.3 ERROR CONDITIONS

Refer to Table 3-3 for how to proceed if any of the error conditions listed appear on the LCD for more than 90 seconds. For some errors the firmware repeats the action, and if the new attempt is successful, the error message will be deleted and normal operation will proceed.

TABLE 3-3. ERROR CONDITIONS

LCD DISPLAY SHOWS	ACTION
WARNING **When the microprocessor is not able to complete its power up sequence, it is possible that uncontrolled high output voltage may be present at the output. Turn off power supply immediately and disconnect any load. Measure the output using a voltmeter set to measure the maximum voltage that can be delivered by the power supply.**	
PROM FAILS CHECK	Refer unit for service by authorized personnel.
RAM FAILS CHECK	Refer unit for service by authorized personnel.
NvRAM & Dpot Err	Restore Factory Calibration as described in PAR. 4.7, then verify that the programmed voltage output is accurate. If problem continues, refer unit for service by authorized personnel.
NVRAM STATUS ERROR	Restore Factory Calibration as described in PAR. 4.7, then verify that the programmed voltage output is accurate. If problem continues, refer unit for service by authorized personnel.
PAGE FAILS CHECK	Refer unit for service by authorized personnel.
CNFG FAILS CHECK	Restore Factory Calibration as described in PAR. 4.7, then verify that the programmed voltage output is accurate. If problem continues, refer unit for service by authorized personnel.
Completely blank, or a blinking underline in the upper left corner	Refer unit for service by authorized personnel.

3.2.4 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.

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.84), or cycling the power supply off then on.

3.2.5 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 **0** to **9**. Press **ENTER** or **CLEAR** to exit menu.

3.2.6 ENABLING/DISABLING AUDIBLE BEEPS

With the power supply in command entry status **(: _ : _ :)**, press **MENU** key 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.

3.2.7 ENABLING/DISABLING DC OUTPUT POWER

When the power supply is turned on, the output is automatically disabled or enabled depending on **OUT on** or **off @Pwr-Up** (see PAR. 3.2.7.4), and the bottom line of the LCD gives voltage and current measurements at the output.

3.2.7.1 DISABLING DC OUTPUT WHEN USING DIGITAL INPUTS ONLY (KEYPAD AND/OR GPIB)

To disable the output, press the red **OUTPUT ON/OFF** key; the top line of the LCD reads: **0FF** and the bottom line displays output voltage and current (zero). When the output is disabled, voltage and current are programmed to zero; 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.

3.2.7.2 DISABLING DC OUTPUT WHEN USING ANALOG CONTROL.

If analog control is used without digital programming, simply set the analog input to a value that brings the output voltage and current to zero without pressing the **OUTPUT ON/OFF** key.

To disable the output if both analog and digital (keypad and/or GPIB) control are used, first press the red **OUTPUT ON/OFF** key; the top line of the LCD reads: **0FF** and the bottom line displays output voltage and current controlled by analog means. Set the analog input to a value that brings the output current and voltage to zero. Pressing the **OUTPUT ON/OFF** key again enables the output: the previously programmed values of voltage and current (from the keypad or GPIB) are restored and the LCD displays the mode (CV or CC) and actual values of output voltage and current. Analog inputs must be restored separately to return to the output settings in effect when the output was disabled.

After disabling the output by pressing the **OUTPUT ON/OFF** key, if the analog input is causing more than approximately 8Vd-c to appear at the output terminals, or if current is being supplied to the load exceeds approximately 0.3% of full scale for the selected range, the unit will beep and enter a controlled shutdown for safety purposes. Shutdown can be avoided by setting the analog input to a value that brings the BHK-MG output below 8Vd-c and output current to less

than 0.3% of full scale for the selected range within 25 seconds. For 15 seconds, the top line of the LCD alternately flashes the messages **DIGITAL IS OFF** and **SET ANALOG OFF**, while the bottom line of the LCD shows the actual output voltage and current. After 15 seconds, the bottom line will alternate a message showing the time remaining before shutdown (e.g **POWER OFF 9 SEC**) with the message **SET ANALOG OFF**. After the 10 second countdown the front panel circuit breaker will trip. (If (due to a defective protection circuit or faulty circuit breaker) the unit does not shut down, the LCD displays ****BHK** **FAILURE **** and beeps constantly.)

3.2.7.3 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, and voltage and current are set to zero (0 LSB for voltage, and power up and reset value (see PAR. 3.2.8.1) for current). The DCL Control setting (see PAR. 3.3.2) determines the output settings when the output is reenabled: either restored to the voltage/current settings in effect at the time shutdown was initiated ("output unchanged") or voltage and current still programmed to zero ("output = 0").

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.

3.2.7.4 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 **Out off @Pwr-Up** or **Out 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.

3.2.8 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. 3.2.8.1), 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 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. The current scale remains unchanged.

3.2.8.1 SETTING POWER-UP & RESET CURRENT

The factory setting of the power-up and reset current is 1.28% of Io 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 followed by the **ENTER** key to validate 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 = Iomax/10 (e.g., for BHK500-0.4MG, xx = 40.0mA). The unit remains in data entry status **(=_=_=)** waiting for a value equal to or less than the 10% of rated current.

3.2.9 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 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: Although the LCD can display up to five decimal places, only two decimal places are actually used for voltage and current settings (except that only one decimal place is used for setting voltage on Models BHK 1000-0.2MG and BHK 2000-0.1MG, and three decimal places are used for setting current on all models when current scale is set to Low range.).

With the power supply in command entry status **(:_:_:)**, an alternative is to use → key (increase) or ← key (decrease) to change the output by the minimum increment (0.025% of $E_O$max for voltage, 0.025% of $I_O$max 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 → and ← keys are reassigned to the active parameter. Once the transition point is reached, each press of the → key increases voltage, then current, changing the mode, from CV to CC or from CC to CV. The → key has 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.3.2.12). The unit returns to {=_=_=) waiting for a value that does not exceed the maximum.

3.2.10 CHANGING CURRENT SCALE

The full scale output current can be changed from the maximum current rating (factory default) of the power supply ($I_O$max) to a value ten times less ($I_O$max/10): e.g., for the BHK 500-0.4MG power supply the full scale current can be either 400mA or 40mA. The relative accuracy and resolution are the same for both current programming scales because the power supply has two independent sensing resistors and the calibration is done separately; relative readback accuracy and resolution are ten times better for $I_O$max/10 scale.

The current scale setting is stored in non-volatile memory and retained when the unit is turned off. When the unit is turned on, the stored current scale setting is in effect.

When the current scale is changed, the output is automatically turned off to avoid transients at the output. After the scale has been changed, press **OUTPUT ON/OFF** key to enable the output and restore the settings of the new current scale. Reprogram output voltage and current if the **RESET** key was pressed,

CAUTION: BEFORE CHANGING CURRENT SCALE, DISCONNECT ANY LOAD CONNECTED TO THE OUTPUT TERMINALS.

With the power supply in command entry status **(:_:_:)**, press **MENU** until the top line of the display presents the message **FS CURRENT (=_=_=) <n> mA**, where <n> represent the actual full scale of the current ($I_O$max or $I_O$max/10); the bottom line reads **1=TOGGLE**. Press **ENTER** or **CLEAR** to exit menu without changing setting. Press **1** key to toggle between $I_O$max and $I_O$max/10; press **ENTER** to accept new full scale current and exit menu or **CLEAR** to exit without change.

When the full scale current is changed from High ($I_O$max) to Low ($I_O$max/10):

- programmed current value remains unchanged if it is less than or equal to the Low maximum current, otherwise it is automatically limited to the Low maximum value.
- programmed overcurrent protection value remains unchanged if it is less than or equal to 1.1 x Low maximum current, otherwise it is automatically limited to (1.1 x Low maximum).
- maximum current value (PAR. 3.2.12) is restored.
- voltage and overvoltage protection settings are unchanged.
- the 40 nonvolatile memory locations for Low range are active.
- Trigger, power up and reset current are divided by 10.

When the full scale current is changed from Low ($I_O$max/10) to High ($I_O$max):

- programmed current value remains unchanged if it is less than or equal to the High maximum current, otherwise it is automatically limited to the High maximum value.
- programmed overcurrent protection value remains unchanged if it is less than or equal to 1.1 x High ($I_O$max). To avoid input power circuit breaker tripping, set overcurrent protection (see PAR. 3.2.11) to either 1.1 x High ($I_O$max) or as desired.
- maximum current value (PAR 3.2.12) is restored from saved value
- voltage and overvoltage protection settings are unchanged.
- the 40 nonvolatile memory locations for High range are active.
- Trigger, power up and reset current are multiplied by 10.

NOTES: 1. When changing from High to Low or Low to High range, even though the settings for current and overcurrent are theoretically unchanged, they may actually be in error by up to 0.15% of full scale current due to rounding errors. To improve accuracy it is recommended that current and overcurrent be set using the keypad after changing range.

2. Changing current scale is not permitted when running a program (see PAR. 3.2.16). All steps must use the same current scale.

3.2.11 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: Although the LCD can display up to five decimal places, only two decimal places are actually used for voltage and current settings (except that only one decimal place is used for setting voltage on Models BHK 1000-0.2MG and BHK 2000-0.1MG, and three decimal places are used for setting current on all models when current scale is set to Low range.).

3.2.12 CHANGING MAXIMUM VOLTAGE OR CURRENT VALUE

The default maximum values of voltage and current are determined by the model, e.g., 500V and 400mA for the BHK 500-0.4MG. 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 500-0.4MG to 100V and 200mA, effectively makes the unit a 100V/200mA power supply.

Maximum values for current are independent for Low Range and High Range (see PAR. 3.2.10). 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 **CLEAR** to exit menu without changing setting. Press **ENTER** to validate displayed value or 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: Although the LCD can display up to five decimal places, only two decimal places are actually used for voltage and current settings (except that only one decimal place is used for setting voltage on Models BHK 1000-0.2MG and BHK 2000-0.1MG, and three decimal places are used for setting current on all models when current scale is set to Low range.).

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 = <Eomax or Iomax>** where $E_O$max or $I_O$max is the rated maximum of the power supply. The unit remains in data entry status **(=_=_=)** waiting for a value equal to or less than the maximum value. Press **CLEAR** to exit without changing the value.

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.

3.2.13 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. 3.2.16). To accommodate the two current scales, there are actually 40 locations for High range

and 40 locations for Low range which are swapped each time the range is changed, so that only one set of 40 locations is active, depending on the current scale selected.

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 **CLEAR** to exit without changing setting. Press **ENTER** to validate the existing location. 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. 3.2.14. The default value at power-up for the Store command is 01. During normal operation, the location last used is displayed.

3.2.14 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. Note that the location retrieved will correspond to the active current scale. The 40 memory locations are different for High and Low range (see PAR. 3.2.13). Press **CLEAR** to exit without changing setting. Press **ENTER** to validate the existing location. 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. The default value at power-up for the Recall command is 01. During normal operation, the location last used is displayed.

3.2.15 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,SSSSSS mm-dd-yyyy,V.zz** where XXXX indicates the power supply model (e.g. XXXX = 1000 for BHK 1000-0.2MG), SSSSSS 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.

3.2.16 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 0.01 and 655.35 seconds) for the programmed settings, and the address of the next memory location in the program. The factory default values for all memory locations is: 0 Volts, 0 Amperes, overvoltage and overcurrent is set to Eomax+10% and Iomax+10%, respectively, time duration is set to 0.01 Sec, and next step is set to 0.

3.2.16.1 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.3.2.16.1.1.

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. 3.2.16.6; to cycle a program continuously, see 3.2.16.4. 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 3-5) and filling in the values before programming the power supply.

3.2.16.1.1 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 **CLEAR** to exit without changing setting. Press **ENTER** to validate the existing location or 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 655.35 seconds) and press **ENTER** to accept new value or press **CLEAR** to exit without changing value. The unit returns to command entry status **(:_:_:)**.

3.2.16.1.2 TIME INTERVAL ACCURACY

The accuracy of the time interval is ±1% through the entire time interval range.

3.2.16.2 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 all the steps are programmed for 0.01 second, the LCD reads ***** RUNNING PROGRAM*****.

3.2.16.3 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.

TABLE 3-4. 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 655.35) (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						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						
35						
36						
37						
38						
39						
40						

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).

3.2.16.4 CYCLING A PROGRAM

To cycle a program, modify the program (see PAR. 3.2.16.1) 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.

3.2.16.5 RUNNING A PROGRAM ONCE

To set up a program to stop after running once, modify the program (see PAR. 3.2.16.1) 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).

3.2.16.6 STOPPING A RUNNING PROGRAM

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

- Press CLEAR key: the program stops after finishing 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 immediately and power on defaults are restored (see PAR. 3.2.8).
- 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.

3.2.16.7 SAMPLE PROGRAM

Table 3-5 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.

TABLE 3-5. SAMPLE PROGRAM (MODEL BHK-MG 500-0.4MG)

MEMORY LOCATION	I SET (Current) (mA)	V SET (Voltage) (V)	OC set (Overcurrent Protection) (mA)	OV set (Overvoltage Protection) (V)	TIMEval (0.01 to 655.35) (Sec)	NEXT STEP (Next location to execute)
1	**400**	**420**	**440**	**550**	**1.5**	**02**
2	**400**	**500**	**440**	**550**	**1.8**	**03**
3	**400**	**250**	**440**	**550**	**1.0**	**01**
NOTE: For each cell of a program OC set and OV set must be at least 2% above the maximum values of voltage and current expected at the load. The limit parameter (I set for voltage mode, or V set for current mode) must be at least 1% above the maximum load current (for I set) or load voltage (for V set).						

3.2.17 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 the IEEE 488 standard communication bus (General Purpose Interface Bus, GPIB). 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. 3.3.5), followed by a detailed explanation of SCPI programming (PAR. 3.5)

3.3.1 IEEE 488 (GPIB) BUS PROTOCOL

Table 3-6 defines the interface capabilities of the BHK-MG 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 3-7 and 3-8 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 power supply operating as either a Talker or a Listener.

TABLE 3-6. 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	T6	Basic talker, serial poll, unaddress if MLA (My Listen Address) (one-byte address)

TABLE 3-6. IEEE 488 (GPIB) BUS INTERFACE FUNCTIONS (CONTINUED)

FUNCTION	SUBSET SYMBOL	COMMENTS
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.84) 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.
Controller	C0	No Capability

TABLE 3-7. 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
OTA	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 3-8. 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. 3.2.8.1). 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. 3.2.8). 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 **0** for "output = 0V" mode where DCL sets the output to 0 volts and current is set to the power-up and reset current value (see PAR. 3.2.8.1).

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 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.58) and CURR:TRIG (PAR B.48) commands.

- Choose external trigger source by sending TRIG:SOUR EXT (PAR. B.92)

- Choose continuous action (by sending INIT:CONT ON (PAR B.12).

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.

3.3.5 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
www.kepcopower.com/drivers/drivers-dl3.htm

Although the software drivers supplied by Kepco are VISA compliant, they also require the installation of the proper 32-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.

3.3.6 PROGRAMMING TECHNIQUES TO OPTIMIZE PERFORMANCE

3.3.6.1 PROGRAMMING VOLTAGE/CURRENT LIMIT AND CURRENT/VOLTAGE LIMIT

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. By changing only the active parameter (e.g., voltage for voltage mode), 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. Recommended programming techniques are:

1. Minimize programmed mode (voltage or current) changes. Unless absolutely required by the test parameters, allow the power supply to automatically switch modes as determined by the load. This will improve response time and reduce undesirable transients. For those power supplies that employ relays (Kepco's MBT with “R” option, MAT and MST) this will also increase the life of the relay.

2. Once the mode (voltage or current) is programmed, program the active parameter to zero and the complementary limit parameter to the maximum anticipated for application. Then program only the active parameter. The active parameter is the parameter that controls the output, e.g., voltage controls the output in voltage mode.

3. Never program both the active and complementary limit parameter to zero. This can result in long response times. Set the active parameter to zero and the complementary limit parameter to a minimum, e.g., 10% of maximum, to ensure that the active mode is defined.

3.3.6.2 MAKING SURE THE PREVIOUS COMMAND IS COMPLETE

Some SCPI commands require a flash memory update and can take an indeterminate amount on time to complete. These commands are:

- *SAV
- CAL:SAVE
- SOUR:CURR:LIM
- SOUR:VOLT:LIM
- SYST:COMM:GPIB:ADDR
- SYST:COMM:SER:BAUD
- SYST:COMM:SER:ECHO
- SYST:COMM:SER:PACE
- SYST:COMM:SER:PROMpt
- SYST:PASS:NEW
- SYST:SEC:IMM

When sending these via the GPIB, these commands require a query to be added to the command string to verify the previous command is complete. When the command is complete, the unit updates the status byte and indicates MAV (Message Available, bit 4 - see Table A-3) is true. MAV indicates that there is a response to be received by the computer, so when it becomes set, the unit is ready for its next command after reading back the data from the query that was added to the command string.

When sending the above commands via the RS 232 bus, data flow control must be enabled (XON) using the SYST:COMM:SER:PACE command (see PAR. B.77) must be enabled for the unit to properly update flash memory.

The *OPC? query is ideal to check if the previous command is complete since it returns either a 1 or 0. It is important that it be sent as a part of the same string as the command that causes a flash update. As an example, sending CAL:SAVE 12/31/2005;:*opc? or *opc?;:CAL:SAVE 12/31/2005 are valid command strings. Sensing the commands separately will not verify that the previous command is complete. Figure 3-2 is a program written in C, incorporating these techniques.

Failure to provide an adequate delay can result in:

- Commands that are not processed,
- The following command may be received in error, causing an error in the transmission,
- Unit lock-up requiring power cycling of the unit. If working via the GPIB bus, sending Interface Clear and Device Clear followed by *RST will unlock the unit.

```
#include <formatio.h>
#include <utility.h>
#include <gpib.h>
#include <ansi_c.h>


/*Overhead for the use of a NATIONAL INSTRUMENTS gpib interface */
int unit_desc;                                  // handle for the national instruments controller
int GPIbus=0;                                   // GPIB card 0
int adr=6;                                      // Power Supply address
char status_byte;                               // status byte from the power supply


#define MAV 0x10 /* bit 4 of the status byte is the Message AVailable bit by 488.2 specification */

/* Function  Send_with_wait

 INPUT: string to be sent to power supply

 Description: adds the *OPC? query and performs serial polls to wait for the command to be completed.


*/

int Send_with_wait(char *command);
char snd[501];                                  // data to be sent to the power supply
char rcv [10];                                  // data from power supply
int j;

sprintf(snd,"%s;:*OPC?,command);                // Add *OPC? to the command
                                                // so there is a response from the
                                                // power supply
Send(GPIbus, adr, snd, strlen(snd), 2);         // Send the data to the power supply
for (j=0;j<500;j++)(                            // loop until ready (5 seconds max)
    Delay(.05);                                 // Wait for command to complete
    ibrsp(unit_desc,&status_byte);              // get status byte
    if ((status_byte& 0x10) ==0x10) break;)     // by looking for data in string
Receive (GPIbus, adr, rev, rev_buf_size,10);    // so the error queue will not receive a 410 error
}

main(                                           // test code to show operation of function.
 unit_desc=ibdev(GPIbus,adr,adr/256,T100ms,1,0x40a);Delay(.005);
Send (GPIbus,adr,"VOLT 10;curr .01",sizeof("VOLT 10;curr .01"),NLEND;
Send_with_wait("*SAV 10");
}
```

FIGURE 3-2. PROGRAMMING EXAMPLE TO VERIFY PREVIOUS COMMAND HAS COMPLETED

3.4 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
- Parity: None
- Data Bits 8
- Stop Bits 1
- Echo ON
- XON OFF

To change baud rate refer to PAR's. B.73 and B.74. To select prompt refer to PAR's. B.79 and B.80. To select echo refer to PAR's. B.75 and B.76. To select XON/XOFF, refer to PAR's. B.77, B.78.

3.4.1 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 = 9600). Use ➔ and ← 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.

3.4.2 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 six 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.

3.4.3 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 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 3-3, 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 3-3 illustrates the default echo mode, the prompt method and the XON XOFF method described in the following paragraphs.

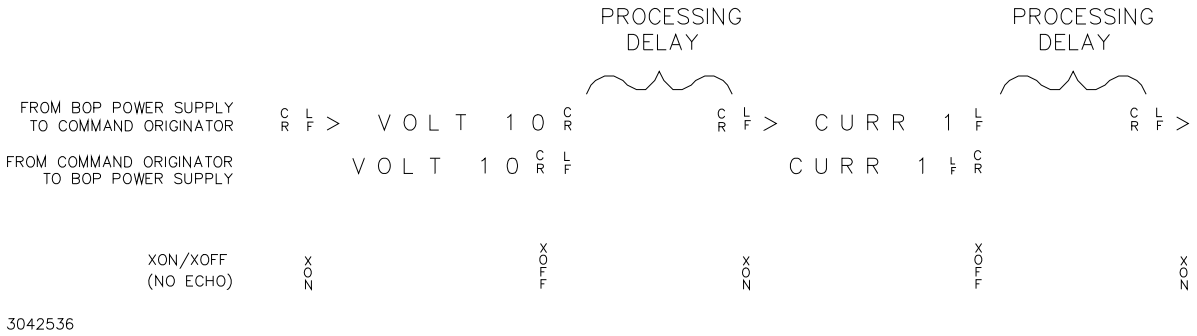


FIGURE 3-3. RS 232 IMPLEMENTATION

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.

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 3-3).

3.4.3.1 ECHO MODE

In echo mode each byte (character) is echoed back to the sender where it is verified as the same character that was just sent.

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 3-3).

3.4.3.2 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.

3.4.3.3 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_H) has been received; the command originator stops sending data after receiving the XOFF (transmission off) character (013_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).

3.4.4 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.

3.5 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 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 Power Supply GPIB address.)

3.5.1 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.

3.5.2 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 3.4.3 through 3.4.6).

3.5.3 SCPI SUBSYSTEM COMMAND/QUERY STRUCTURE

Subsystem commands/queries are related to specific power supply functions (such as setting output voltage, current limit, etc.) Figure 3-5 is a tree diagram illustrating the structure of SCPI subsystem commands used in the BHK-MG 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.

3.5.3.1 ABORT SUBSYSTEM

This subsystem allows pending trigger levels to be cancelled.

3.5.3.2 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.

3.5.3.3 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.

3.5.3.4 MEASURE SUBSYSTEM

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

3.5.3.5 OUTPUT SUBSYSTEM

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

3.5.3.6 INSTRUMENT SUBSYSTEM

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

3.5.3.7 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.

3.5.3.8 SYSTEM SUBSYSTEM

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

3.5.3.9 TRIGGER SUBSYSTEM

This subsystem controls the remote triggering of the power supply.

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

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

3.5.3.11 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.

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 than 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 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 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.

3.5.4 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 sepa-

rated 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 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.

3.5.4.1 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 4-1.

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 4-5.

TABLE 3-9. 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
	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).

3.5.4.2 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).

3.5.4.3 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?).

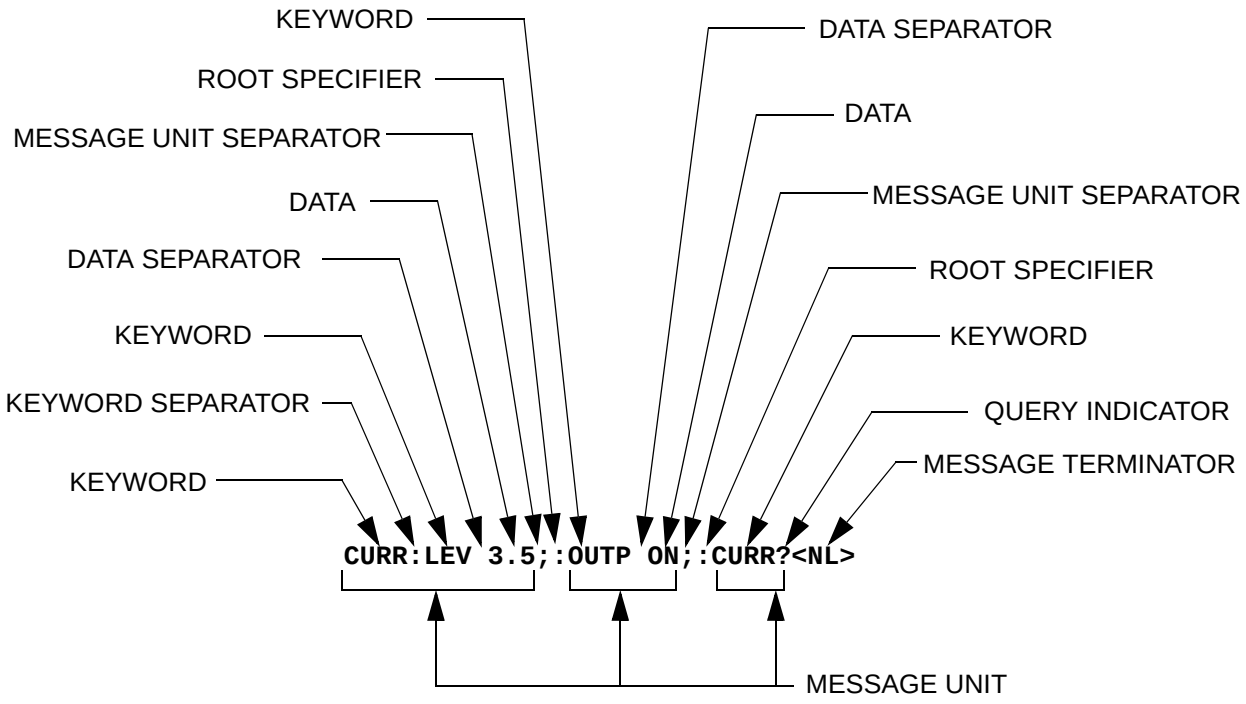


FIGURE 3-4. MESSAGE STRUCTURE

3.5.4.4 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

3.5.4.5 DATA SEPARATOR

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

3.5.4.6 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).

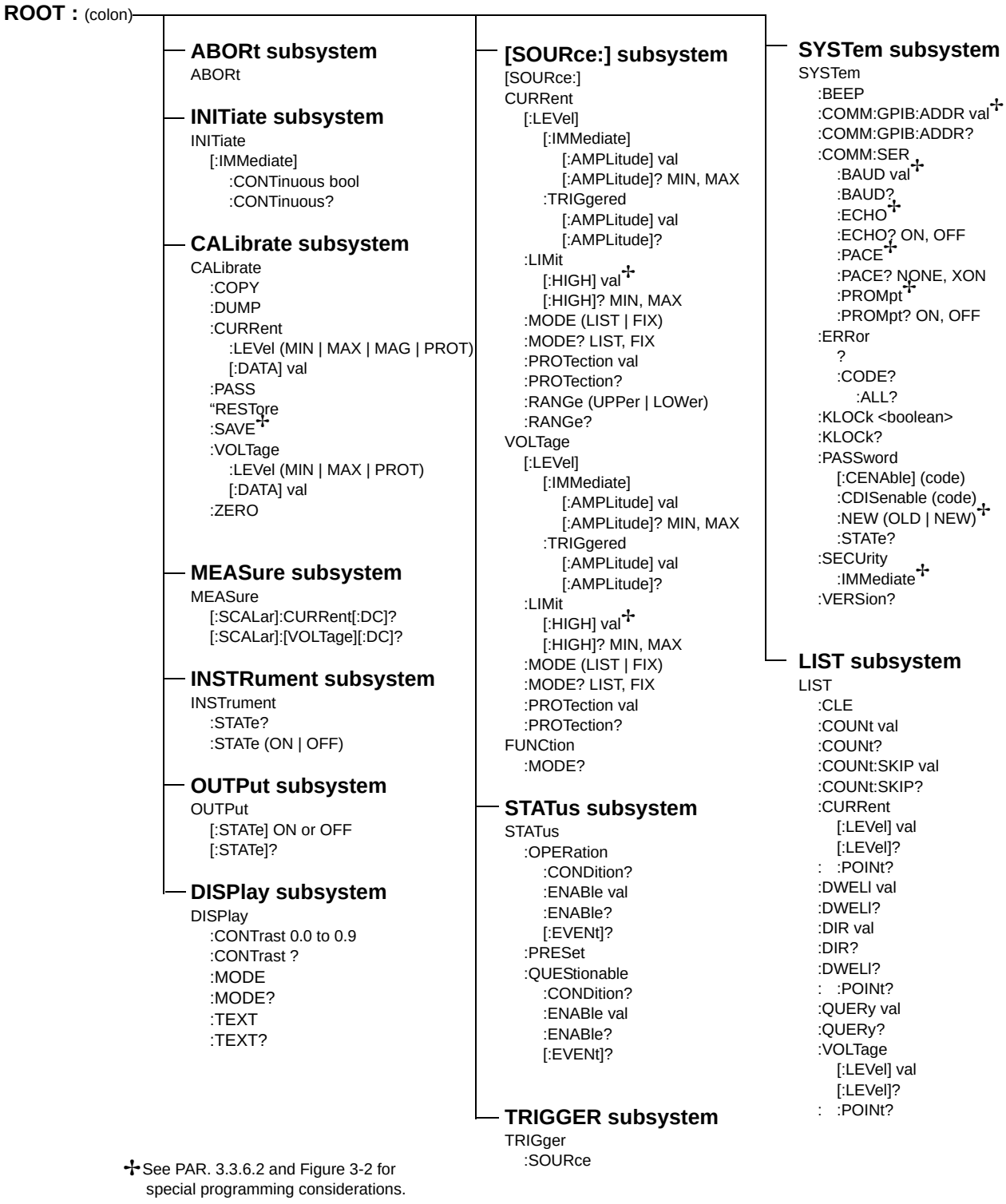


FIGURE 3-5. TREE DIAGRAM OF SCPI COMMANDS USED WITH BHK-MG POWER SUPPLY

3.5.4.7 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 4-3) 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.

3.5.4.8 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.

3.5.5 UNDERSTANDING THE COMMAND STRUCTURE

Understanding the command structure requires an understanding of the subsystem command tree illustrated in Figure 3-5. 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 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.

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.

3.5.6 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**

3.5.7 SCPI PROGRAM EXAMPLES

Refer to Appendix B, Figures B-1 through B-7 for examples illustrating the use of SCPI commands.

Figure 3-6 is an example of a program using SCPI commands to program the BHK-MG 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() {
   adr = ibfind("DEV6");                // Open DEV6 (defined by IBCONF)
   bd = ibfind ("GPIB0");               // Open GPIB card
   ibsic (bd);                          // Send Interface Clear
   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

   strset(rd_str,'\0');                 // Clear input buffer
   ibrd(adr,rd_str,64);                 // Read result of measure
   printf("received : %s\n",rd_str);    // Print voltage and current

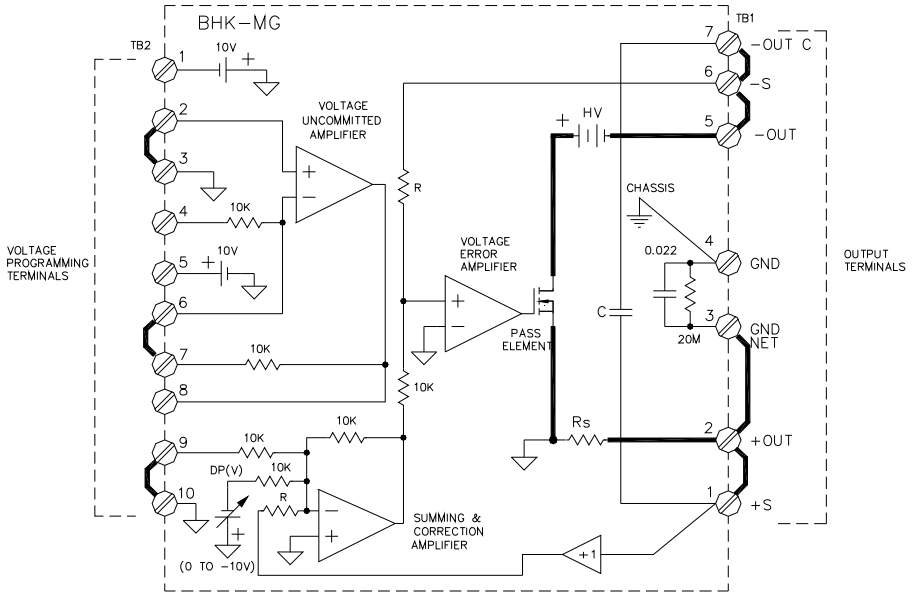
}
```

FIGURE 3-6. TYPICAL EXAMPLE OF BHK-MG POWER SUPPLY PROGRAM USING SCPI COMMANDS

3.6 REMOTE PROGRAMMING USING ANALOG PROGRAMMING TERMINALS

The BHK-MG power supply is designed with separate, but similar, circuits for analog voltage programming (Figure 3-7) and analog current programming (Figure 3-8). 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.

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 and correction 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 and correction 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.

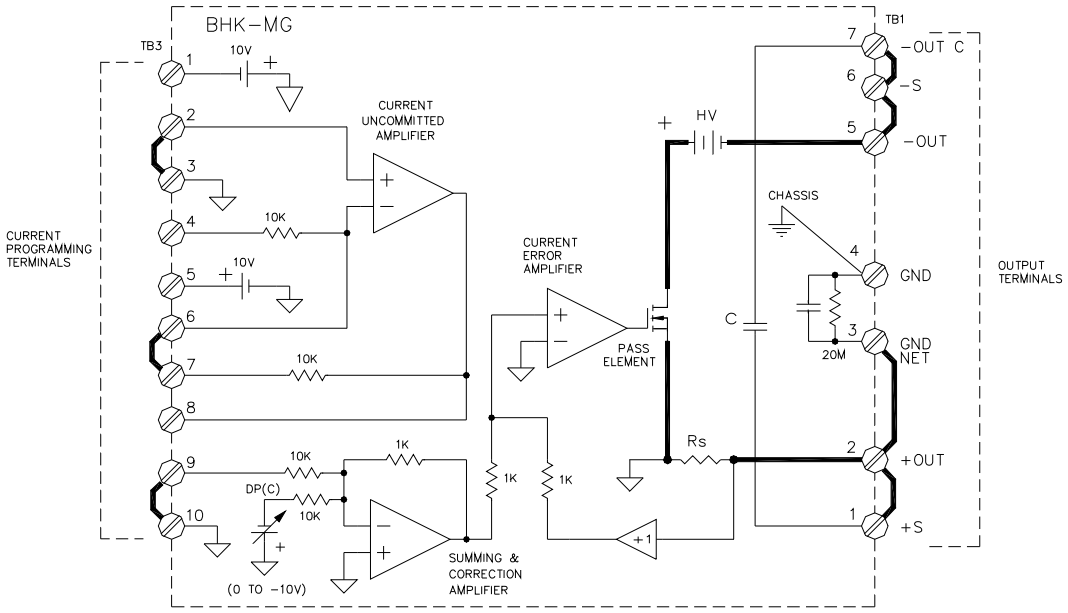


NOTES:

1. TERMINAL BLOCK CONNECTIONS (LINKS) SHOWN IN FACTORY DEFAULT CONFIGURATION.
2. HV = UNREGULATED HIGH VOLTAGE (RAW DC)
3. Rs = SENSING RESISTOR
4. R = INTERNAL FEEDBACK RESISTANCE (EQUAL TO CORRECTION RESISTANCE).
4. DP(V) = VOLTAGE (0 TO –10V) DETERMINED BY DIGITALLY PROGRAMMED VOLTAGE SETTING.

3041356

FIGURE 3-7. ANALOG VOLTAGE PROGRAMMING, SIMPLIFIED DIAGRAM



NOTES:

1. TERMINAL BLOCK CONNECTIONS (LINKS) SHOWN IN FACTORY DEFAULT CONFIGURATION.
2. HV = UNREGULATED HIGH VOLTAGE (RAW DC)
3. Rs = SENSING RESISTOR
4. DP(C) = VOLTAGE (0 TO –10V) DETERMINED BY DIGITALLY PROGRAMMED CURRENT SETTING.

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FIGURE 3-8. ANALOG CURRENT PROGRAMMING, SIMPLIFIED DIAGRAM

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 $-\left(10 - Eout_{dp} \times \frac{10}{Eomax}\right)$ 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
$Iout_{dp}$ = 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 500-0.4MG 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.

3.6.1 ANALOG PROGRAMMING WARNINGS AND CAUTIONS

WARNING

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 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.

WARNING

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.”

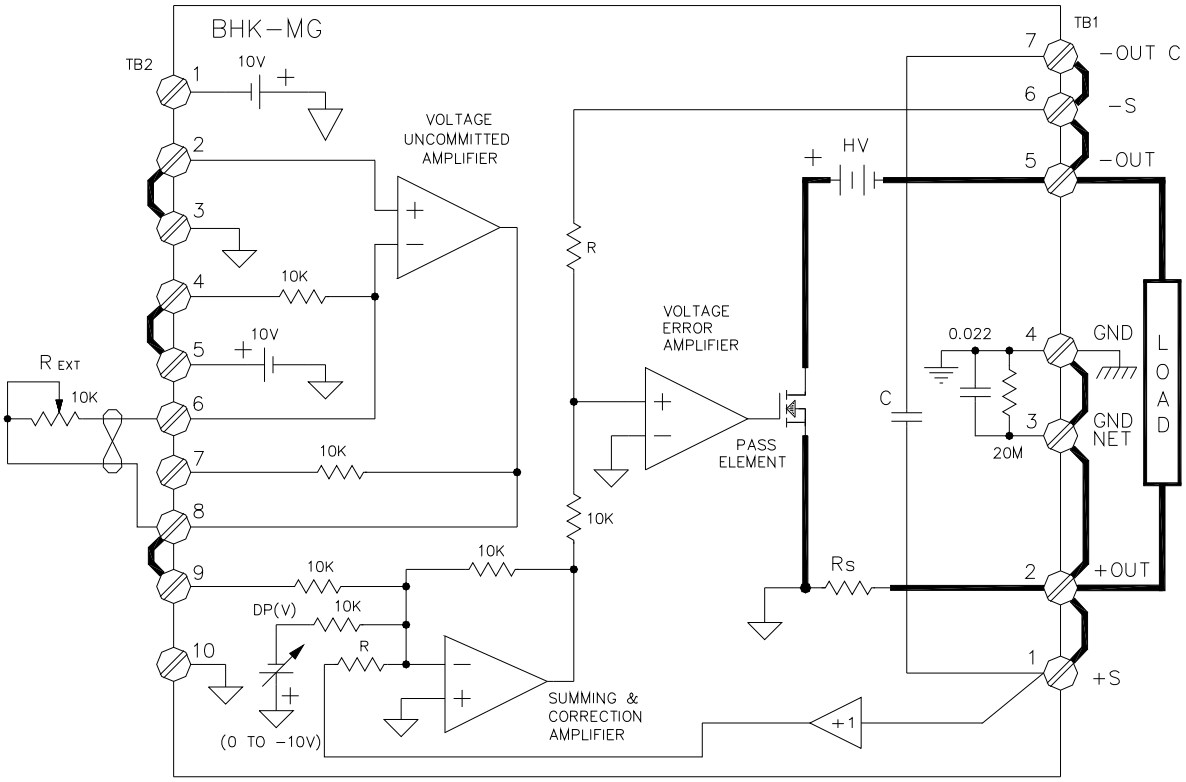
- If the power supply must operate isolated from ground (floating), any external equipment connected to the ANALOG PROGRAMING TERMINALS must also be isolated (battery operated or connected to a-c source power using an isolating transformer).

Safety Messages

The BHK-MG can be controlled by digital and/or analog inputs. When OUTPUT is set to off from the keypad or the GPIB, an analog input will still produce an output from the BHK-MG which will be indicated on the LCD. If the analog input is causing more than 8Vd-c to appear at the output terminals, or if current being supplied to the load exceeds 1mA, the unit will beep and enter a controlled shutdown for safety purposes unless the override jumper has been installed (see Table 2-9).

3.6.2 PROGRAMMING WITH EXTERNAL RESISTANCE

Figures 3-9 and 3-10 are simplified diagrams of the BHK-MG showing the jumper configuration and external connections required for analog programming using an external resistance. Figures 3-9 shows programming of either output voltage when the unit is in voltage mode, or voltage limit when the unit is in current mode. Figure 3-10 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.



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

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

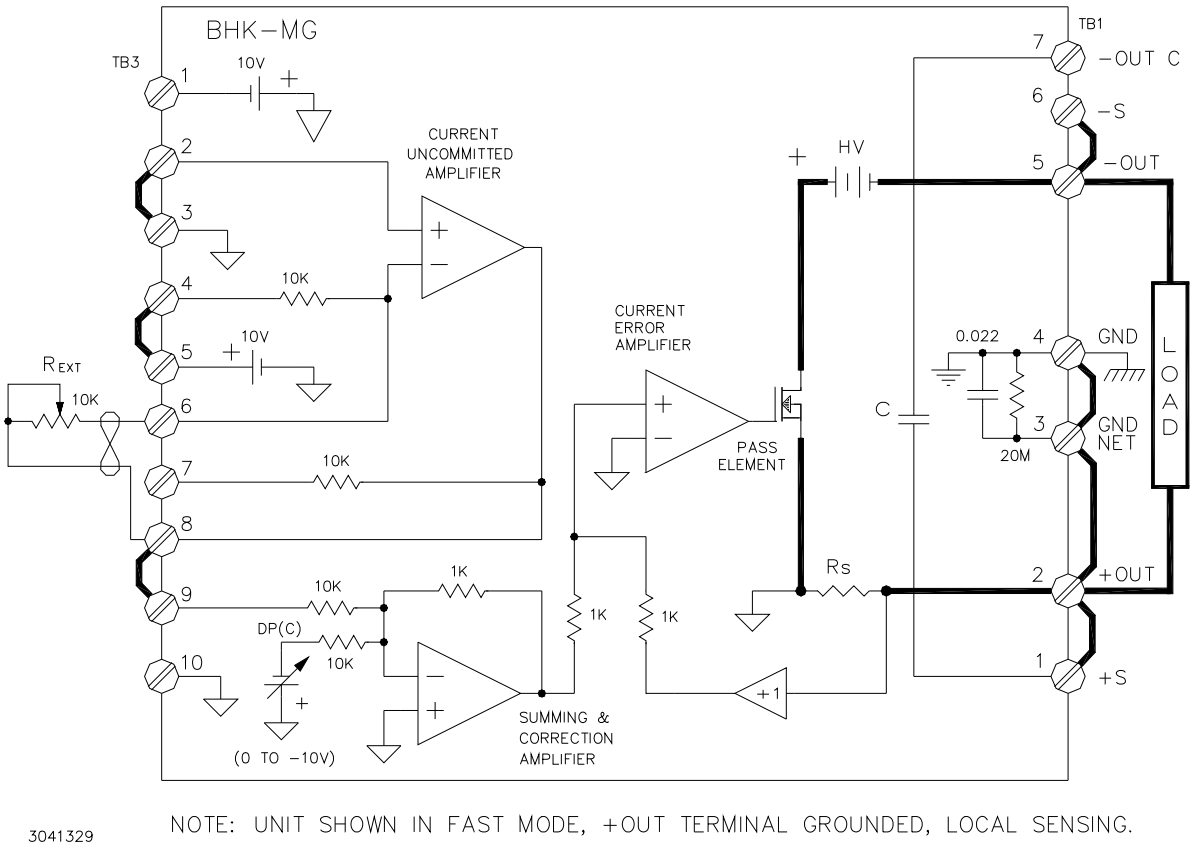


FIGURE 3-10. ANALOG PROGRAMMING OF OUTPUT CURRENT (CURRENT MODE) OR CURRENT LIMIT (VOLTAGE MODE) USING RESISTANCE

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 and correction amplifier. For voltage programming, the other input to the summing and correction 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 and correction amplifier, DP (C), is from the current portion of the digital programming circuitry (either from the keypad or the GPIB bus).

TABLE 3-10. FEEDBACK RESISTOR AND CURRENT SENSING RESISTOR VALUES

RESISTOR	SCALE	BHK 500-0.4MG	BHK 1000-0.2MG	BHK 2000-0.1MB
Voltage Feedback Resistor R		500K*	1000K*	2000K*
Current Sensing Resistor Rs	HIGH CURRENT	0.0025K*	0.005K*	0.010K*
	LOW CURRENT	0.025K*	0.05K*	0.10K*
* All resistors are 1% tolerance.				

3.6.2.1 VOLTAGE MODE

With the power supply in voltage mode (see Figure 3-9) 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) x (R_{EXT}/10K) x (–1) (10K/10K) x (–1) (R/10K)
= (–1) (0.1 x R) x R_{EXT}
= –0.1R x 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 equal to correction resistance (K-ohms), determined by Model (see Table 3-10).

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. 3.6.

3.6.2.2 CURRENT MODE

With the power supply in current mode (see Figure 3-10) 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 Iomax with a slope of (0.0001 x Iomax) mA per ohm. The following equation gives the output current as determined by external resistance R_{EXT}.

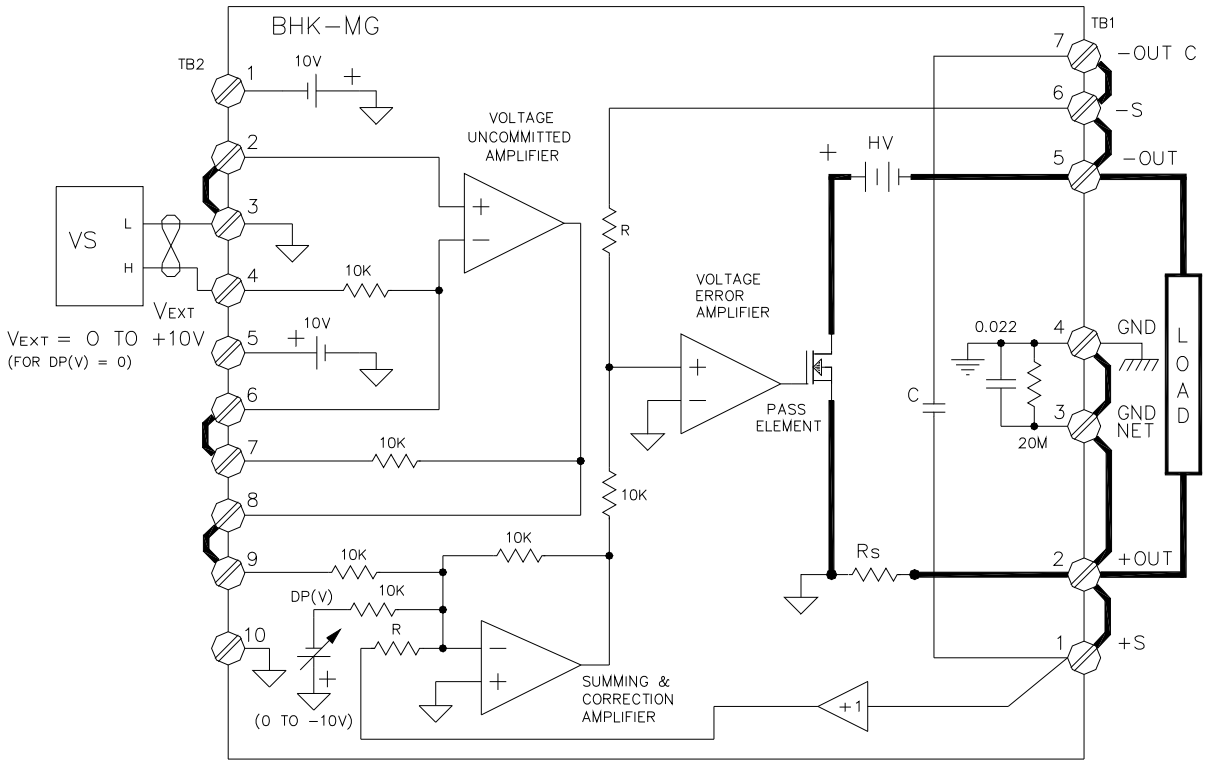
Io = [(–1) (10V) x (R_{EXT}/10K) x (–1) (1K/10K) x (–1) (1K/1K)]/Rs
= (–1) (0.1/ Rs) x R_{EXT}
= (–0.1/Rs) x R_{EXT} (mA d-c)

where

Rs = Internal shunt resistance (K-ohms), determined by Model (see Table 3-10).
(See above for definition of R_{EXT}.)

3.6.3 PROGRAMMING WITH EXTERNAL VOLTAGE USING A LOW IMPEDANCE VOLTAGE SOURCE

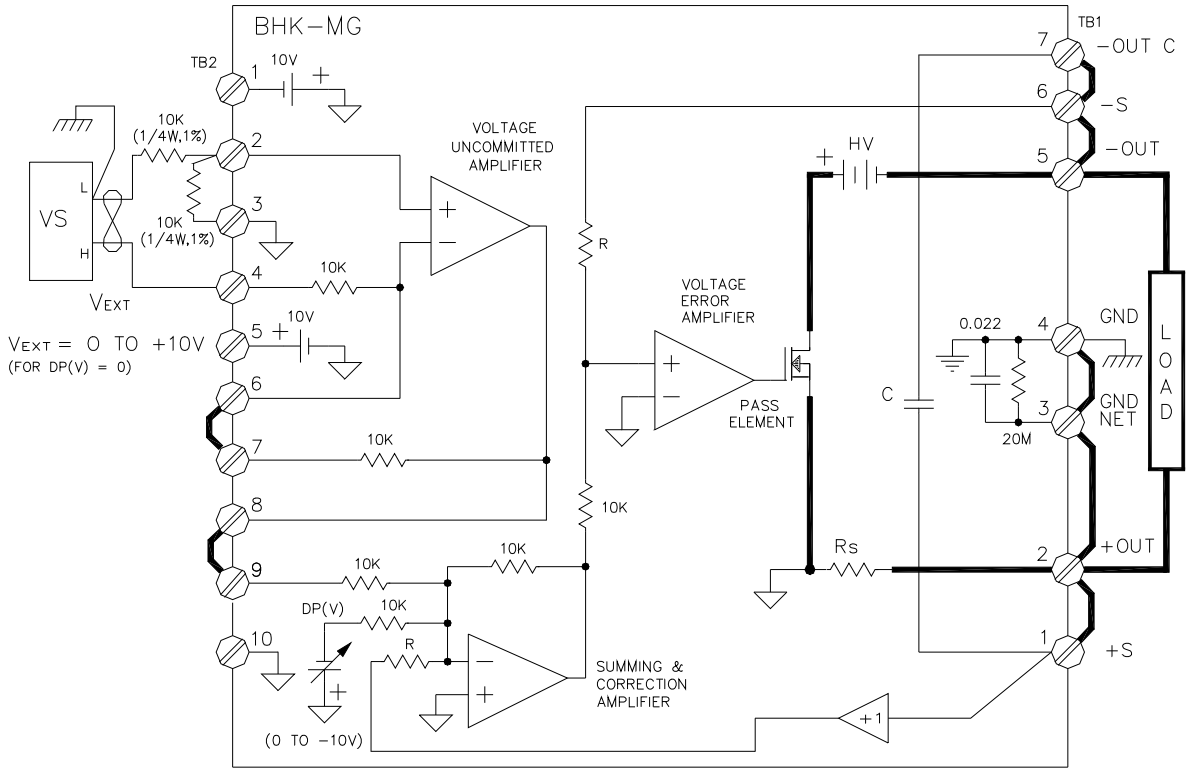
Figures 3-11 through 3-14 are simplified diagrams of the BHK-MG showing the jumper configuration and external connections required for analog programming using a low impedance voltage source. Figure 3-11 shows an isolated voltage source, Figure 3-12 shows a grounded voltage source for programming of either output voltage when the unit is in voltage mode, or voltage limit when the unit is in current mode. Figures 3-13 (isolated voltage source) and 3-14 (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.



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.

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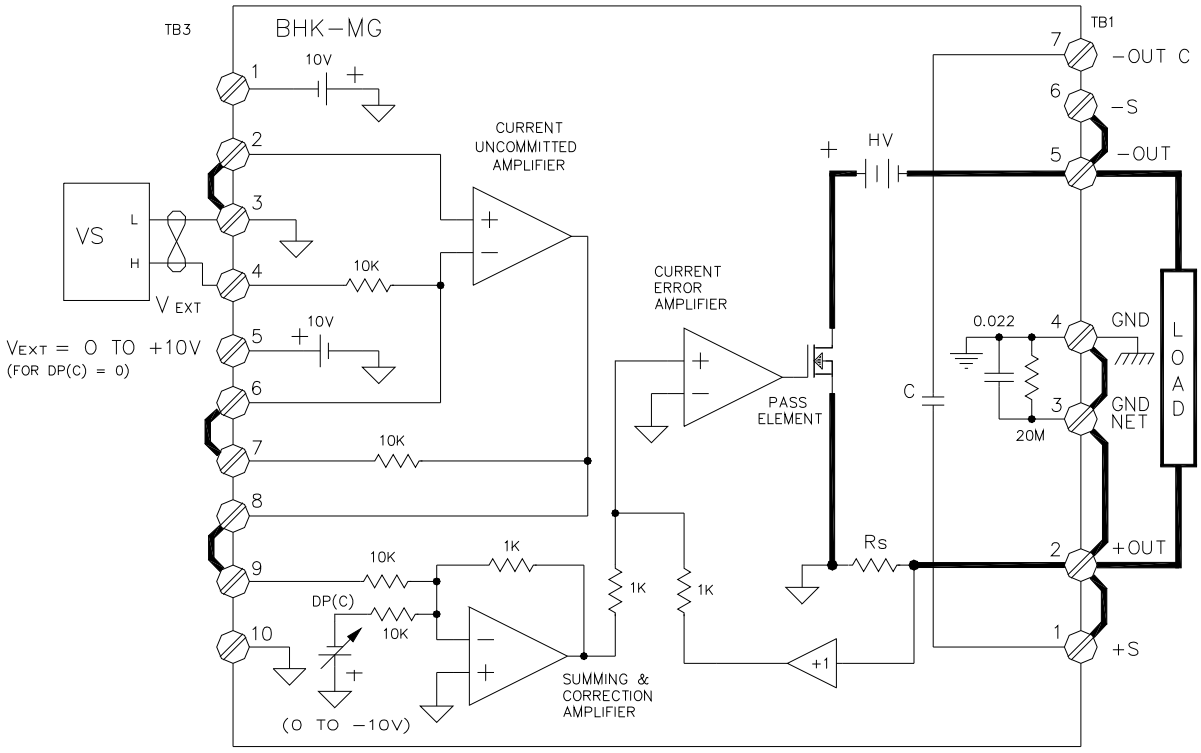
FIGURE 3-11. ANALOG PROGRAMMING OF OUTPUT VOLTAGE (VOLTAGE MODE) OR VOLTAGE LIMIT (CURRENT MODE) USING ISOLATED (FLOATING) LOW IMPEDANCE VOLTAGE SOURCE (VS)



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.

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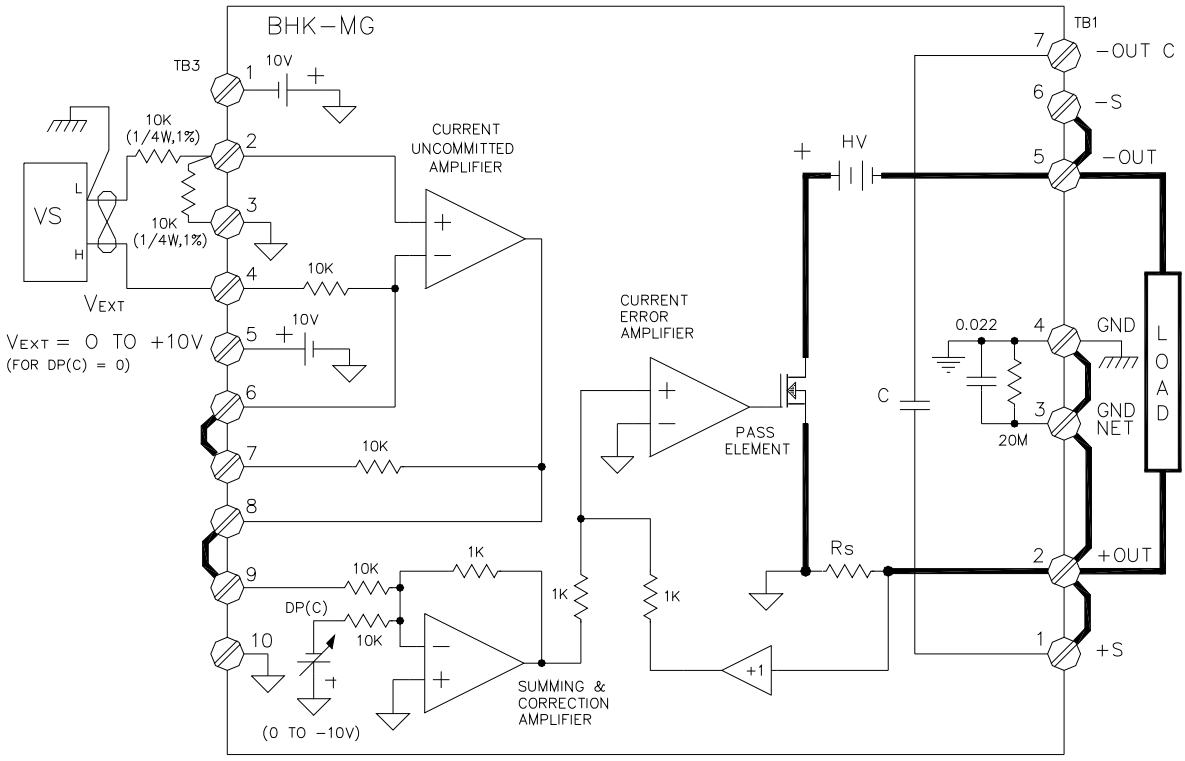
FIGURE 3-12. ANALOG PROGRAMMING OF OUTPUT VOLTAGE (VOLTAGE MODE) OR VOLTAGE LIMIT (CURRENT MODE) USING GROUNDED LOW IMPEDANCE VOLTAGE SOURCE (VS)



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.

3041330

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



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.

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FIGURE 3-14. ANALOG PROGRAMMING OF OUTPUT CURRENT (CURRENT MODE) OR CURRENT LIMIT (VOLTAGE MODE) USING GROUNDED LOW IMPEDANCE VOLTAGE SOURCE (VS)

The external voltage source is applied to the input of the uncommitted amplifier which is configured either as an inverting repeater (Figures 3-11 and 3-13) for isolated voltage sources or a differential amplifier having a gain of –1 (Figures 3-12 and 3-14) 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 3-11 and 3-13), 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 3-12 and 3-14.

3.6.3.1 VOLTAGE MODE

With the power supply in voltage mode (see Figure 3-11 or 3-12) 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_{EXT}.

ANALOG PROGRAMMING, DIGITAL PROGRAMMING = 0:

Eo = $(-1)\ (V_{EXT})$ x (10K/10K) x (–1) (10K/10K) x (–1) (R/10K)
= (–1) (0.1 x R) x V_{EXT}
= –0.1R x V_{EXT} (V d-c)

where

R = Internal feedback resistance (K-ohms), determined by Model (see Table 3-10).

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 x R x 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}.)

3.6.3.2 CURRENT MODE

With the power supply in current mode (see Figure 3-13 or 3-14) 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 Iomax with a slope of (0.1 x Iomax) 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}) x (10K/10K) x (–1) (1K/10K) x (–1) (1K/1K)]/Rs
= (–1) (0.1/ Rs) x V_{EXT} (mA d-c)
= –(0.1/Rs) x V_{EXT} (mA d-c)

where

Rs =Internal shunt resistance (K-ohms), determined by Model (see Table 3-10).
(See above for definition of V_{EXT}.)

ANALOG PROGRAMMING COMBINED WITH DIGITAL PROGRAMMING:

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

where

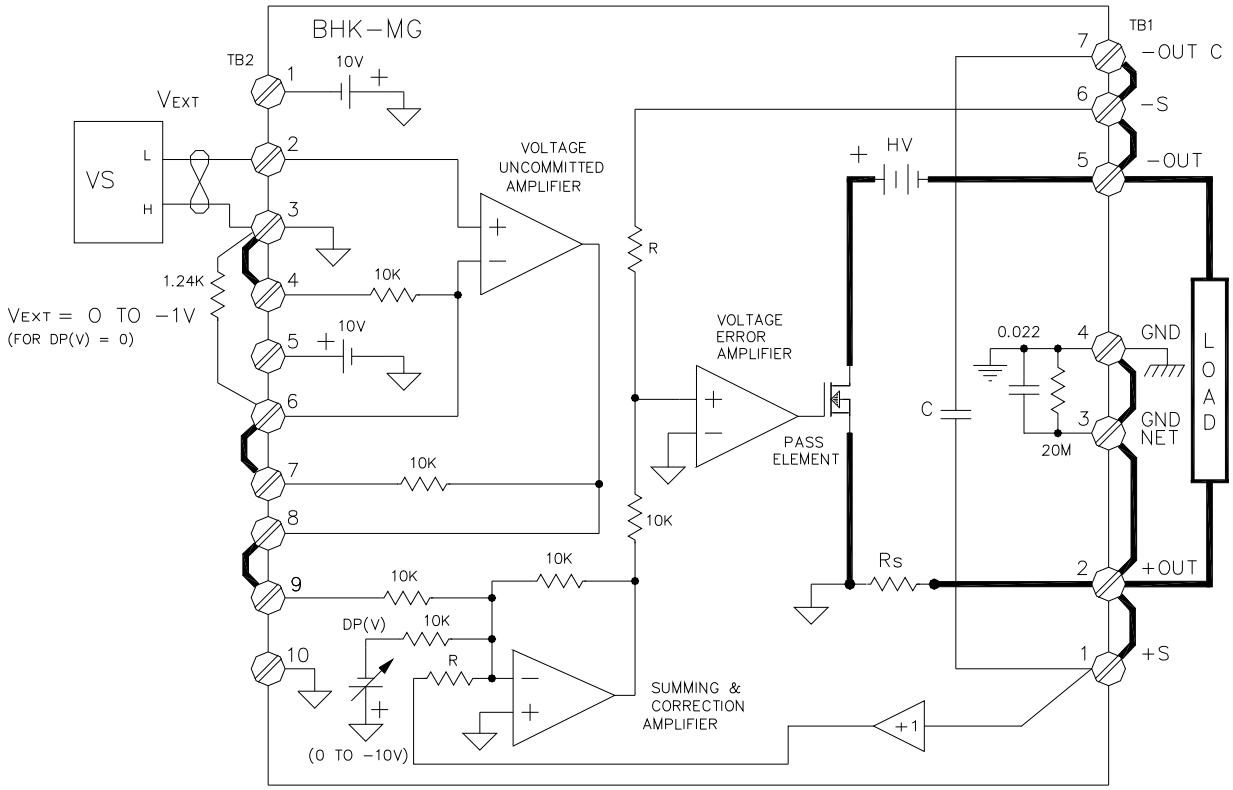
$Iout_{DP}$ = Output current programmed digitally (from either local keypad or remote GPIB bus)
(See above for definitions of Rs and V_{EXT}.)

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

Figures 3-15 and 3-16 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 3-15 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 3-16 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

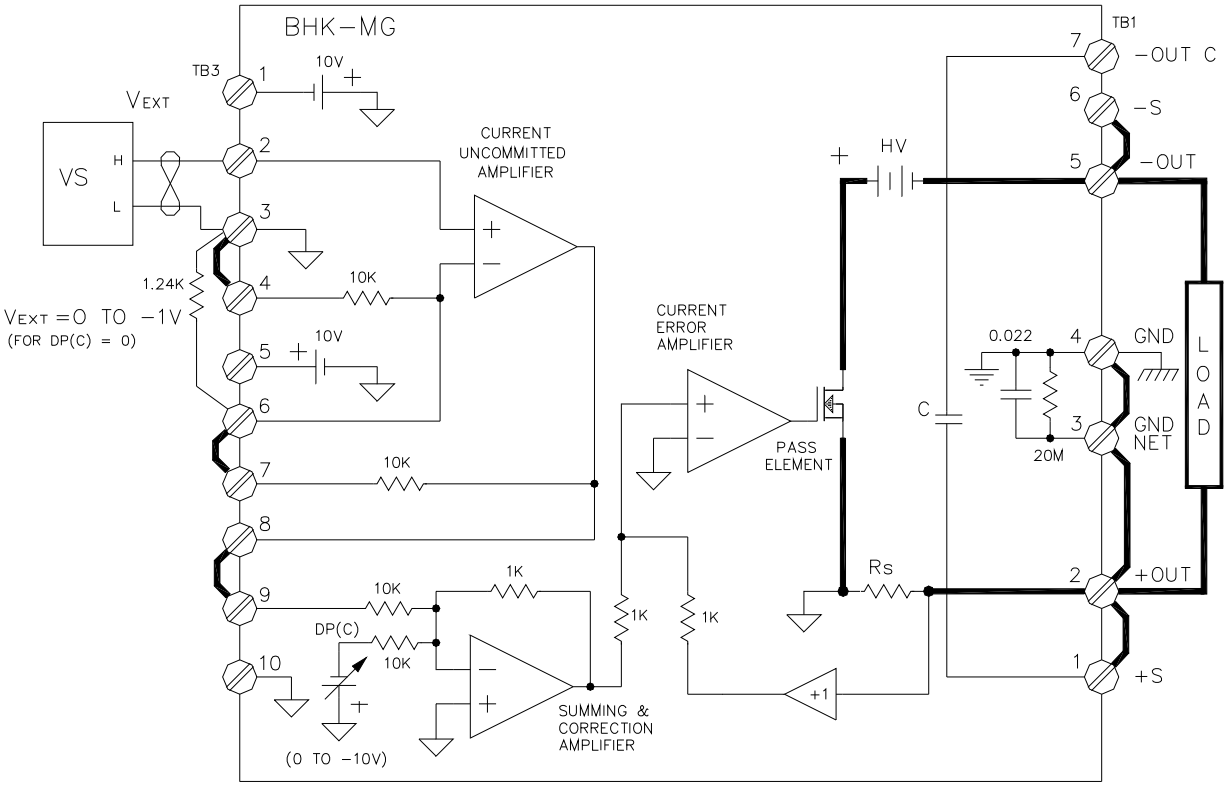
Observe the following to avoid damage to the power supply. The external voltage source output must be isolated from ground (floating output), or be powered from an a-c source that is isolated from ground to avoid short-circuiting the internal sensing resistor.



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.

3041350

FIGURE 3-15. 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.

3041331

FIGURE 3-16. ANALOG PROGRAMMING OF OUTPUT CURRENT (CURRENT MODE) OR CURRENT LIMIT (VOLTAGE MODE) USING HIGH IMPEDANCE, LOW LEVEL (1V) VOLTAGE SOURCE (VS)

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.

3.6.4.1 VOLTAGE MODE

With the power supply in voltage 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 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}) x (11.1K/1.1K) x (–1) (10K/10K) x (–1) (R/10K)
= –(R) x $|V_{EXT}|$ (V d-c)

where

R = Internal feedback resistance equal to correction resistance (K-ohms), determined by Model (see Table 3-10).

V_{EXT} = External low impedance voltage source. 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 x $|V_{EXT}|$) – $Eout_{DP}$ (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}.)

3.6.4.2 CURRENT MODE

With the power supply in current mode (see Figure 3-16) 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 Iomax with a slope of (Iomax) 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 = [(V_{EXT}) x (11.1K/1.1K) x (–1) (1K/10K) x (–1) (1K/1K)]/Rs
= –(1/Rs) x $|V_{EXT}|$ (mA d-c)

where

Rs =Internal shunt resistance (kOhms), determined by Model (see Table 3-10).
(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

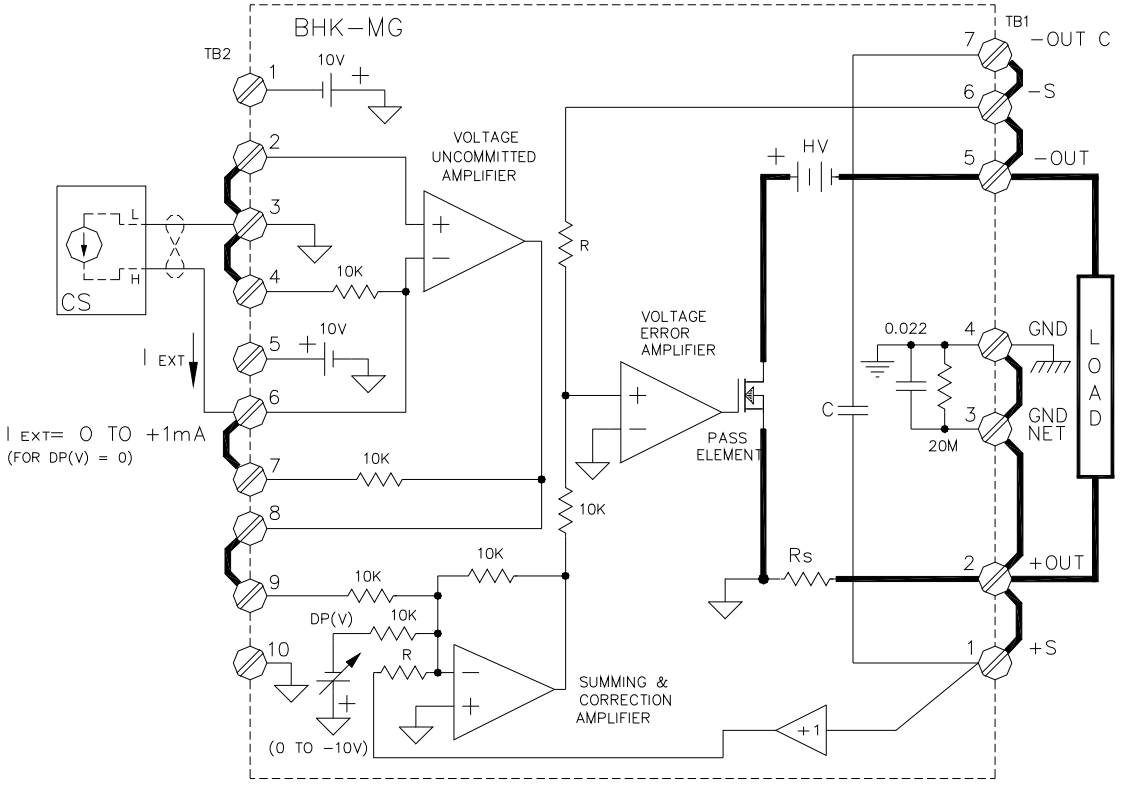
$Iout_{DP}$ = Output current programmed digitally (from either local keypad or remote GPIB bus)
(See above for definitions of Rs and V_{EXT}.)

3.6.5 PROGRAMMING WITH EXTERNAL CURRENT SOURCE (1 mA)

Figures 3-17 and 3-18 are simplified diagrams of the BHK-MG showing the jumper configuration and external connections required for analog programming using a current source (1mA). Figure 3-17 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 3-18 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

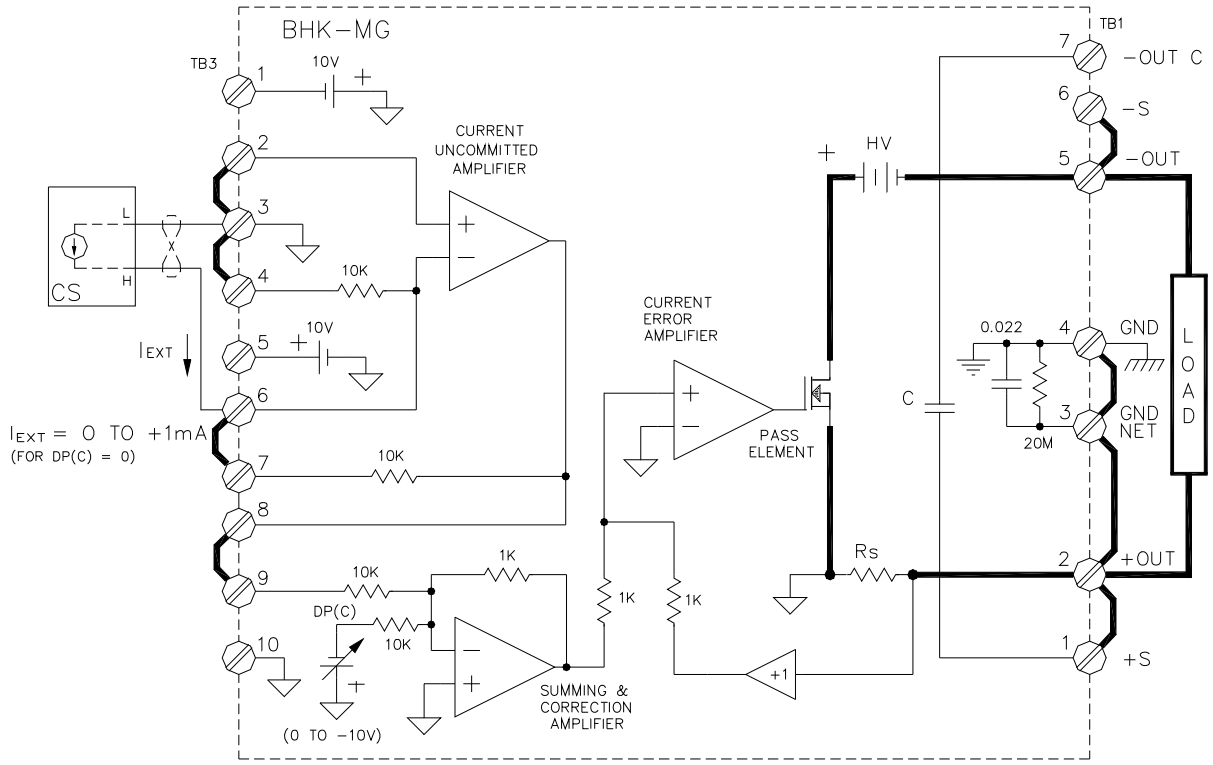
Observe the following to avoid damage to the power supply. The external current source output must be isolated from ground (floating output), or be powered from an a-c source that is isolated from ground to avoid short-circuiting the internal sensing resistor.



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.

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



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.

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FIGURE 3-18. 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.

3.6.5.1 VOLTAGE MODE

With the power supply in voltage 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 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 = $(-1)I_{EXT}$ x (10K) x (–1) (10K/10K) x (–1) (R/10K)
= –(R) x I_{EXT} (V d-c)

where

R = Internal feedback resistance equal to correction resistance (K-ohms), determined by Model (see Table 3-10).

I_{EXT} = External current source. 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 x 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}.)

3.6.5.2 CURRENT MODE

With the power supply in current mode (see Figure 3-18) 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 Iomax with a slope of (Iomax) mA per mA. The following equations give the output current as determined by the external current source I_{EXT}.

ANALOG PROGRAMMING, DIGITAL PROGRAMMING = 0:

Io = [(-1) I_{EXT} x (10K) x (–1) (1K/10K) x (–1) (1K/1K)]/Rs
= –(1/Rs) x I_{EXT} (mA d-c)

where

Rs =Internal shunt resistance (K-ohms), determined by Model (see Table 3-10).
(See above for definition of V_{EXT}.)

ANALOG PROGRAMMING COMBINED WITH DIGITAL PROGRAMMING:

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

where

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

3.7 OPERATING MODES

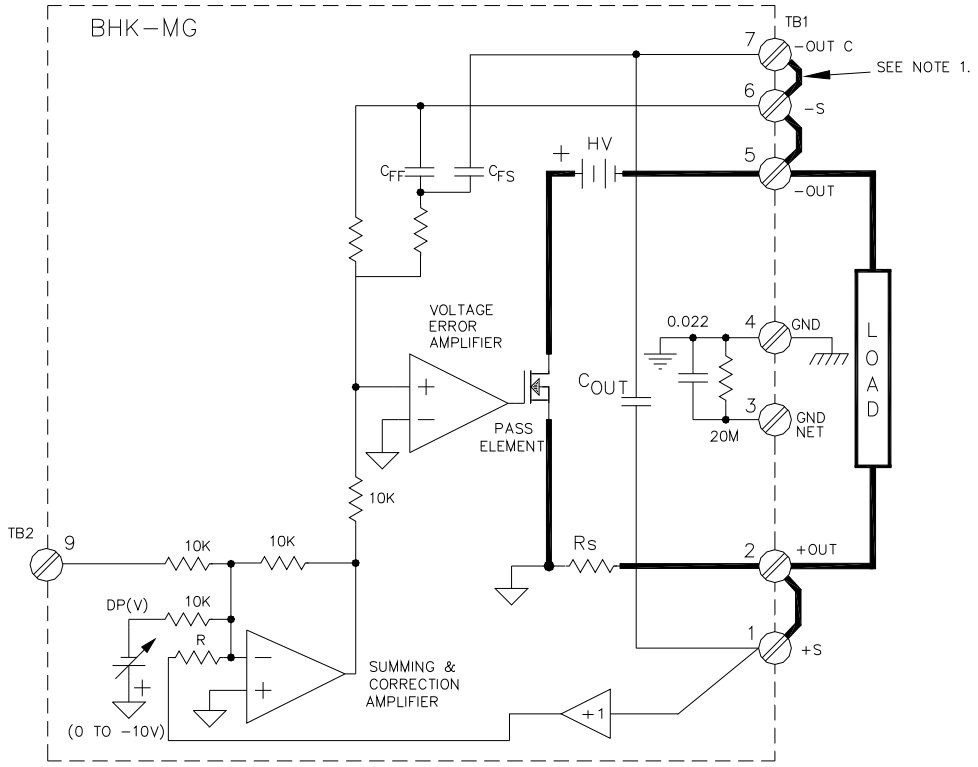
This section describes the following operating modes for the BHK-MG power supply

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

3.7.1 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 7 (-OUT.C) and terminal 6 (-S). 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 3-19). 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 7 (-OUT.C) and terminal 6 (-S). 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.



NOTES: 1. UNIT SHOWN IN SLOW MODE, LOCAL SENSING. REMOVE LINK BETWEEN TERMINAL 6 AND 7 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 C_{FF} AND C_{FS} ARE ACTIVE IN SLOW MODE.

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FIGURE 3-19. SLOW MODE/FAST MODE OPERATION

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 3-19).

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.

c. 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 TB1-6 and TB1-7. If the external capacitor is compara-

ble or larger than the internal C_{OUT}, it is advisable to connect the internal C_{OUT} across the output by installing the link between terminals TB1-6 and TB1-7, 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.

3.7.2 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. 3.7.2.1) and master-slave (PAR. 3.7.2.2).

WARNING

HANDLING HIGH VOLTAGE, LOW IMPEDANCE EQUIPMENT IS DANGEROUS, AND POTENTIALLY LETHAL. OBSERVE ALL PRECAUTIONS LISTED IN PAR. 3.6.1., 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 2000-0.1MG 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. 3.6.1).

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. 3.6.1).

e. Each BHK-MG power supply contains an internal, reverse-biased diode across the output which protects the power supply by limiting the opposite polarity voltage at the output. This diode is rated for the nominal output voltage of each model (see Table 1-1). When BHK-MG power supplies are series-connected, this diode will protect each sup-

ply against a short circuit at the load, with one exception. The current rating of the reverse-biased diode used on model BHK 2000-0.1MG is 0.2A. When this unit is connected in series with a model BHK 500-0.4MG, which has a maximum current rating of 0.4A, it is necessary to connect an external (reverse-biased) diode across the output of the 2000V unit which is rated for 3kV reversed voltage and 0.4A direct current.

NOTE: The simplified schematic diagrams (Figures 3-20 through 3-22) 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.

3.7.2.1 AUTOMATIC SERIES OPERATION

This operating configuration (see Figure 3-20) 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:

$Eo = Eo_A + Eo_B$

$Io = Eo / R_{LOAD}$

where

Eo, Io 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 3-20). 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., 500-0.4MG and 1000-0.2MG, unit A must be the one with the lower current capacity: 1000-0.2MG

a. Program IsetA to the current limit for the power assembly.

b. Program VsetA to: $Vset = Eo\frac{EomaxA}{(EomaxA + EomaxB)}$ (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 500-0.4MG),
- EomaxB is the rated maximum output voltage for unit B.

c. Program overcurrent value of unit A (IocsetA) to 1.1 x current limit for power assembly (step 3a).

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 (IocsetB) to 1.1 x IsetB (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.

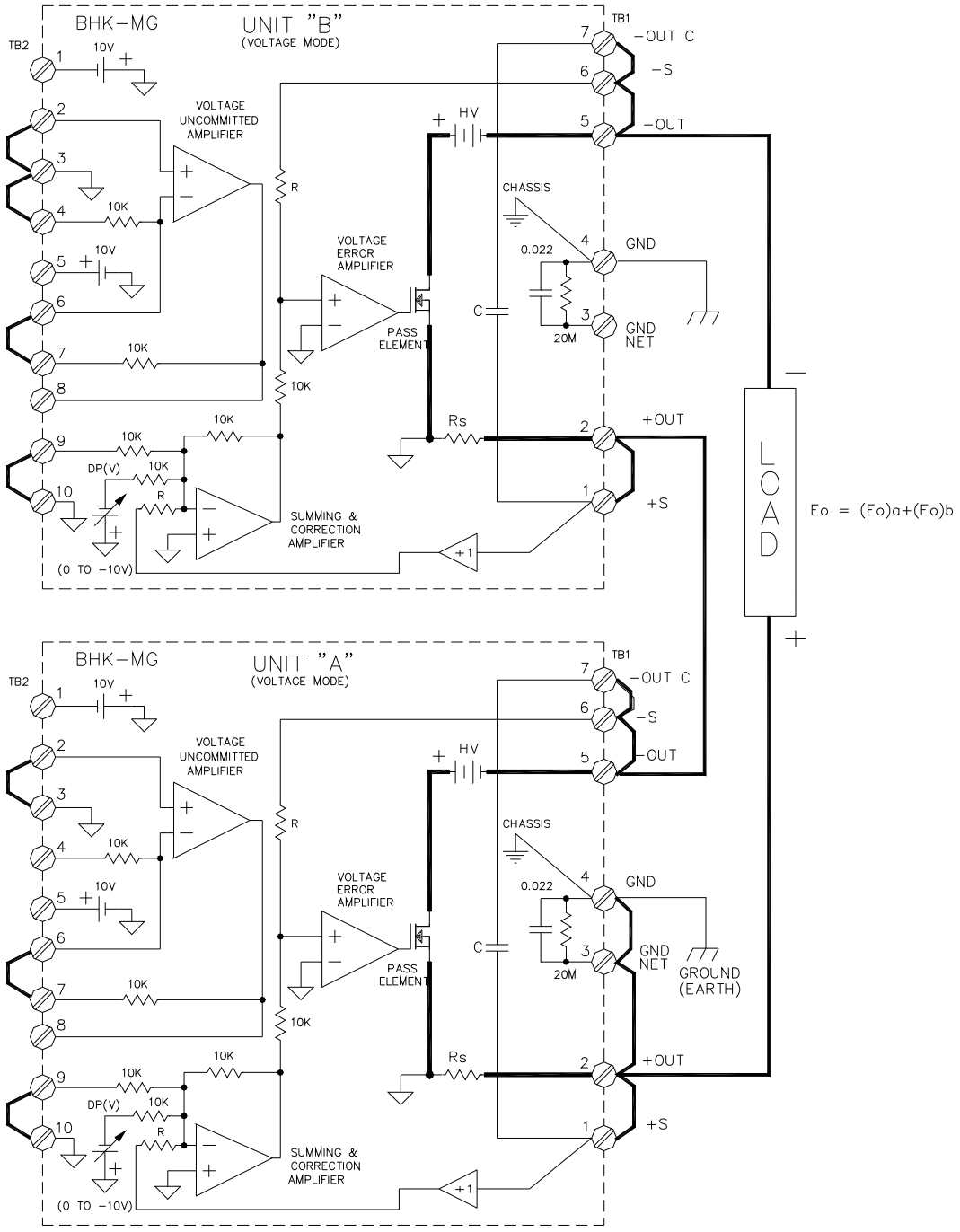
b. If load switch not used, press POWER ON/OFF key (once) on unit B, then unit A.

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.

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FIGURE 3-20. SERIES AUTOMATIC CONFIGURATION

3.7.2.2 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 3-21 configured to operate in voltage mode, and in Figure 3-22 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. 3.6.2). The external resistor (R_{EXT}) becomes the input resistor of the uncommitted amplifier (slave) which is configured as an inverting amplifier.

3.7.2.2.1 VOLTAGE MODE OPERATION

When the series combination (Figure 3-21) 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,

$$\begin{aligned} Eo &= Eo_M + Eo_S \\ &= Eo_M + [Eo_M \times (10/R_{EXT}) \times (Eomax_S/10)\,] \\ &= Eo_M + [Eo_M \times (Eomax_S/R_{EXT})] \end{aligned} \qquad \text{(eq1)}$$

where

Eo_M, Eo_S are the output voltages of the master and slave unit, respectively, in Volts
$Eomax_S$ is the maximum output voltage of the slave unit, in Volts
R_{EXT} is the external programming resistor of the slave unit, in K-ohms.

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

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 K-ohms) 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,

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

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 3-21). If possible, use a properly rated switch between the power supply and the load. Use $R_{EXT} = Eomax_M$ (see PAR. 3.7.2.2.1).

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 ($Iocset_S$) to 1.1 x $Iset_S$ (step 3a).

   d. Program overvoltage value of slave unit ($Vovset_S$) to

   $$1.1 \times \frac{(Eo)(Eomax_S)}{(Eomax_M) + (Eomax_S)} .$$

   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.

   b. Program $Vset_M$ to $\frac{(Eo)(Eomax_M)}{(Eomax_M) + (Eomax_S)}$.

   c. Program overcurrent value of master unit ($Iocset_M$) to 1.1 x $Iset_M$ (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.

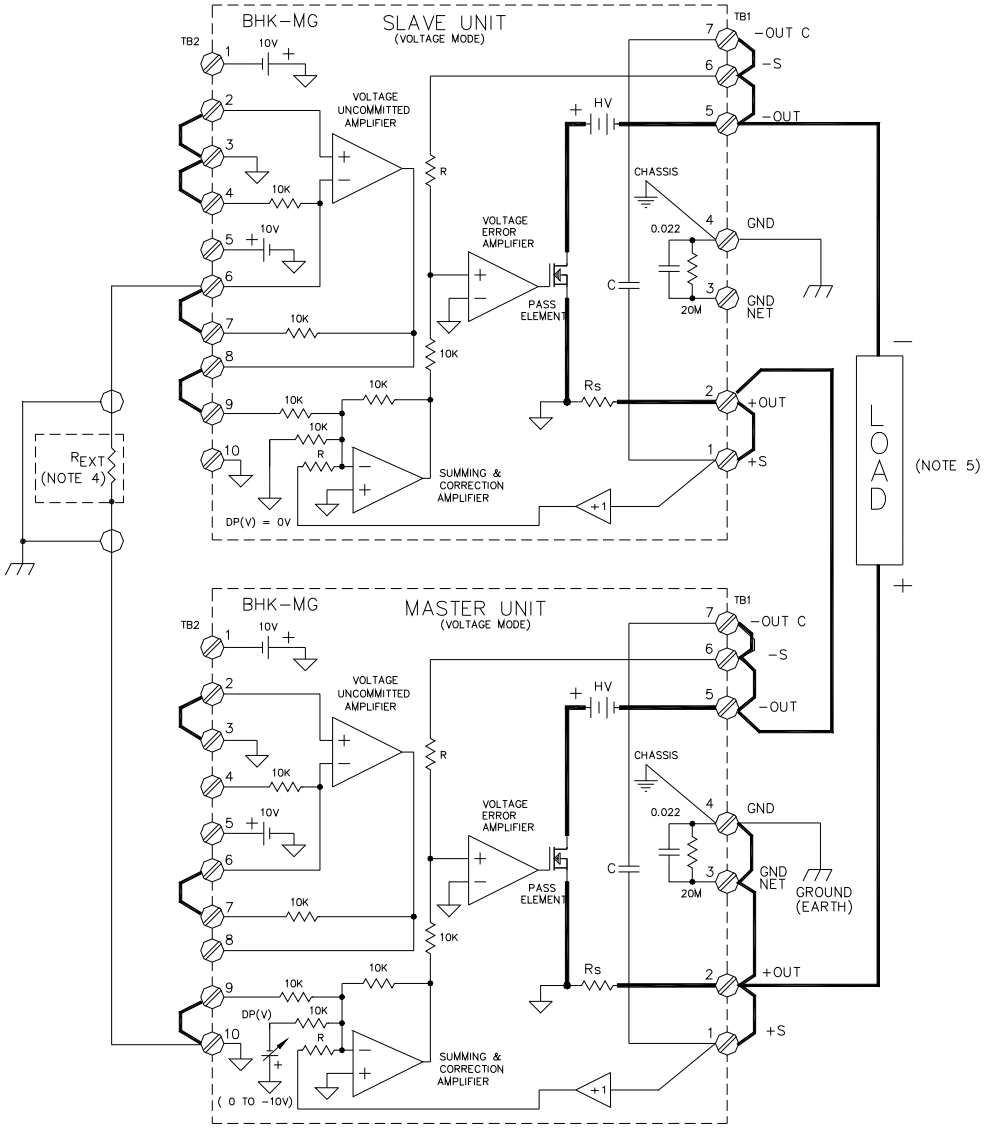
b. If load switch not used, press POWER ON/OFF key (once) on master unit, then slave unit.

6. To disable power to the load:

c. If load switch used, open the switch.

d. If load switch not used, press POWER ON/OFF key: once on the master unit, then once on the slave unit.

e. Alternative: Turn both units off by setting POWER switch to off (down) position, first on master unit, then on slave unit.



NOTES:

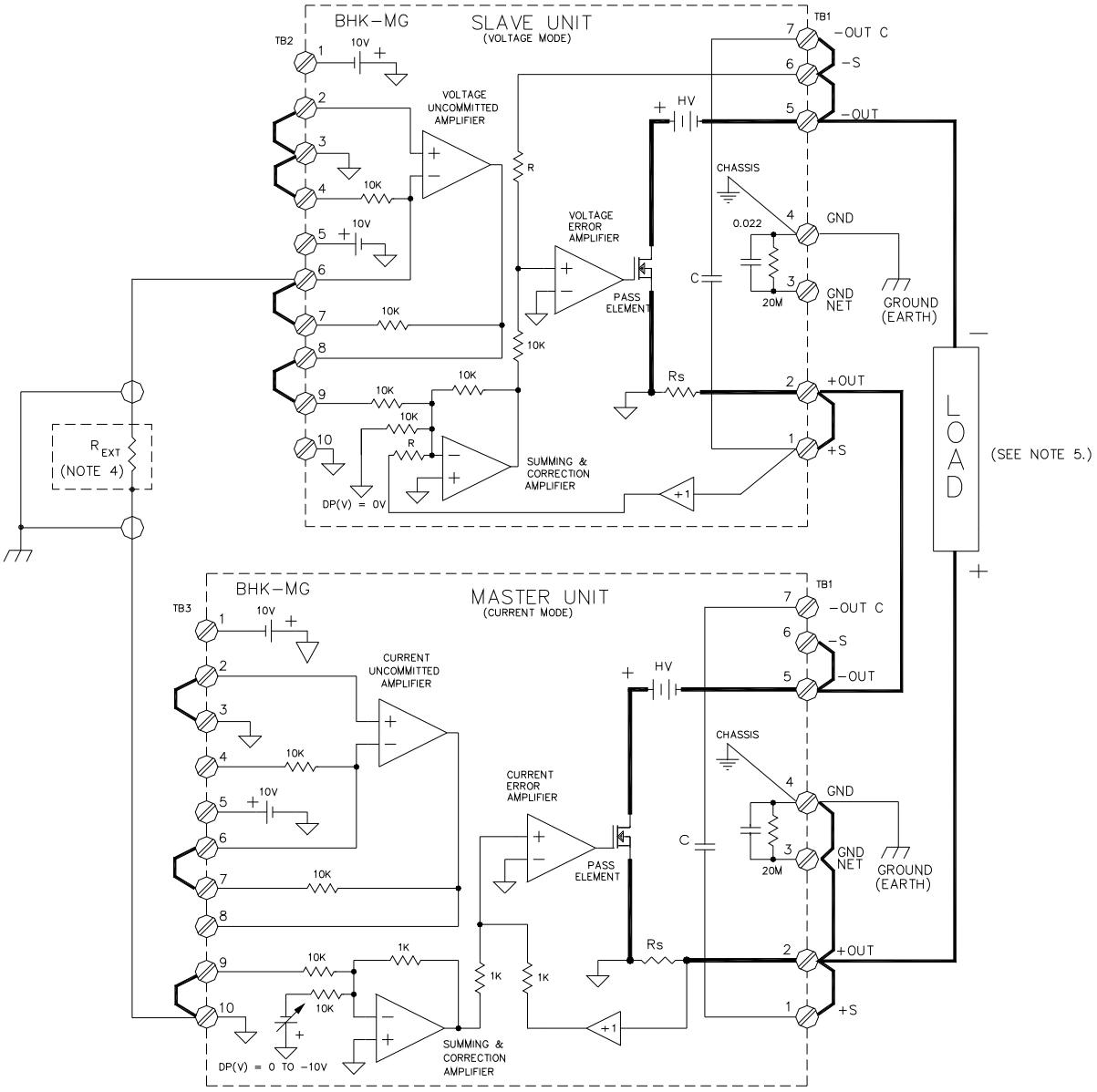
1) THE SERIES COMBINATION IS SHOWN USING LOCAL SENSING, SLOW MODE, OPERATING IN VOLTAGE MODE WITH "+OUTPUT" TERMINAL GROUNDED.
2) CONTROL OF THE MASTER UNIT IS DONE BY DIGITAL PROGRAMMING (DP(V)), EITHER LOCAL OR REMOTE; ANALOG PROGRAMMING CAN ALSO BE USED.
3) CONTROL OF THE SLAVE UNIT CAN BE DONE ONLY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

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

3.7.2.2.2 CURRENT MODE OPERATION

When the series combination is operating in current mode (see Figure 3-22), 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:

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)
5) $Io = Io_M \quad M \frac{Eomax_S}{Eomax_M}$

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FIGURE 3-22. SERIES MASTER-SLAVE (CURRENT MODE) CONFIGURATION

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 = Io_M x 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 3-22). Use R_{EXT} = $Eomax_M$ (see PAR. 3.7.2.2.1) 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 $Iset_S$ to approximately 1.01 to 1.02 x nominal output current Io 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 ($Iocset_S$) to 1.1 x $Iset_S$ (step 3a).

   d. Program overvoltage value of slave unit ($Vovset_S$) to $\frac{(1.1)(E_{LIM})(Eomax_S)}{Eomax_M + Eomax_S}$ where:

      - 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 $Iset_M$ to the desired output current, I_O of the power assembly.

   b. Program $Vset_M$ to $\frac{(E_{LIM})(EomaxM)}{(EomaxM + EomaxS)}$.

c. Program overcurrent value of master unit ($Iocset_M$) to 1.1 x $Iset_M$ (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.

3.7.3 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. 3.7.2.1) and master-slave (PAR. 3.7.2.2).:

WARNING

HANDLING HIGH VOLTAGE, LOW IMPEDANCE EQUIPMENT IS DANGEROUS, AND POTENTIALLY LETHAL. OBSERVE ALL PRECAUTIONS LISTED IN PAR. 3.6.1., 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. 3.6.1).

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 and have “fully insulated controls and chassis” features (see also PAR’s. 3.6.2 through 3.6.5).

NOTE: The simplified schematic diagrams (Figures 3-23 through 3-25), 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.

3.7.3.1 AUTOMATIC PARALLEL OPERATION

This operating configuration (see Figure 3-23) 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 3-23). If possible, use a properly rated switch between the power supply and the load.

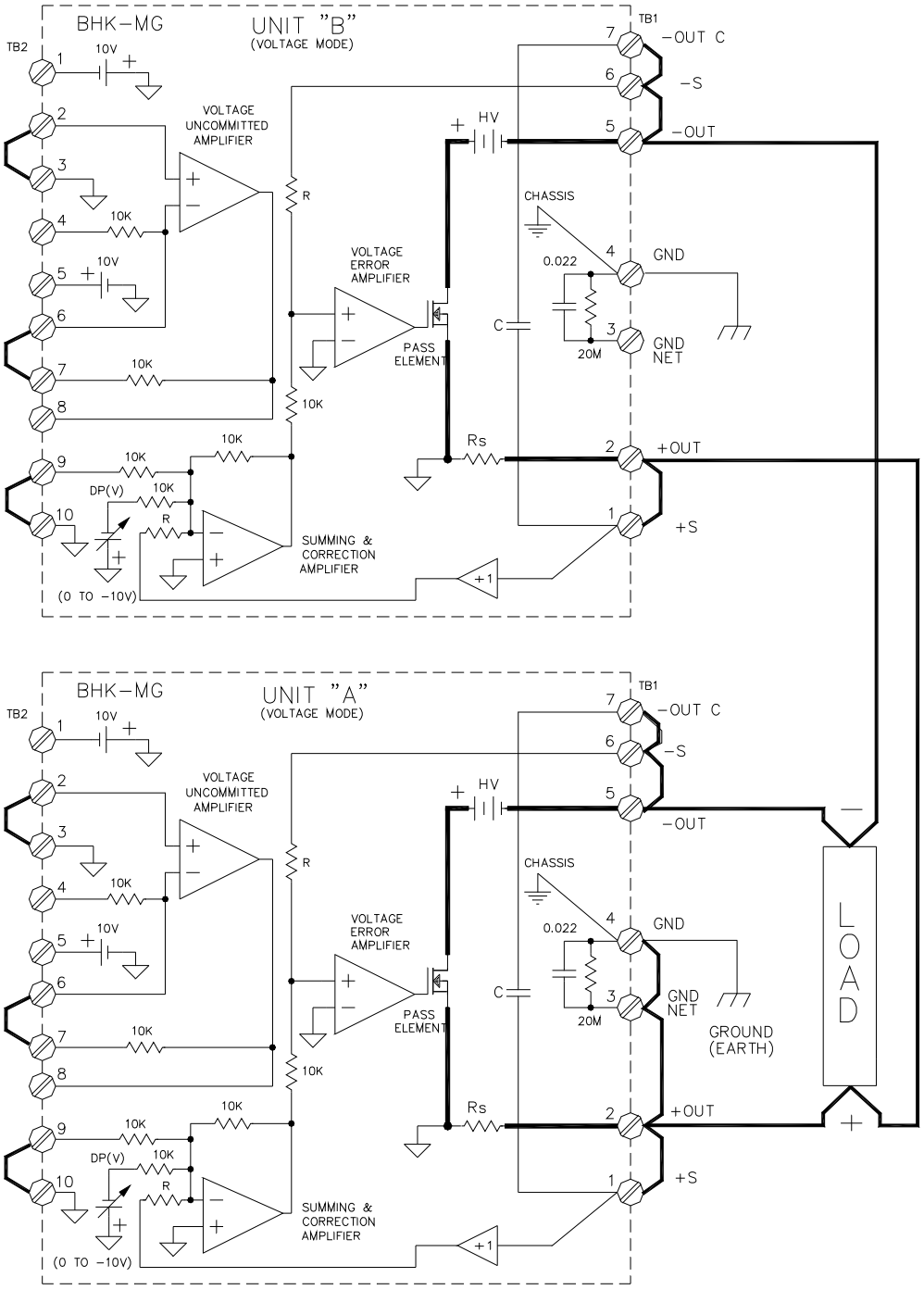
2. Apply power to the units:

    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: $I_{LOAD}/2$.



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 3-23. PARALLEL AUTOMATIC CONFIGURATION

b. Program VsetA to: $Eo + \frac{EomaxA}{2500}$ 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 500-0.4MG).

c. Program overcurrent value of unit A (IocsetA) to 1.1 x IsetA (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., 400 (mA) for BHK 500-0.4MG.

b. Program VsetB to Eo.

c. Program overcurrent value of unit B (IocsetB) to 1.1 x the rated maximum current for unit B (IomaxB), e.g., 1.1 x 400 = 440 mA for BHK 500-0.4MG.

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.

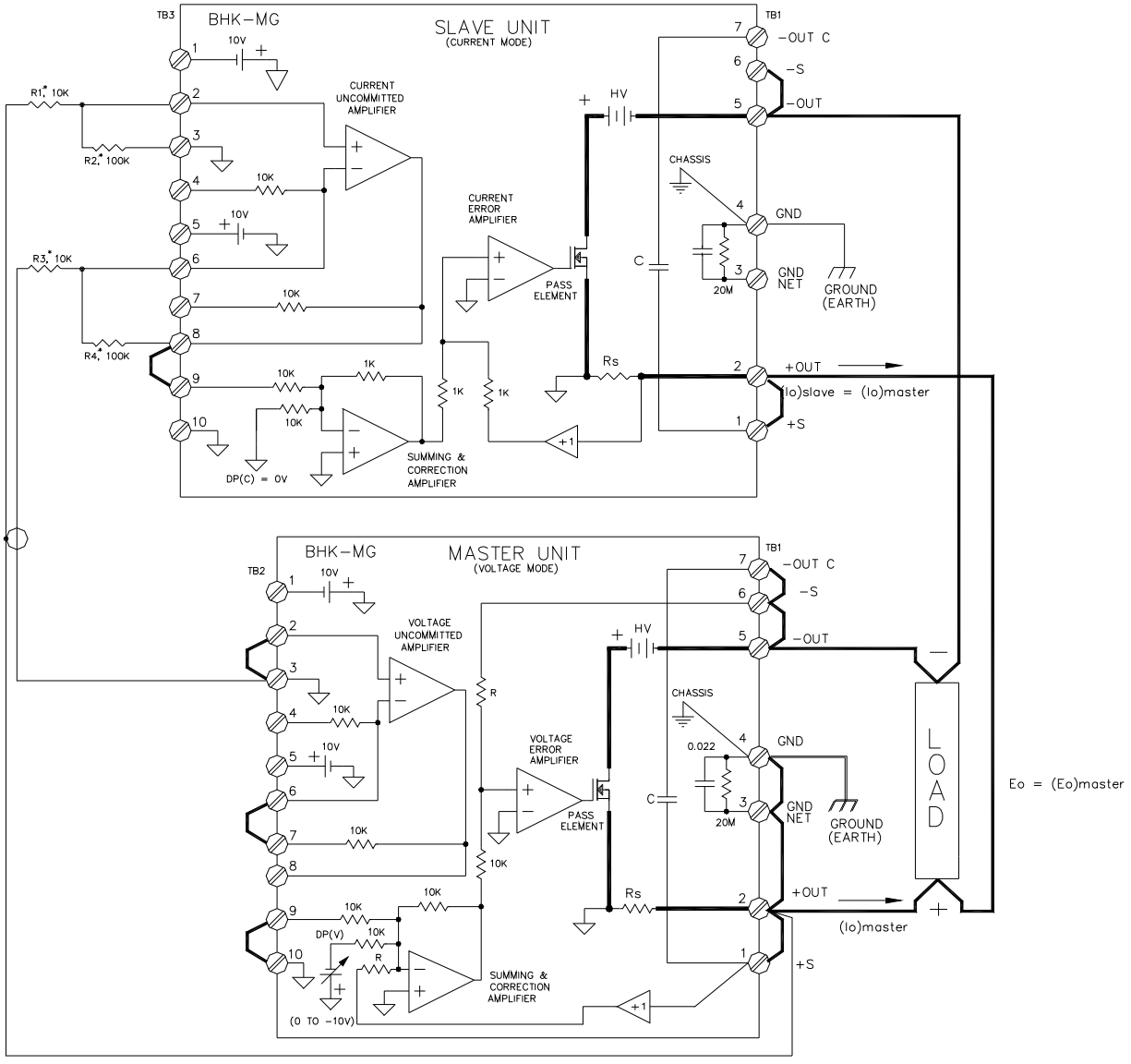
3.7.3.2 MASTER-SLAVE PARALLEL OPERATION

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 3-24 configured to operate in voltage mode, and in Figure 3-25 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.

3.7.3.2.1 VOLTAGE MODE OPERATION

When the parallel combination is configured to operate in voltage mode (see Figure 3-24), 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) = 0V), AS SHOWN.

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

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

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

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

The load current is given by the equation,

$Io = Eo / R_{LOAD}$.

The individual currents of the master and slave supplies are,

$Io_M = Io_S = Io / 2$.

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 3-24). 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 BHK1000-0.2MG set $Vset_S = 1000$).

    c. Program overcurrent value of slave unit ($Iocset_S$) to 1.1 x rated maximum current of slave unit (e.g., for BHK 1000-0.2MG, program $Iocset_S = 220$ (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 $Iset_M$ to 1/2 the desired current limit, I_{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 ($Iocset_M$) to 1.1 x $Iset_M$ (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.

3.7.3.2.2 CURRENT MODE OPERATION

When the parallel combination is configured to operate in current mode (see Figure 3-25), 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

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

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 3-25.

2. The current of the slave unit will be slightly larger than the current of the master unit (minimum of 5% for BHK 500-0.4MG) due to the voltage drop on the wire connecting the internal sensing resistor to the externally accessible terminal TB1-2 (see Figure 3-25).

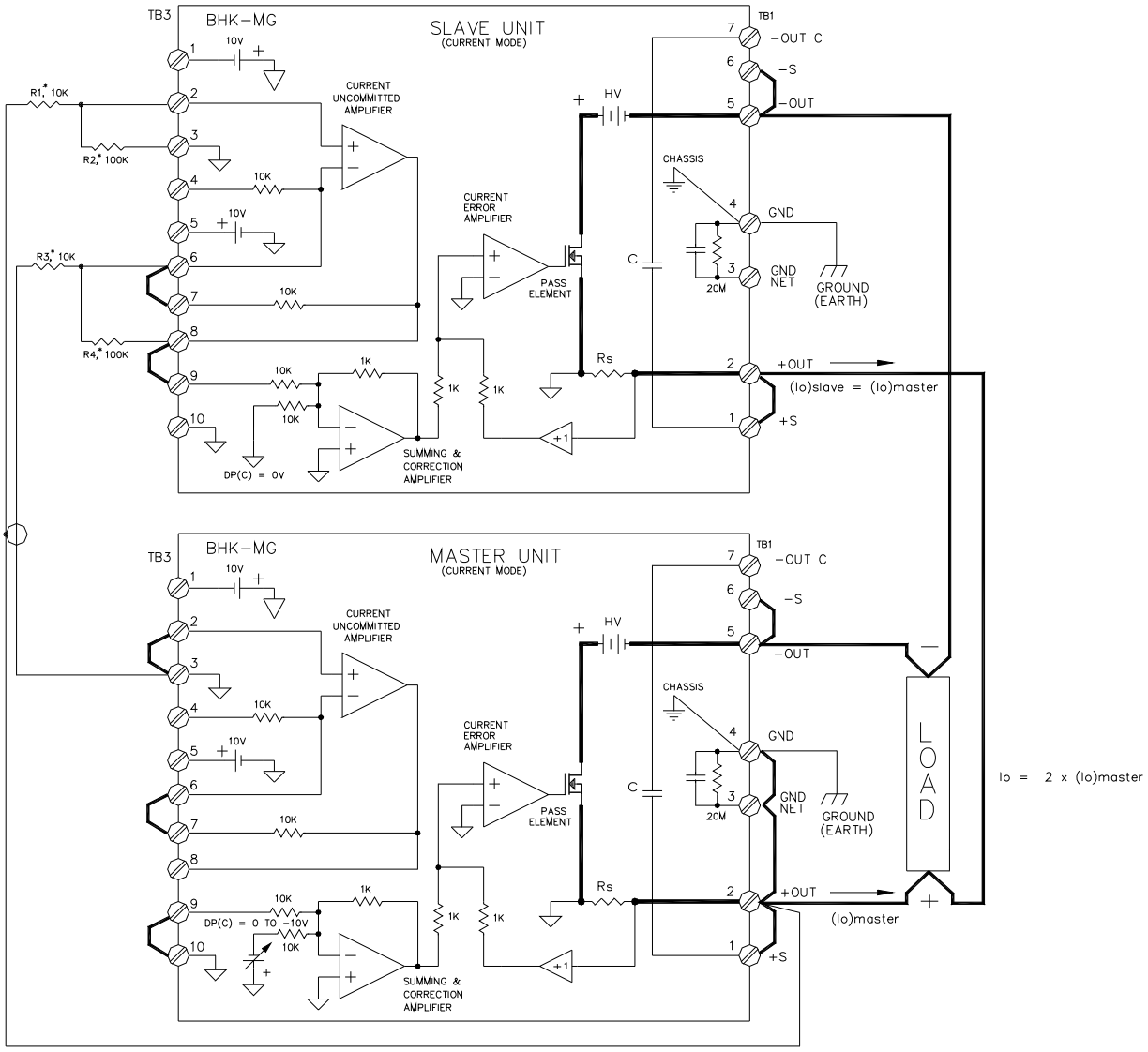
RECOMMENDED PROCEDURE. The following steps are recommended to ensure the combination of power supplies (power assembly) configured for parallel master-slave operation is connected and set up properly for current mode operation. Identical models are recommended for parallel operation.

1. With the units turned off, perform all external wiring (see Figure 3-25). 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.



NOTES:

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 3-25. PARALLEL MASTER-SLAVE (CURRENT MODE) CONFIGURATION

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 BHK1000-0.2MG set $Vset_S$ = 1000).

    c. Program overcurrent value of slave unit ($Iocset_S$) to 1.1 x rated maximum current of slave unit, $Iomax_S$ (e.g., for BHK 1000-0.2MG, program $Iocset_S$ = 220 (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 ($Iocset_M$) to 1.1 x $Iset_M$ (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.

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 consist of a voltage calibration and a current calibration. Both voltage and current calibrations consist of a zero and a full scale calibration. Calibration of current requires full scale calibration of both scales: High (Io_{MAX}) and Low ($Io_{MAX}/10$).

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.

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 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 300-0.6MG: 1.67 Ohm, 0.01%, 50W
  - BHK 500-0.4MG: 2.5 Ohm, 0.01%, 25W
  - BHK 1000-0.2MG: 5 Ohm, 0.01%, 10W
  - BHK 2000-0.1MG: 10 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 power supply.
- Proper cooling of the external precision shunt resistor ensures the accuracy of the calibration.

4.3 CALIBRATION PROCEDURES USING FRONT PANEL KEYPAD

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 volt-

age calibration the digital voltmeter will be connected to the sense terminals (TB1, terminals 1 and 6) of the power supply. For current calibration after disconnecting all loads an appropriate shunt resistor will be connected across the power output terminals (TB1, terminals 2 and 5) and the digital voltmeter will be connected across the sense terminals of the shunt resistor.

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.

1. Turn the unit on at least 15 minutes prior to calibration to allow for thermal stabilization. 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.

2. Enter password (4 digits) and press **ENTER**. If password is incorrect, ****WRONG PASSWORD**** flashes, then LCD returns to command status. See PAR. 4.5 to change the password. (Press **RESET** or **CLEAR** to exit calibration.)

3. If password is correct, LCD reads **VOLTAGE CALIB**. Enter **1** for voltage calibration (see PAR. 4.3.1), enter **0** to proceed to high current calibration. (Press **RESET** or **CLEAR** to exit without saving calibration values.)

4. LCD reads **HIGH CURRENT CAL**. Enter **1** for high current calibration (see PAR. 4.3.3), enter **0** to proceed to low current calibration. (Press **RESET** or **CLEAR** to exit calibration without saving values.)

5. LCD reads **LOW CURRENT CAL**. Enter **1** for low current calibration (see PAR. 4.3.2), enter **0** to proceed to next step. (Press **RESET** or **CLEAR** to exit calibration without saving values.)

6. Disconnect the external shunt when instructed by the message displayed on the LCD.

7. Press **ENTER** to save calibration values.

4.3.1 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 value. E.g., for BHK 500-0.4MG, 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 remains connected or the 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 the load/shunt, then refer to PAR. 4.3, step 1 to restart calibration.

4.3.2 HIGH CURRENT CALIBRATION

1. If LCD reads **`CONNECT SHUNT <nn OHM >zz A`** (nn and zz values are determined by BHK-MG model being calibrated.; e.g., for BHK 2000-0.1MG, LCD reads **`<50 OHM >10 W`**). (Refer to PAR. 4.2 for shunt requirements.) Connect Precision Shunt across output terminals and press **ENTER**.

2. If 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 **`Curr 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 **`Curr F.S.adj. **WAIT**`** then **`Curr 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 current as necessary to get V_{DVM} reading as close as possible to value listed below.

   V_{DVM} = Rs x Io_{MAX} (mV)

where

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

BHK 300-0.6MG:	0.6A = 600mA
BHK 500-0.4MG:	0.4A = 400mA
BHK 1000-0.2MG:	0.2A = 200mA
BHK 2000-0.1MG:	0.1A = 100mA

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

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. Connect the proper shunt across the power output terminals (TB1, terminals 2 and 5) and refer to PAR. 4.3, step 1 to restart calibration.

5. LCD will show **`Curr 10x adj`** then **`value =____mA`**. Monitor DVM and convert V_{DVM} to mA as follows, then note the value of $Io_{10\%HFS}$ (milliAmps).

   $Io_{10\%HFS}$ (mA) = V_{DVM} (mV)/Rs (Ohms)

where

$Io_{10\%HFS}$ (milliAmps) is the 10% full scale value of high range output current (10% of I_{OMAX})

Rs (Ohms) is the actual value of the external shunt resistor (the same shunt resistor can be used for Low scale, High scale and 10% full scale current calibration).

6. Use the keypad to enter the value of $Io_{10\%HFS}$ (milliAmps) noted in step 5 and press **ENTER**. If the value is out of range, the message **`Out of range`** then **`Measure again`** will be displayed. Repeat steps 5 and 6 until directed to disconnect the shunt by the LCD message.

7. Press **ENTER** when complete and proceed to PAR.4.3, step 5.

4.3.3 LOW CURRENT CALIBRATION

1. LCD reads **`CONNECT SHUNT <nn OHM >zz A`** (nn and zz values are determined by BHK-MG model being calibrated.; e.g., for BHK 2000-0.1MG, LCD reads **`<50 OHM >10 W`**). (Refer to PAR. 4.2 for shunt requirements.) Connect Precision Shunt across power output terminals (TB1, terminals 2 and 5) 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 **`Curr 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 **`Curr F.S.adj. **WAIT**`** then **`Curr 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 current as necessary to get V_{DVM} reading as close as possible to value listed below.

   V_{DVM} = Rs x Io_{MAX} (mV)

where

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

BHK 300-0.6MG:	0.6/10 = 0.06A = 60mA
BHK 500-0.4MG:	0.4/10 = 0.04A = 40mA
BHK 1000-0.2MG:	0.2/10 = 0.02A = 20mA
BHK 2000-0.1MG:	0.1/10 = 0.01A = 10mA

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

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. Connect the proper shunt across the power output terminals (TB1, terminals 2 and 5) and refer to PAR. 4.3, step 1 to restart calibration.

5. LCD will show **`Curr 10x adj`** then **`value =____mA`**. Monitor DVM and convert V_{DVM} to mA as follows, then note the value of $Io_{10\%LFS}$ (milliAmps).

   $Io_{10\%LFS}$ (mA) = V_{DVM} (mV)/Rs (ohms)

where

$Io_{10\%LFS}$ (milliAmps) is the 10% full scale value of low range output current (1% of I_{OMAX})

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

6. Use the keypad to enter the value of $Io_{10\%LFS}$ (milliAmps) noted in step 5 and press **ENTER**. If the value is out of range, the message **`Out of range`** then **`Measure again`** will be displayed. Repeat steps 5 and 6 until directed to proceed to High Current calibration.

7. Press **ENTER** when complete and proceed to PAR.4.3, step 6.

4.4 CALIBRATION USING IVI DRIVER

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.

Calibration of the BHK-MG 200W Power Supply is performed using SCPI commands implemented through the Instrument driver. The driver provides a graphical interface with informational displays and prompts which lead you through the calibration of the Power Supply. This IVI compliant driver works with many GPIB cards from suppliers like National Instruments and Hewlett-Packard.

This driver requires a helper application (visa32.dll) to be installed on the computer being used. VISA uses resource strings (see Table 4-1) to address the unit.

TABLE 4-1. VISA RESOURCE STRING CORRESPONDING TO INTERFACE

INTERFACE	VISA RESOURCE STRING	COMMENT
GPIB	GPIB::xx::INSTR	The GPIB address replaces xx.
SERIAL	ASRLy::INSTR	The com port number replaces y.

4.4.1 SETUP

1. The following calibration procedure uses a calibration panel which is part of the IVI driver for the BHK-MG 200W which can be downloaded from the Kepco website at:
   www.kepcopower.com/drivers/drivers-dl3.htm
   Unzip the files and double-click on setup.exe to install the driver in
   \Program Files\KepcodcPower\bhk\

2. After the program is installed, double click on
   \Program Files\KepcodcPower\bhk\KepcoControlPanel.exe
   to run the program. Two windows appear: the VISA Resource Descriptor Input panel (Figure 4-1) and the Main Control panel (with display blank) as shown in Figure 4-2.

3. Enter the VISA resource descriptor of the BHK-MG unit into the VISA Resource Descriptor Input panel (Figure 4-1), or leave blank to use the default setting (GPIB::6), then click OK.

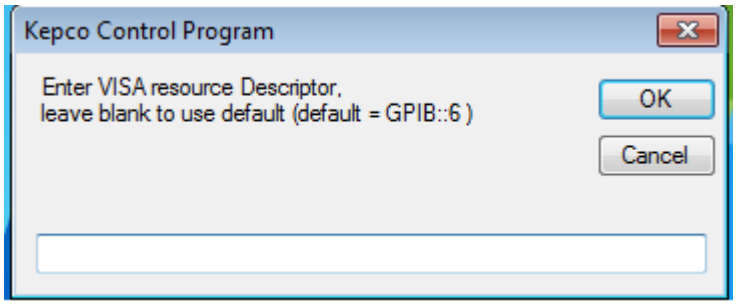


FIGURE 4-1. INPUT VISA RESOURCE DESCRIPTOR

4. The program will attempt to connect to the BHK-MG. If connection is successful, the Main Control Panel display now shows the Instrument Model and Driver Revision as shown in Fig-

ure 4-2. If an **Initialization Error** message appears, either the IVI Shared components or VISA-COM was not installed correctly. Return to step 1 and reinstall the driver.

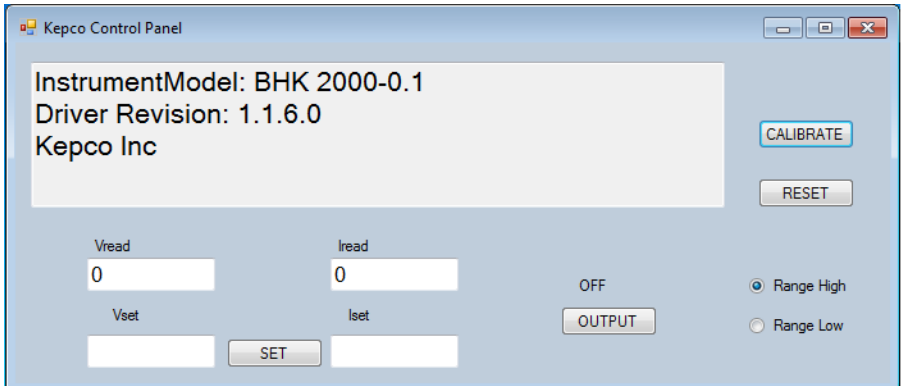


FIGURE 4-2. MAIN CONTROL PANEL, TYPICAL

4.4.2 MAIN CONTROL PANEL

The main control panel allows setting the voltage and current, enabling and disabling the output, selecting the current range (full rack units), resetting the unit, and calibrating the unit.

1. To set the unit's voltage and current, enter the values into the **Vset** and **Iset** boxes, respectively, and click the **SET** button.

2. To enable or disable the output, click the **OUTPUT** button.

3. To reset the unit to power-up state (output OFF, voltage and current set to 0), click the **RESET** button.

4. Range High and Range Low radio buttons allow range selection (full rack units only).

4.4.3 CALIBRATION CONTROLS

NOTE: Before performing calibration, set BHK for local sensing (connect +S to + OUT terminal and connect –S to –OUT terminal at the rear panel). **After turning the unit on it is necessary to wait 15 minutes before calibrating the unit to allow for thermal stabilization.**

NOTE: The left and right single arrow buttons (**<** and **>**) that appear on the calibration screens are equivalent to the front panel left and right arrow keys. The left double arrow button (**<<**) is equivalent to the **1** key on the front panel keypad; the right double arrow button (**>>**) is equivalent to the **3** key.

All adjustments are done using the four arrow buttons that appear during Calibration (see Figure 4-3 and Table 4-2). The double arrow buttons **<<** and **>>** either increase (**>>**) or decrease (**<<**)

the output by a maximum of 18 steps (each step is one LSB (Least Significant Bit), equivalent to 0.024% of nominal value) at a time; the **>** and **<** buttons either increase (**>**) or decrease (**<**) the output one step at a time.

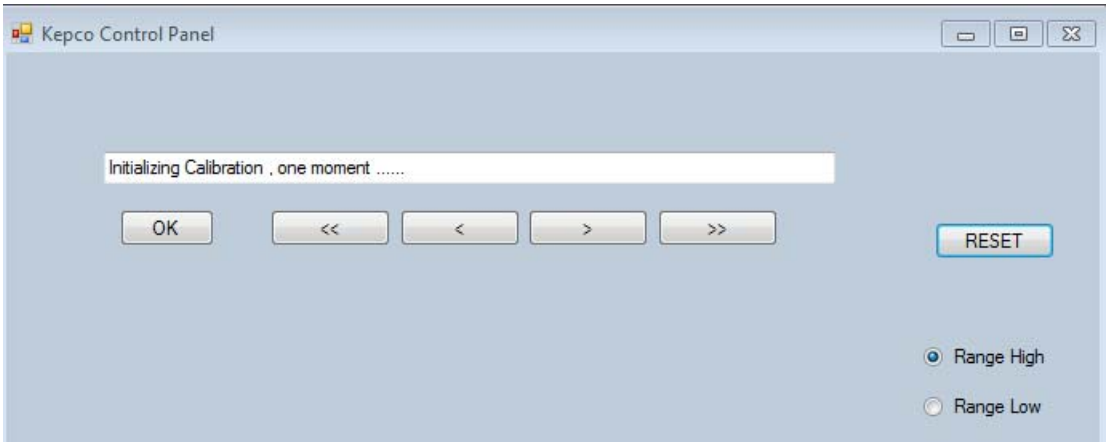


FIGURE 4-3. CALIBRATION CONTROLS

TABLE 4-2. CALIBRATION PANEL FUNCTIONS

BUTTON OR WINDOW	Function
<< button	Coarse Adjustment - Decreases the output value by a maximum of 18 LSBs.
>> button	Coarse Adjustment - Increases the output value by a maximum of 18 LSBs.
< button	Fine Adjustment - Decreases the output value by one LSB.
> button	Fine Adjustment - Increases the output value by one LSB.
OK button	Enters the value displayed in the text field and advances calibration to next step.

4.4.4 CALIBRATION PROCEDURE

1. Click on the **Calibrate** button on the main control panel (see Figure 4-2). This opens a calibration panel (see Figure 4-3 and Table 4-2) that allows calibration in either voltage or current mode.

2. After initializing, the password window appears (see Figure 4-4). The password has been set at the factory (see Table 4-3). Type the proper password in the text box and click **OK**. If the password has been forgotten, consult factory. If the password is correct, calibration can be accomplished by following the screen prompts.

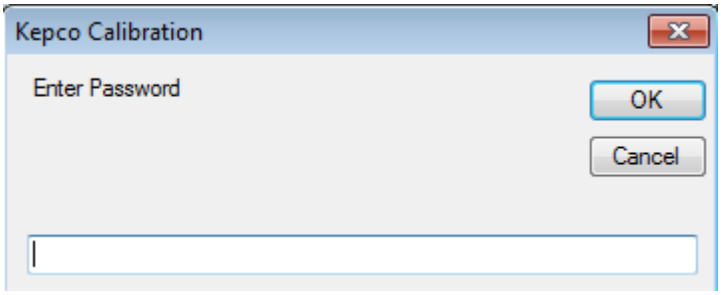


FIGURE 4-4. PASSWORD ENTRY

3. For Voltage Calibration, click **YES** button (see Figure 4-5).

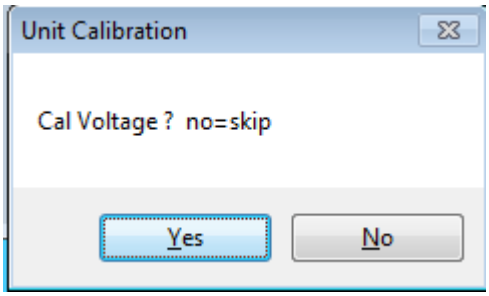


FIGURE 4-5. VOLTAGE CALIBRATION

4. The text window reads **`Connect DVM to Output Sense, Remove Shunt`**. Remove any connections between +OUT and –OUT. Connect DVM (high) to +OUT and DVM (low) to –OUT, then click **OK** button.

NOTE: Use external DVM for all measurements.

5. The text window reads **`Vout ZERO adjust`**. Using the **<** and **>** buttons (see PAR. 4.4.3), adjust the output voltage until the DVM is as close to 0 as possible but slightly positive, then click **OK** button.

6. The text window reads **`Vout F.S.`** Using the coarse **<<** and **>>** and fine **<** and **>** buttons (see PAR. 4.4.3), adjust the output voltage until the DVM is as close as possible, but above, the rated nominal voltage, then click **OK** button.

7. The text window reads **`Cal Current High Range? no=skip.`** Click **YES** button to perform high range current calibration.

8. The text window reads **`Connect shunt across output`**. Connect precision shunt resistor (see PAR. 4.2) across +OUT and –OUT terminals. After connecting the shunt click **OK** button.

9. The text window reads **`With shunt connected across output, connect DVM across shunt`**. Connect DVM (high) to the shunt sensing terminal that correlates to +OUT and DVM (low) to the shunt sensing terminal that correlates to –OUT. Click **OK** button to proceed to next step.

10. The text window reads **CURR ZERO Adjust**. Using the fine adjust **<** and **>** buttons (see PAR. 4.4.3), adjust output until DVM is as close to 0 as possible but slightly positive, then click **OK** button.

11. The text window reads **CURR F.S.Adjust**. Using the coarse **<<** and **>>** and fine **<** and **>** buttons (see PAR. 4.4.3), adjust output current until the DVM voltage reading corresponds as closely as possible, but above, the rated maximum current. Use I = E/R where E is the DVM reading (Volts), R is measured value of the precision shunt resistor (Ohms) used to indirectly measure I, the rated BHK-MG current in Amperes. Click the **OK** button when complete.

12. The Current Magnifier window opens (see Figure 4-6). The unit automatically sets output current to less than 1/10th the rated nominal current (approximately 8% of nominal current range). The DVM measures the voltage across the shunt. Indirectly measure the output current in Amperes using I = E/R where E is the DVM reading (Volts) and R is measured value of the precision shunt resistor (Ohms). Enter the indirectly measured current value (in milli-Amperes) in the field provided and click **OK**.

NOTE: The range of useful values for calibrating current magnification has a tolerance of ±10%. For example, if the measured value entered for the BHK 1000-0.2MG is between 22 and 18 mA, current magnification will be calibrated. If the value is outside this range the unit uses the default value of 20 mA and current magnification is not calibrated. Note that this calibration only improves the accuracy of the output current readback value, and does not affect the setting value.

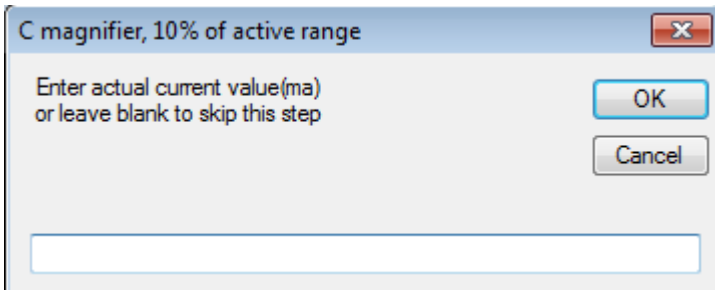


FIGURE 4-6. CURRENT MAGNIFIER WINDOW

13. The text window reads **Cal Current LO Range? no=skip.** Click **YES** button to perform low range current calibration.

14. The text window reads **Connect shunt across output**. If the shunt is not already connected, connect precision shunt resistor (see PAR. 4.2) across +OUT and –OUT terminals. After connecting the shunt click **OK** button.

15. The text window reads **With shunt connected across output, connect DVM across shunt**. Connect DVM (high) to the shunt sensing terminal that correlates to +OUT and DVM (low) to the shunt sensing terminal that correlates to –OUT. Click **OK** button to proceed to next step.

16. The text window reads **CURR ZERO Adjust**. Using the fine adjust **<** and **>** buttons (see PAR. 4.4.3), adjust output until DVM is as close to 0 as possible but slightly positive, then click **OK** button.

17. The text window reads **`CURR Lo Range Adjust`**. Using the coarse **<<** and **>>** and fine **<** and **>** buttons (see PAR. 4.4.3), adjust output current until the DVM voltage reading corresponds as closely as possible, but above, 10% of rated maximum current, e.g., above 0.020 Amperes (20 mA) for the BHK 1000-0.2MG. Use `I` = E/R where E is the DVM reading (Volts), R is measured value of the precision shunt resistor (Ohms) used to indirectly measure `I`, the rated BHK-MG current in Amperes. Click the **OK** button when complete.

18. The Current Magnifier window opens (see Figure 4-6). The unit automatically sets output current to less than 1/10th the rated nominal current (approximately 8% of nominal current range). The DVM measures the voltage across the shunt. Indirectly measure the output current in Amperes using `I` = E/R where E is the DVM reading (Volts) and R is measured value of the precision shunt resistor (Ohms). Enter the indirectly measured current value (in milli-Amperes) in the field provided and click **OK**.

NOTE: The range of useful values for calibrating current magnification has a tolerance of ±10%. For example, if the measured value entered for the BHK 1000-0.2MG is between 2.2 and 1.8 mA, current magnification will be calibrated. If the value is outside this range the unit uses the default value of 2.0 mA and current magnification is not calibrated. Note that this calibration only improves the accuracy of the output current readback value, and does not affect the setting value.

19. The text window reads **`CAL Done, Disconnect Shunt`**. Click **OK**. Current calibration is complete and automatically saved. Disconnect the external shunt and DVM.

4.5 CHANGING THE CALIBRATION PASSWORD

The 4-digit password is required to enter calibration mode. The factory default passwords are listed in Table 4-3.

TABLE 4-3. FACTORY DEFAULT CALIBRATION PASSWORDS

MODEL	PASSWORD
BHK 300-0.6MG	0300
BHK 500-0.4MG	0500
BHK 1000-0.2MG	1000
BHK 2000-0.1MG	2000

1. With the power supply in command entry status **`(:_:_:)`**, press **MENU** key until the 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 0500 for BHK 500-0.4MG, 1000 for BHK 1000-0.2MG and 2000 for BHK 2000-.01MG.

3. 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. 4.6), or **MENU** for additional menu screens.

4.6 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. With the power supply in command entry status **(:_:_:)**, press **MENU** key until the LCD reads **GoTo Previous CALIB? 1(=_=_=)YES**.

2. Press **1**, then ENTER. LCD reads **Calibration ! PassWord(=_=_=)**.

3. Enter 4-digit password and press **ENTER**. Previous calibration values are restored.

4.7 RESTORING FACTORY CALIBRATION VALUES

The original factory calibration values can be restored.

1. With the power supply in command entry status **(:_:_:)**, press **MENU** key until the LCD reads **GoTo Factory CALIB? 1(=_=_=)YES**.

2. Press 1, then **ENTER**. LCD reads **Calibration ! PassWord(=_=_=)**.

3. Enter 4-digit password and press **ENTER**. Factory calibration values are restored.

4.8 CALIBRATION STORAGE

The BHK-MG Power Supply. maintains the calibration tables in Flash Memory until a PACK is executed. There are six calibration areas maintained in Flash Memory: Working, Prior, Oldest, Factory, Master, and First. The calibration password is required In order to store the calibration.

The calibration can be copied to another area using the CAL:DUMP? and CAL:COPY command. The syntax is as follows: CAL:DUMP? [source];:CAL:COPY [destination], where [source] and [destination] refer to the areas of Flash memory where calibration data is stored, designated as: WORKing, PRIor, OLDest, FACTory, MASTer, FIRst. Source refers to the calibration area that is to be copied, destination to the area that the calibration will be copied into.

The ability to save to the FACTORY area is prohibited. If a user needs to overwrite the factory calibration, a special firmware needs to be created to provide a special password for this capability. Each customer that requests this capability will be provided a password that the company can specify. it must contain at least one alpha, one numeric and one punctuation character (!@#$%^&*) and be at least 6 characters long and not longer than 20 characters in length. All alpha data must be upper case and no control nor space characters are allowed.

The Master calibration should never be overwritten. Factory, Master, and First are set to the same values when the power supply is calibrated at the factory. 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 Prior, and the values previously stored in Prior are moved to Oldest. The values previously stored in Oldest are no longer available. Table 4-4 illustrates calibration storage and the use of the CAL:DUMP? query and CAL:COPY command.

TABLE 4-4. CALIBRATION STORAGE

COMMAND	WORKing	PRIor	OLDest	FACTory	MASTer	FIRst
1. CAL:SAVE	Cal 1 values			Factory cal.	Master cal.	First cal.
2. CAL:SAVE	Cal 2 values	Cal 1 values		No Change	No Change	No Change
3. CAL:SAVE	Cal 3 values	Cal 2 values	Cal 1 values	No Change	No Change	No Change
4. CAL:SAVE	Cal 4 values	Cal 3 values	Cal 2 values	No Change	No Change	No Change
5. CAL:DUMP? FACTory;:CAL:COPY WORKing	Factory cal.	Cal 4 values	Cal 3 values	No Change	No Change	No Change
6. CAL:DUMP? PRIor;:CAL:COPY WORKing	Cal 4 values	Factory cal.	Cal 4 values	No Change	No Change	No Change

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 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 quick reference of all IEEE 488.2 commands and queries supported in the BHK-MG 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

A.2 *CLS — CLEAR STATUS COMMAND *CLS

Syntax: *CLS

Description: **Clears status data.** Clears the following registers without affecting the corresponding Enable Registers: 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

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

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

PON	Power On
NU	(Not Used)
CME	Command Error
EXE	Execution Error
DDE	Device Dependent Error
QUE	Query Error
OPC	Operation Complete

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

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) 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 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 up to 10 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 complete (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, overvoltage 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.)

*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? query 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: BHK-500-0.4 04-20-2004,E123456, V7.0.
LIST:IND 21	Selects memory location 21.
LIST:CURR 2.35E-1	Sets output current value of memory location 21 to 0.235A.
LIST:VOLT 400	Sets output voltage value of memory location 21 to 400V.
*OPC	Allows status bit 0 to be set when pending operations complete
*ESR	Returns 129 (128 + 1, power on, bit 7 = 1, operation complete, bit 1 = 1)
*ESR?	Returns 1 (event status register cleared by prior *ESR?)
VOLT 415;CURR 1.5E-1	Sets output voltage to 415V, output current to 0.15A,
*OPC?	Puts “1” on output bus when command operations are complete.
*RCL 21	Values in memory location 21 recalled (400V, 0.235A).
*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 250	Power supply voltage commanded to 250V.
VOLT:TRIG 312	Programs power supply voltage to 312V when *TRG received.
INIT:CONT ON	Trigger event is initialized.
*TRG	Power supply reverts to commanded output voltage of 312V.
*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 reset values.** See PAR. 3.3.2 for a detailed description of the reset state. Reset is also affected by DCL (Device Clear) control, described in PAR. 3.3.2. In addition, *RST also causes the unit to store the following parameters:
INIT:CONT 0, LIST:DIR UP and DISP:MODE NORMAL. (See example, 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] and VOLT:PROT[:LEV]. The stored values can be restored by the *RCL command. (See PAR. 3.3.6.2 and Figure 3-2 for special programming considerations.)

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 programmed.

Description: **Sets the condition of the Service Request Enable register.** The Service Request Enable register 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
MSS	Master Status Summary
RQS	Request for Service
ESB	Event Status Byte summary
MAV	Message available
QUES	QUEStionable Status Summary
ERR QUE	1 or more errors occurred (see PAR. B.81)
NU	(Not Used)

A.13 *SRE? — SERVICE REQUEST ENABLE QUERY *SRE?

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 or 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, Figure 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. *TRG is an addressed command (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 Power Supply. Subsystem commands are defined in PAR. B.3 through B.91, arranged Alphabetically in groups as they appear in the tree diagram, Figure 3-5. Table B-1 provides a quick reference of all SCPI subsystem commands and queries used in the BHK-MG Power Supply.

TABLE B-1. SCPI SUBSYSTEM COMMAND/QUERY INDEX

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

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 4×10^8. 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.

B.3 ABORt COMMAND — ABOR

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 is executed each time power is turned on. Related Commands: *RST, *TRG. (See example, Figure B-1.)

B.4 CAL COMMANDS AND QUERIES — CAL

CAL commands and queries are used to perform calibration of the unit via the control interface. These commands must be issued in a specific sequence in order to properly calibrate the unit. To use these commands, refer to Kepco's website (www.kepcopower.com/drivers) and download the LabWindows/CVI Version 5 driver for BHK-MG. This file provides remote calibration capability and uses the following supported commands and queries:

CAL:COPY command
CAL:DUMP command
CAL:CURR[:DATA] command
CAL:CURR:LEV command
CAL:PASS command
CAL:RESTore command
CAL:SAVE command
CAL:STAT command and query
CAL:VOLT:LEV command
CAL:VOLT[:DATA] command
CAL:ZERO command

B.5 DISPlay:CONTrast COMMAND — DISP:CONT

Syntax: Short Form: DISP:CONT <num_value> (0.0 to 0.9 or 0 to 9)
Long Form: DISPlay:CONTrast <num_value> (0.0 to 0.9 or 0 to 9)

Description: **Sets the contrast of the front panel LCD.** The contrast value from (0.0 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-2.)

B.6 DISPlay:CONTrast? QUERY — DISP:CONT?

Syntax: Short Form: DISP:CONT? Long Form: DISPlay:CONTrast?
Return Value: Numerical value from 0.0 to 0.9 indicating contrast setting.

Description: **Identifies LCD contrast setting.** Returns contrast value (0.0 to 0.9). (See example, Figure B-2.)

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. 3.3.6 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 5E-2	Power supply output programmed to go to 221V, current limit 50mA
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 0.0325A, power supply returns 3.25E-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, 50mA (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 50mA.
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 5E-2 (programmed current 50mA)
CURR? MAX	Returns 4E-1 (assuming maximum allowable current for power supply being addressed is 400mA, i.e. BHK 500-0.4MG).
CURR? MIN	Returns 0 (minimum allowable current).
CURR:PROT 3.8E-2	Current protection set to 38mA.
CURR?	Returns 5E-2 (programmed current 50mA)
CURR:PROT?	Returns 3.8E-2 , indicating programmed overcurrent protection current value = 38mA.
CURR:PROT? MAX	For BHK 500-0.4MG, returns 4.4E-1 (440mA, see Table 1-2).
SYST:VERS?	Returns 2003.0.

FIGURE B-1. PROGRAMMING THE OUTPUT

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 IS IN USE”	Second line of display reads **BHK IS IN USE.
DISP:MODE?	Returns “TEXT”
DISP:TEXT?	Returns “**BHK IS IN USE”

FIGURE B-2. USING DISPLAY COMMANDS

B.7 DISPlay:MODE COMMAND — DISP:MODE

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 normal 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-2.)

B.8 DISPlay:MODE? QUERY — DISP:MODE?

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 display is in text mode. Related Commands: DISP:MODE, DISP:TEXT, *RST. (See example, Figure B-2.)

B.9 DISPlay:TEXT COMMAND — DISP:TEXT

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 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, DISP:MODE NORM is restored. Related Commands: DISP:TEXT?, DISP:MODE, DISP:MODE?, *RST. (See example, Figure B-2.)

B.10 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 within quotation marks 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-2.)

B.11 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] generates the trigger signal. After completing the trigger cycle, the unit returns to the idle state. (See example, Figure B-1.)

B.12 INItiate:CONTinuous COMMAND — INIT:CONT

Syntax: Short Form: INIT:CONT {ON | OFF} or {1 | 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] triggers a single event. If INIT:CONT is ON, then the trigger system is continuously armed. Executing *RST command sets INIT:CONT to OFF. Related Commands: TRIG:SOUR. (See example, Figure B-1.)

B.13 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 disabled (INIT:CONT OFF). (See example, Figure B-1.)

B.14 INSTrument:STATe COMMAND — INST:STAT

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

Description: Operation is identical to OUTPut:STATe command (PAR. B.36) and is provided for compatibility with other vendors products.

B.15 INSTrument:STATe? QUERY — INST:STAT?

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

Description: Operation is identical to OUTPut:STATe? query (PAR. B.37) and is provided for compatibility with other vendors products.

B.16 [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:COUN 1 to DSEQ, Related Commands: All LIST commands (See example, Figure B-3.)

B.17 [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-3.)

B.18 [SOURce:]LIST:COUNt? QUERY — LIST:COUN?

Syntax: Short Form: LIST:COUN? 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-3.)

B.19 [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-3.)

B.20 [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-3.)

B.21 [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:CURR is entered only for location 0, that current will apply to all steps when VOLT:MODE LIST is executed. Related Commands: LIST:CURR:POIN?. (See example, Figure B-3.)

B.22 [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. (See example, Figure B-3.)

B.23 [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. Related Commands: LIST:CURR. (See example, Figure B-3.)

B.24 [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).** LIST:CLEar sets the list to the UP direction (beginning to end)**.** Related Commands: LIST:DWEL?. (See LIST example, Figure B-3.)

B.25 [SOURce:]LIST:DIRection? QUERY — LIST:DIR?

Syntax: Short Form: LIST:DIR? Long Form: LIST:DIRection?
Return Value: <value> (1 or 0)

Description: **Identifies the direction (1 = up or 0 = down) for executing the list established by LIST:DIR.** Related Commands: LIST: DIR. (See example, Figure B-3.)

B.26 [SOURce:]LIST:DWELl COMMAND — LIST:DWEL

Syntax: Short Form: LIST:DWEL <value> (0.010 to 655.35),<value>,<value>, . . . to maximum of 250 values
Long Form: LIST:DWELl <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 Commands: VOLT:MODE, LIST:CURR, LIST:VOLT, LIST:DWEL? (See example, Figure B-3.)

B.27 [SOURce:]LIST:DWELl? QUERY — LIST:DWEL?

Syntax: Short Form: LIST:DWEL? Long Form: LIST:DWELl?
Return Value: <value>,<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-3.)

B.28 [SOURce:]LIST:DWELl:POINTS? QUERY — LIST:DWEL:POIN?

Syntax: Short Form: LIST:DWEL:POIN? Long Form: LIST:DWELl:POINts?
Return Value: <value> (0 to 250)

Description: **Identifies the number of locations for which time values have been entered and the next location 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-3.)

B.29 [SOURce:]LIST:QUERy COMMAND — LIST:QUER

Syntax: Short Form: LIST:QUER n Long Form: LIST:QUERy n
n = int_value = 0 to 250

Description: **Determines first location to be queried by LIST:VOLT?, LIST:CURR?, and LIST:DWEL? queries.** Note that n = 0 points to location 0, otherwise n points to location (n-1). Related Commands: LIST:QUER?, LIST:VOLT?, LIST:CURR?, LIST:DWEL?. (See example, Figure B-3.)

B.30 [SOURce:]LIST:QUERy? QUERY — LIST:QUER?

Syntax: Short Form: LIST:SEQ? Long Form: LIST:SEQuence?
Return Value: n (n = <int_value>)

Description: **Identifies first location to be queried by LIST:VOLT?, LIST:CURR?, LIST:DWEL? queries.** Note that n = 0 points to location 0, otherwise n points to location (n-1). Related Commands: LIST:QUER, LIST:VOLT?, LIST:CURR?, LIST:DWEL?. (See example, Figure B-3.)

B.31 [SOURce:]LIST:VOLTage COMMAND — LIST:VOLT

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:VOLT is entered for only location 0, that voltage will apply to all steps when CURR:MODE LIST is executed. Related Commands: LIST:VOLT:POIN?, LIST:CLE, *RST. (See example, Figure B-3.)

B.32 [SOURce:]LIST:VOLTage? QUERY — LIST:VOLT?

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. (See example, Figure B-3.)

B.33 [SOURce:]LIST:VOLTage:POINts? QUERY — LIST:VOLT:POIN?

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. Related Commands: LIST:VOLT. (See example, Figure B-3.)

NOTE: Examples below are intended only to illustrate command functions. Refer to PAR. 3.3.6 for programming 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 points.
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 20).
LIST:QUERY 16	Start LIST queries from location 15.
LIST:QUERY 32	Start LIST queries from location 31.
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 100 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 milliseconds 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 sawtooth is similar to the previous sawtooth, except the waveform is inverted.

FIGURE B-3. USING LIST COMMANDS AND QUERIES (SHEET 1 OF 2)

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,.01	
	Enters dwell time of 0.01 seconds in locations 1 through 9.
LIST:DWELL 1	Enters dwell time of 1 second in location 10.
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
LIST:VOLT:POINTS?	Returns 24 to indicate the voltage list has 24 entries.
LIST:DWELL .01,.01,.01,.01,.01,.01,.01,.01,.01,.01,.1,.1,.1	
	Dwell times are entered in locations 11 through 23.
LIST:DWELL:POINTS?	Returns 24 indicating there are now 24 step dwell times on the list.
LIST:QUER?	Returns 0 indicating list queries will start from location 0
LIST:QUER 18	Causes list queries to start at location 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 seconds 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
VOLT?	Returns 0 (the last step in the list set the unit to -20V.
VOLT 4	Programs output to 4V.

FIGURE B-3. USING LIST COMMANDS AND QUERIES (SHEET 2 OF 2)

B.34 MEASure[:SCALar]:CURRent[:DC]? QUERY — MEAS:CURR?

Syntax: Short Form: MEAS[:SCAL]:CURR[:DC]? Long Form: MEASure[:SCALar]:CURRent[: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.)

B.35 MEASure:VOLTage[:SCALar][:DC]? QUERY — MEAS:VOLT?

Syntax: Short Form: MEAS[:SCAL]:VOLT[:DC]? Long Form: MEASure[:SCALar]:VOLTage[:DC]?

Description: **Measures actual voltage.** This query 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.)

B.36 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. 3.2.7.2for 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.37 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.38 [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 CURR:LIM[:HIGH] value, error message -222,"Data out of range" is posted in output queue. Related Commands: *RCL, *SAV, CURR:LIM[:HIGH]. (See example, Figure B-1.)

B.39 [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? MIN returns minimum current allowed for power supply (always 0). Related Commands: CURR. (See example, Figure B-1.)

B.40 [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 exceeds the current protection value (set by CURR:PROT, see PAR. B.44), error message -222,"Data out of range" 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 will not accept trigger values higher than the programmed limit. Related Commands: CURR. (See example, Figure B-4. See PAR. 3.3.6.1 and Figure 3-2 for special programming considerations.)

B.41 [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 Commands: CURR:LIM[:HIGH], CURR. (See example, Figure B-4.)

B.42 [SOURce:]CURRent:MODE COMMAND CURR:MODE

Syntax: Short Form: [SOUR:]CURR:MODE (FIX | LIST)
Long Form: [SOURce:]CURRent:MODE (FIXed | LIST)

Description: **Allows the user to execute or stop a list.** The default mode is FIX: the power supply executes commands normally, and LIST commands can be issued to establish the parameters and sequence of a list.

When CURR:MODE LIST is issued, a list is executed (See LIST commands and Figure B-3). While the list is being executed, LIST commands are not accepted and will produce a command error.

Issuing CURR:MODE FIX while the list is running will stop the execution of the list and return power supply to settings in effect prior to running the list. If the list runs to completion, the settings of the last step of the list will be in effect.

Related Commands: LIST commands. (See example, Figure B-3.)

B.43 [SOURce:]CURRent:MODE? QUERY — CURR:MODE?

Syntax: Short Form: [SOUR:]CURR[:LEV]:MODE?
Long Form: [SOURce:]CURRent[:LEVel]:MODE?
Return value: FIXED or LIST

Description: **Identifies active voltage mode.** Returns LIST while list is being executed. Returns FIXED while in fixed (default) mode of operation. Related Commands: LIST commands. (See example, Figure B-3.)

B.44 [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 overcurrent 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, the power supply circuit breaker trips. (See example, Figure B-4.)

B.45 [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-4.)

Description: **Returns the current value established by CURR:TRIG command.** (See example, Figure B-1.)

B.46 [SOURce:]CURRent:RANGe COMMAND — CURR:RANG

Syntax**:** Short Form: [SOUR:]CURR:RANG:LOW or [SOUR:]CURR:RANG:UPP
Long Form: [SOURce:]CURRent:RANGe:LOWer or [SOURce:]CURRent:RANGe:UPPer

Description: **Selects high scale or low scale Current range.** CURR:RANG:LOW selects Low scale, CURR:RANG:UPP selects High scale. Low scale = $Io_{MAX}/10$, High scale = Io_{MAX}. This command sets the output to OFF before executing the command, regardless of which range is currently active. Refer to PAR. 3.2.10 for complete description.

B.47 [SOURce:]CURRent:RANGe? QUERY — CURR:RANG?

Syntax**:** Short Form: [SOUR:]CURR:RANG? Long Form: [SOURce:]CURRent:RANGe?
Return Value: 0 or 1

Description: **Identifies current scale selected.** Returns 0 for low scale, 1 for high scale.

B.48 [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 CURR:LIM[:HIGH] value, error message -222,"Data out of range" is posted in output queue. Related Commands: CURR. (See example, Figure B-1.)

B.49 [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 value representing voltage value to be programmed by *TRG command established by CURR:TRIG command).** (See example, Figure B-1.)

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. 3.3.6 for programming techniques to optimize performance.

OUTP ON	Output enabled.
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 stays at 0.011A, error message -222 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 1.25E-1	Unit shuts down if current exceeds 125 mA.

FIGURE B-4. PROGRAMMING CURRENT

B.50 [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPlitude] COMMAND VOLT

Syntax: Short Form: [SOUR:]VOLT[:LEV][:IMM][:AMP] <exp_value>
Long Form: [SOURce:]VOLTage[:LEVel][: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 VOLT:LIM[:HIGH] value, error message -222,"Data out of range" is posted in output queue. Related Commands: *RCL, *SAV, VOLT:LIM[:HIGH]. (See example, Figure B-1.

B.51 [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-5.)

B.52 [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 exceeds the voltage protection value (set by VOLT:PROT, see PAR. B.56), error message -222,"Data out of range" 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-5. See PAR. 3.3.6.2 and Figure 3-2 for special programming considerations.

B.53 [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 Commands: VOLT:LIM[:HIGH], VOLT. (See example, Figure B-5.)

B.54 [SOURce:]VOLTage:MODE COMMAND — VOLT:MODE

Syntax: Short Form: [SOUR:]VOLT:MODE (FIX | LIST)
Long Form: [SOURce:]VOLTage:MODE (FIXed | LIST)

Description: **Allows the user to execute or stop a list.** The default mode is FIX: the power supply executes commands normally, and LIST commands can be issued to establish the parameters and sequence of a list.

When VOLT:MODE LIST is issued, a list is executed (See LIST commands and Figure B-3). While the list is being executed, LIST commands are not accepted and will produce a command error.

Issuing VOLT:MODE FIX while the list is running will stop the execution of the list and return power supply to settings in effect prior to running the list. If the list runs to completion, the settings of the last step of the list will be in effect.

Related Commands: LIST commands. (See example, Figure B-3.)

B.55 [SOURce:]VOLTage:MODE? QUERY — VOLT:MODE?

Syntax: Short Form: [SOUR:]VOLT[:LEV]:MODE?
Long Form: [SOURce:]VOLTage[:LEVel]:MODE?
Return value: FIXED or LIST

Description: **Identifies active voltage mode.** Returns LIST while list is being executed. Returns FIXED while in fixed (default) mode of operation. Related Commands: LIST commands. (See example, Figure B-3.)

B.56 [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 queue. If the power supply output exceeds the voltage protection level programmed, the power supply circuit breaker trips. (See example, Figure B-5.)

B.57 [SOURce:]VOLTage:PROTection[:LEVel]? QUERY — VOLT:PROT?

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: **Returns value representing voltage protection level.** 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-4.)

B.58 [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 VOLT:LIM[:HIGH] value, error message -222,"Data out of range" is posted in output queue. (See example, Figure B-1.)

B.59 [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.60 [SOURce:]FUNCTion:MODE? QUERY FUNC:MODE?

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 intended only to illustrate command functions. Refer to PAR. 3.3.6 for programming techniques to optimize performance.

OUTP ON	Output enabled.
VOLT 218;CURR 1.1E-1	Power supply programmed to 218V, 0.11A.
VOLT 2.157E2	Power supply programmed to go to 215.7V.
VOLT?	Returns 2.157E2, indicating programmed voltage = 215.7V.
VOLT? MAX	For BHK 500-0.4MG, returns 500 (500V).
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 500-0.4MG, returns 5.5e+2 (550V).
VOLT 221;CURR 1.1E-1	Power supply programmed to go to 221V, 0.11A.
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-5. 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-6.)

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:OPERation: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-6.)

NOTE: The power supply is assumed to be operating in CV (constant voltage) mode.

OUTP ON	Output enabled.
VOLT 3;CURR 1E-2	Power supply programmed to 3V, 0.01A.
STAT:OPER:ENAB 1056	Mask 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 Enable and Questionable Condition Enable registers are preset.
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.
--- MOMENTARILY SHORT POWER SUPPLY OUTPUT ---	
STAT:OPER?	Returns 1312, 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 8, (Power supply still in overtemperature condition).
SYST:ERR?	Power supply returns 0,“No error” message.

FIGURE B-6. USING STATUS COMMANDS AND QUERIES

B.63 STATus:OPERation: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).

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-6.)

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-6.)

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-6.)

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-6.)

TABLE B-3. QUESTIONABLE EVENT REGISTER, QUESTIONABLE CONDITION REGISTER AND QUESTIONABLE CONDITION ENABLE REGISTER BITS

CONDITION	NU	OT	NU
BIT	15 - 4	3	2 - 0
VALUE	32,768 - 16	8	4 - 1

OT - OVERTEMPERATURE CONDITION
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-6.)

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-6.)

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 Commands: STAT:QUES?. (See example, Figure B-6.)

B.70 SYSTem:BEEP COMMAND SYST:BEEP

Syntax: Short Form: SYST:BEEP Long Form: SYSTem:BEEP

Description:Causes the unit to emit a brief audible tone

B.71 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.** See PAR. 3.3.6.2 and Figure 3-2 for special programming considerations.

B.72 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.73 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.** See PAR. 3.3.6.2 and Figure 3-2 for special programming considerations.

B.74 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.75 SYSTem:COMMunication:SERial:ECHO COMMAND SYST:COMM:SER:ECHO

Syntax**:** Short Form: SYST:COMM:SER:ECHO {ON | OFF} or {01 | 00}
Long Form: SYSTem:COMMunication:SERial:ECHO {ON | OFF} or {01 | 00}

Description: **Enables (ON) or disables (OFF) echo mode** (see PAR. 3.4.3.1). Sending ON or 01 causes all subsequent characters to be echoed back. Sending OFF or 00 turns off the character echo after the next line terminator character. The *RST command has no effect on echo status. See PAR. 3.3.6.2 and Figure 3-2 for special programming considerations.

B.76 SYSTem:COMMunication:SERial:ECHO? QUERY SYST:COMM:SER:ECHO?

Syntax**:** Short Form: SYST:COMM:SER:ECHO?
Long Form: SYSTem:COMMunication:SERial:ECHO?
Return Value: {01 | 00}

Description: **Returns 01 when echo mode is active (ON) or 00 when disabled (OFF)** (see PAR. 3.4.3.1).

B.77 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. 3.4.3.3).** See PAR. 3.3.6.2 and Figure 3-2 for special programming considerations.

B.78 SYSTem:COMMunication:SERial:PACE? QUERY SYST:COMM:SER:PACE?

Syntax**:** Short Form: SYST:COMM:SER:PACE?
Long Form: SYSTem:COMMunication:SERial:PACE?
Return Value: {01 | 00}

Description: **Returns 01 when data flow control via the serial interface is enabled (XON) or 00 when disabled (NONE)** (see PAR. 3.4.3.3).

B.79 SYSTem:COMMunication:SERiaL:PROMpt COMMAND SYST:COMM:SER:PROM

Syntax**:** Short Form: SYST:COMM:SER:PROM {ON | OFF} or {0 | 1}
Long Form: SYSTem:COMMunication:SERial:PROMpt {ON | OFF} or {0 | 1}

Description: **Enables (1 or ON) or disables (0 or OFF) prompt** (see PAR. 3.4.3.2). Sending 1 or ON causes the unit to return > character after the command is parsed. See PAR. 3.3.6.2 and Figure 3-2 for special programming considerations.

B.80 SYSTem:COMMunication:SERial:PROMpt? QUERY SYST:COMM:SER:PROM?

Syntax**:** Short Form: SYST:COMM:SER:PROM?
Long Form: SYSTem:COMMunication:SERial:PROMpt?
Return Value: {1 | 0}

Description: **Returns 1 when prompt is enabled (ON) or 0 when disabled (OFF).** (See PAR. 3.4.3.2.)

B.81 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 corresponding 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.82 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.83 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.84 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 Commands: SYST:KLOCK?. (See example, Figure B-7.)

B.85 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-7.)

SYST:VERS	Returns 2003.0.
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-7. USING SYSTEM COMMANDS AND QUERIES

B.86 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 all the calibration commands to operate.

B.87 SYSTem:PASSword:CDISable COMMAND — SYST:PASS:CDIS

Syntax: Short Form: SYST:PASS:CDIS <val> Long Form: SYSTem:PASSword:CDISable <val>

Description: Clears the password enable state if the value matches the current password.

B.88 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 PAR. 3.3.6.2 and Figure 3-2 for special programming considerations.

B.89 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

Description: Returns a 1 if the password state is enabled or a 0 if it is disabled.

B.90 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, minimum Amperes, overvoltage and overcurrent to be set to Eomax+10% and Iomax+10%, respectively, time value to be set to 0.01 Sec. It also initializes the power -up state to have DC Output Control off (see PAR 3.2.7.4). The calibration password is reset per Table 4-3. See PAR. 3.3.6.2 and Figure 3-2 for special programming considerations.

B.91 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-7.)

B.92 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 trigger (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
0,"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.
-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.

TABLE B-4. ERROR MESSAGES (CONTINUED)

ERROR MESSAGE	ESR ERROR BIT SET (SEE PAR. A.5)	EXPLANATION
-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 656 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.

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