


# OPERATOR'S MANUAL

## BOP 1000W

### HIGH POWER BIPOLAR POWER SUPPLY

KEPCO INC.  
An ISO 9001 Company.

	
<b>MODEL BOP 1000W POWER SUPPLY</b>	
<input type="text" value="ORDER NO."/>	<input type="text" value="REV. NO"/>

#### IMPORTANT NOTES:

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

MODEL	SERIAL NO.	REV. NO.
- 2) A Change Page may be included at the end of the manual. All applicable changes and revision number changes are documented with reference to the equipment serial numbers. Before using this Instruction Manual, check your equipment serial number to identify your model. If in doubt, contact your nearest Kepco Representative, or the Kepco Documentation Office in New York, (718) 461-7000, requesting the correct revision for your particular model and serial number.
- 3) The contents of this manual are protected by copyright. Reproduction of any part can be made only with the specific written permission of Kepco, Inc.

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P/N 243-1027R6C





## Declaration of Conformity

Application of Council directives: **73/23/EEC (LVD)**  
**93/68/EEC (CE mark)**

Standard to which Conformity is declared:

**EN61010-1:1993 (Safety requirements for electrical equipment for measurement, control and laboratory use)**

Manufacturer's Name and Address: **KEPCO INC.**  
**131-38 SANFORD AVENUE**  
**FLUSHING, N.Y. 11352 USA**

**REPRESENTATIVE COPY**

Importer's Name and Address:

Type of Equipment: **Component Power Supply**

Model No.: *[PRODUCT MODEL NUMBER]*

Year of Manufacture:

I, the undersigned, declare that the product specified above, when used in conjunction with the conditions of conformance set forth in the product instruction manual, complies with the requirements of the Low Voltage Directive 73/23/EEC, which forms the basis for application of the CE Mark to this product.

Place: **KEPCO Inc.**  
**131-38 Sanford Ave.**  
**Flushing, N.Y.11352 USA**

Saul Kupferberg  
(Full Name)

Date: \_\_\_\_\_

VP OF SALES  
(position)

## Conditions of Conformance

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

1. For European applications, requiring compliance to the Low Voltage Directive, 73/23/EEC, this power supply is considered a component product, designed for "built in" applications. Because it is incomplete in construction, the end product enclosure must provide for compliance to any remaining electrical safety requirements and act as a fire enclosure. (EN61010-1 Cl. 6, Cl. 7, Cl.8, Cl. 9 and EN61010-1 annex F)
2. This power supply is designed for stationary installation, with mains power applied via a detachable power supply cord or via direct wiring to the source power terminal block.
3. This power supply is considered a Class 1 (earthed) product, and as such depends upon proper connection to protective earth for safety from electric shock. (EN61010-1 Cl. 6.5.4)
4. This power supply is intended for use as part of equipment meant for test, measurement and laboratory use, and is designed to operate from single phase, three wire power systems. This equipment must be installed within a suitably wired equipment rack, utilizing a three wire (grounded) mains connection. See wiring section of this manual for complete electrical wiring instructions. (EN61010-1 Cl. 6.5.4 and Cl.6.10.1)
5. This power supply has secondary output circuits that are considered hazardous, and which exceed 240 VA at a potential of 2V or more.
6. The output wiring terminals of this power supply have not been evaluated for field wiring and, therefore, must be properly configured by the end product manufacturer prior to use.
7. This power supply employs a supplementary circuit protector in the form of a circuit breaker mounted on the front panel. This circuit breaker protects the power supply itself from damage in the event of a fault condition. For complete circuit protection of the end product, as well as the building wiring, it is required that a primary circuit protection device be fitted to the branch circuit wiring. (EN61010-1 Cl. 9.6.2)
8. Hazardous voltages are present within this power supply during normal operation. All operator adjustments to the product are made via externally accessible switches, controls and signal lines as specified within the product operating instructions. There are no user or operator serviceable parts within the product enclosure. Refer all servicing to qualified and trained Kepco service technicians.

# SAFETY INSTRUCTIONS

## 1. Installation, Operation and Service Precautions

This product is designed for use in accordance with EN 61010-1 and UL 3101 for Installation Category 2, Pollution Degree 2. Hazardous voltages are present within this product during normal operation. The product should never be operated with the cover removed unless equivalent protection of the operator from accidental contact with hazardous internal voltages is provided:



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



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



This product is factory-wired for the nominal a-c mains voltage indicated on the rating nameplate 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, the product must be modified by a trained service technician.

## 2. Grounding

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



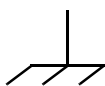
The PROTECTIVE EARTHING CONDUCTOR TERMINAL must be properly connected prior to application of source power to the product (see instructions on installation herein) in order to ensure safety from electric shock.



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



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



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

## 3. Electric Shock Hazards

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



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



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

# OPERATOR SAFETY INSTRUCTIONS

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





Do not touch the output terminals. The 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.

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.

The liquid in the LCD is hazardous: do not lick or swallow. Wash skin and clothes immediately and thoroughly upon exposure.

## SAFETY SYMBOLS

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

## 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.

DO NOT: wipe the front panel with hard materials, nor apply excessive force to the surface. DO NOT expose to extended periods of bright sunshine or UV light.


## Safety Messages

The BOP protection circuitry is designed to protect the load against unregulated high voltages and protect the BOP from extensive damage in the event of a component failure. Refer to Table 1-2 for more information regarding the protection circuits.

# LIST OF WARNINGS AND CAUTIONS

PAGE	WARNING/CAUTION
3-11	<b>WARNING:</b> Accessing the BOP after the output is disabled in BATTERY mode is hazardous because (1) high current arcing is possible and (2) either the external battery voltage, or the voltage ( $\pm$ Voltage Protection max) on the BOP output terminals may be dangerous. It is recommended that two external switches be installed for safety: one in series with the battery, and one across the BOP output. After the unit is set to OFF, first open the switch in series with the battery, then close the switch across the BOP output to ensure safety before handling BOP connections. When connecting the battery, the switch across the output should be opened after the connections are complete and then the switch in series with the battery should be closed.
3-17	<b>WARNING:</b> For inductive loads, and especially superconducting magnet type loads, the inherent offset of the BOP in the OFF state may generate significant current in the circuit. A switch in parallel with a series resistor must be connected between the power supply and the load. The switch must be open and the BOP front panel LCD must read 0V, 0A before removing or installing connections between BOP and load.
3-17	<b>WARNING:</b> For both reactive loads and constant-current-type active electronic loads when the BOP output is set to OFF, a path is provided for absorbing either the energy accumulated in the reactance of the load during the ON state, or energy delivered by an electronic load. This prevents damage to the load and power supply as well as providing safety for the user. However, in addition to the built-in safety features, constant-current-type active electronic loads must be adjusted to zero and the BOP front panel LCD must read 0V, 0A before handling the power supply-to-load connections.
3-17	<b>WARNING:</b> For battery and constant-voltage-type active electronic loads it is recommended that two external switches be installed for safety: one in series with the battery, and one across the BOP output. After the unit is set to OFF, first open the switch in series with the battery, then close the switch across the BOP output to ensure safety before handling BOP connections. When connecting the battery, the switch across the output should be opened after the connections are complete and then the switch in series with the battery should be closed. If the constant-voltage-type active electronic load is adjusted to zero before handling the power supply-to-load connections, only the switch across the BOP output is required. These precautions are necessary to avoid high energy arcing or high voltage safety hazard.
4-6	<b>WARNING:</b> The sense resistor will be dissipating full rated current of the BOP. If it is hot to the touch, the sense resistor value, power rating and/or cooling are incorrect; refer to PAR. 4.3 and Table 4-1.
4-13	<b>WARNING:</b> The sense resistor will be dissipating full rated current of the BOP. If it is hot to the touch, the sense resistor value, power rating and/or cooling are incorrect; refer to PAR. 4.4 and Table 4-1.
2-3	<b>CAUTION:</b> When an external shut-down signal is sent to the unit, the shut-down condition is latched and the red FAULT indicator on the front panel is ON. To resume normal operation it is necessary to cycle power off, then on (preferred) or briefly press the RESET key on the front panel.
2-7	<b>CAUTION:</b> The rack must provide support at the rear (within 6 inches of the rear panel). Optional slides can also be used (see PAR. 2.4.2).

# LIST OF WARNINGS AND CAUTIONS

PAGE	WARNING/CAUTION
2-7	<b>CAUTION:</b> When working with active loads, the voltage or current of the active load must not exceed the maximum voltage or current rating of the BOP. Otherwise the overvoltage or overcurrent protection will shut down the power supply.
2-9	<b>CAUTION:</b> The safety features incorporated into the BOP to handle energy from Active loads are unable to protect the power supply or the load if input power to the bop is lost. It is recommended that the user monitor "Power OK" flag pins 3 and 4 of the external Protect Port (see Table 2-4) and implement a fast-acting means of disconnecting or crowbaring the load to prevent damage to both the BOP and the load in the event of input power loss.
2-12	<b>CAUTION:</b> For parallel configurations, Remove links between (com s) and (com out) terminals of all slaves to prevent damage to the unit and maintain system accuracy.
2-18	<b>CAUTION:</b> The units are now configured as slave(s) to be controlled only by the master. Do not use the slave keypad, RS 232 port or GPIB port to try to control the slave(s).
3-3	<b>CAUTION:</b> Pressing RESET will cause voltage transients to appear at the output which may damage a connected load.
3-9	<b>CAUTION:</b> When the ADJUST control is rotated, the active parameter is immediately effective if the output is enabled (on = STANDBY indicator not lit) and the voltage/current applied to the load changes as the ADJUST control is rotated.
3-11	<b>CAUTION:</b> Pressing RESET will cause voltage transients to appear at the output which may damage a connected load. Switch is recessed to prevent inadvertent activation.
3-15	<b>CAUTION:</b> When working with active loads, always adjust the BOP protection limits to be above the maximum values of voltage or current expected from the load. For example, when the BOP is operating in voltage mode sinking energy from a constant current type load, set the current protection limits of the BOP above the maximum current expected from the load.
3-29	<b>CAUTION:</b> When the serial port has received an XOFF, the error message -400, QUE error will be placed in the queue to indicate the loss of transmitted information due to a received XOFF character. When XON is received, the unit will transmit all data in it's buffer followed by the exclamation character (!). This (!) character is not part of any message from the BOP and indicates the transmission buffer has been cleared and the BOP is idle.
4-10	<b>CAUTION:</b> If the CALIBRATE ZERO  function is available, perform this function first, as it affects all other output calibrations.



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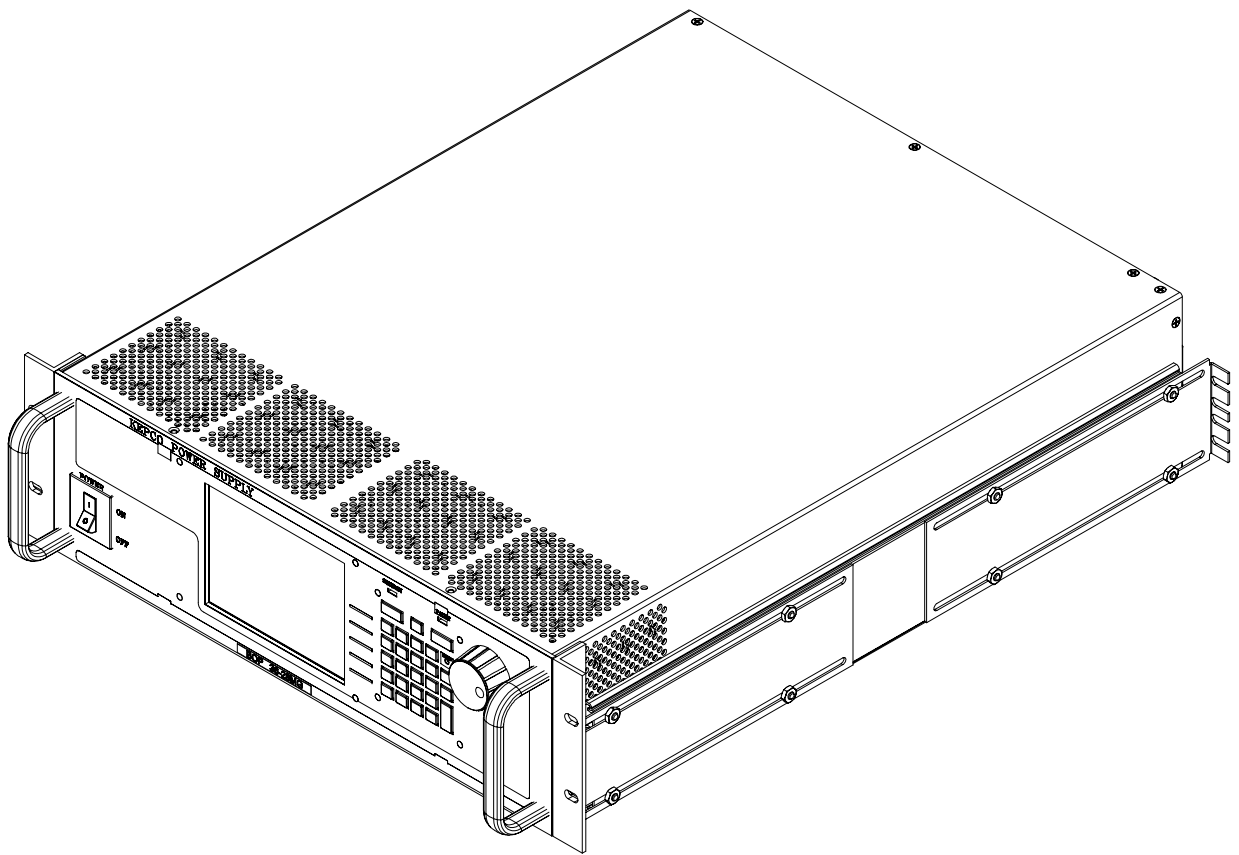
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**FIGURE 1-1. HIGH POWER BOP SERIES POWER SUPPLY**



## SECTION 1 - INTRODUCTION

### 1.1 SCOPE OF MANUAL

This manual contains instructions for the installation, operation and servicing of the BOP series of 1000 Watt rack-mounted, 4-quadrant bipolar, programmable, voltage and current stabilized d-c power supplies manufactured by Kepco, Inc., Flushing, New York, U.S.A.

### 1.2 GENERAL DESCRIPTION

The BOP Series (Figure 1-1), hereafter referred to as BOP, are true 4-quadrant programmable voltage and current power supplies, meaning they are capable of both sourcing and sinking power. These bipolar power supplies pass smoothly through zero without switching to provide true  $\pm$  voltage and  $\pm$  current. These BOP power supplies use switch mode technology for low dissipation. A bi-directional, isolating, a-c input power factor correcting (PFC) circuit recuperates energy sunked from an active load and sends it back into the line to maintain low dissipation.

These BOP power supplies are controlled digitally from a menu-driven front-panel keypad or one of the standard remote digital interfaces (GPIB or RS 232) to set voltage and current and the four protection limits (+voltage, -voltage, +current and -current.) A front panel rotary adjuster allows real-time adjustment of the output. A large LCD displays the settings, mode and the actual output voltage and current. Additionally, these BOP models can be remotely controlled by an analog  $\pm 10V$  input for the main channel (voltage or current), and a 0 to +10V input for the limit channels. This mode is selected by the keypad from the menu, or remotely, through the IEEE 488 controller.

BOP models are suitable for driving inductive loads such as large magnets or motors, and for exercising batteries. They are also suitable for characterizing solar cell arrays, and powering many electrochemical reactions.

### 1.3 SPECIFICATIONS

Table 1-1 below indicates parameters that vary for different 1000 Watt BOP models; Table 1-2 lists general specifications that apply to all 1000 Watt BOP models.

**TABLE 1-1. BOP 1000 WATT MODEL PARAMETERS**

Model	d-c Output Range		Closed Loop Gain	
	$E_O$ Max	$I_O$ Max	Voltage Channel	Current Channel
1000 WATT MODELS				
BOP 10-75MG	$\pm 10V$ d-c	$\pm 75A$ d-c	1.0	7.5
BOP 20-50MG	$\pm 20V$ d-c	$\pm 50A$ d-c	2.0	5.0
BOP 36-28MG	$\pm 36V$ d-c	$\pm 28A$ d-c	3.6	2.8
BOP 50-20MG	$\pm 50V$ d-c	$\pm 20A$ d-c	5.0	2.0
BOP 72-14MG	$\pm 72V$ d-c	$\pm 14A$ d-c	7.2	1.4
BOP 100-10MG	$\pm 100V$ d-c	$\pm 10A$ d-c	10.0	1.0
NOTE: When connecting active loads, the steady-state voltage of the active load must not exceed the maximum voltage rating of the BOP. Otherwise the overvoltage protection will shut down the power supply.				

**TABLE 1-2. BOP GENERAL SPECIFICATIONS**

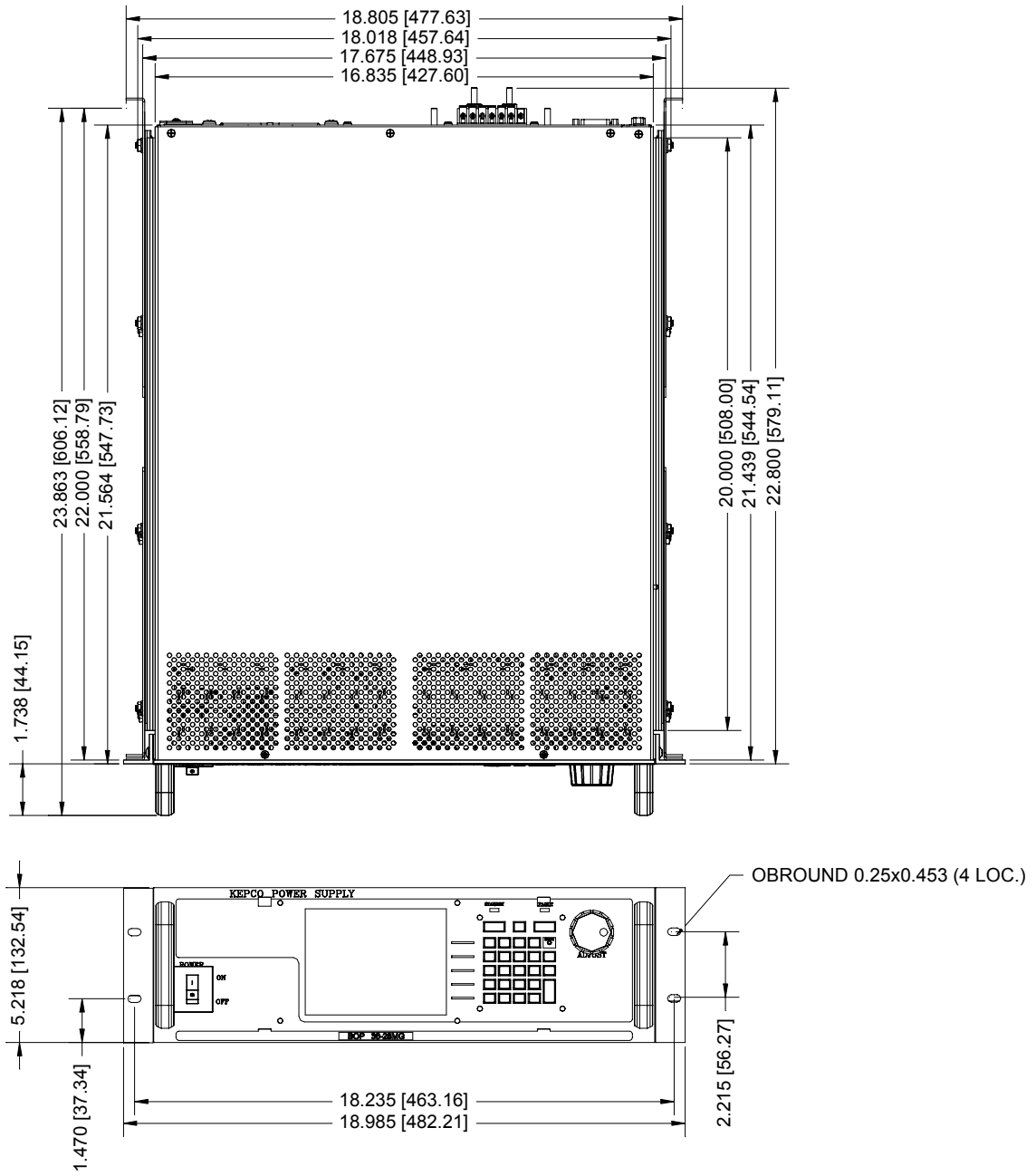
SPECIFICATION		RATING/DESCRIPTION	CONDITION
<b>INPUT CHARACTERISTICS</b>			
a-c voltage	nominal	230 Va-c	Single phase
	range	176 - 264 Va-c	
Frequency	nominal	50-60 Hz	>65 Hz, leakage exceeds spec
	range	47 - 65 Hz	
Current	176 Va-c	9.5A	maximum
	264 Va-c	6.4A	maximum
Power factor	Source	0.99 minimum	nominal output power
	Sink	0.97 minimum	
Efficiency		65%	minimum
Switching frequency		70 KHz	PFC Stage
EMC Compliance		EN61326-1 (1997)	Class A equipment
EMC immunity to:	ESD	EN61000-4-2	Electrostatic discharge
	Radiated RF	EN61000-4-3	
	EFT	EN61000-4-4	Electrical fast transient/burst
	Surges	EN61000-4-5	
	Conducted RF	EN61000-4-6	
EMC emissions	Conducted	EN61000-3-2	harmonics
		EN61000-3-3	fluctuation & flicker
	Conducted	EN55011/CISPR11	0.15 to 30 MHz
	Radiated	EN55011/CISPR11	30 to 1000 MHz
Leakage current		3.5 mA	230V a-c 47-63 Hz
Insulation coordination	Input	Installation Category II	
		Overvoltage Category II	
	Output	Installation Category II	
		Overvoltage Category II	
Pollution degree		2	
<b>OUTPUT CHARACTERISTICS</b>			
Type of stabilizer		Voltage-current, 4-quadrant	Switch mode
Switching frequency		100KHz	Output Stage
Source adjustment range	voltage	-100% to +100% of rating	0 to 50 deg C
	current	-100% to +100% of rating	
Sink adjustment range	voltage	-100% to +100% of rating	Recuperated energy is sent back into line for reuse
	current	-100% to +100% of rating	
Programming resolution / accuracy	Voltage	14 bits / 0.03%	
	Current	14 bits / 0.1%	
	Voltage Limit	12 bits / 0.3%	
	Current Limit	12 bits / 0.5%	
Readback resolution / accuracy	Voltage	16 bits / 0.05%	main or limit channel
	Current	16 bits / 0.1%	main or limit channel
Readback rate/array	measurement rate	1 ms (default)	range: 0.25-25ms
	measurement array	64 samples	

**TABLE 1-2. BOP GENERAL SPECIFICATIONS (Continued)**

SPECIFICATION		RATING/DESCRIPTION	CONDITION
<b>OUTPUT CHARACTERISTICS (Continued)</b>			
Voltage stabilization in voltage mode	source effect	0.05% of rating	min-max input voltage
	load effect	0.1% of rating	0-100% load current
	time effect (drift)	0.05% of rating	0.5 through 24 hours
	temperature	0.05%/deg C of rating	0 to 50 deg C
	ripple and noise	2% E <sub>0</sub> max p-p	Includes switching noise
Current stabilization in current mode	source effect	0.05% of rating	min-max input voltage
	load effect	0.2% of rating	0-100% load voltage
	temperature	0.05%/deg C of rating	0 to 50 deg C
	ripple and noise	2% I <sub>0</sub> max p-p	Includes switching noise
Error sensing		0.25V per wire	Above rated output
Transient recovery in voltage mode	maximum excursion	5% of nominal output	nominal voltage, 50% load step
	Recovery time	200 μsec	Return within 0.1% of set voltage
Isolation	voltage	300V	Output to ground
Series operation		Master/slave	Maximum of 3 units, up to 300V max.
Parallel operation		Master/slave	Maximum of 5 units
Output limiting		voltage and current limited in four quadrants	
Output Stage Protection		Heatsink overtemperature, switchers overcurrent	Triggers latched shutdown protection of the output module and PFC stage
Input Stage Protection (PFC)		Overvoltage, undervoltage, overcurrent, heat sink overtemperature, fan inoperative	Triggers latched shutdown protection of the PFC stage and output module. Reset and started by digital control
		Circuit breaker overcurrent	Trips circuit breaker to shut off unit
<b>PROGRAMMING/DISPLAY CHARACTERISTICS</b>			
Small signal Bandwidth	voltage channel	2 KHz minimum	into nominal resistive load 10% of rating
	current channel	800 Hz minimum	Into short circuit, 10% of rating
Analog control	voltage channel	-10V to +10V	Full range output, 10K Ohm input impedance
	current channel	-10V to +10V	
Rise/Fall time	voltage channel	250/200 μSec	Into nominal resistive load, measured from 10 to 90%, from 0 to ±100% of rating
	current channel	0.7/1.2 mSec	Into short circuit, measured from 10 to 90%, from 0 to ±100% of rating
Digital control	local	Panel-mounted keypad	Direct Entry
	remote	IEEE 488-2 (GPIB)	SCPI
	remote	RS 232	
	remote	RS 485 (BITBUS)	IEEE 1118
Display	front panel	4" backlit LCD displays all functions	
	remote	All parameters read back on GPIB or RS 232 buses	

**TABLE 1-2. BOP GENERAL SPECIFICATIONS (Continued)**

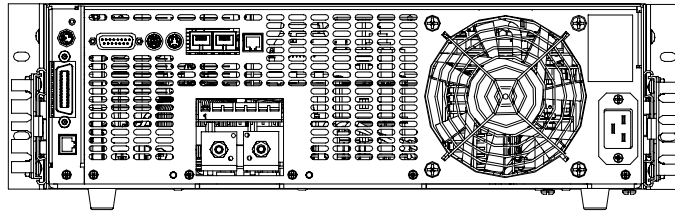
SPECIFICATION		RATING/DESCRIPTION	CONDITION
<b>INTERFACE CHARACTERISTICS</b>			
Storage	non-volatile	FLASH-type EEPROM 24Kbytes	
<b>GENERAL (ENVIRONMENTAL) CHARACTERISTICS</b>			
Temperature	operating	0 to +50 deg C	Full rated load
	storage	-20 to +85 deg C	
Cooling		Two internal fans	exhaust to the rear
Humidity		0 to 95% RH	non-condensing
Shock		20g. 11msec ±50% half sine	non-operating
Vibration	5-10HZ:	10mm double amplitude	3 axes, non-operating
	10-55HZ:	2g	3 axes, non-operating
Altitude		sea level to 10,000 feet	
Safety Certification	a-c power	UL 3101-1 and EN 6101-1	Pending
<b>PHYSICAL CHARACTERISTICS</b>			
Dimensions	English	5.25' X 19" X 21.5"	H X W X D
	metric	133.3mm X 482.6mm X 546.1mm	H X W X D
Weight, 1000W models	English	53 lbs	
	metric	24.1Kg	
Connections	Source power	3-pin IEC connector	
	Load connections	Nickel-plated copper bus bars	
Sensing Output Terminal Block		7-pin terminal block	Default: 3 links installed for local sensing and ground network connected.
Analog I/O control port		15-pin D female	See Table 2-10
PAR/SER CTRL IN port		8-pin mini DIN connector	See Table 2-7
PAR/SER CTRL OUT port		4-pin mini DIN connector	See Table 2-6
PAR/SER PROT IN port		8-pin phone jack	See Table 2-8
PAR/SER PROT OUT port		8-pin phone jack	See Table 2-9
EXT PROT port		6-pin phone jack	See Table 2-4
Primary digital port		24-pin GPIB connector	IEEE 488 port - See Table 2-11
Secondary digital ports		6-pin phone jack	RS 232 port - See Table 2-5
		5-pin mini DIN female connector	IEEE 1118 port - See Table 2-2
External Trigger		4-pin stereo audio phone jack	See Table 2-3



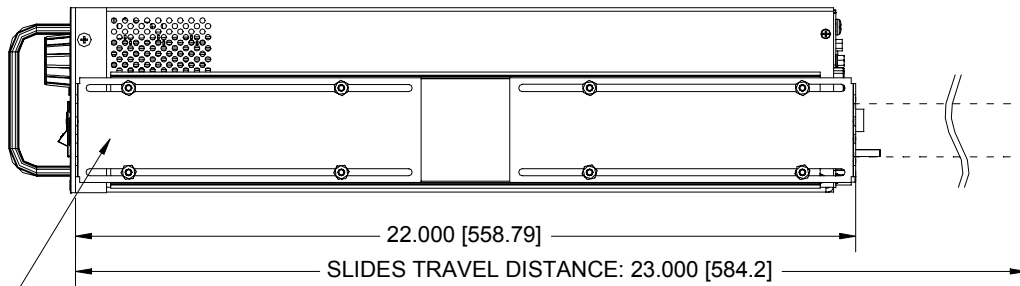
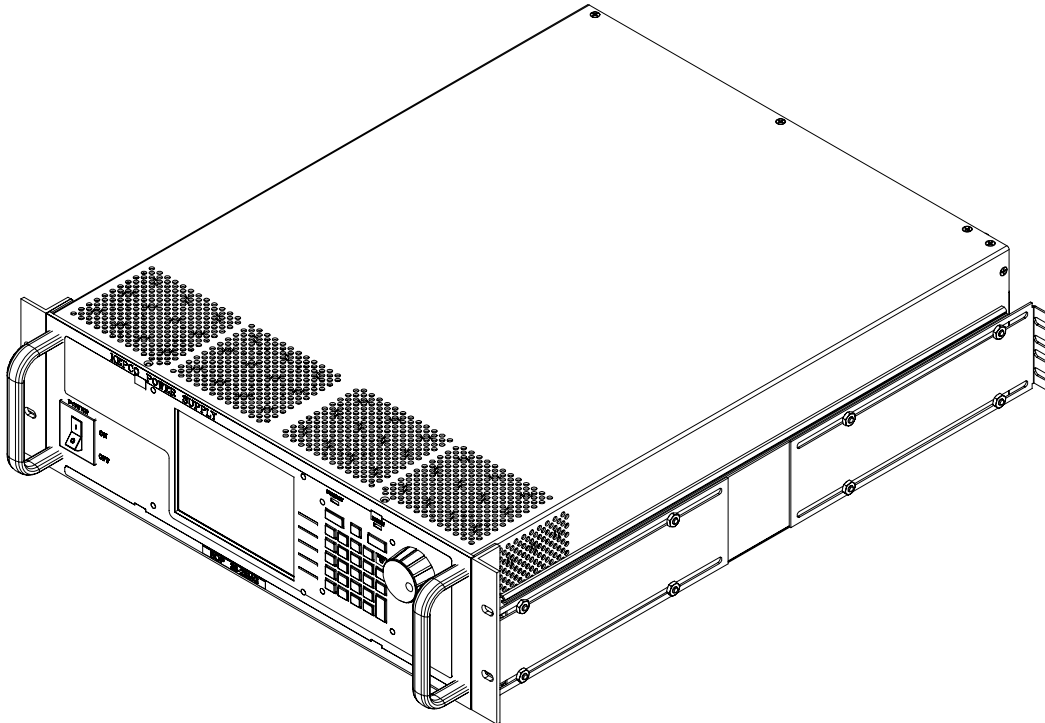
- NOTES:
1. MATERIAL: A) CHASSIS: #11 GA. C.R.S.  
 B) FRONT PANEL: 1/8 THICK 6061-T6 ALUMINUM.  
 C) COVER: #16 GA. C.R.S.  
 D) BACK PLATE: 0.064 THICK 5052-H32 ALUMINUM.
  2. FINISH: A) CHASSIS & COVER : CADMIUM PLATE WITH CROMATE WASH.  
 B) BACK PLATE: IRIDITE GOLD  
 C) FRONT PANEL: SEE 1311145 PAGE 2 OF 3.
  3. DIMENSION IN PARENTHESSES ARE IN MILLIMETERS.
  4. TOLERANCES ARE  $\pm 1/32$  (0.8), EXCEPT AS NOTED.
  5. PRIOR TO INSTALLATION, REMOVE FOUR FEET.
  6. OPTIONAL SLIDES (KEPCO KIT P/N 219-0435) SHOWN INSTALLED.

3010256

**FIGURE 1-1. 1000W BOP POWER SUPPLY, OUTLINE DRAWING (SHEET 1 OF 2)**



REAR VIEW



SEE NOTE 6.

3010256

FIGURE 1-1. BOP POWER SUPPLY, OUTLINE DRAWING (SHEET 2 OF 2)



## **1.4 LOCAL CONTROL**

Either the front panel keypad or the adjust control can set and adjust output voltage and current under local control. The display provides a digital display of output voltage and current as well as a pictorial display of real-time analog voltage and current meters.

The keypad includes five function keys which provide access to the menu-driven functions of the unit. The top menu screens provide access to save, recall, display reference and settings menus which are used to configure the unit (see PAR. 3.3).

Context-sensitive help screens are available by pressing the HELP key. Actual output voltage and current displays are available while the help screens are displayed.

## **1.5 REMOTE CONTROL**

The BOP Power Supply can be remotely controlled directly via either the IEEE 488.2 (GPIB) bus (see PARs. 3.4 and 3.5) or RS232C (see PAR.3.7) interface using SCPI commands (see and Appendix A and B). All features available in local mode can also be accessed remotely. The unit can be controlled with a VISA (Virtual Instrumentation Software Architecture) driver to facilitate remote programming of the BOP Power Supply (see PAR. 3.6). The VISA driver translates function calls made in standard C language to SCPI commands.

The BITBUS is used to allow communication between BOP units that are connected in series and/or parallel to expand the voltage or current range (see PAR. 2.8).

## **1.6 FEATURES**

### **1.6.1 DIGITAL CALIBRATION**

The BOP Power Supply contains no internal adjustments. Calibration is done entirely via the keypad (or remotely via the GPIB or RS 232 interface) using digital entries and a calibrated DVM and precision shunt resistor. Calibration instructions appear on the front panel after a password is entered; previous calibration values are saved and can be restored if desired. The original factory calibration values can also be restored. (Refer to Section 4.)

### **1.6.2 OVERVOLTAGE/OVERCURRENT PROTECTION**

Positive and negative overvoltage and overcurrent protection values can be individually programmed. Refer to PAR. 3.3.2.

### **1.6.3 EXTERNAL REFERENCE (ANALOG CONTROL)**

An external reference, provided through the rear external port connector, allows the BOP to be controlled by an external analog signal. The external reference may be applied directly or can be attenuated and modulated by the digital controls. The BOP will limit its output based on the user configurable limits so that, in the event of a failure in the external reference, the devices connected to the output are protected.

#### 1.6.4 EXTERNAL LIMITS

When the unit is controlled by an external reference, the protection limits can also be controlled by analog signals that are digitally calibrated. The BOP samples the limit channel inputs and applies the proper limit levels at a 5 millisecond rate with the positive and negative limits being sampled alternately. The external limit inputs are hardware-protected against overvoltage.

#### 1.6.5 USER-DEFINED VOLTAGE/CURRENT MAXIMUM VALUES

The BOP output can be programmed not to exceed user-defined values. For example, the BOP 36-28MG, which has a maximum capacity of  $\pm 36V$ ,  $\pm 28A$ , can be limited to  $+30V$ ,  $-10V$ ,  $+5A$ ,  $-1A$  for working with circuitry that might be damaged by higher levels. Once the limits are set, values exceeding the limit values will not be accepted, including external references and protection limits. Refer to PAR. 3.3.5.2.1.

#### 1.6.6 PARALLEL AND SERIES CONFIGURATIONS

BOP units may be configured in series or parallel (see PAR. 2.8). If a series/parallel configuration is enabled, communication between the master BOP and those configured as slave units occurs via the BITBUS.

#### 1.6.7 ENERGY RECUPERATION

The BOP is a four-quadrant device as shown in Figure 1-2. Operating as a source, it delivers energy into a passive load, and as a sink it operates as an electronic load, absorbing and dissipating energy from an active load. To minimize energy dissipation, the BOP employs energy recuperation, where energy sunk from an active load is passed backwards through the output circuit and the bidirectional input power factor correcting circuit to the a-c power lines, where it becomes available for reuse. This technology allows high power levels using switch-mode technology while maintaining high efficiency and reduced size and weight.

### 1.7 EQUIPMENT SUPPLIED

Equipment supplied with the BOP power supply is listed in Table 1-3.

**TABLE 1-3. EQUIPMENT SUPPLIED**

ITEM	FUNCTION	PART NUMBER
Source Power Entry mating connector	Mates with source power entry connector	142-0381 (Kepco) (IEC 320)

### 1.8 ACCESSORIES

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

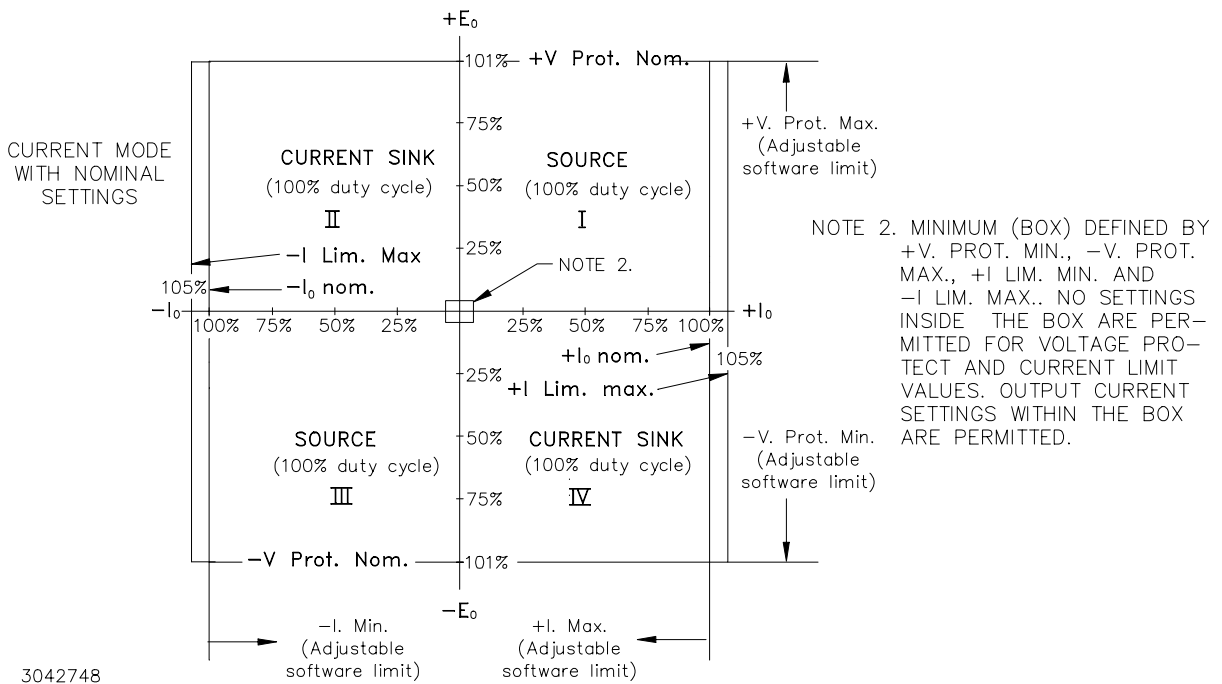
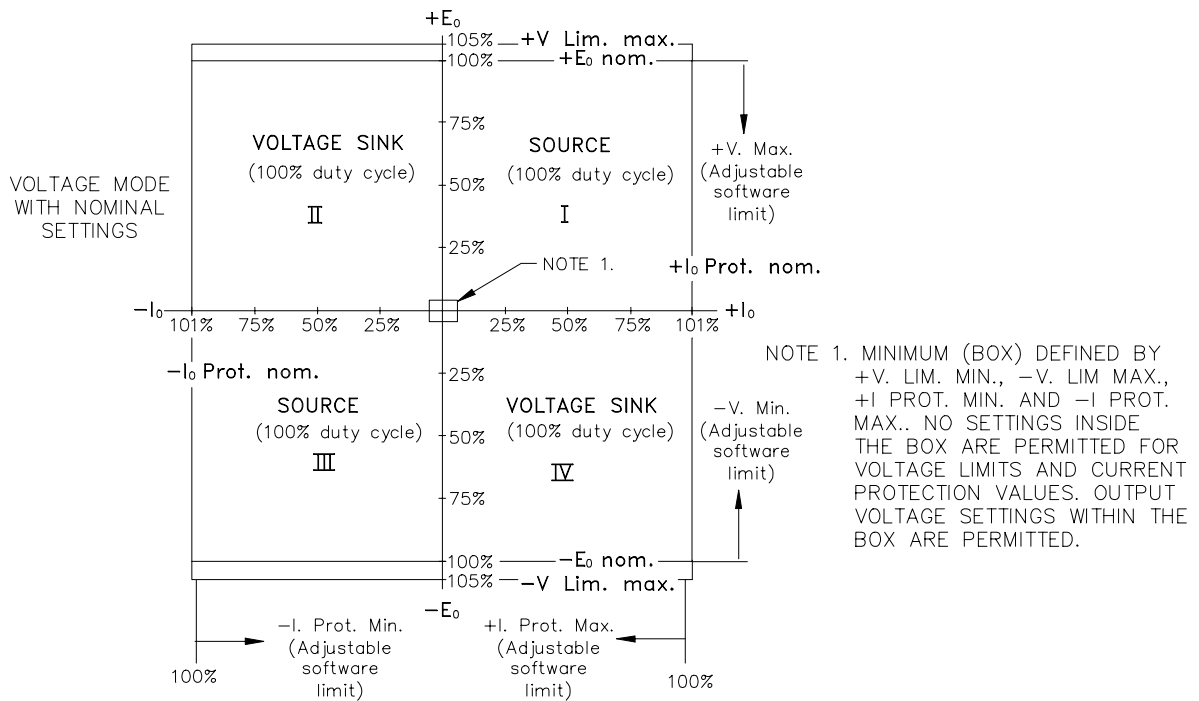


FIGURE 1-2. BOP OUTPUT CHARACTERISTICS



**TABLE 1-4. ACCESSORIES**

ITEM	FUNCTION	PART NUMBER
Mating Connector, External Trigger	Mates with External Trigger port.	142-0527 (Kepco) SP2501 (CUI Stack)
RS 232 Port Adapter Cable Kit	Converts 8-pin telephone jack type connector to 9-pin connector for connection to RS 232 bus.	KIT 219-0436 (Kepco)
IEEE 1118 (BITBUS) Mating connector	Allows connection to IEEE 1118 (BITBUS) port.	1420485 (Kepco) KMDLA-5P (Kycon Inc.)
IEEE 488 Cable, (1 meter long)	Connects BOP power supply to GPIB bus.	SNC 488-1
IEEE 488 Cable, (2 meter long)	Connects BOP power supply to GPIB bus.	SNC 488-2
IEEE 488 Cable, (4 meter long)	Connects BOP power supply to GPIB bus.	SNC 488-4
Interconnection Kit for multiple power supplies in parallel (increase current)	Cables required to connect multiple BOP models in parallel for increased current capability, e.g., connecting two BOP 10-75MG models in parallel to produce a virtual BOP 10-150MG.	219-0449 (2 in parallel) 219-0446 (3 in parallel) 219-0447 (4 in parallel) 219-0448 (5 in parallel)
Interconnection Kit for multiple power supplies in series (increase voltage)	Cables required to connect multiple BOP models in series for increased voltage capability, e.g., connecting two BOP 10-75MG models in series to produce a virtual BOP20-75MG.	219-0443 (2 in series) 219-0444 (3 in series)
Slides	Allows easy withdrawal of unit from rack (see Figure 1-1). (Model CM 04 includes slides, brackets, all mounting hardware and installation instructions.)	CM 04
RS 232 Adapter (Male pins)	Allows RS 232 port to be connected to DTE equipment	142-0487 (L-COM RA098M)
RS 232 Adapter (Female pins)	Allows RS 232 port to be connected to a PC (personal computer).	142-0506 (L-COM RA098F)
Line Cord (250V, 20A)	Provides connection to a-c mains via Nema 6-20P connector.	118-1087
Line Cord (250V, 20A)	Provides connection to a-c mains via Nema L6-20P locking type connector.	118-1088
RS 232 Cable Kit	Contains 6-pin to 8-pin Serial Patch cord, 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 PC (personal computer), two RS 232 Loop Back test Connectors (one 6-pin and one 8-pin) to test RS 232 communication and aid in isolating RS 232 communication problems.	KIT 219-0436

## 1.9 SAFETY

Service must be referred to authorized personnel. Using the power supply in a manner not specified by Kepeco, Inc. may impair the protection provided by the power supply. Observe all safety precautions noted throughout this manual (see listing on page E, preceding the Table of Contents). Table 1-5 lists symbols used on the power supply or in this manual where applicable.

**TABLE 1-5. SAFETY SYMBOLS**

<b>SYMBOL</b>	<b>Meaning</b>
	WARNING! 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

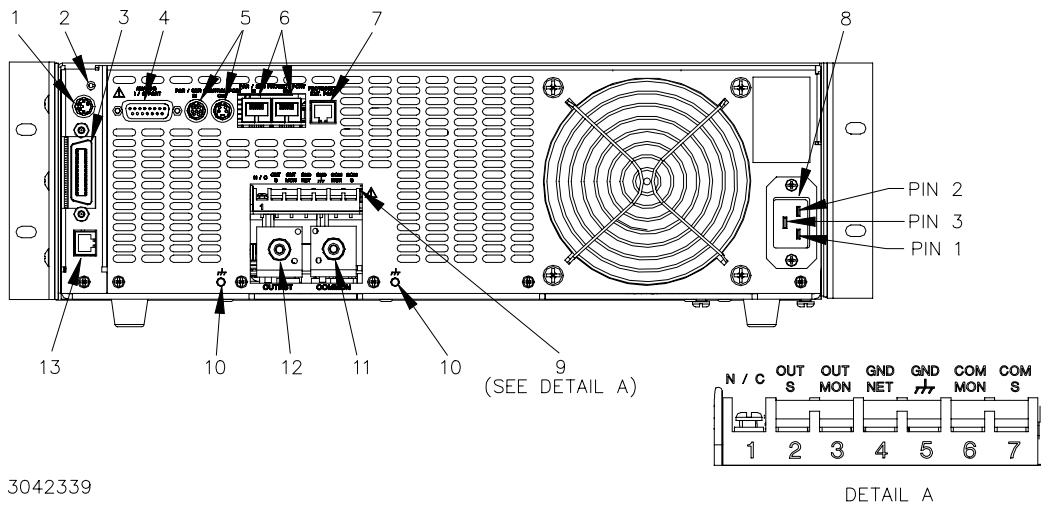
### 2.1 UNPACKING AND INSPECTION

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. 2.3. 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 3-1 and Table 3-1.

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




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**FIGURE 2-1. BOP SERIES REAR PANEL**

**TABLE 2-1. REAR PANEL CONNECTOR FUNCTIONS**

NUMBER (FIGURE 2-1)	CONNECTOR/TERMINAL (REFERENCE DESIGNATOR)	FUNCTION
1	IEEE 1118 (BITBUS) PORT <sup>(1)</sup> (connector A1J4)	Used for multiple BOP master/slave parallel and series configurations (refer to PAR. 2.8, see Table 2-2).
2	TRIGGER (connector A1J3)	May be used to initiate BOP output. (See Table 2-3.)
3	IEEE 488 (GPIB) PORT <sup>(1)</sup> (connector A1J6)	Used for Remote control of the BOP via the IEEE 488 (GPIB) interface (See Table 2-11.)
4	ANALOG I/O PORT <sup>(1)</sup> (connector A2A5J6)	Provides interface for analog input/output signals. (See Table 2-10.)
5	PARALLEL/SERIAL CONTROL PORT <sup>(1)</sup> (connectors A2A5J3, IN and A2A5J4, OUT)	Provides interconnections used to control parallel or serial configurations of identical BOP's as a single power supply (see Table 2-7 for A2A5J3, IN and Table 2-6 for A2A5J4, OUT).

**TABLE 2-1. REAR PANEL CONNECTOR FUNCTIONS (CONTINUED)**

NUMBER (FIGURE 2-1)	CONNECTOR/TERMINAL (REFERENCE DESIGNATOR)	FUNCTION
6	PARALLEL/SERIAL PROTECT PORT <sup>(1)</sup> (connectors A2A5J1, IN and A2A5J2 OUT)	Provides interconnections used to control protection shutdown of power supplies connected in parallel or serial configurations (see Table 2-8 for A2A5J1, IN and Table 2-9 for A2A5J2, OUT).
7	EXT PROTECT PORT <sup>(1)</sup> (connector A2A5J7)	Provides means for controlling protection via external circuitry and provides status flags to external circuitry. (See Table 2-4.)
8	INPUT connector <sup>(1)</sup> (connector A7J1)	Connects source power to unit. Pin 1 - Line (or Line 1 without Neutral connection) Pin 2 - Neutral (or Line 2 without Neutral connection) Pin 3 - Ground (Protective conductor terminal)
9	Monitor and Sensing terminal block (terminal block A7A1TB1)	Terminal block provides external connections as follows: OUT S: Sense line connection to load (compensate for voltage drop on connections to load.) See PAR. 2.5.6 and 2.5.7 (Terminal 2). OUT MON: Monitor connection used to monitor output voltage at power terminals and to implement local sensing (Terminal 3). GND NET: Grounding network connection (Terminal 4). See PAR. 2.5.3.1. GND: Chassis ground connection (Terminal 5). COM MON: Monitor return connection (Terminal 6). Used to monitor output voltage at power terminals and to implement local sensing. COM S: Sense line return connection from load (Terminal 7) See PAR. 2.5.6 and 2.5.7
10	 terminals	Frame or chassis terminals
11	COMMON (terminal A7J3)	Power output return from load.
12	OUTPUT (terminal A7J2)	Power output connection to load.
13	RS232 PORT <sup>(1)</sup> (connector A1J5)	Used for Remote control of the BOP via the RS 232 serial interface. (See Table 2-5 for details.)
(1) See Appendix C, Figure C-1 for pin identification and interconnections.		

**TABLE 2-2. IEEE 1118 CONNECTOR INPUT/OUTPUT PIN ASSIGNMENTS**

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
IEEE 1118 (BITBUS) PORT (connector A1J4)	1, 5 (shorted)	CONTROL BUS "A"	IEEE 1118, referenced to pins 3, 6 (2-Wire Differential Interface)
	3, 6 (shorted)	CONTROL BUS "B"	IEEE 1118, referenced to pins 1, 5 (2-Wire Differential Interface)
	8	TERMINATOR	Connect to pin 1 or 5 to add an internal 120 Ohm termination to first/last unit on the daisy chain.

**TABLE 2-3. TRIGGER PORT PIN ASSIGNMENTS**

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
TRIGGER PORT (connector A1J3)	1	LOGIC GND	Return for TRIGGER and SHUTDOWN signals.
	2	SHUTDOWN	Logic 0 causes unit to shut down.
	3	TRIGGER	Logic 0 triggers BOP to previously stored setting (see PAR. B.137.)
	4	NOT USED	



**TABLE 2-4. EXTERNAL PROTECTION CONNECTOR INPUT/OUTPUT PIN ASSIGNMENTS**

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
EXT. PROTECT PORT (connector A2A5J7)	1	SD_EXT_K	Cathode of LED optocoupler (through a 510 ohm resistor) which is used for external isolated shutdown. Anode of LED is connected to (A2A5J7) pin 2. A positive voltage (3.5 to 15V) at pin 2 (referenced to pin 1) shuts down the unit (see CAUTION below).
	2	SD_EXT_A	Anode of LED optocoupler which is used for external isolated shutdown. (See pin 1 above.)
	3	PG_EXT_C	Collector of optocoupler-transistor which is used for external isolated "power OK" flag. Transistor emitter is connected to (A2A5J7) pin 4. When unit is operating normally, transistor is saturated. Current through transistor should not exceed 5mA and supply voltage should not exceed 15V.
	4	PG_EXT_E	Emitter of optocoupler-transistor which is used for external isolated "power OK" flag. (See pin 3 above.)
	5	EXT_C	Collector of optocoupler-transistor which is used for external isolated "Output OFF" flag. Transistor emitter is connected to (A2A5J7) pin 6. When output is OFF, transistor is saturated. Current through transistor should not exceed 3mA and supply voltage should not exceed 15V.
	6	EXT_E	Emitter of optocoupler-transistor which is used for external isolated "output OFF" flag. (See pin 5 above.)
<p><b>CAUTION:</b>When an external shut-down signal is sent to the unit, the shut-down condition is latched and the red <b>FAULT</b> indicator on the front panel is <b>ON</b>. To resume normal operation it is necessary to cycle power off, then on (preferred) or briefly press the <b>RESET</b> key on the front panel.</p>			

**TABLE 2-5. RS232C PORT INPUT/OUTPUT PIN ASSIGNMENTS**

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
RS 232 PORT A1J5	1	RTS	Request To Send (protocol not used)
	2	RXD	Receive Data
	3	TXD	Transmit Data
	4	LOGIC GND	Logic Ground
	5	LOGIC GND	Logic Ground
	6	CTS	Clear To Send (protocol not used)

**TABLE 2-6. PARALLEL/SERIAL CONTROL OUT PORT PIN ASSIGNMENTS**

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
PARALLEL/SERIAL CONTROL OUT PORT (A2A5J4)	1	SGND	Local signal ground
	2	No connection	
	3	S_IN_PARALLEL	Relayed signal for daisy chain connection. (See PARALLEL/SERIAL IN PORT (A2A5J3) pin 3)
	4	No connection	

**TABLE 2-7. PARALLEL/SERIAL CONTROL IN PORT PIN ASSIGNMENTS**

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
PARALLEL/SERIAL CONTROL IN PORT (A2A5J3)	1	SGND	Local signal ground
	2	No connection	
	3	S_IN_PARALLEL	Input for programming output current of a parallel-connected slave. Provided by master unit. Level: -10V to +10V controls the current between $-I_{Onom}$ to $+I_{Onom}$ .
	4	No connection	
	5	No connection	
	6	IOUT_M_UNIT	Output for programming slave current when the unit is a parallel-connected master Level: -10V to +10V programs slave current to $-I_{Onom}$ to $+I_{Onom}$ .
	7	No connection	
	8	S_IN_SERIAL	Input for programming output voltage of a series-connected slave. Provided by master unit or from previous slave if multiple slaves connected. Level: $-E_{Onom}$ to $+E_{Onom}$ controls programs output voltage from $+E_{Onom}$ to $-E_{Onom}$ .

**TABLE 2-8. PARALLEL/SERIAL PROTECT IN PORT PIN ASSIGNMENTS**

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
PARALLEL/SERIAL PROTECT IN PORT (A2A5J1)	1	SD_A	Anode of LED optocoupler which is part of protection circuit for parallel or series combination. Cathode of LED is connected to PARALLEL/SERIAL PROTECT OUT PORT (A2A5J2) pin 1 (see Table 2-9). When activated, the optocoupler shuts down the unit. LEDs from all units of the parallel or series combination are connected in series.
	2	PGOUT_C	Collector of optocoupler transistor which is part of protection circuit for parallel or series combination. Transistor emitter is connected to PARALLEL/SERIAL PROTECT OUT PORT (A2A5J2) pin 2 (see Table 2-9). When unit is operating normally, transistor is saturated. Transistors from all units of the parallel or series combination are connected in series.
	3	SD_RETURN	Completes return connection for the protection circuit which receives energy from the master unit.
	4	No connection	
	5	No connection	
	6	No connection	
	7	GND	Local power ground.
	8	ALLOW EXT_ERR	Provides energy for the protection circuit (master unit only). Disabled at power up to prevent shutdown during power up.

**TABLE 2-9. PARALLEL/SERIAL PROTECT OUT PORT PIN ASSIGNMENTS**

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
PARALLEL/SERIAL PROTECT OUT PORT (A2A5J2)	1	SD_K	Cathode of LED optocoupler which is part of protection circuit for parallel or series combination. (See IN port (A2A5J1) pin 1, Table 2-8.)
	2	PGOUT_E	Emitter of optocoupler transistor which is part of protection circuit for parallel or series combination. (See IN port (A2A5J1) pin 2, Table 2-8.)
	3	SD_RETURN	Relayed connection, provides return for the protection circuit which receives energy from the master unit.
	4	No connection	
	5	No connection	
	6	No connection	
	7	No connection	
	8	No connection	

**TABLE 2-10. ANALOG I/O PORT INPUT/OUTPUT PIN ASSIGNMENTS**

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
ANALOG I/O PORT A2A5J6	1	NC	
	2	VM-/CM	External input signal, TTL logic referenced to pin 9, controls the mode of operation when using external reference (goes to the digital board that changes VM-/CM signal). Logic 0V (or pin grounded) = current mode, logic 1 (or pin not connected, the default) = voltage mode (see PAR. 3.3.5.4.4).
	3	IOUT_DMM	Output analog signal through 2K ohm resistor referenced to pin 4 for monitoring overall output current, 0V to ± 10V corresponds to zero to ± full scale current.
	4	SGND	Signal Ground used for IOUT_DMM (pin 3) return.
	5	- I_LIM_EXT	Analog input signal referenced to pin 12, 0V to +10V sets the negative current limit between zero and $-I_{Omax}$ . +10V corresponds to rated maximum current (e.g., for BOP 36-28MG +10V sets negative current limit to -28A) (see PAR. 3.3.6.2). Open = disabled (see NOTE 1).
	6	- V_LIM_EXT	Analog input signal, 0V to +10V, sets the negative voltage limit between zero and $-E_{Omax}$ . +10V corresponds to rated maximum voltage (e.g., for BOP 36-28MG +10V sets negative voltage limit to -36V). Open = disabled. (See PAR. 3.3.6.2.) Open = disabled (see NOTE 1).
	7	NC	
	8	NC	
	9	GND	Ground - Used for VM-/CM (pin 2) return
	10	SGND	Signal Ground (used for EXT_REF (pin 11) return
	11	EXT_REF	External analog reference signal referenced to pin 10, used for both voltage mode and current mode, 0V to ±10V corresponds to zero to ± rated nominal (full scale), voltage or current (see PAR. 3.3.6.1.2).
	12	GND1	Ground (Used for pin 5, 6, 13 and 14 return)
	13	+I_LIM_EXT	Analog input signal referenced to pin 12, 0V to +10V sets the positive current limit between zero and $I_{Omax}$ ; +10V corresponds to rated maximum current (e.g., for BOP 36-28MG +10V sets positive current limit to +28A) (see PAR. 3.3.6.2). Open = disabled (see NOTE 1).
	14	+V_LIM_EXT	Analog input signal, 0V to +10V sets the positive voltage limit between zero and $E_{Omax}$ . +10V corresponds to rated maximum voltage (e.g., for BOP 36-28MG +10V sets positive current limit to +36V. Open = disabled. (See PAR. 3.3.6.2.) (see NOTE 1).
	15	NC	

NOTE 1. When disabled, the external limit channels are automatically set 20% higher than BOP nominal references.

### 2.3 PRELIMINARY OPERATIONAL CHECK

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 3-1 for location of operating controls and electrical connections. Tables 3-1 and 3-2 explain the functions of operating controls/indicators and keypad keys, respectively. Refer to PAR. 3.2 for a description of basic operating techniques.

1. With POWER switch set to off position, connect the power supply to source power (see PAR. 2.5.2).
2. With no load connected, set POWER switch to the ON position. Each time the unit is turned on an internal self-test is performed. The alphanumeric display (LCD) shows the processor firmware revision history and lists various tests performed during the internal self-test. As each test is completed, PASS or FAIL is displayed. If all tests pass, the unit goes into the

default mode. If a failure occurs, the failure is displayed. Figure 3-3 shows the factory configured power on defaults displayed on the LCD.

**TABLE 2-11. IEEE 488 PORT INPUT/OUTPUT PIN ASSIGNMENTS**

CONNECTOR	PIN	SIGNAL NAME	FUNCTION
IEEE 488 PORT J5	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

3. Connect a digital voltmeter (DVM) (resolution and accuracy of 0.01% or better) to the OUTPS and COMS terminals at the rear panel terminal block.
4. Use the keypad to enter the rated maximum voltage of the power supply (e.g., enter 36 for a model BOP 36-28MG) and press **ENTER**.
5. Verify DVM voltage reading agrees with programmed voltage within 0.03% of rated maximum voltage and agrees with displayed voltage on LCD within 0.05% of rated maximum voltage.

## 2.4 INSTALLATION

### 2.4.1 RACK MOUNTING

The unit is shipped with four feet attached to bottom of the unit which must be removed prior to installation (see Figure 1-1). The BOP is designed to be rack mounted in a standard 19-inch wide rack using the mounting ears (supplied) attached to the front panel (see Figure 1-1). **CAUTION: THE RACK MUST PROVIDE SUPPORT AT THE REAR (WITHIN 6 INCHES OF THE REAR PANEL). OPTIONAL SLIDES CAN ALSO BE USED (SEE PAR. 2.4.2).**

### 2.4.2 SLIDE INSTALLATION


Optional slides are available for rack mounting (see Table 1-4 and Figure 1-1).

## 2.5 WIRING INSTRUCTIONS

Interconnections between an a-c power source and a 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.

**CAUTION: WHEN WORKING WITH ACTIVE LOADS, THE VOLTAGE OR CURRENT OF THE ACTIVE LOAD MUST NOT EXCEED THE MAXIMUM VOLTAGE OR CURRENT RATING OF THE BOP. OTHERWISE THE OVERVOLTAGE OR OVERCURRENT PROTECTION WILL SHUT DOWN THE POWER SUPPLY.**

### 2.5.1 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 2-1) is connected to the 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. As a precaution, always connect the stud marked  at the rear panel to proper earth ground.

### 2.5.2 SOURCE POWER CONNECTIONS

Source power is connected to the power supply via three-wire input power using the source power mating connector supplied (see Table 1-3). See Table 1-2 for source power specifications. This power supply operates from single phase a-c mains power over the specified voltage and frequency ranges (Table 1-2) without any need for range selection.

### 2.5.3 D-C OUTPUT GROUNDING

Connections between the power supply and the load and sensing connections may, despite all precautions such as shielding, twisting of wire pairs, etc., be influenced by radiated noise, or "noise 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, 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 OUTPUT or COMMON output terminals 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 and common terminals of BOP power supplies are d-c isolated (“floating”) from the chassis in order to permit the user maximum flexibility in selecting the best single point ground location. Care must be taken in measuring the ripple and noise at the power supply: measuring devices which are a-c line operated can often introduce additional ripple and noise into the circuit.

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

### **2.5.3.1 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. Decoupling capacitors from each of the two output terminals to the chassis via a terminal block link form a grounding network. The grounding network is designed to reduce high frequency noise and 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 TB1-4 (GND NET) and TB1-5 (GND). To disconnect the grounding network from the output, remove the connection across TB1-4 and TB1-5.

### **2.5.4 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 constantly modulated or step-programmed; has primarily reactive characteristics; or where the dynamic output response of the power supply is critical to load performance.

### **2.5.5 LOAD CONNECTION - GENERAL**

Load connections to the BOP power supply are achieved via the OUTPUT and COMMON terminals located on the rear panel. A barrier strip is provided at the rear panel for connection to the load (system applications).

**NOTE** REGARDLESS OF OUTPUT CONFIGURATION, OUTPUT SENSE LINES MUST BE CONNECTED FOR OPERATION.

1. **OBSERVE POLARITIES:** The **OUT S** sensing wire must be connected to the **OUTPUT** load wire, and the **COM S** sensing wire must be connected to the **COMMON** load wire.

2. IF LOCAL SENSING IS USED, INSTALL LINKS (see Figure 2-2).

**CAUTION: THE SAFETY FEATURES INCORPORATED INTO THE BOP TO HANDLE ENERGY FROM ACTIVE LOADS ARE UNABLE TO PROTECT THE POWER SUPPLY OR THE LOAD IF INPUT POWER TO THE BOP IS LOST. IT IS RECOMMENDED THAT THE USER MONITOR "POWER OK" FLAG PINS 3 AND 4 OF THE EXTERNAL PROTECT PORT (SEE TABLE 2-4) AND IMPLEMENT A FAST-ACTING MEANS OF DISCONNECTING OR CROWBARRING THE LOAD TO PREVENT DAMAGE TO BOTH THE BOP AND THE LOAD IN THE EVENT OF INPUT POWER LOSS.**

### **2.5.6 LOAD CONNECTION USING LOCAL SENSING**

Figure 2-2 shows a typical configuration using local sensing and a grounded load; for local sensing with an isolated ("floating") load, do not install the ground connection (see Figure. 2-2, Note 2).

### **2.5.7 LOAD CONNECTION USING REMOTE SENSING**

Figure 2-3 shows a typical configuration using remote sensing and a grounded load; for remote sensing with an isolated ("floating") load, do not install the ground connection (see Figure. 2-3, Note 2).

## **2.6 COOLING**

The power devices used within the power supply are maintained within their operating temperature range by means of internal heat sink assemblies and by two cooling fans. Periodic cleaning of the power supply interior is recommended. If the power supply is located within a confined

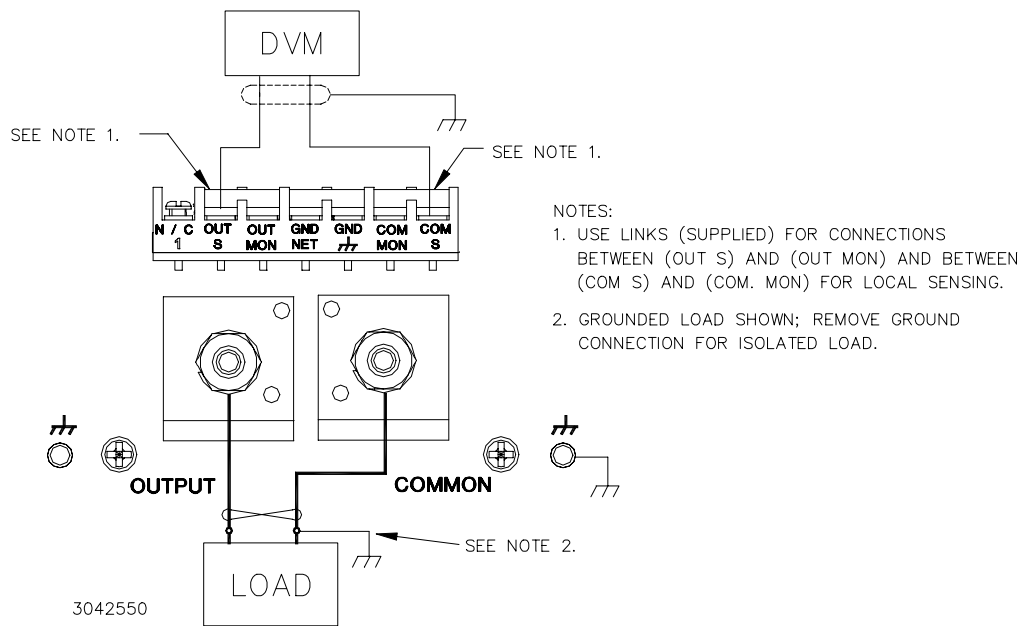
space, take care that the ambient temperature, which is the temperature of the air immediately surrounding the power supply, does not rise above the specified limits (see Table 1-2).

## 2.7 SETTING UP THE UNIT

The following paragraphs describe the connections and initial BOP setup needed to operate in the desired mode.

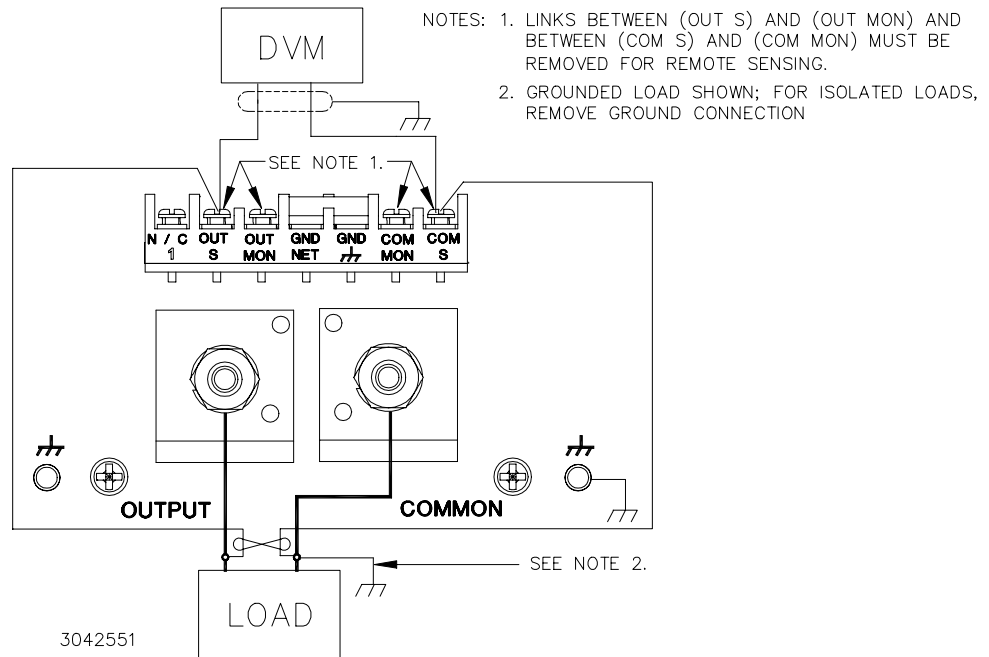
### 2.7.1 SETUP FOR LOCAL OPERATION

With all power off, connect the load to the BOP using either local or remote sensing (refer to PAR. 2.5). If units are to be connected in series or parallel, refer to PAR. 2.8.) Then refer to PAR. 3.2 for power supply basics and local operation. The factory default configuration allows local operation with no further setup required.



**FIGURE 2-2. LOAD CONNECTIONS, LOCAL SENSING**





**FIGURE 2-3. LOAD CONNECTIONS, REMOTE SENSING**

### 2.7.2 SETUP FOR REMOTE OPERATION VIA GPIB

With all power off, connect the load to the BOP using either local or remote sensing. If units are to be connected in series or parallel, refer to PAR. 2.8.). Connect the GPIB connector to the GPIB port (see Figure 2-1 and Table 2-1). Turn power on and refer to PAR. 3.2 for power supply basics and PAR. 3.4 for remote mode programming.

The default GPIB address is 6; to change it refer to PAR 3.4.3.4. The default configuration allows both local and remote operation; to prevent local operation once the unit is being controlled from the GPIB, see PAR. B.127. Refer to PAR. 3.4.3.4 to configure the GPIB Port.

SCPI programming is described in PAR. 3.8; Appendices A and B provide syntax for SCPI common and subsystem commands and queries implemented in this unit. All the features described for Local Mode operation can be accomplished using remote SCPI commands.

### 2.7.3 SETUP FOR REMOTE OPERATION VIA RS 232C

With all power off, connect the load to the BOP using either local or remote sensing (refer to PAR. 2.5). If units are to be connected in series or parallel, refer to PAR. 2.8.). Connect the RS 232 connector to the RS 232 port (see Figure 2-1 and Table 2-1). Turn power on and refer to PAR. 3.2 power supply basics and PAR. 3.7 for RS 232 operation. SCPI programming is described in PAR. 3.8; Appendices A and B provide syntax for SCPI common and subsystem commands and queries implemented in this unit. Refer to PAR. 3.4.3.5 to configure the RS 232 Port.

## 2.8 PARALLEL/SERIES CONFIGURATIONS

Parallel and series configurations of identical BOP units increases the rated voltage and current range of the power supply. Up to five units can be connected in parallel to increase the current:  $I_{MAX (one\ unit)} \times N_P = I_{MAX (parallel\ combination)}$  where  $N_P$  = number of units in parallel. Similarly, up to three units can be connected in series to increase the voltage:  $E_{MAX (one\ unit)} \times N_S = E_{MAX (parallel\ combination)}$  where  $N_S$  = number of units in series. Series and parallel configurations require the appropriate Interconnection Kit (see Table 1-4).

Additional hex nuts are provided in the interconnection kit for sufficient cable separation so they can be oriented as needed to fit onto the terminal.

NOTE: The following procedure assumes that both individual units are properly calibrated. (Units shipped from Kepco have been factory-calibrated.) If not, refer to Section 4 to calibrate the individual units prior to connecting them in parallel or series.

Before powering up the units to be configured, first connect the units in parallel or series. Figures 2-4 (local sensing) and 2-5 (remote sensing) show the connections for three parallel-connected units; Figures 2-6 (local sensing) and 2-7 (remote sensing) show the connections for three series-connected units.

**CAUTION: FOR PARALLEL CONFIGURATIONS, REMOVE LINKS BETWEEN (COM S) AND (COM OUT) TERMINALS OF ALL SLAVES TO PREVENT DAMAGE TO THE UNIT AND MAINTAIN SYSTEM ACCURACY.**

The following connections are required.

- Power cables
- Sense connections (either local or remote)
- Bitbus cable (supplied in Kit; see Table 1-4 for part number)
- Protection Cable(s), Master Termination and Last Slave Termination (supplied in Kit; see Table 1-4 for part number) (see PAR. 2.8.1 for additional information).
- For Parallel only: Parallel Control cable(s) and Master Parallel Control Termination. (supplied in Kit; see Table 1-4 for part number)
- For Series only: Series Control cable (supplied in Kit; see Table 1-4 for part number)

### 2.8.1 PARALLEL OR SERIES PROTECTION

For both parallel and series configurations it is necessary to configure the protection for the multiple units so that a fault will shut down all the interconnected power supplies. Figure 2-2 is a simplified diagram showing typical interconnections for master slave configurations.

CAUTION: REMOVE LINK BETWEEN (COM S) AND (COM MON) AT ALL SLAVES TO PREVENT DAMAGE TO THE BOP AND MAINTAIN SYSTEM ACCURACY.

- NOTE: 1. INSTALL LINKS BETWEEN (OUT S) AND (OUT MON) AND BETWEEN (COM S) AND (COM MON) AT MASTER FOR LOCAL SENSING.  
 2. REMOVE LINK BETWEEN (GND NET) AND (GND) AT ALL SLAVES.  
 3. REFER TO CABLE KIT FOR PART NO.  
 4. PARALLEL STAR CONFIGURATION (SHOWN) IS REQUIRED.

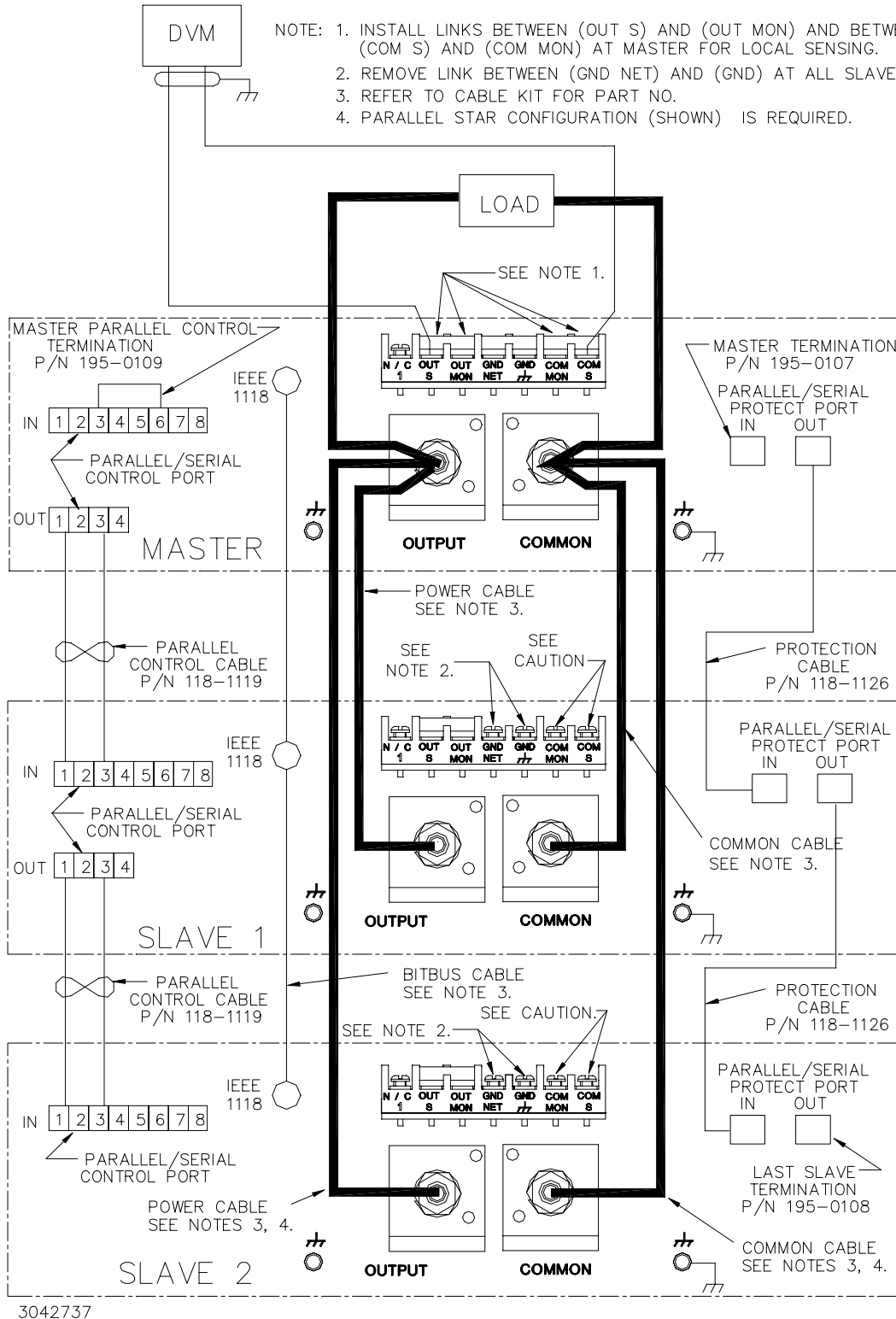


FIGURE 2-4. PARALLEL CONFIGURATION, LOCAL SENSING, TYPICAL

CAUTION: REMOVE LINK BETWEEN (COM S) AND (COM MON) AT ALL SLAVES TO PREVENT DAMAGE TO THE BOP AND MAINTAIN SYSTEM ACCURACY.

- NOTE: 1. REMOVE LINKS BETWEEN (OUT S) AND (OUT MON) AND BETWEEN (COM S) AND (COM MON) AT MASTER FOR REMOTE SENSING.  
 2. REMOVE LINK BETWEEN (GND NET) AND (GND) AT ALL SLAVES.  
 3. REFER TO CABLE KIT FOR PART NO.  
 4. PARALLEL STAR CONFIGURATION (SHOWN) IS REQUIRED.  
 5. USE #22 AWG WIRE FOR ALL SENSE CONNECTIONS.

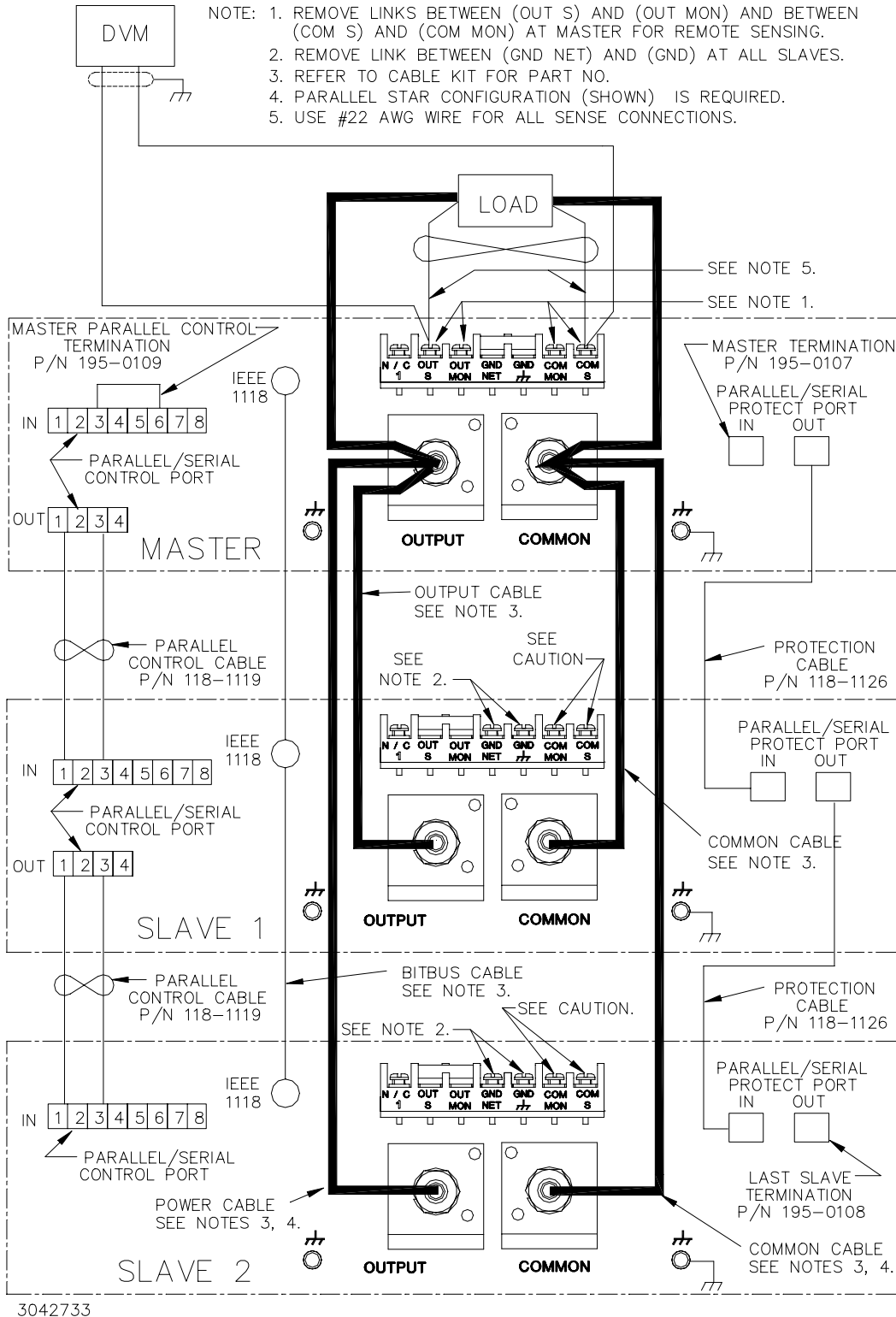
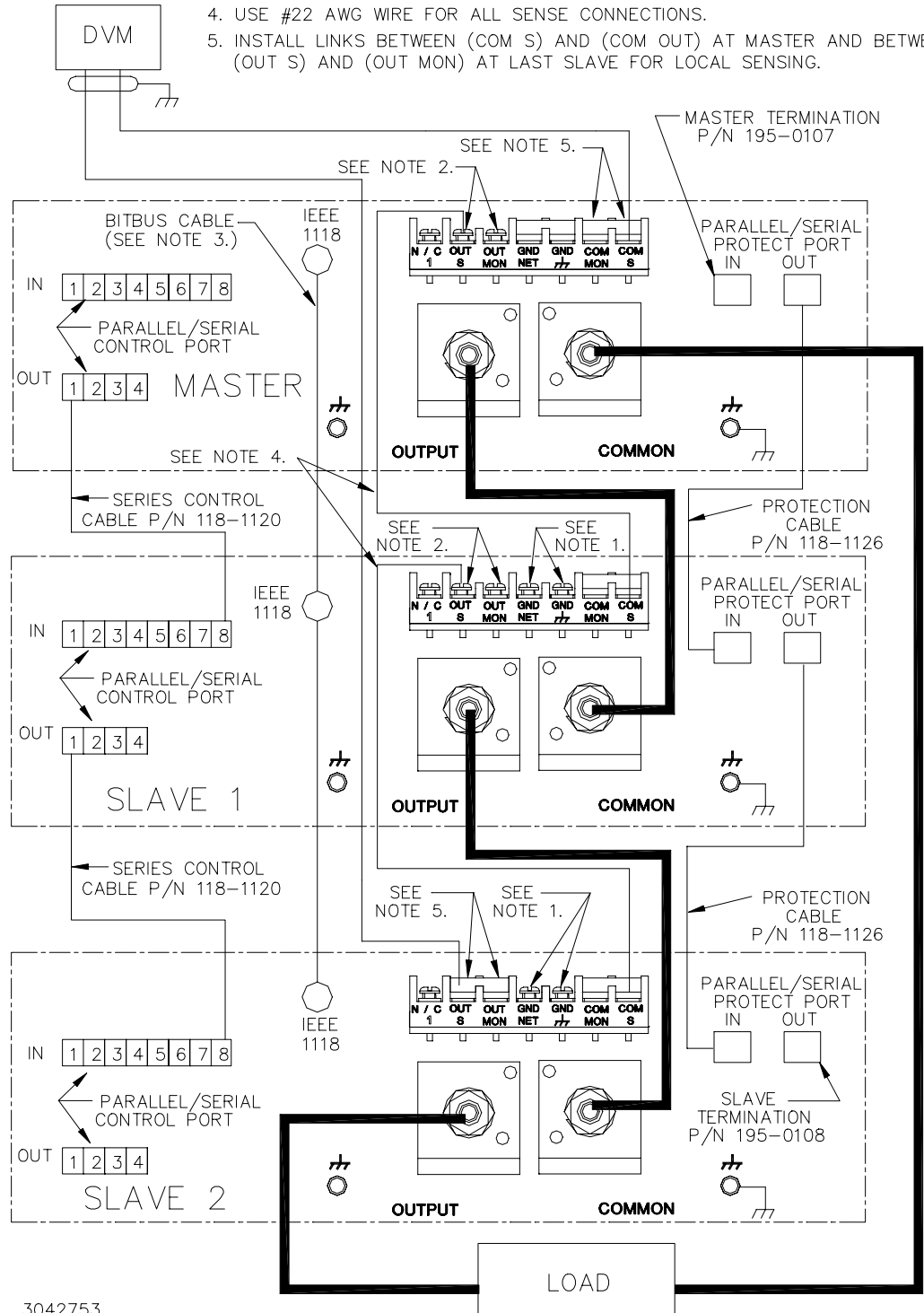


FIGURE 2-5. PARALLEL CONFIGURATION, REMOTE SENSING, TYPICAL

- NOTES: 1. REMOVE LINK BETWEEN (GND NET) AND (GND) FOR ALL SLAVES.  
 2. REMOVE LINK BETWEEN (OUT S) AND (OUT MON) AT MASTER AND AT FIRST SLAVE TO COMPENSATE FOR DROP IN POWER CONNECTIONS.  
 3. REFER TO CABLE KIT FOR PART NO.  
 4. USE #22 AWG WIRE FOR ALL SENSE CONNECTIONS.  
 5. INSTALL LINKS BETWEEN (COM S) AND (COM OUT) AT MASTER AND BETWEEN (OUT S) AND (OUT MON) AT LAST SLAVE FOR LOCAL SENSING.



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FIGURE 2-6. SERIES CONFIGURATION, LOCAL SENSING, TYPICAL

- NOTES: 1. REMOVE LINK BETWEEN (GND NET) AND (GND) FOR ALL SLAVES.  
 2. REMOVE LINK BETWEEN (OUT S) AND (OUT MON) AT FIRST SLAVE TO COMPENSATE FOR DROP IN POWER CONNECTIONS.  
 3. REMOVE LINK BETWEEN (COM S) AND (COM MON) AT MASTER AND BETWEEN (OUT S) AND (OUT MON) AT LAST SLAVE FOR REMOTE SENSING.  
 4. REFER TO CABLE KIT FOR PART NO.  
 5. USE #22 AWG WIRE FOR ALL SENSE CONNECTINS.

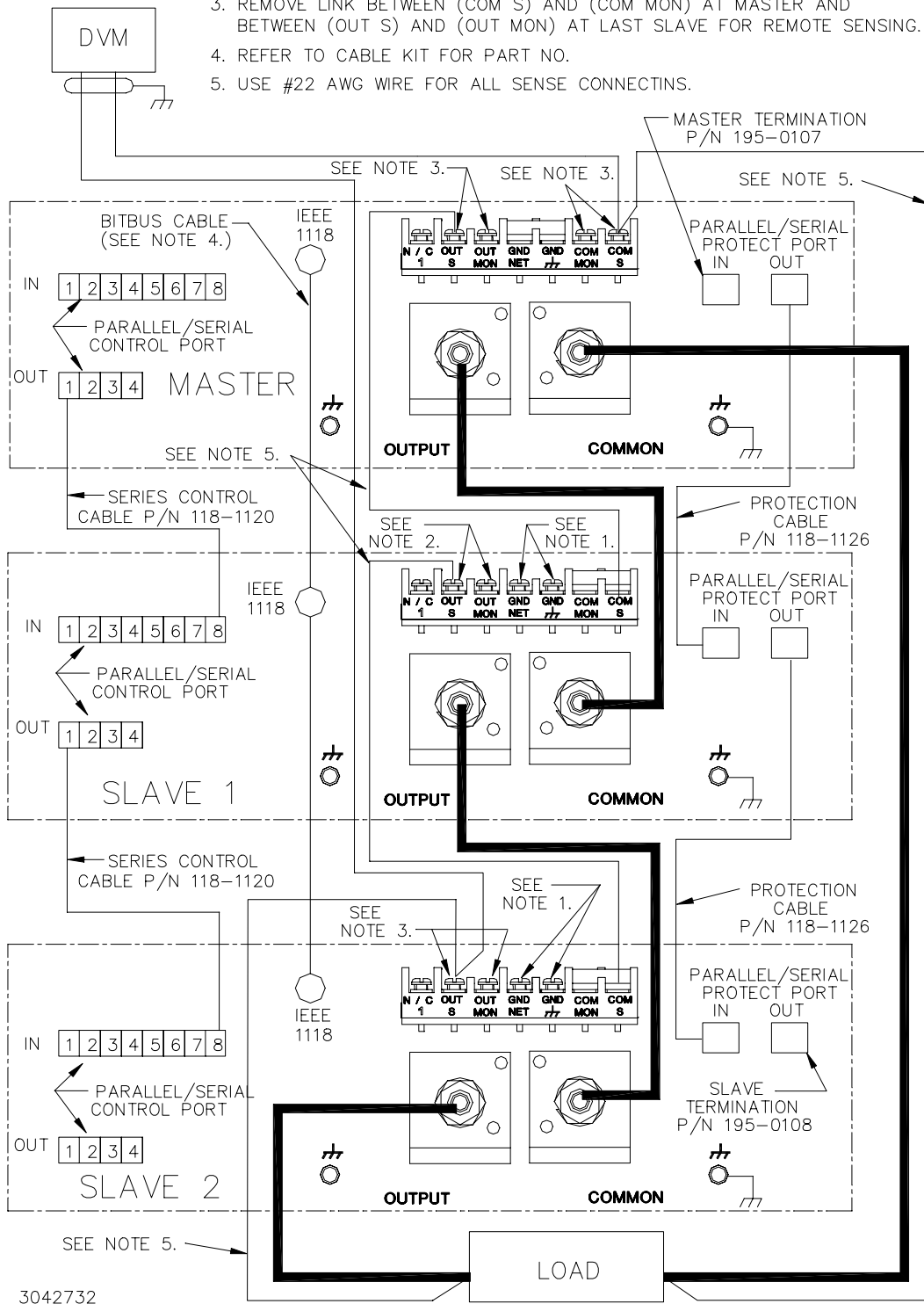
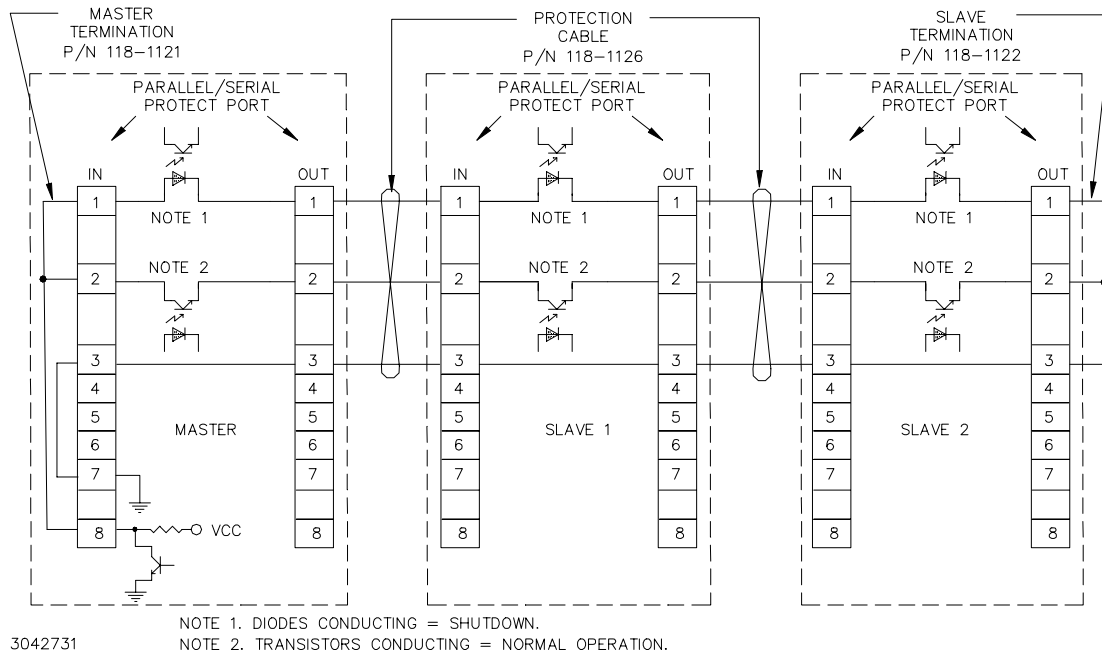


FIGURE 2-7. SERIES CONFIGURATION, REMOTE SENSING, TYPICAL











**FIGURE 2-8. TYPICAL MASTER/SLAVE PROTECTION INTERCONNECTIONS**

Upon startup, PAR/SER PROT IN PORT pin 8 of the master goes low, and stays low until all slaves are powered up. Normal power up of a unit causes the transistor connecting PAR/SER PROT IN PORT pin 2 and PAR/SER PROT OUT PORT pin 2 to conduct. The transistors of all units are connected in series, effectively shorting out all the shutdown diodes (the shutdown diodes of all units are also connected in series) connecting PAR/SER PROT IN PORT pin 1 and PAR/SER PROT OUT PORT pin 1. After all the units are powered up and operating normally, the low at PAR/SER PROT IN PORT pin 8 changes to high, but the conducting transistors keep the voltage at pin 8 low and the diodes are cut off. If a fault occurs, the transistor between PAR/SER PROT IN PORT pin 2 and PAR/SER PROT OUT PORT pin 2 of the defective unit is cut off, allowing current to flow through the shutdown diodes. This develops internal shutdown signals that shut down all units.









### 2.8.2 CONFIGURING PARALLEL OR SERIES COMBINATION


**NOTE:** To power down the combination, first press the **STANDBY** key on the master to disable the output, then turn off the slave(s) followed by the master.

1. To configure a unit to be designated as a slave proceed as follows:
  - a. Turn on power only to the unit to be designated as a slave.
  - b. From the main screen (power on default), press **F5** to enter the Settings Menu.
  - c. From the Settings menu, gain access to the Protected Settings menu by first entering the password. Scroll through the password characters using **ADJUST** control and **RIGHT** or **LEFT** to select the character position, then press **ENTER**. The status message changes to **Protected settings enabled**. (If unsuccessful, use **RIGHT** or **LEFT** to highlight the incorrect character and **ADJUST** control to fix it, or press **CLEAR** to start over.)
  - d. Press **F4** to enter the Protected Settings Menu.

- e. From the Protected Settings menu, highlight **Unit Type** (use **ADJUST** control or the  or  keys) and press  to modify. Highlight **SLAVE #1** and press  to apply the change.
- f. From the Protected Settings menu, under **Unit Type** highlight **Expansion** and press  to modify. Highlight **Parallel** if connected in parallel or **Series** if connected in series and press  to apply the change.
- g. Exit the Protected Settings menu and return to main screen by pressing  to save the settings upon power-up. The unit goes to REMOTE mode, the status message reads **MASTER Module not found**, the Fault indicator is lit, and the unit continues to beep once a minute until the master is found. The only function key displayed is  - LOCAL.

**CAUTION: THE UNITS ARE NOW CONFIGURED AS SLAVE(S) TO BE CONTROLLED ONLY BY THE MASTER. DO NOT USE THE SLAVE KEYPAD, RS 232 PORT OR GPIB PORT TO TRY TO CONTROL THE SLAVE(S).**

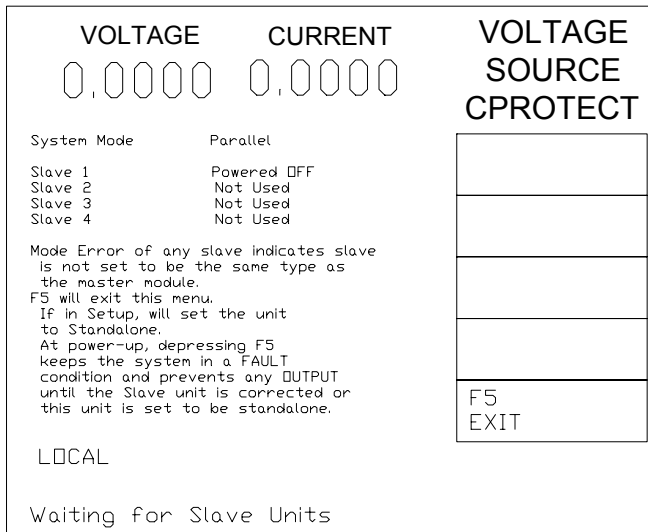
2. Repeat step 1 as necessary to configure all slaves, but at step e highlight **SLAVE #2**, **SLAVE #3**, or **SLAVE #4** as appropriate. **Each slave MUST have a different number that is sequentially assigned.**
3. Turn on the unit to be configured as a master and note that upon power up the **FAULT** light will go on (this is normal). Proceed as follows:
  - a. From the main screen, press  to enter the Settings Menu.
  - b. From the Settings menu, gain access to the Protected Settings menu by first entering the password (see Step 1c above).
  - c. From the Protected Settings menu, highlight **Unit Type** (use **ADJUST** control or  or  keys) and press  to modify. Highlight **Master +1**, **Master +2**, **Master +3**, Or **Master +4** (**Master +3**, Or **Master +4** not permitted for series connections) and press  to apply the change.
  - d. From the Protected Settings menu, under **Unit Type** highlight **Expansion** and press  to modify. Highlight **Parallel** if connected in parallel or **Series** if connected in series and press  to apply the change.
  - e. Exit the Protected Settings menu by pressing  to test the system and to save the settings for subsequent power-up cycles. The display shows the master power-up screen (see Figure 2-9).

NOTE: Pressing  to exit will cause the unit to revert to a standalone unit.

- f. The power-up master module screen (Figure 2-9) changes to show the status of the slave(s). Refer to Table 2-12 for an explanation of status indications for the slave(s).

If all the slaves are recognized as ready, after about 10 seconds the master LCD reverts to the Power On Default screen (see Figure 2-10). The slaves display the Slave Power On Default screen (see Figure 2-11), except the unit will be in Current Mode for parallel configurations and Voltage mode for series configurations and the message will indicate the unit is operating as a slave. Press the **HELP** key for instructions to return the slave to standalone operation. The fault indicators on all units are off.





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**FIGURE 2-9. MASTER POWER UP SCREEN**

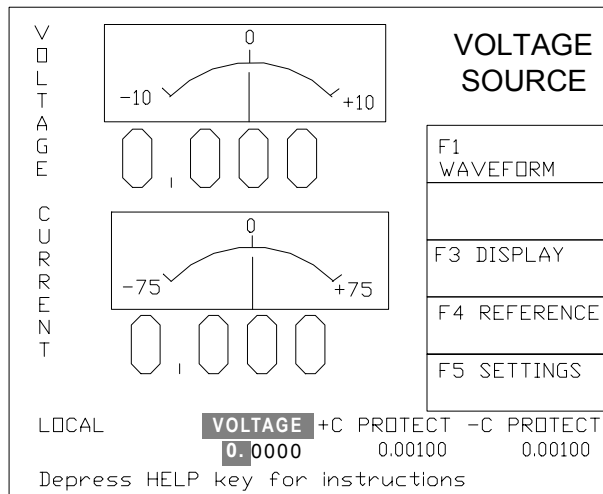
**TABLE 2-12. SLAVE STATUS MESSAGE DEFINITIONS**

Slave Status Message Displayed on Master Power Up Screen (see Figure 2-9)	MEANING
Ready	Unit is ready for operation.
STANDBY	If unit's FAULT indicator is on, hardware error has NOT been detected, output is ready to be turned on
Powered OFF	Unit is not responding to polls via BITBUS.
Failed	Unit's FAULT indicator is on to indicate a hardware error has been detected.
Not Used	Unit is not part of parallel configuration
Unknown	Waiting for interface communication

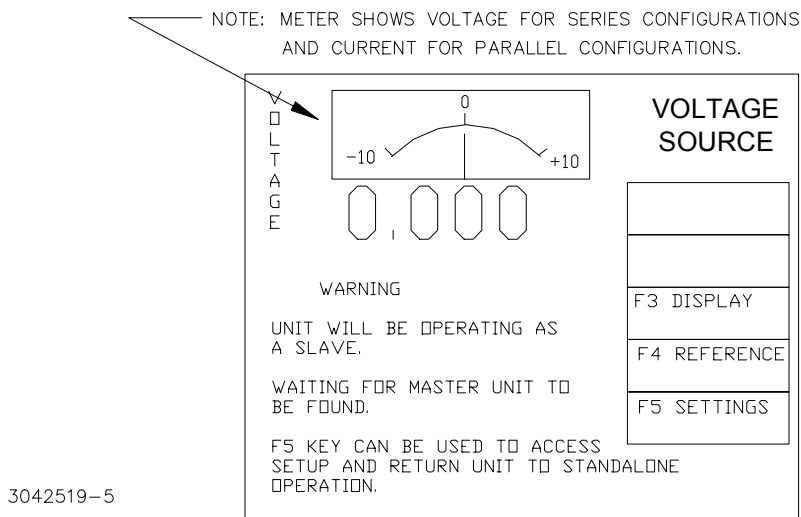
If the master power-up screen is still displayed after 10 seconds, a slave was not properly recognized. Pressing **F5** or turning power off, then on again, reconfigures the unit as a standalone unit. Verify that the BITBUS cable is installed correctly. Verify that the slave has been properly configured as a slave per step 1 above. Repeat step 3. If the power up screen still does not revert to the power on default screen, refer to troubleshooting.

4. Adjust the limits to reflect the increased current capacity of the parallel combination as follows:
  - a. From the main screen, press **F5** to enter the Settings Menu.
  - b. From the Settings menu, press **F2** to enter the Modify Limits menu. Press **F2** to restore defaults. The values for +Current Max, -Current Min and ±Current Protect Max/Min should now be for the parallel combination.
  - c. Exit the Modify Limits menu by pressing **F4** to save the settings upon power-up.

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**FIGURE 2-10. POWER ON DEFAULT SCREEN FOR MASTER UNIT**





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**FIGURE 2-11. POWER ON DEFAULT SCREEN FOR SLAVE UNIT**

### 2.8.3 OPERATING INSTRUCTIONS FOR PARALLEL OR SERIES COMBINATIONS

1. Apply power to the combination by first turning on the master, then turn on the slave. If the master is in STANDBY, depress the STANDBY key on the master to apply power to the output terminals. (To power down the combination, first press the STANDBY key on the master to disable the output, then turn off the slave, followed by the master.
2. When the units of a parallel/series combination are first turned on there is a brief delay until all units are communicating over the BITBUS to form the combined assembly.
  - When the master is turned on, the unit initially displays the Serial number as well as the Firmware Revision levels and power up test results for the Display, Interface and Analog processors, then displays the Master Power Up screen (Figure 2-9).

- When a slave is turned on, the unit initially displays the Slave Power Up screen (Figure 2-11), the Fault indicator is lit, and the unit continues to beep once a minute until the master is found. Press the **HELP** key for instructions to return the unit to standalone operation. Once the slave is up and running, the  key indicates LOCKOUT and the  key shows DISPLAY (see PAR. 3.2.5).
- When the master finally recognizes all the slaves, the master LCD reverts to the Power On Default screen (see Figure 2-10). The slave(s) display the voltage meter (for series configurations) or current meter (for voltage configurations), and the message indicates the unit is operating as a slave. The fault indicators on both units are off. Press the slave's **HELP** key for instructions as to how to restore standalone operation.
- Operation of a parallel combination is done by operating the master as described for a single unit. SCPI commands and front panel control actions applied to the master affect the parallel combination. The LCD display of the master refers to the parallel combination, while the front panel LCD of the slave shows the actual voltage (series) or current (parallel) provided by the slave.



## SECTION 3 - OPERATION

### 3.1 GENERAL

This section explains how to operate the 1000 Watt BOP Power Supply. The power supply can be operated either in Local mode (see PAR's. 3.2 and 3.3) using the front panel keypad, ADJUST control and graphical display, or in Remote mode (see PAR. 3.4). Remote mode can either be analog or digital. Analog remote uses analog signals from the Analog I/O port to control the output (see PAR. 3.9).

Digital remote uses either the built-in GPIB (IEEE 488) (see PAR. 3.5) or RS 232 (see PAR. 3.7) to communicate with a remote computer. GPIB or RS 232 communication is via one of two protocols: 1) SCPI commands which afford full functionality of the BOP (see PAR. 3.8, Appendix A and Appendix B) or 2) CIL commands (for compatibility with older Kepco products. Operation in remote mode can be simplified by the use of the VISA driver supplied with the power supply (see PAR. 3.6).

### 3.2 POWER SUPPLY BASICS

The following paragraphs describe basic operation of the front panel controls, and how they are used to configure and operate the power supply. This includes a description of the keypad (PAR. 3.2.1), graphical display (LCD (PAR. 3.2.2), and how to turn the unit on (PAR. 3.2.3). A detailed explanation of how to use the front panel controls (PAR. 3.2.4) provides basic techniques needed to use the ADJUST control and function, arrow and numeric keys in conjunction with the LCD to operate the power supply. Refer to Table 3-1 and Figure 3-1 for a description of front panel controls and indicators

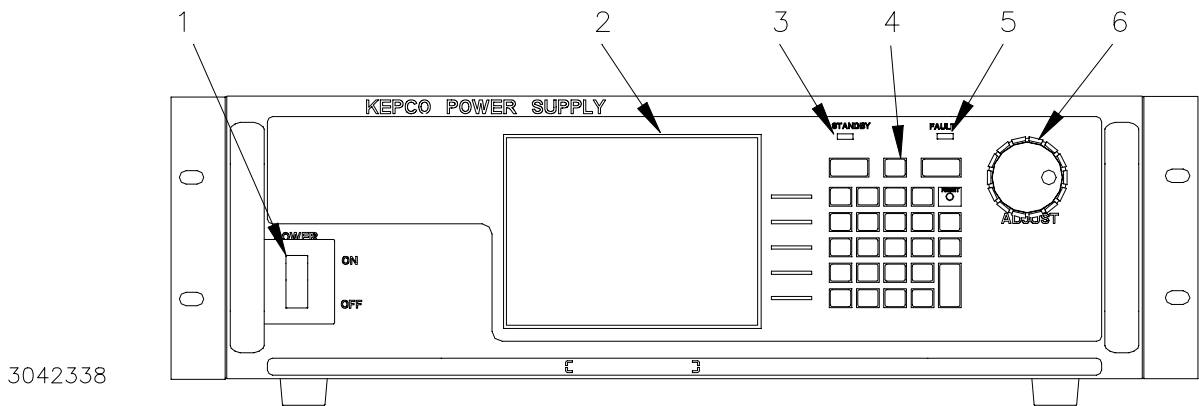


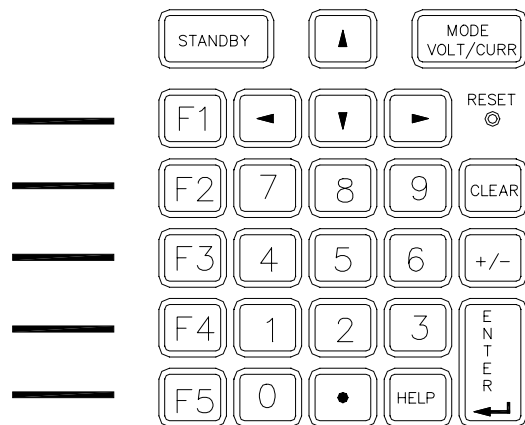
FIGURE 3-1. BOP SERIES FRONT PANEL

**TABLE 3-1. 'FRONT PANEL CONTROLS AND INDICATORS**

NUMBER (FIGURE 3-1)	CONTROL/INDICATOR	FUNCTION
1	POWER ON/OFF circuit breaker A7CB1	Applies source power to unit
2	Alphanumeric/graphic Display (LCD)	Displays output voltage and current as well as information in response to keypad and ADJUST control entries. Displays function of soft function keys F1 through F5, and displays information as required to perform all local functions.
3	STANDBY indicator	Lights to indicate when the unit is in Standby mode. Behavior of the unit in Standby (Output off) is determined by the options chosen for Output Mode (see PAR. 3.3.5.4.2). The default Output mode is ACTIVE: in Standby the unit is set to voltage mode, voltage is set to zero, current protection is set to the nominal, and voltage limit is set to maximum.
4	Keypad	Access all local functions (see PAR. 3.2.1, Figure 3-2 and Table 3-2 for details).
5	FAULT indicator	Lights when a fault is detected. The failure of the following assemblies cause the FAULT indicator to go on: A1 (any control function failure), A2 (overtemperature, instant internal overcurrent, output overvoltage/overcurrent, local +15V failure), A4 (input under/overvoltage, input overcurrent, output under/overvoltage, output overcurrent, overtemperature, fan failure, local -15V failure). When the FAULT indicator lights, the LCD will briefly display messages about the fault (see Table B-5, Appendix B for details), however the FAULT indicator remains lit. When the fault has been removed, normal operation is restored by cycling power off, then on (preferred) or by briefly pressing the RESET key on the front panel to initiate a shut down and power up sequence (see RESET key, Table 3-2).
6	ADJUST control	Allows manual entry of various parameters as an alternative to the keypad. If the output is enabled, voltage and current adjustments are immediately present at the output without pressing the ENTER key.

**3.2.1 KEYPAD DESCRIPTION (SEE FIGURE 3-2)**


The front panel keypad is comprised of 28 keys, eleven for 10 digits (0 - 9) plus decimal point, five dedicated to software functions (F1 to F5) indicated by the display, four direction keys (←, →, ↑, ↓) that can position the highlighted parameter in the display, and seven dedicated function keys (STANDBY, MODE, RESET, CLEAR, +/-, ENTER and HELP) that are defined in Table 3-2.



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**FIGURE 3-2. FRONT PANEL KEYPAD**

**TABLE 3-2. SPECIAL KEY FUNCTIONS**

KEY	FUNCTION
<b>STANDBY</b>	The STANDBY key toggles the unit between output on (enabled, STBY indicator off) and Standby: output off (disabled, STBY indicator on). When on, the output goes to the programmed settings. Behavior of the unit in Standby (Output off) is determined by the options chosen for Output Mode (see PAR. 3.3.5.4.2) . The default Output mode is ACTIVE: in Standby the unit is set to voltage mode, voltage is set to zero, current protection is set to the nominal, and voltage limit is set to maximum.
<b>MODE</b>	Depressing this key shifts the operating mode from voltage to current and vice versa, and at the same time sets the unit to STANDBY permitting the user to introduce new settings for the selected operating mode. The operating mode is indicated at the upper right of the LCD. Setting the unit to STANDBY when the mode is changed only occurs when using the MODE key.
<b>CLEAR</b>	Clears numeric value to 0 (zero). To apply 0 to BOP output, depress CLEAR a second time and press ENTER key.
<b>+/-</b>	Switches the sign between + and – when inputting numerical values. The sign change applies only to the main channel: voltage in voltage mode, current in current mode. <b>CAUTION: Pressing +/- key while the power is applied to the load will reverse the polarity of voltage applied to the load.</b>
<b>ENTER</b>	Activates highlighted parameters. When setting voltage/current values using the keypad, the values entered are not present at the output until ENTER is pressed.
<b>HELP</b>	Provides context-sensitive help to assist in using the keypad and display to program the unit.
 <b>THROUGH</b>	The “soft” function keys are software dependent, and will change depending on the operation being performed. The key function is indicated by a box in the LCD which is aligned with the key (see PAR. 3.2.2).
<b>RESET switch</b>	Switch is recessed and requires the use of a tool to prevent inadvertent activation. Pressing RESET briefly causes the unit to shut down followed by execution of a power on sequence which results in the unit being set to the power on defaults (see Figure 3-3). To restore normal operation after a fault has been cleared it is recommended that the unit be powered off, then on again instead of using the RESET key. <b>CAUTION: Pressing RESET will cause voltage transients to appear at the output which may damage a connected load.</b>

### 3.2.2 LCD DISPLAY DESCRIPTION

The LCD display (Figure 3-3) is a 320 x 240 pixel monochrome window. Analog and digital representations of the actual BOP output are displayed in the center of the display. At the upper right of the display, the mode of operation is displayed:

- Voltage source
- Voltage source - Current protect
- Voltage sink
- Current source
- Current source - voltage protect
- Current sink

When in Voltage mode, the power supply will (within the configured and rated limits) provide output voltage programmed. Current is determined by the load, and cannot exceed the Current Protect limits. Mode displayed at the upper right is VOLTAGE SOURCE. If the protect limit is reached, the displayed mode is VOLTAGE SOURCE - CURRENT PROTECT.

When in Current mode, the power supply will (within the configured and rated limits) provide output current programmed. Voltage is determined by the load, and cannot exceed the Voltage

Protect limits. Mode displayed at the upper right is CURRENT SOURCE. If the protect limit is reached, the displayed mode is CURRENT SOURCE - VOLTAGE PROTECT.

When in Source mode, the power supply is delivering (sourcing) energy to a passive load.

When in Sink mode, the power supply is operating as an electronic load, absorbing and recuperating the energy of an active load; recuperated energy is passed back into the a-c source power line. Mode displayed at the upper right is VOLTAGE SINK when the unit is in voltage mode and an external constant current is injected into the BOP. Correspondingly, CURRENT SINK is displayed when the unit is in current mode and an injected current from an external constant voltage is presented at the output of the BOP.

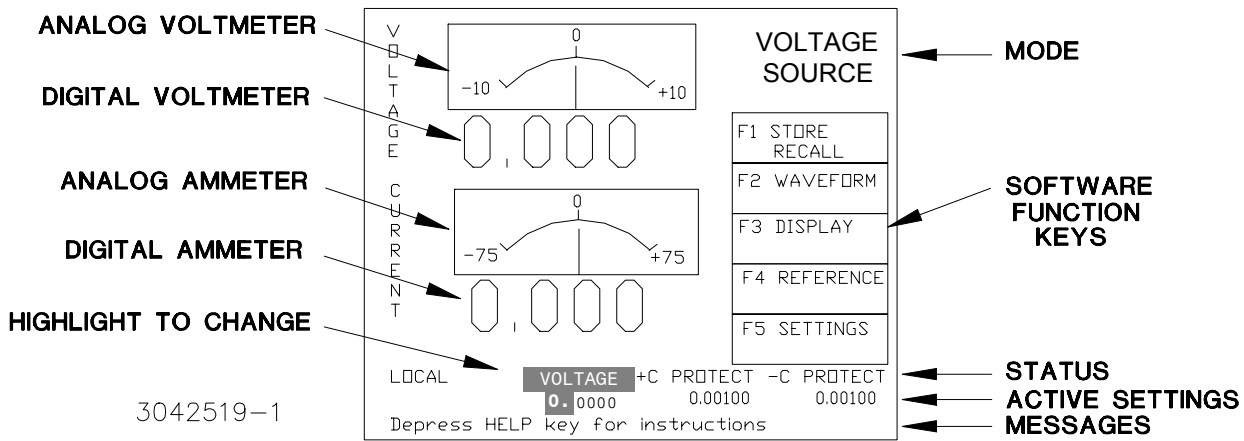


FIGURE 3-3. GRAPHICAL LCD, POWER ON DEFAULT VALUES

The bottom lines of the display provide STATUS, ACTIVE SETTINGS and MESSAGES (including error messages), and change depending on the particular screen being displayed. Error messages are displayed for both local and remote operation, and only appear briefly. For the top menu the STATUS line indicates whether local or remote operation is enabled, the value of the active (highlighted) parameter, and protect setting of the complementary parameter. Active settings can be changed using the keypad or **ADJUST** control after highlighting. The active and complementary setting can be configured for control by external signals, e.g, the STATUS line shows VOLTEXTL (see PAR. 3.3.6.1.3 for details) and +CProt<EXT (see PAR. 3.3.6.2 for details).


In addition, at the right of the display, a menu comprised of five boxes indicates the active function of the keypad soft function keys, **F1** through **F5**. Depressing the corresponding key on the keypad activates the function shown on the display. These functions are arranged in a menu format.

### 3.2.3 TURNING THE POWER SUPPLY ON

The power supply is turned on by setting the POWER ON/OFF Circuit Breaker (1, Figure 3-1) to ON. When the power supply is turned on, it performs a self-test and displays the default values shown in Figure 3-3. If an error is detected, the FAULT indicator will light, information about the error will be briefly displayed on the LCD.



If the unit powers up in REMOTE mode, press  (see PAR. 3.3.1) to set the unit to LOCAL mode.













NOTE: If the unit is a Slave of a multiple unit configuration, the unit will power up in REMOTE and will display LOCAL LOCKOUT once the Master has taken control of the Slave. To restore LOCAL control of a Slave, power down both master and slave, then turn on only the slave and press  (see PAR. 3.3.1) to set the unit to LOCAL mode.

If the display is not viewable, see PAR. 3.2.5.1

### 3.2.4 HOW TO ACCESS THE MENUS


From the top menu, pressing the Function keys indicated on the LCD opens the associated menu. The menu opened may list submenus that can be opened by pressing the associated Function keys.


Menus and submenus will display a list of parameters, with the top one highlighted. The function keys generally offer the following choices:





-  allows the highlighted parameter to be modified. After changing the parameter, the following choices are available.
  -  - ABORT to abort the change.
  -  - --SAVE to save the change
  -  - EXIT to exit to the previous menu.
-  - RESTORE DEFAULT restores factory defaults for the parameters displayed. The factory defaults may be saved as power-up defaults by pressing .
-  - The function varies, depending on the menu. Generally,  is used to abort a change in process. In Operator Convenience menus  is used to adjust contrast. In the Protected Settings menu  is used to enter Calibration.
-  - SAVE POWER-UP Saves the configuration shown as a power-up default.
-  - EXIT exits to the previous menu.

#### 3.2.4.1 HOW TO ACCESS A PASSWORD PROTECTED MENU

The Protected Settings Menu, including Calibration submenus, are password protected. The bottom line of the Settings menu reads **Enter Password to access protected settings**, and at the right, one character will be highlighted below the word **PASSWORD** (see Figure 3-4). Proceed as follows:

NOTE: If you press  without entering the password, the message **Depress ENTER to verify Password** is displayed; simply proceed to step 1 below.

1. Use the  key or **ADJUST** control to scroll through numbers and letters to highlight the first character of the password.

2. Press the  and repeat step 1 for the next character of the password.
3. Repeat step 2 until the correct password is displayed, then press **ENTER**. If the bottom line on the LCD reads **Protected settings enabled**, press the  key to enter to password protected menu. If the bottom line of the LCD reads **Improper Password entered - try again** correct mistakes by using the  and  keys to highlight the incorrect character, or press the **CLEAR key** to start over.








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**FIGURE 3-4. ENTERING PASSWORDS**


### 3.2.4.2 HOW TO MODIFY A PARAMETER

First access the parameter by accessing the proper menu as described above (PAR 3.2.4); Tables 3-3 through 3-10 list the menu parameters. To modify a parameter listed in a menu or submenu, proceed as follows:










1. Highlight the parameter using the **ADJUST** control or  and  keys.
2. When the desired choice is highlighted, press  to modify the active setting.
3. The choices are displayed with the active setting highlighted. In the case of numerals, the units digit is highlighted.
4. To change the setting use the arrow keys or **ADJUST** control to highlight the desired choice. In the case of alphanumeric data, press **CLEAR key**, then  and  keys or the **ADJUST** control act to continuously increase or decrease the number/letter to the desired value (characters start with space, /, period, 0-9, then A-Z). Then use the function keys to proceed:
  - Press  to apply the change and return to the menu (to change another parameter, repeat steps 1 through 4).
  - To abort (return to the menu without applying the change, press .

NOTE: Press **HELP key** for more information, press **HELP** again to see multiple screens; press **CLEAR key** to exit the help screen.

### 3.2.5 OPERATOR CONVENIENCE FUNCTIONS (DISPLAY MENU)

From the top menu (Figure 3-3), pressing  opens the operator convenience functions menu (see Table 3-3). The functions listed can be modified using the techniques described in PAR.3.2.4). This function is always available, whether in Local, Remote or Local/Lockout mode.

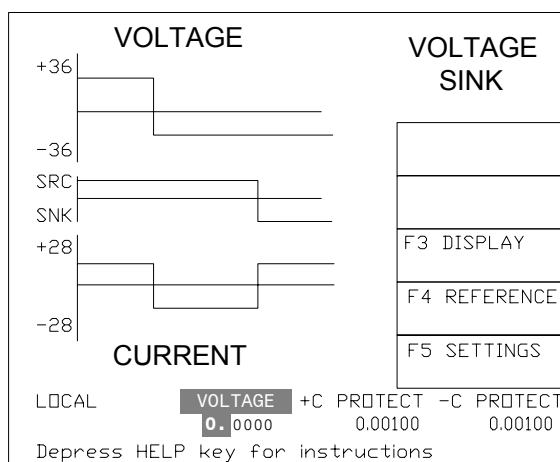
#### 3.2.5.1 ADJUSTING LCD BRIGHTNESS, CONTRAST AND BACKGROUND

From the top menu, (Figure 3-3), pressing ,  initiates contrast adjustment. The contrast will gradually alternate between light and dark. When the contrast is acceptable, press  to apply the change and exit contrast adjust. Pressing  through  will immediately alter the contrast:  and  are the extremes,  is in the middle, or for fine adjustment rotate the **ADJUST** control, and press  to apply the change and exit contrast adjust.

**TABLE 3-3. DISPLAY (OPERATOR CONVENIENCE) MENU FUNCTIONS**

SETTING	CHOICES ( <b>BOLD</b> = Factory Default)	FUNCTION
DISPLAY LEVEL	<i>Can not be highlighted.</i> (see PAR. 3.2.5.1) NORMAL 16 REVERSE 25	Control display brightness by using <b>F3</b> or any number key (see PAR. 3.2.5.1) The contrast adjustment keys ( 0-9) and the <b>F3</b> key operate on the contrast level appropriate to DISPLAY BACKGROUND of either NORMAL or REVERSE mode. If the user changes from NORMAL to REVERSE, the menu immediately takes on the appearance of the new mode and uses the correct contrast level so that it does not have to be changed if the DISPLAY BACKGROUND is changed.
DISPLAY BACK- GROUND	<b>REVERSE</b> NORMAL	<b>REVERSE</b> - selects white background, dark letters, soft function keys reversed. <b>NORMAL</b> - selects dark background, white letters, soft function keys reversed.
KEY PRESS BEEP	ON <b>ERROR ONLY</b> OFF	ON - provides an audible beep for each key press and for each error received. ERROR ONLY - silences the beeps for each key press; errors will still cause beep. OFF - silences all beeps including key presses and errors.

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**FIGURE 3-5. LCD SHOWING TIME LINE**

### 3.2.5.2 ENABLING/DISABLING AUDIBLE BEEPS

From the top menu (Figure 3-3), press **F4**, then refer to Table 3-3 and modify the setting using the techniques described in PAR.3.2.4). Even though audible beeps are set to off, the beeps will still sound upon power-up or detection of a power supply input/output error.

Press **F5** then **F1** and refer to Table 3-3.

### 3.2.6 VOLTAGE AND CURRENT LIMITS

The BOP has an extremely flexible system for limiting output voltage or current. The limits function to protect both the BOP and the load. The limits are applied either to the main channel (voltage in voltage mode or current in current mode) or the complementary channel (current in voltage mode and voltage in current mode) and are defined in the following paragraphs.

#### 3.2.6.1 SOFTWARE LIMITS FOR MAIN CHANNEL

The software limits for the main channels (+voltage max, -voltage min, +current max and -current min, see Table 3-4) are the positive and negative values for voltage and current. These four values can be adjusted independently. For example, a BOP 36-28MG, capable of delivering

$\pm 36\text{V}$  in voltage mode can be configured to allow voltage to be adjusted from  $-1\text{V}$  to  $+15\text{V}$  by setting  $-\text{voltage min}$  to  $-1$  and  $+\text{voltage max}$  to  $+15$ . Similarly, a BOP 36-28MG, capable of delivering  $\pm 28\text{A}$  in current mode can be configured to allow current to be adjusted from  $-0.5\text{A}$  to  $+10\text{A}$  by setting  $-\text{current min}$  to  $-0.5$  and  $+\text{voltage max}$  to  $+10$ . Adjustment range is between 0 and  $E_{\text{Onom}}$  for voltage and 0 and  $I_{\text{Onom}}$  for current.

### **3.2.6.2 SOFTWARE LIMITS FOR COMPLEMENTARY CHANNEL**

The software limits for the complementary channels ( $+\text{voltage protect max}$ ,  $-\text{voltage protect min}$ ,  $+\text{current protect max}$  and  $-\text{current protect min}$ , see Table 3-4) prevent the unit from delivering voltage or current that exceed these software limit values. In voltage mode current (the complementary channel) is clamped to the limit value; in current mode voltage is clamped. Adjustment range is between a minimum (box) value (see Figure 1-2) and 1% above the nominal (rated) value.

### **3.2.6.3 VOLTAGE AND CURRENT PROTECT LIMITS**

These values are the references for the complementary channels: voltage in current mode and current in voltage mode. The range for these values is between a minimum (box) value (see Figure 1-2) and 1% above the software limit (see PAR. 3.2.6.2). If the unit is in voltage mode, it will enter current protect mode when the load demands more current and energy than permitted by the  $\pm\text{current protect}$  settings. Similarly, if the unit is in current mode, it will enter voltage protect mode if the load demands more voltage and energy than permitted by the  $\pm\text{voltage protect}$  settings.

### **3.2.6.4 HIDDEN VOLTAGE AND CURRENT PROTECT LIMITS**

The BOP employs two back-up channels which function as safety backups if a main channel fails. The backup channel limits are fixed and not user accessible. These limits are set to 5% over the nominal (rated) values for voltage or current. If the software limits for a main channel is changed (PAR. 3.2.6.1) the corresponding backup channel limit is automatically changed to be 5% of the nominal (rated) value above the user-programmed software limit.

### **3.2.6.5 EXTERNAL LIMITS**


These limits are external analog signals which are converted within the BOP to digital signals that program the protection channels only: current protect in voltage mode and voltage protect in current mode. The range of each analog input signal is zero to  $+10\text{V}$ , corresponding to a range for clamping the output between minimum (box) value ( $+\text{min}/-\text{max}$ ) (see Figure 1-2) to  $+\text{max}/-\text{min}$  of nominal rating. Referring to table 3-10, choosing LESSER LIMIT option from the Reference Menu allows the lesser of the following two options to control the complementary protect channel: 1) internal protect setting and 2) external limit.


Table 3-4 explains the effect that these limits have in both voltage and current mode, and references the corresponding paragraph for changing the parameter in either local or remote mode.

## **3.3 LOCAL MODE OPERATION**

Local operation of the BOP power supply can be accomplished from the front panel via the 24 key keypad, and the ADJUST knob. All indications are provided by the 4-inch graphical display (LCD).

### 3.3.1 SETTING LOCAL MODE



When the power supply is turned on, it is automatically set to Local mode. If the unit is in REMOTE mode and the display shows **F1-LOCAL**, pressing  sets the unit to LOCAL mode.

If the display shows **F1-LOCAL LOCK OUT** the  key is disabled. The keyboard can only be unlocked by sending the following SCPI command: **SYSTem:KEYBoard ENABLE** or by cycling BOP power off, then on.

#### 3.3.1.1 KEYPAD LOCKOUT








To prevent the unit from entering local mode from the front panel once remote mode has been entered, send the following SCPI command: **SYSTem:KEYBoard DISable**. The keyboard can only be unlocked by sending command: **SYSTem:KEYBoard ENABLE**.

### 3.3.2 SETTING OUTPUT VOLTAGE OR CURRENT AND CORRESPONDING PROTECT LIMIT


The settable voltage/current parameters are displayed at the bottom of the LCD above the HELP message (see Figure 3-3). Use  and  as necessary to highlight a digit (the parameter designation above the highlighted digit will also be highlighted, indicating the parameter is active. (Figure 3-3 shows voltage as the active parameter).

**CAUTION: WHEN THE ADJUST CONTROL IS ROTATED, THE ACTIVE PARAMETER IS IMMEDIATELY EFFECTIVE IF THE OUTPUT IS ENABLED (ON = STANDBY INDICATOR NOT LIT) AND THE VOLTAGE/CURRENT APPLIED TO THE LOAD CHANGES AS THE ADJUST CONTROL IS ROTATED.**

There are two ways to set or change the active parameter in local mode. These methods can be used either when the output is disabled (STANDBY indicator ON) or enabled.:

1. Use the **ADJUST** control to increase or decrease the value of the active parameter (e.g., voltage when the unit is in voltage mode). Start with the units digit, then use  to highlight the next digit. For fine adjustment press the **ADJUST** control in while rotating the knob to modify the least significant digit.
2. Enter the desired value on the keypad using the number keys. For example, to program the BOP to 75.8V, press the following keys in order  then press **ENTER**. For fine adjustment use  and  to modify the least significant digit. To correct the entry before activation press the **CLEAR** key to set the value to zero and start over. When the desired value is displayed, press **ENTER**. This causes the new value to appear at the output and be applied to the load if the output is enabled.

NOTE: The value entered for the main channel and the protect channel is automatically prevented from exceeding the present maximum software limit (see PAR. 3.2.6).

When setting the corresponding Protect channel, press  repeatedly until the units digit and the associated Protect channel are active (highlighted). Then set the value using either of the two methods described above.

NOTE: After the unit is powered up, or the mode of operation (voltage or current) is changed, it is necessary to set the values for both the main channel and the protect channel.

**TABLE 3-4. VOLTAGE AND CURRENT PARAMETER DEFINITIONS**

Term	Definition	To modify refer to PAR	
		Local	Remote
+E <sub>Onom</sub> -E <sub>Onom</sub>	The nominal (rated) output voltage of the unit determined by model; e.g. for a BOP 36-28MG, ±E <sub>Onom</sub> is 36V.	N/A	N/A
+I <sub>Onom</sub> -I <sub>Onom</sub>	The nominal (rated) output current of the unit determined by model; e.g. for a BOP 36-28MG, ±I <sub>Onom</sub> is 28A.	N/A	N/A
+Voltage -Voltage	<b>Voltage mode only.</b> Positive (+) and negative (-) output voltage values established by keypad or remote command. Range (+): 0 to +Voltage max Range (-): 0 to -Voltage min	3.3.2	B.82
+Voltage max -Voltage min	<b>Voltage mode only.</b> Maximum (positive) and minimum (maximum negative) voltage that can be set. Value (+): 0 to +E <sub>Onom</sub> Value (-): 0 to -E <sub>Onom</sub>	3.3.5.2.1	B.84, B.85, B.86, B.87
+Current Protect -Current Protect	<b>Voltage mode only.</b> Defines maximum (+) current and Minimum (maximum negative) (-) that unit can source or sink. Range (+): +Current Protect min to +Current max Range (-): -Current Protect max to -Current min	3.3.2	B.72, B.73, B.75, B.74
+Current Protect Max -Current Protect Min	<b>Voltage mode only.</b> Maximum setting for +Current Protect and Minimum (maximum negative) setting for -Current Protect. Value (+): +Current Protect min to (1.01 x +Current max) Value (-): -Current Protect max to (1.01 x -Current min)	3.3.5.2.3	B.76, B.77, B.79, B.78
Minimum (box) +Current Protect Min -Current Protect Max	<b>Voltage mode only.</b> Minimum (positive) setting for +Current Protect and maximum (maximum negative) setting for -Current Protect. Values of ±Current Protect between +Current Protect Min and -Current Protect Max (near zero) are not allowed. This zone (also referred to as the minimum (box) is automatically calculated by the BOP (see Figure 1-2).	N/A	N/A
+Voltage Protect -Voltage Protect	<b>Current mode only.</b> Maximum positive (+) and minimum (maximum negative) (-) voltage that can appear at the output. Range (+): +Voltage Protect min to +Voltage Protect max Range (-): -Voltage Protect max to -Voltage Protect min	3.3.2	B.90, B.91, B.93, B.92
+Voltage Protect Max -Voltage Protect Min	<b>Current mode only.</b> Maximum (positive) setting for +Voltage Protect and Minimum (maximum negative) setting for -Voltage Protect. Value (+): +Voltage Protect min to (1.01 x +Voltage max) Value (-): -Voltage Protect max to (1.01 x -Voltage min)	3.3.5.2.3	B.94, B.95, B.97, B.96
Minimum (box) +Voltage Protect Min -Voltage Protect Max	<b>Current mode only.</b> Minimum (positive) setting for +Voltage Protect and maximum (maximum negative) setting for -Voltage Protect. Values of ±Voltage Protect between +Voltage Protect Min and -Voltage Protect Max (near zero) are not allowed. This zone (also referred to as the <b>minimum (box)</b> is automatically calculated by the BOP (see Figure 1-2) .	N/A	N/A
+Current -Current	<b>Current mode only.</b> Positive and negative output current established by keypad or remote command. Range (+): 0 to +Current max Range (-): 0 to -Current min	3.3.2	B.64
+Current max -Current min	<b>Current mode only.</b> Maximum (positive) and minimum (maximum negative) current that can be set. Value (+): 0 to +I <sub>Onom</sub> Value (-): 0 to -I <sub>Onom</sub>	3.3.5.2.1	B.66, B.67, B.69, B.68

### 3.3.3 ENABLING/DISABLING DC OUTPUT POWER

The BOP output can be disabled (OFF) or enabled (ON) by toggling the STANDBY key in local mode or sending the SCPI OUTPut ON or OUTPut OFF command (see PAR. B.38) via the selected digital remote control bus (see PAR. 3.4). The behavior of the unit when disabled depends on the OUTPUT OFF mode setting (see PAR. 3.3.5.4.2 and Table 3-9 for details).

The default mode is ACTIVE which is suitable for reactive loads and can also be used with resistive loads. When the output is disabled, the unit is set to voltage mode, voltage is set to zero and both current protect and voltage limit are set to maximum. When the unit is enabled, the pre-existing settings for voltage, current protect and voltage limit are restored.

For battery type loads the BOP should be set to BATTERY mode (see PAR. 3.3.5.4.2 and Table 3-9 for details). When the output is disabled (set to OFF), the BOP will go to current mode, current will be set to zero, with voltage protect and current limit set to maximum. In this way the battery will not be discharged while the output is OFF.








**Accessing the BOP after the output is disabled in BATTERY mode is hazardous because (1) high current arcing is possible and (2) either the external battery voltage, or the voltage ( $\pm$ Voltage Protection max) on the BOP output terminals may be dangerous. It is recommended that two external switches be installed for safety: one in series with the battery, and one across the BOP output. After the unit is set to OFF, first open the switch in series with the battery, then close the switch across the BOP output to ensure safety before handling BOP connections. When connecting the battery, the switch across the output should be opened after the connections are complete and then the switch in series with the battery should be closed.**


### 3.3.4 RESET

**CAUTION: PRESSING RESET WILL CAUSE VOLTAGE TRANSIENTS TO APPEAR AT THE OUTPUT WHICH MAY DAMAGE A CONNECTED LOAD. SWITCH IS RECESSED TO PREVENT INADVERTENT ACTIVATION.**

Pressing **RESET** causes the power supply to execute a complete power on sequence to reset the power supply to the power on defaults. Output OFF, Voltage mode, voltage to 0V, current protect and voltage limit set to minimum (box) values (see Figure 1-2) .

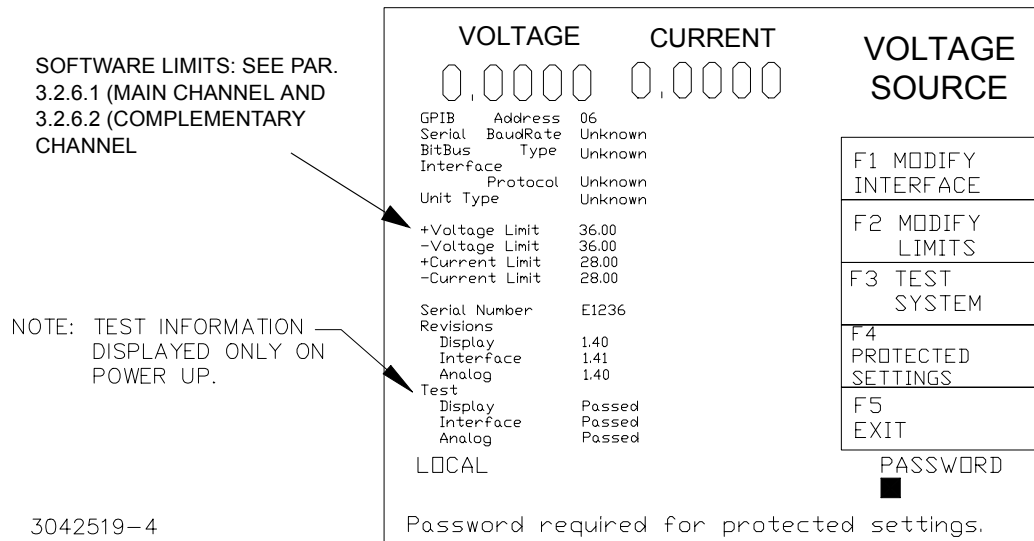
### 3.3.5 SETTINGS MENU

The settings menu (Figure 3-6) is opened by pressing  from the top menu (Figure 3-3). The power-up and status screen lists: the status of key parameters (GPIB Address, Serial Baud Rate, Interface protocol, Unit type), the  $\pm$ voltage and  $\pm$ current protection limits, unit serial number, firmware revisions, and (on power-up only) shows the results of internal tests of the three microprocessors. From the settings menu, the function keys provide access to four submenus: : Modify Interface, : Modify Limits, : Test System, : Protected Settings (including Calibration) described in the following paragraphs.

NOTE: To exit the Settings Menu, press  to return to the top menu

### 3.3.5.1 MODIFY INTERFACE SUBMENU

The interface submenu is entered by pressing **F5** from the top menu (Figure 3-3), then **F1** from the settings menu (Figure 3-6). The parameters listed in Table 3-5 can be modified using the techniques described in PAR. 3.2.4.



**FIGURE 3-6. SETTINGS MENU (WITH POWER-UP AND STATUS SCREEN)**

**TABLE 3-5. MODIFY INTERFACE SUBMENU FUNCTIONS**

SETTING	CHOICES ( <b>BOLD</b> = Factory Default)	FUNCTION
INTERFACE DATA FOR-MAT	<b>SCPI</b> CIIL	SCPI (Standard Commands for Programmable Instruments) - see PAR. 3.8. and Appendix B. CIIL - Provides compatibility with early Kepco power supplies and controllers.
GPIB ADDRESS	0 - 30 ( <b>06</b> )	Assigns address used by external GPIB controller to communicate with BOP.
DEVICE CLEAR	<b>SCPI</b> MATE	SCPI - sending Device Clear (DCL) or selected DCL has no effect on output voltage and current per IEEE specification 488.2. MATE - When device clear is received, the power supply output is set to zero volts.
SERIAL BAUD RATE	<b>DISABLE</b> 9600 19200	Selects RS 232 serial port baud rate.
SERIAL XON/XOFF	<b>ENABLE</b> DISABLE	ENABLE - Allows BOP to control when data is received (see PAR. 3.7.2.3). DISABLE - Disables XON/XOFF. If both Serial XON/XOFF and Prompt functions are disabled, Echo mode is the default (see PAR. 3.7.2.1).
SERIAL PROMPT	<b>DISABLE</b> ENABLE ENAB+ECHO	ENABLE - Enables Serial Prompt (see PAR. 3.7.2.2). DISABLE - Disables Prompt. If both Serial XON/XOFF and Prompt functions are disabled, Echo mode is the default (see PAR. 3.7.2.1). ENAB+ECHO - Enables Serial Prompt (see PAR. 3.7.2.2) and Echo (see PAR. 3.7.2.1) modes. Prompt is returned when the unit is ready and any received characters are echoed back to the sender.

### 3.3.5.2 MODIFY LIMITS (SYSTEM LIMITS) SUBMENU

The Modify Limits (system limits) submenu (Table 3-6.) is entered by pressing **F2** from the settings menu (Figure 3-6). The limits submenu lists the system's software-controlled voltage and



current limits (+Voltage Max, –Voltage Min, +Current Max, –Current Min) as well as the corresponding protection limits organized by operating mode. The default values of the system limits are established by the Model: the nominal (rated) values for voltage and current and 1.01 x the nominal (rated) values for protection. The default values can be reduced by modifying the highlighted parameter. The unit will not accept local or remote commands that exceed the system limits. The system limits are always in effect, even when the unit is controlled by an external reference. **If system limits are changed, the protection limits must be changed to correspond to the new system limits.** As an example, changing +Voltage Max and –Voltage Min of a BOP 36-28MG to ±3V, respectively, causes the unit to behave as if it was a BOP 3-28MG. In this case it is important to change the +V Protect Max and –V Protect Min limits (e.g., to ±3.3V, respectively) so that the load is protected when operating in Current Mode. System limits are absolute values (do not use minus sign for negative limits).

The calculated parameters +Current Protect Min, –Current Protect Max, +Voltage Protect Min, and –Voltage Protect Max are displayed to completely define the permissible window for current when operating in Voltage mode. When operating in Current mode, the corresponding Voltage Protect parameters are displayed to illustrate the limits of permitted voltage.

**TABLE 3-6. MODIFY LIMITS SUBMENU FUNCTIONS**

SETTING	CHOICES ( <b>BOLD</b> = Factory Default)	FUNCTION
PROTECT ENTRY	<b>BIPOLAR</b> INDEPENDENT	BIPOLAR - Causes a single protection limit value (one for voltage, one for current) to apply to both ± limits. Only one value is displayed and edited from the keypad. INDEPENDENT - Allows + and – protection limits to be set independently. from the keypad (see PAR. 3.3.5.2.2 for considerations when using remote mode).
<b>VOLTAGE MODE</b>		
+Voltage Max	(value) <b>+Eomax</b>	Defines the maximum voltage level that can be set in voltage mode. Default = Rated +Output voltage (e.g., for BOP 36-28MG, Eomax = 36). To modify, see PAR. 3.3.5.2.1.
–Voltage Min	(value) <b>–Eomax</b>	Defines the minimum (maximum negative) voltage level that can be set in voltage mode. Default = Rated –Output voltage (e.g., for BOP 36-28MG, Eomax = 36). To modify, see PAR. 3.3.5.2.1.
+C Protect Max	(value) model specific up to <b>lomax + 1%</b>	Defines the maximum value for +Current Protect. To modify refer to 3.3.5.2.1.
+C Protect Min	<i>(calculated value)</i> <i>Not Adjustable</i>	Defines the minimum value that +Current Protect can be set to. This is a calculated value and is not adjustable from the front panel.
–C Protect Max	<i>(calculated value)</i> <i>Not Adjustable</i>	Defines the maximum (minimum negative) value that –Current Protect can be set to. This is a calculated value and is not adjustable from the front panel.
–C Protect Min	(value) model specific up to <b>lomax + 1%</b>	Defines the minimum (maximum negative) value for –Current Protect. To modify refer to 3.3.5.2.1.
<b>CURRENT MODE</b>		
+Current Max	(value) <b>+lomax</b>	Defines the maximum current level that can be set in current mode. Default = Rated +Output current (e.g., for BOP 36-28MG, lomax = 28). To modify, see PAR. 3.3.5.2.1.
–Current Min	(value) <b>–lomax</b>	Defines the minimum (maximum negative) current level that can be set in current mode. Default = Rated –Output current (e.g., for BOP 36-28MG, lomax = 28). To modify, see PAR. 3.3.5.2.1.
+V Protect Max	(value) <b>Eomax +1%</b>	Defines the maximum value that +Voltage Protect can be set to. To modify refer to 3.3.5.2.1.
+V Protect Min	<i>(calculated value)</i> <i>Not Adjustable</i>	Defines the minimum value that +Voltage Protect can be set to. This is a calculated value and is not adjustable from the front panel.
–V Protect Max	<i>(calculated value)</i> <i>Not Adjustable</i>	Defines the maximum (minimum negative) value that –Voltage Protect can be set to. This is a calculated value and is not adjustable from the front panel.
–V Protect Min	(value) <b>Eomax + 1%</b>	Defines the minimum (maximum negative) value for –Voltage Protect. To modify refer to 3.3.5.2.1.

### 3.3.5.2.1 CHANGING MAXIMUM ACCEPTED VOLTAGE OR CURRENT

The maximum acceptable values of voltage and current are determined by the model, e.g., 36V and 28A for the BOP 36-28MG. These values can be lowered by the user, e.g., to prevent inadvertent damage to a specific circuit under test. When the maximum values are lowered, the unit will not accept values that exceed the new maximums. If the user attempts to enter values that exceed the new limit, the unit will continue to function; in local mode a Limit Exceeded message is displayed, in remote mode a 120 error will result and the message **VoLtaGe Out of Range** or **CurReNt Out of Range** will be displayed.

The positive and negative maximums can be set independently, so that the maximum voltage limit of a BOP 36-28MG, for example, could be changed from +36V and -36V to +10V and -15V. These software limits are not the same as the Protect Limits.

From the top menu press **F5** from the top menu, then **F2** to enter the Limits submenu. Use **↑** or **↓** to select the limit and press **F1** to change it. Use arrow keys and number keys to change the setting, then **F1** to save, **F3** to abort, or **F5** to exit and return to the top menu.

Upon return to the main screen, the main channel (voltage or current) is compared against the limits in effect. If the main channel exceeds the limit, the main channel (voltage or current) is set to zero.

### 3.3.5.2.2 BIPOLAR/INDEPENDENT PROTECTION LIMITS

The PROTECT ENTRY parameter of the Limits Submenu establishes whether the protection limits are bipolar or independent. Selecting Independent protection limits means that the positive and negative limits are displayed (and can be modified) independently. Bipolar means that for each protection limit (voltage or current) a single value applies to both the positive and negative limits; only one value is displayed and can be edited for both  $\pm$  protection limits.

Selection of Bipolar does not change the protect limits; it changes how the protect settings are displayed and set from the main screen. So if *maximum/minimum* protection limits were set to different values, e.g, +V Protect Max = 25V and -V Protect Min = 7V, when BIPOLAR is selected, the previous protection values (+25, -7) will remain in place until a new value is entered in the Voltage Protection field. When a new Voltage Protect setting, e.g., 22V, is entered with BIPOLAR mode selected, +Voltage Protect is set to +22V and -Voltage Protect to -22V.

When going from independent limits to bipolar limits, upon return to the main screen, the lesser of the independent limits will apply to both positive and negative settings until a new bipolar limit is entered. This means that for the above case, prior to entering the new Voltage Protection setting of 22V, both positive and negative voltage settings cannot exceed 7V, limits of changing the protection limits,

NOTE: The use of remote programming (via RS 232 or GPIB) automatically asserts Independent protection limits. Once the unit is returned to local mode, the unit is automatically returned to BIPOLAR mode.

### 3.3.5.2.3 MAXIMUM/MINIMUM PROTECTION LIMITS

The  $\pm$  protection limits establish the maximum and minimum (maximum negative) levels of voltage and current that cannot be exceeded. The default protection limits are 1% above  $E_{Omax}$  or 1% above  $I_{Omax}$ . E.g., in voltage mode, the maximum amount of source or sink current is defined by  $\pm$ Current Protect.

**CAUTION: WHEN WORKING WITH ACTIVE LOADS, ALWAYS ADJUST THE BOP PROTECTION LIMITS TO BE ABOVE THE MAXIMUM VALUES OF VOLTAGE OR CURRENT EXPECTED FROM THE LOAD. FOR EXAMPLE, WHEN THE BOP IS OPERATING IN VOLTAGE MODE SINKING ENERGY FROM A CONSTANT CURRENT TYPE LOAD, SET THE CURRENT PROTECTION LIMITS OF THE BOP ABOVE THE MAXIMUM CURRENT EXPECTED FROM THE LOAD.**

Press **F5** from the top menu (Figure 3-3), then **F2** to enter the Limits submenu (Figure 3-6). Use **↑** or **↓** to select the protection limit max/min and press **F1** to change it. Use arrow keys and number keys to change the setting, then **F1** to save, **F3** to abort, or **F5** to exit and return to the top menu.

Upon return to the main screen, the main channel (voltage or current) is compared against the protection limits in effect. If the main channel setting exceeds the protection limit, the main channel (voltage or current) is set to zero.

**3.3.5.3 TEST SYSTEM SUBMENU**

The Test System submenu is entered by pressing **F3** from the settings menu. Table 3-7 lists the tests that can be run. Highlight the choice and press **F3** to run the selected test.

**TABLE 3-7. TEST SUBMENU FUNCTIONS**

SETTING	CHOICES ( <b>BOLD</b> = Factory Default)	FUNCTION
MAXIMUM OUTPUT	<b>(Cannot be highlighted)</b> VOLTAGE XX CURRENT YY	Displays rated output voltage and current of power supply. including all slaves
OUTPUT MODE	<b>(Cannot be highlighted, see Protected Settings Menu, Table 3-8)</b> <b>ACTIVE</b> RESISTIVE BATTERY	ACTIVE - Allows discharge of reactive load energy to BOP when output set to off. See PAR. 3.3.5.4.2 for details. RESISTIVE - Allows disabling of resistive load to BOP when output set to off. See PAR. 3.3.5.4.2 for details. BATTERY - Prevents discharge of battery to BOP when output set to off. See PAR. 3.3.5.4.2 for details.
<b>TEST</b> NOTE: Test status is as follows: UNTESTED Initial status when first entering menu. TESTING Test is running. PASSED Test was successful. FAILED Test failed. FAIL EXT SERIAL test failed - verify loop back connector installed (see PAR. 3.7.4). Highlight adjacent status and press <b>F3</b> to run applicable test.		
DISPLAY	Status (see NOTE above)	Puts pattern on screen
KEYPAD	Status (see NOTE above)	Requires depressing keys indicated on LCD. This test requires pressing every key on the keypad, plus moving the ADJUST control clockwise and counterclockwise, with the ADJUST control depressed and released. As the keys and control function pass the tests, the corresponding function on the LCD is highlighted. When the last test is successful, the LCD displays "passed." The test must be completed within two minutes, otherwise a "Failed" indication is displayed.
INTERFACE	Status (see NOTE above)	Automatic test, reports failure codes.
SERIAL	Status (see NOTE above)	Automatic test of serial port - requires installation of loop back test connector.
ANALOG	Status (see NOTE above)	Automatic test which does not affect unit output.

### 3.3.5.4 PROTECTED SETTINGS MENU



The Protected Settings submenu is entered from the settings menu (Figure 3-6) by entering the password (see PAR. 3.2.4.1), then pressing . To view the protected settings (except for the password) prior to entering the Protected Settings submenu, press  - TEST SYSTEM

Table 3-8 lists the parameters that can be modified using the techniques described in PAR. 3.2.4.

**TABLE 3-8. PROTECTED SETTINGS MENU FUNCTIONS**

SETTING	CHOICES ( <b>BOLD</b> = Factory Default)	FUNCTION
UNIT PASSWORD	<b>DEFAULT</b>	Limits access to PROTECTED SETTINGS and CALIBRATION menus. See PAR. 3.2.4.1 for details.
OUTPUT MODE	<b>ACTIVE</b> RESISTIVE BATTERY	ACTIVE - Allows discharge of reactive load energy to BOP when output set to off. See PAR. 3.3.5.4.2 for details. RESISTIVE - Allows disabling of resistive load when output set to off. See PAR. 3.3.5.4.2 for details. BATTERY - Prevents discharge of battery-type load when output set to off. See PAR. 3.3.5.4.2 for details.
@ ReSeT OUTPUT is	<b>OFF</b> ON	OFF - Power-up of BOP or *RST command results in output off. See PAR. 3.3.5.4.3 for details. ON - Power-up of BOP or *RST command results in output on with predetermined settings. See PAR. 3.3.5.4.3 for details.
(V/I) MODE CONTROL	<b>KEYPAD</b> EXTERNAL	KEYPAD - Allows Voltage/Current mode selection using the front panel MODE key. EXTERNAL - Allows selection of Voltage/Current mode by using the EXT VM/CM signal at pin 2 of the Analog I/O Port (see Table 2-10 and PAR. 3.3.5.4.4). This setting is temporary and is not saved when the unit is turned off.
UNIT TYPE	<b>STANDALONE</b> MASTER +1 MASTER +2 MASTER +3 MASTER +4 SLAVE #1 SLAVE #2 SLAVE #3 SLAVE #4	STANDALONE - Unit operates independently, no additional units connected. MASTER+1 - Unit is the master (controller), with one slave unit connected. MASTER+2 - Unit is the master (controller), with two slave units connected. MASTER+3 - Unit is the master (controller), with three slave units connected. MASTER+4 - Unit is the master (controller), with four slave unit connected. SLAVE #1 - Unit is slave no. 1 in configuration using one to four slave units. SLAVE #2 - Unit is slave no. 2 in configuration using two to four slave units. SLAVE #3 - Unit is slave no. 3 in configuration using three to four slave units. SLAVE #4 - Unit is slave no. 4 in configuration using four slave units. (see NOTE below.)
EXPANSION	<b>NO ADDITIONAL</b> SERIES PARALLEL	NO ADDITIONAL - Used with Unit Type - STANDALONE SERIES - Used when units are connected in series (increase output voltage). PARALLEL - Used when units are connected in parallel (increase output current). (see NOTE below.)
NOTE: For details, refer to the associated instruction sheet provided with the parallel or series cable kit (see Table 1-4).		

#### 3.3.5.4.1 CALIBRATION SUBMENU

The Calibration submenu is entered by pressing  from the Protected settings menu; refer to PAR. 4.4 for calibration procedures.

#### 3.3.5.4.2 OUTPUT (OFF)

The BOP supports three Output OFF selections (see Tables 3-7, 3-8 and 3-9). These selections are designed to provide proper operation with different load types. It is important to note the Output OFF condition does not affect the settings of the power supply for ON state; it only affects the main internal reference level and the protection levels during the OFF state.

**WARNING**

For inductive loads, and especially superconducting magnet type loads, the inherent offset of the BOP in the OFF state may generate significant current in the circuit. A switch in parallel with a series resistor must be connected between the power supply and the load. The switch must be open and the BOP front panel LCD must read 0V, 0A before removing or installing connections between BOP and load.

**ACTIVE.** Active mode (default setting) is necessary for the power supply to function properly and safely with reactive loads and constant-current-type active electronic loads. Active mode can also be used with resistive loads. Table 3-9 indicates how the power supply responds to a command to go from Output ON to OFF.

**WARNING**

For both reactive loads and constant-current-type active electronic loads when the BOP output is set to OFF, a path is provided for absorbing either the energy accumulated in the reactance of the load during the ON state, or energy delivered by an electronic load. This prevents damage to the load and power supply as well as providing safety for the user. However, in addition to the built-in safety features, constant-current-type active electronic loads must be adjusted to zero and the BOP front panel LCD must read 0V, 0A before handling the power supply-to-load connections.

**RESISTIVE.** This mode, as the name suggests, is useful for resistive loads. Table 3-9 indicates how the power supply responds to a command to go from Output ON to OFF.

**BATTERY.** This mode is necessary for the power supply to function properly and safely with either battery or constant-voltage-type active electronic loads. This mode prevents the battery from discharging during the OFF state. For constant-voltage-type active electronic loads this mode stops energy flow during the OFF state. Table 3-9 indicates how the power supply responds to a command to go from Output ON to OFF.

**WARNING**

For battery and constant-voltage-type active electronic loads it is recommended that two external switches be installed for safety: one in series with the battery, and one across the BOP output. After the unit is set to OFF, first open the switch in series with the battery, then close the switch across the BOP output to ensure safety before handling BOP connections. When connecting the battery, the switch across the output should be opened after the connections are complete and then the switch in series with the battery should be closed. If the constant-voltage-type active electronic load is adjusted to zero before handling the power supply-to-load connections, only the switch across the BOP output is required. These precautions are necessary to avoid high energy arcing or high voltage safety hazard.

### 3.3.5.4.3 @ (AT) RESET OUTPUT IS (ON/OFF)

The Protected Settings menu (see Table 3-8) allows the user to select whether the output is OFF or ON when the \*RST command is received or the unit is powered up .

When OFF is selected, powering up the unit or sending the \*RST command sets the BOP to voltage mode, output voltage to zero, current protect set to minimum (box) value (see Figure 1-2) and voltage limit to minimum. When ON is selected.

When ON is selected, powering up the unit or sending the \*RST command will set the unit to predetermined values.

The operation of the power supply for these selections depends upon the Output Mode selection as described in Table 3-9.

### 3.3.5.4.4 V/I MODE CONTROL

When V/I MODE CONTROL on the Protected Settings Menu is set to KEYPAD the MODE key on the front panel is used to select the operating mode: Voltage or Current. When V/I MODE CONTROL on the Protected Settings Menu is set to EXTERNAL, the EXT\_VM/CM logic signal at pin 2 of the Analog I/O Port referenced to Ground (pin 9) selects the operating mode (either voltage or current). TTL logic 0 or a short to ground selects current mode. TTL logic 1 or open circuit) selects voltage mode. This setting is temporary and is not saved when the unit is turned off. Each time (V/I) MODE CONTROL is toggled between KEYPAD and EXTERNAL, the unit generates an internal \*RST reset command (see PAR. A.11) requiring the BOP output to be reprogrammed

**TABLE 3-9. POWER SUPPLY BEHAVIOR WHEN OUTPUT IS SET TO OFF**

OUTPUT SETTING (SEE PAR. 3.3.5.4.2.)	If unit was in Voltage Mode when output OFF command issued.	If unit was in Current Mode when output OFF command issued.
ACTIVE	<ul style="list-style-type: none"> <li>• Unit remains in voltage mode.</li> <li>• Voltage set to zero.</li> <li>• Both ± Current Protect set to maximum.</li> <li>• Both ± Voltage Limit. remain at maximum.</li> </ul>	<ul style="list-style-type: none"> <li>• Unit set to voltage mode.</li> <li>• Voltage set to zero.</li> <li>• Both ± Current Protect. remain at maximum.</li> <li>• Both ± Voltage Limit set to maximum.</li> </ul>
RESISTIVE	<ul style="list-style-type: none"> <li>• Unit remains in voltage mode.</li> <li>• Voltage set to zero.</li> <li>• Both ± Current Protect set to minimum box values.</li> <li>• Both ± Voltage Limit. remain at maximum.</li> </ul>	<ul style="list-style-type: none"> <li>• Unit set to voltage mode.</li> <li>• Voltage set to zero.</li> <li>• Both ± Current Protect set to minimum box values.</li> <li>• Both ± Voltage Limit set to maximum,</li> </ul>
BATTERY	<ul style="list-style-type: none"> <li>• Unit set to current mode.</li> <li>• Current set to zero.</li> <li>• Both ± Voltage Protect. remain at maximum.</li> <li>• Both ± Current Limit set to maximum.</li> </ul>	<ul style="list-style-type: none"> <li>• Unit remains in current mode,</li> <li>• Current set to zero.</li> <li>• Both ± Voltage Protect set to maximum.</li> <li>• Both ± Current Limit remain at maximum.</li> </ul>

### 3.3.6 REFERENCE MENU

The Reference menu is entered by pressing  from the top menu (see Figure 3-3). Table 3-10 lists the parameters that can be modified using the techniques described in PAR. 3.2.4.

**TABLE 3-10. REFERENCE MENU FUNCTIONS**

SETTING	CHOICES ( <b>BOLD</b> = Factory Default)	FUNCTION
REFERENCE	<b>INTERNAL</b> EXTERNAL EXTL REF LVL	INTERNAL: Any external reference applied to the Analog I/O port pin 11 is ignored and the internal reference is used (see PAR. 3.3.6.1.1). EXTERNAL: The internal reference is ignored, and the external reference applied to the Analog I/O port pin 11 is used (see PAR. 3.3.6.1.2). EXTL REF LVL (see NOTE): Allows the gain of the BOP to be established by the maximum output voltage or current introduced in the main channel field. (see PAR. 3.3.6.1.3).
LIMIT CONTROL	<b>INTERNAL</b> EXTERNAL LESSER LIMIT	INTERNAL - Allows the limits to be controlled by digital signals from either the keypad (local) or SCPI command (remote). EXTERNAL: Allows the limits to be controlled by analog signals applied to the analog port; limits set from the keypad or SCPI command have no effect (see PAR. 3.3.6.1). LESSER LIMIT: Allows protect limit to be automatically selected from either 1) the external analog voltage applied to the Analog I/O port or 2) the value set from the keypad or SCPI command). Whichever limit has a lower absolute value (closest to zero) has effect
NOTE: Temporary setting that can not be saved and restored on power-up.		

### 3.3.6.1 REFERENCE

The REFERENCE setting of the Reference Menu determines the method of control over output voltage/current.

#### 3.3.6.1.1 REFERENCE - INTERNAL

When the REFERENCE INPUT on the Reference Menu is set to INTERNAL, the output voltage is controlled by digital means, either using the local front panel keypad (see PAR. 3.3.2) or remote SCPI commands (see Appendix B). The external reference at pin 11 is ignored.

#### 3.3.6.1.2 REFERENCE - EXTERNAL

The BOP allows external control of the output using voltages applied to the analog I/O port. When the REFERENCE INPUT on the Reference Menu is set to EXTERNAL, EXT\_REF (pin 11) of the Analog I/O Port (see Table 2-10) referenced to Signal Ground (pin 4) controls the output. This 0 to  $\pm 10V$  analog signal controls the output voltage or current from zero to  $\pm$ full scale. For details on using External Reference, refer to PAR. 3.9.2.1. Control of either voltage or current is determined by (V/I) MODE CONTROL on the Protected Settings Menu (see PAR. 3.3.5.4.4).

NOTE: If the system limits have been modified (PAR. 3.3.5.2), the output of the power supply will never exceed the modified system limits. E.g, for a BOP 36-28MG, if the system voltage limit is modified to  $\pm 18V$ , applying a positive analog voltage to pin 11 that starts at zero and rises to +10V causes the output to rise from zero and reach +18V when the external reference reaches +5V. The output stays at +18V while the reference increases from +5V to +10V since the system voltage limits for this example are  $\pm 18V$ .

#### 3.3.6.1.3 REFERENCE - EXTL REF LVL

When REFERENCE on the Reference Menu is set to EXTL REF LVL, the gain of the BOP is established by entering the desired full scale output in the main channel field on the ACTIVE

SETTINGS line of the LCD (see Figure 3-3) using the same techniques for setting voltage or current (see PAR. 3.3.2). This determines the full scale output to be produced by a 10V external reference. This selection applies only when using an external reference.

The gain in voltage mode is  $G_V = V_{SET}/10$  where  $V_{SET}$  is the desired full scale voltage (in Volts) entered at the front panel.

The gain in current mode is  $G_A = I_{SET}/10$  where  $I_{SET}$  is the desired full scale current (in Amperes) entered at the front panel.

For a BOP 36-28MG operating in current mode, e.g., setting the main channel to 1A means that the maximum (full scale) current obtained for 10V applied at the external reference input is 1A. Consequently the gain  $G_A = 1/10$ , or 0.1.

The range for full scale voltage or current is between zero and the rated (nominal) values associated with the BOP Model, corresponding to a range for gain between zero and the rated (nominal) values of the unit.

If the maximum voltage or current values are below the above chosen full scale by adjusting the software limits +Vmax and -Vmin for voltage or +Imax and -Imin for current then at one point the BOP output is clamped to the software limit. This is useful for generating “clipped” waveforms such as a trapezoidal waveform from a triangle waveform input.

### 3.3.6.2 LIMIT CONTROL

When LIMIT CONTROL on the Reference Menu is set to INTERNAL, the protect limits are under digital control and can be set from the local front panel keypad (see PAR. 3.3.2) or by remote SCPI command (see Appendix B).

When LIMIT CONTROL on the Reference Menu is set to EXTERNAL, the protect limits are determined by four analog signals referenced to Ground (pin 12) which are applied to the Analog I/O Port. All four signals are active, however only the complementary protect channel is affected,  $\pm$ current protect limit for voltage mode and  $\pm$ voltage protect limit for current mode.

- **-I\_LIM\_EXT (pin 5)** - This 0 to +10V analog signal sets the negative current protect limit from zero to -full scale current. +10V corresponds to rated minimum (maximum negative) current (e.g., for BOP 36-28MG, +10V sets negative current limit to -28A).
- **-V\_LIM\_EXT (pin 6)** - This 0 to +10V analog signal sets the negative voltage protect limit from zero to -full scale voltage. +10V corresponds to rated minimum (maximum negative) voltage (e.g., for BOP 36-28MG, +10V sets negative voltage limit to -36V).
- **+I\_LIM\_EXT (pin 13)** - This 0 to +10V analog signal sets the positive current protect limit from zero to full scale current. +10V corresponds to rated maximum current (e.g., for BOP 36-28MG, +10V sets positive current limit to +28A).
- **+V\_LIM\_EXT (pin 14)** - This 0 to +10V analog signal sets the positive voltage protect limit from zero to full scale voltage. +10V corresponds to rated maximum voltage (e.g., for BOP 36-28MG, +10V sets positive voltage limit to +36V).

When LIMIT CONTROL on the Reference Menu is set to LESSER LIMIT, the protect limits are automatically selected from either 1) the external analog voltage applied to the Analog I/O port or 2) the value set from the keypad or SCPI command. Whichever limit has a lower absolute value (closest to zero) has effect.



### **3.3.6.3 SYSTEM LIMITS AND EXTERNAL REFERENCE**

The external reference should allow full operation of the power supply, but this may not be true when the software-controlled system limits have been altered. The system limits are applied to the controlling channel in all REFERENCE INPUT modes. To allow full operation of the power supply, see PAR. 3.3.5.2 and restore the system limits to the default values.

## **3.4 DIGITAL REMOTE MODE PROGRAMMING**

BOP models may be digitally programmed over a control bus using SCPI (Standard Commands for Programmable Instruments). SCPI provides a common language conforming to IEEE 488.2 for instruments used in an automatic test system. The control bus used must be either the IEEE 488 standard communication bus (General Purpose Interface Bus, GPIB), or the RS 232C Serial Bus.

Refer to Table 2-11 for input/output signal allocations for communication via the GPIB, Table 2-5 for RS 232, and Table 2-2 for the BITBUS. All power supply functions available from the keypad can be programmed via remote SCPI commands. In addition, some features that are not available from the keypad may be implemented using remote commands (see PAR. 3.4.1).

This section includes a discussion of GPIB bus protocols (PAR. 3.5), instructions for changing the GPIB address (PAR. 3.5.1), a discussion of the VISA (Virtual Instrumentation Software Architecture) driver supplied with the unit (PAR. 3.6), RS 232C Operation (PAR. 3.7), followed by a detailed explanation of SCPI programming (PAR. 3.8).

### **3.4.1 OPERATING FEATURES AVAILABLE ONLY BY REMOTE COMMANDS**

The following paragraphs describe features of the BOP that are not available from the front panel, but can be implemented using remote commands.

#### **3.4.1.1 ADDITIONAL SETUP SAVE AND RECALL CAPABILITY**

The \*SAV command (see PAR. A.12) can save up to 99 setups that are separate from the 99 setups that can be saved from the front panel. The \*RCL command (see PAR. A.10) can recall any of the 198 setups, whether entered from the front panel, or remotely using \*SAV.

#### **3.4.1.2 EXPANDED PROGRAMS**

Refer to the documentation supplied with the VISA driver included with the BOP for more detailed information regarding programs, including examples of how to create a table to load the variables.

### **3.4.2 PROGRAMMING TECHNIQUES TO OPTIMIZE PERFORMANCE**

#### **3.4.2.1 PROGRAMMING VOLTAGE/CURRENT LIMIT AND CURRENT/VOLTAGE LIMIT**

Kepeco'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 Kepeco'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 (Kepeco'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.

### 3.4.2.2 MAKING SURE THE PREVIOUS COMMAND IS COMPLETE

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

- \*SAV
- MEM:PACK
- MEM:UPD
- CAL:SAVE
- SOUR:CURR:LIM
- SOUR:VOLT:LIM
- SOUR:CURR:PROT:LIM
- SOUR:VOLT:PROT:LIM
- SYST:PASS:NEW
- SYST:SEC:IMM
- SYST:SET

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.118) 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 3-7 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 AAvailable 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 3-7. PROGRAMMING EXAMPLE TO VERIFY PREVIOUS COMMAND HAS COMPLETED**

### 3.4.3 REMOTE MODE SETUP

The BOP can be conveniently substituted for a standard BOP that is currently being used with one of Kepco's BIT cards by using one of the Compatibility Modes provided (see PAR. 3.4.3.1 through 3.4.3.3).

When any of the two interface ports are in use, PAR's 3.4.3.4 (GPIB), 3.4.3.5 and (RS 232) describe how to configure the port to meet the user's requirements.

The **SYSTEM:SET** and **SYSTEM:LANGUage** commands can be used to configure the BOP to operate in a manner consistent with earlier models of Kepco's 100W, 200W and 400W BOP power supplies.

#### 3.4.3.1 BIT 4882 COMPATIBILITY.

To replace a standard BOP/BIT 4882 card combination with a BOP with minimal reconfiguration of existing test setups, send **SYSTEM:SET 4882** followed by **MEMORY:UPDATE INTERFACE**.

#### 3.4.3.2 BIT 4886 COMPATIBILITY

To replace a standard BOP/BIT 4886 card combination with a BOP High Power with minimal reconfiguration of existing test setups, send **SYSTEM:SET 4886** or send **SYSTEM:SET 4885**.



#### 3.4.3.3 BIT 488B OR BIT 488D COMPATIBILITY

To replace a standard BOP/BIT 488B or 488D card combination with a BOP High Power with minimal reconfiguration of existing test setups, refer to the Modify Interface submenu (see Table 3-5) and set INTERFACE DATA FORMAT to SNH to replace a BOP with BIT 488B card or SND to replace a BOP with BIT 488D card.

#### 3.4.3.4 GPIB PORT SETUP



The following paragraphs describe the how to configure the GPIB port.

##### 3.4.3.4.1 CHANGING THE GPIB ADDRESS

The default address is 6. To change the GPIB address press  from the top menu, then press  to enter the Interface menu and refer to Table 3-5.

##### 3.4.3.4.2 CONFIGURE DEVICE CLEAR (DCL) CONTROL

The device clear (DCL) and selected device clear can be set to operate in two modes. In the MATE mode, when the device clear is received, the output of the power supply is set to zero volts. In the SCPI mode sending DCL or selected DCL has no effect on out- put voltage and current as required by IEEE specification 488.2. The factory default value is SCPI mode.

The Device Clear can be configured to act the same way as the \*RST command (see PAR. A.11). From the top menu press , then press  to enter the Interface menu, highlight DCL and select the desired option. See Table 3-5.

##### 3.4.3.4.3 CONFIGURE \*RST

When the "@ ReSeT OUTPUT is" parameter of the Modify Interface submenu (Table 3-5) is set to OFF the \*RST command sets the output to off, requiring OUTPut ON to energize the output.

When the “@ ReSeT OUTPUT is” parameter is set to ON the \*RST command sets the output to 0V, 0A but any subsequent VOLTage or CURRent commands will affect the output accordingly.

### **3.4.3.5 RS 232 SERIAL PORT SETUP**

Paragraphs 3.4.3.5.1 through 3.4.3.5.3 below describe the setup required for the BOP to communicate via the RS 232C Serial bus using SCPI commands.



#### **3.4.3.5.1 SELECT BAUD RATE**

From the top menu press , then press  to enter the Interface menu, highlight SERIAL BAUD RATE and select the desired option. See Table 3-5.

#### **3.4.3.5.2 CONFIGURE XON/XOFF PROTOCOL**

From the top menu press , then press  to enter the Interface menu, highlight SERIAL XON/XOFF and select the desired option. See Table 3-5.

#### **3.4.3.5.3 CONFIGURE PROMPT MODE**

From the top menu press , then press  to enter the Interface menu, highlight SERIAL PROMPT and select the desired option. Prompt may be enabled either with or without echoing of characters. See Table 3-5.

#### **3.4.3.6 ESTABLISH COMMUNICATION LANGUAGE**

Communication via GPIB port can be executed using either SCPI or CIIL protocols.

### **3.5 IEEE 488 (GPIB) BUS PROTOCOL**

Table 3-11 defines the interface capabilities of the BOP 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 3-12 and 3-13 define the messages sent to the BOP, or received by the BOP, 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 BOP power supply operating as either a Talker or a Listener.

### 3.5.1 CHANGING THE GPIB ADDRESS

See PAR. 3.4.3.4.1.

**TABLE 3-11. 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)
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 BOP 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 function key. LOCAL function key can be disabled using keypad lockout command (see Appendix B, PAR. B.127) so that only the controller or a power on condition can restore Local mode.
Parallel Poll	PP0	No Capability
Device Clear	DC1	Complete Capability. BOP accepts DCL (Device Clear) and SDC (Selected Device Clear).
Device Trigger	DT1	Respond to *TRG and <GET> trigger functions.
Controller	C0	No Capability

**TABLE 3-12. IEEE 488 (GPIB) BUS COMMAND MODE MESSAGES**

MNEMONIC	MESSAGE DESCRIPTION	COMMENTS
ATN	Attention	Received
DAC	Data accepted	Received or Sent
DAV	Data Valid	Received or Sent
DCL	Device Clear	Received (see PAR. 3.4.3.4.2)
IFC	Interface Clear	Received
MLA	My Listen Address	Received
MTA	My Talk Address	Received
OTA	Other Talk Address	Received
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 3-13. IEEE 488 (GPIB) BUS DATA MODE MESSAGES**

<b>MNEMONIC</b>	<b>MESSAGE DESCRIPTION</b>	<b>COMMENTS</b>
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

### **3.6 BOP VISA INSTRUMENT DRIVER**

The VISA instrument driver for the BOP power supply, available for download at [www.kepcopower.com/drivers.htm](http://www.kepcopower.com/drivers.htm), simplifies programming with a VISA compatible GPIB controller. Included are:

- source code (C) for all VISA functions (kp\_bophi.c)
- a complete programming reference manual (kp\_bophi.doc)
- a sample application of the VISA functions (written in C) which can be used to program one or more BOP power supplies using a virtual front panel observed on a computer monitor (kp\_appl.c)

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

### **3.7 RS232-C OPERATION**

The BOP 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, or select prompt, echo or XON/XOFF, refer to PAR. 3.2.4 and Table 3-5.

### 3.7.1 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 six special control characters are:

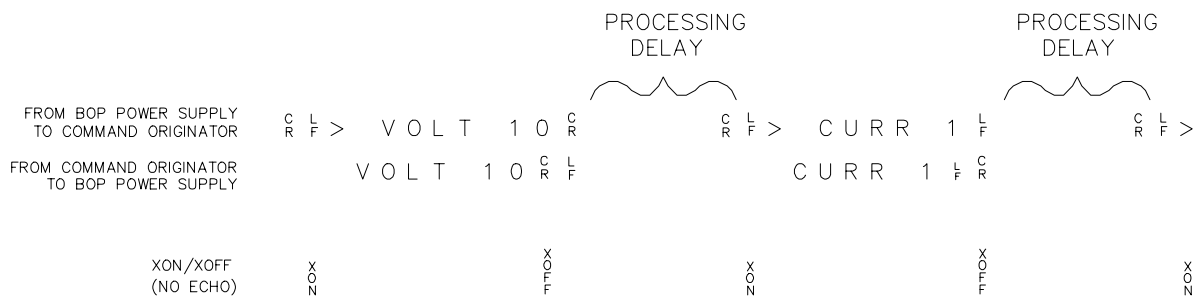
- Escape (1B<sub>H</sub>) Causes the input buffer to be cleared. This character is used to ensure that the buffer is empty when the host powers on since it is possible that the TMA 4882-27 controller was previously powered on and received some characters prior to the initialization of the host computer.
- Backspace (08<sub>H</sub>) Causes the last character in the input buffer to be removed from the input buffer queue.
- Carriage Return (0D<sub>H</sub>) Causes the input buffer to be parsed by the BOP.
- Line Feed (0A<sub>H</sub>) Causes the input buffer to be parsed by the BOP.

### 3.7.2 RS 232 IMPLEMENTATION

The following paragraphs are provided to help the user understand how the RS 232 serial interface is implemented in the BOP. 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 BOP power supply, thus avoiding a more complex “handshake” protocol.

When the BOP is in the RS 232 echo mode it returns all data sent to the host controller. The BOP 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 BOP. As shown in Figure 3-8, there are times when the BOP 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 3-8 illustrates the default echo mode, the prompt method and the XON XOFF method described in the following paragraphs.



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**FIGURE 3-8. RS 232 IMPLEMENTATION**



Only seven control characters (characters between 00<sub>H</sub> and 1F<sub>H</sub>) are acknowledged by the power supply:

- Carriage Return (CR, 0D<sub>H</sub>)
- Line Feed (LF, 0A<sub>H</sub>)
- Back Space (BS, 08<sub>H</sub>)
- Escape (ESC, 01B<sub>H</sub>)
- XON (011<sub>H</sub>)
- XOFF (013<sub>H</sub>)
- CAN (018<sub>H</sub>)

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 BOP by the command originator. When the line is parsed and the commands are sent to the analog processor, the BOP sends the line terminator sequence CR LF to the command originator.

The ESC character is used for synchronization, causing the BOP to reset its input buffer and return a CR LF sequence.

The XON character enables the transmitter if XON/XOFF flow control is enabled (see PAR. 3.3.5 and Table 3-5).

The XOFF character stops data transmission if XON/XOFF flow control is enabled (see PAR. 3.3.5 and Table 3-5).

The CAN character resets the receive and transmit pointers and queues.

**CAUTION:** When the serial port has received an XOFF, the error message *-400, QUE error* will be placed in the queue to indicate the loss of transmitted information due to a received XOFF character. When XON is received, the unit will transmit all data in its buffer followed by the exclamation character (!). This (!) character is not part of any message from the BOP and indicates the transmission buffer has been cleared and the BOP is idle.

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 3-8).

### 3.7.2.1 ECHO MODE

Echo mode is one method of ensuring data is transferred without errors. This mode should only be enabled when errors in operation are detected.

Each byte (character) is echoed back to the sender where it is verified as the same character that was just sent. If the wrong character is echoed back, sending the ESC character clears the line to allow retransmission of the character. It is important the CR and LF characters are NOT sent until the verification process is complete.

When working in echo mode, it is possible to receive the NAK (15 hex) from the BOP. This indicates an unknown quantity of echoed characters have been lost due to a queue overflow problem. The error queue will also contain the *-400, QUE error* message. To prevent this, please insure the received data string does not exceed 127 characters between line terminators and no more than four queries are sent between line terminators in SCPI or SN mode of operation

All non-control characters are sent via the serial port of the command originator.

### 3.7.2.2 PROMPT METHOD

The command originator sends a message line (command) to the BOP and waits until the prompt sequence CR LF > (3E<sub>H</sub>, 62<sub>10</sub>) is received. The BOP 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. This method is useful in an interactive mode as well as with certain process controllers.

### 3.7.2.3 XON XOFF METHOD

The XON XOFF method allows the BOP 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<sub>H</sub>) has been received; the command originator stops sending data after receiving the XOFF (transmission off) character (013<sub>H</sub>), 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 BOP returns the normal sequence of CR LF (if echo mode is enabled).

### 3.7.3 USING SCPI COMMANDS FOR RS 232 COMMUNICATION.

The unit must be in remote mode before the RS 232 commands to affect the output can be executed (e.g., VOLT 10;OUTP ON). This can be accomplished by sending SYST:REM ON prior to sending any commands that affect the power supply output. (See PAR. B.131 and Figure B-7)

### 3.7.4 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 1-4) installed.

1. With the power supply in local mode, press  key to enter the SETTINGS menu (see PAR 3.3.5), then press  to enter the Test Subsystem menu.
2. Press the  key to run the test with the Loop Back Test connector NOT installed and verify the LCD reads **FAIL.EXT**. 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  key to rerun the test. If the LCD reads **PASSED**, the power supply is operating properly. If the LCD reads **FAILED** or **FAIL.EXT**, 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 step 3 above. If the LCD display reads **FAIL.EXT**, 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](http://www.kepcopower.com/support).

## **3.8 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 BOP 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.3.5.1 to establish the BOP Power Supply GPIB address.)

### **3.8.1 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.

### **3.8.2 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).

### **3.8.3 SCPI SUBSYSTEM COMMAND/QUERY STRUCTURE**

Subsystem commands/queries are related to specific power supply functions (such as setting output voltage, current limit, etc.) Figure 3-9 is a tree diagram illustrating the structure of SCPI subsystem commands used in the BOP 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.

#### **3.8.3.1 ABORT SUBSYSTEM**

This subsystem allows pending trigger levels to be cancelled.

### **3.8.3.2 DISPLAY SUBSYSTEM**

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

### **3.8.3.3 INITIATE SUBSYSTEM**

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

### **3.8.3.4 LIST SUBSYSTEM**

The LIST subsystem allows the BOP to generate complex waveforms by executing a series of points in order. Each point contains a value for the main channel (either voltage or current) and the duration (dwell) that the value will appear at the output (from 230 microseconds to 10 seconds). The list system supports from 2000 to 3999 points per waveform, depending on the number of different dwells in the waveform: For example, if each point in the list has the same duration (a single dwell time), 3999 points are supported; if no more than 128 different dwell times are specified, 3000 points are supported, and if each point has a different dwell, a maximum of 2000 points are supported. The number of points supported is determined automatically by the BOP firmware.

### **3.8.3.5 MEASURE SUBSYSTEM**

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

### **3.8.3.6 OUTPUT SUBSYSTEM**

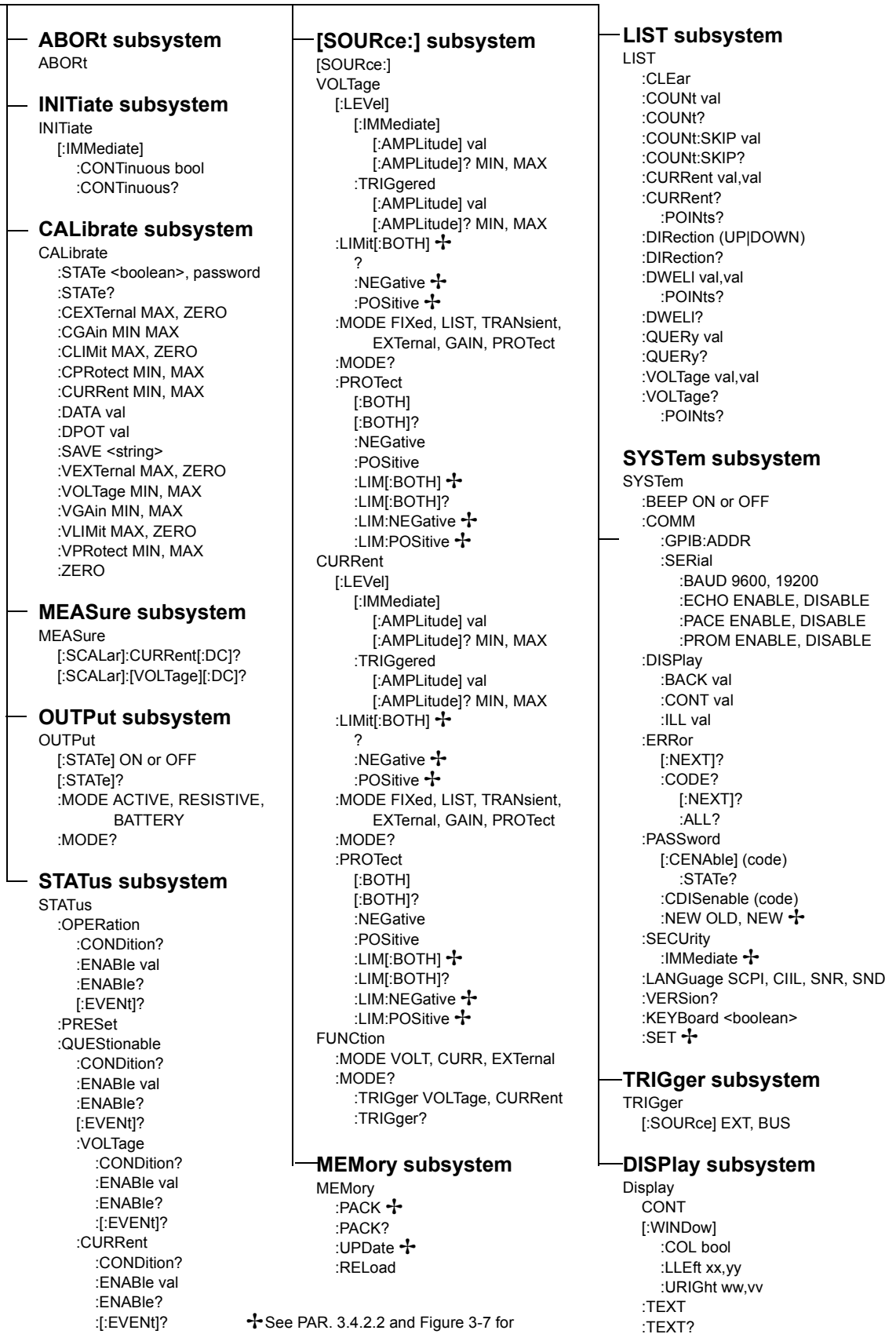
This subsystem controls the power supply's voltage and current outputs

### **3.8.3.7 MEMORY SUBSYSTEM**

This subsystem controls the Flash Memory used by the BOP microprocessors and is used for storing setup parameters and for storing a list for later recall and execution

The unit's configuration, voltage and current, saved setups (\*SAV and \*RCL command) and Calibration values are stored in Flash Memory. Since the Flash EEPROM cannot be modified by writing a single data byte, the block must be erased and then the data written into the correct locations.

ROOT : (colon)



† See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

FIGURE 3-9. TREE DIAGRAM OF SCPI COMMANDS USED WITH BOP POWER SUPPLY

Saved setups are accomplished by the 99 memory locations (groups of settings) which are stored in the nonvolatile memory. Each setting contains values for: Mode, main channel setting (voltage or current), Reference setting, positive and negative protect values, External Protect setting (see Table 3-11), and the keypad state (locked/unlocked. If the keypad is locked (SYST:KEYB DISable), the \*SAV command creates a protected setting that can not be altered from the front panel.

The BOP accomplishes this by partitioning the Flash memory. As the amount of Flash memory used becomes larger with each subsequent data update, the Flash memory can fill up and needs to be compressed. The compression of the Flash EEPROM, called packing, is automatically handled by the BOP microprocessor's code. The packing process can take a half a second to accomplish. Because it is automatically executed, it can occur after any \*SAV, Memory:UPDATE, or save of Calibration. When the memory is out of space, the internal microprocessor copies the live data to a backup flash area, erases the main flash data area, copies the current control variables into this clean space and then erases the backup flash area. The pack process can take 500 milliseconds to complete. Packing is automatically invoked during power up initialization if the BOP finds that any storage area is over 90% utilized.

The following statistics are a guide as to when a MEMORY PACK will occur.

- Save area - Approximately 300 \*SAV operations can be completed before a PACK will occur automatically.
- Variable area - around 30 updates can be completed prior to an automatic PACK occurring. Variable areas also include serial number updates and password updates.
- Calibration - 16 calibrations can be saved before a PACK is required.

If the memory is over 80% full, the user can also initiate packing by sending the command MEMORY:PACK. Issuing a MEMORY:PACK command if the memory is less than 80% full will have no effect. Because this command may take a long time to complete, it is recommended that the user send MEMORY:PACK;\*OPC?. The computer can then perform serial polls to wait for the command to complete. The command will be complete when the serial poll byte indicates there is data in the output buffer. (bit 4 set in the returned status byte).

#### **3.8.3.8 STATUS SUBSYSTEM**

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

#### **3.8.3.9 TRIGGER SUBSYSTEM**

This subsystem controls the remote triggering of the power supply.

#### **3.8.3.10 [SOURCE:]VOLTAGE AND [SOURCE:]CURRENT SUBSYSTEMS**

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

#### **3.8.3.11 CALIBRATE SUBSYSTEM**

The BOP 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 (performed on the main channels only) and positive and negative full scale calibrations with both internal and external references. In addition, the external reference and variable gain are also calibrated. 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 then stored in the non volatile memory.

Refer to PAR. 4.2 for calibration equipment requirements.



During voltage calibration, the voltage, voltage protect and voltage readback are calibrated and during current calibration the current, current protect 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 sensing terminals (OUT S and COM S) 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.

### 3.8.3.12 SYSTEM SUBSYSTEM

This subsystem controls system-level commands, including setup of the GPIB and Serial ports, error queries, front panel setup (keyboard lockout, display illumination, and audible beeps), passwords, command language, setup of device clear, line feed and reset, and restoring factory calibration.

#### 3.8.3.12.1 PASSWORD SETUP.

The unit is shipped with the password set to **DEFAULT**. To change the password:

1. Press  from the top menu, then enter the current password (see PAR. 3.2.4.1), then press  to enter the Protected settings menu
2. highlight the current password, then modify per PAR. 3.2.4.2.

NOTE: The password can also be modified by sending the following SCPI commands:

```
SYST:PASS:CEN DEFAULT
```

```
SYST:PASS:NEW DEFAULT new_password
```

#### 3.8.3.12.2 FORGOTTEN PASSWORDS

If the password is lost, it is possible to enable the password interface by sending

```
SYST:PASS:CEN POWERSUPPLIER
```

Once enabled, the password can be set to **DEFAULT** by sending

```
SYST:SEC:OVERRIDE
```

### 3.8.4 PROGRAM MESSAGE STRUCTURE

SCPI program messages (commands from controller to power supply) consist of one or more *message units* ending in a *message terminator*. 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). Sending a character with EOL line asserted is another way of sending a message terminator. The message unit is a keyword consisting of a single command or query word followed by a message terminator (e.g., CURR?<newline> or TRIG<end-of-line>). The message unit may include a data parameter after the keyword separated by a space; the parameter is usually numeric (e.g., CURR 5<newline>), but may also be a string (e.g., OUTP ON<newline>). Figure 3-10 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.

#### 3.8.4.1 KEYWORD

Keywords are instructions recognized by a decoder within the BOP, referred to as a “parser.” Each keyword describes a command function; all keywords used by the BOP are listed in Figure 3-9.

Each keyword has a long form and a short form. For the long form the word is spelled out completely (e.g. STATUS, OUTPUT, VOLTAGE, and TRIGGER are long form keywords). For the short form only the first three or four letters of the long form are used (e.g., STAT, VOLT, OUTP, and TRIG). The rules governing short form keywords are presented in Table 3-14.

**TABLE 3-14. 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).

#### 3.8.4.2 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 3.8.4.7).



### 3.8.4.3 QUERY INDICATOR

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

### 3.8.4.4 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).

### 3.8.4.5 DATA SEPARATOR

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

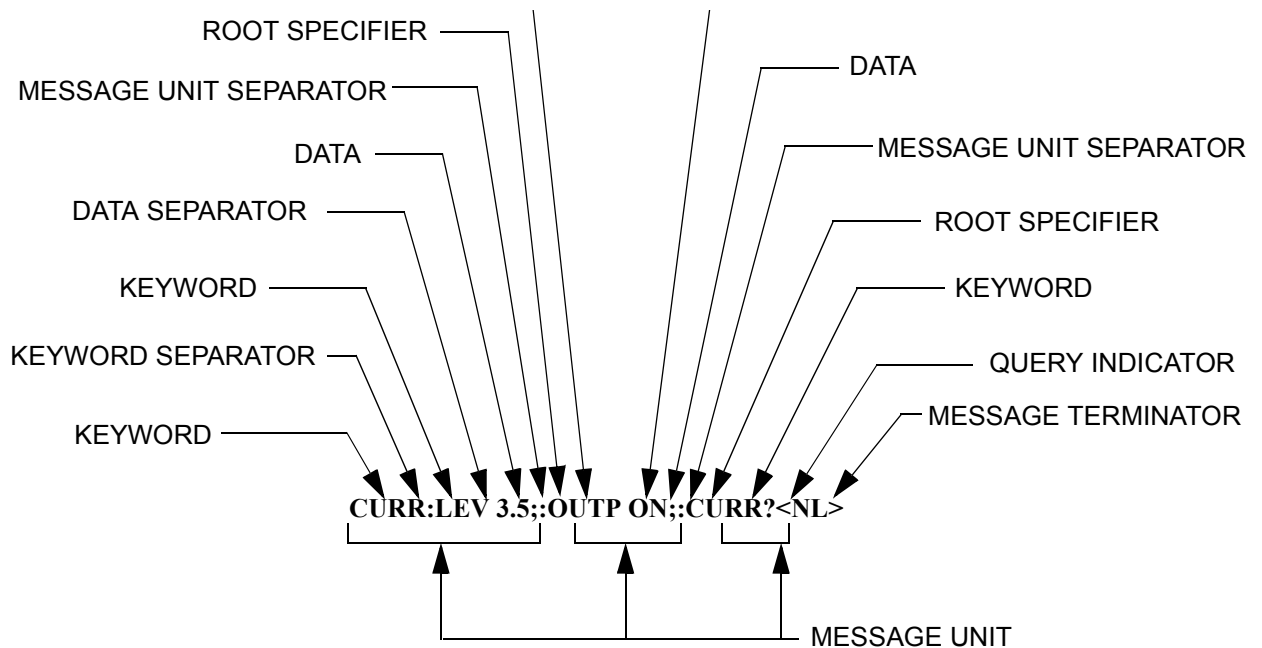


FIGURE 3-10. MESSAGE STRUCTURE

### 3.8.4.6 MESSAGE UNIT SEPARATOR

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

### 3.8.4.7 ROOT SPECIFIER

The root specifier is a colon (:) that precedes the first keyword of a program message. This places the parser at the root (top left, Figure 3-9) 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.

#### 3.8.4.8 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.

#### 3.8.5 UNDERSTANDING THE COMMAND STRUCTURE

Understanding the command structure requires an understanding of the subsystem command tree illustrated in Figure 3-9. 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 BOP 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.

### 3.8.6 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, therefore 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**

### 3.8.7 STATUS REPORTING

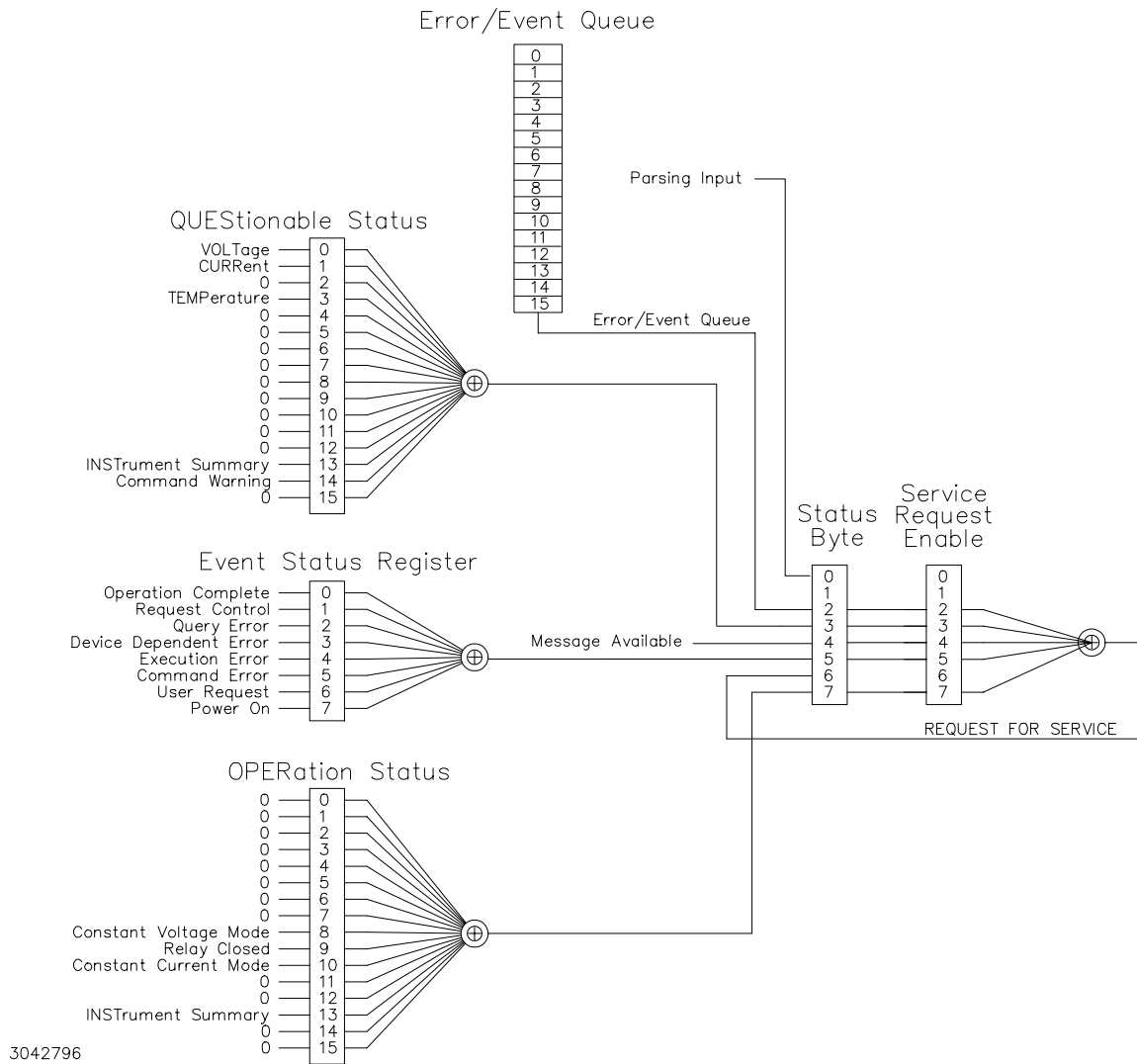
The status reporting of the BOP power supply follows the SCPI and IEEE 488.2 requirements. The serial poll response of the BOP power supply provides summary bits of the status and error reporting system. The simplest status report is the command valid reporting and data availability. This successful decoding of a command string generates no error and is indicated by the bit 3 of the serial poll response being a zero. The setting of bit 4 in the status byte indicates data is available to the controller in response a command query message.

#### 3.8.7.1 STATUS REPORTING STRUCTURE

The status reporting of the BOP uses four status registers, illustrated in Figure 3-11. These registers are the Questionable, Operation, Standard Event and Service Request registers. The Questionable and Operation registers are 16 bit registers and the Standard Event and Service Request registers are 8 bits. These four registers are referred to as condition registers. Each of the four condition registers is associated with two related registers: an event register which holds unlatched events reported in real-time by the instrument and is cleared by reading the register, and an enable register which allows the contents of the event register to be passed through to set the associated condition register.

A zero to one transition of a condition register is added to the event register if the specific bit in the enable register is also a 1. Reading an event register clears all of the bits found in the event register. If any bits are set in an event register, the following condition register bit is then set. For example, if the STAT:QUES:ENB (enable) register has bit 0 set and a voltage error is detected, the event registers bit 0 is set. The 1 in the event register causes bit 3 of the status byte to be asserted. The Service Request register is ANDed with its enable register for all bits except bit 6. The result is placed in bit 6 of the Service Request register. If bit 6 is a 1 (true), it causes the MBT-G power supply to assert the SRQ line to the host controller.

Figure 3-11 also shows that if the error/event queue is not empty, bit 3 is set in the Service Request register and bit 4 indicates that a message is available in the output buffer.



**FIGURE 3-11. STATUS REPORTING STRUCTURE**

### 3.8.7.2 OPERATIONAL STATUS REGISTER

The OPERational condition register contains conditions which are a part of the instrument's normal operation. The definition of each of these bits (condition register) is as follows:

- 1 through 7 - Not Used — always zero.
- 8 - Constant Voltage — 1 indicates the instrument is in constant voltage mode.
- 9 - Not Used — always zero.
- 10 - Constant Current — 1 indicates the instrument is in constant current mode.
- 11 through 15 - Not Used — always zero.

### 3.8.7.3 QUESTIONABLE STATUS REGISTER

The QUESTIONable condition register (see Figure 3-11) contains status bits representing data/signals which give an indication of the quality of various aspects of the signal.

A bit set in the QUESTIONable condition register indicates that the data currently being acquired or generated is of questionable quality due to some condition affecting the parameter associated with that bit.

- 0 - Voltage Mode — 1 indicates the instrument is in Voltage mode.
- 1 - Current Mode — 1 indicates the Power Supply is in Current mode. Changes in this bit do not affect the event register.
- 2 - Not Used — always zero.
- 3 - Thermal Error — 1 indicates a thermal error has been detected.
- 4 - 11 - Not Used — always zero.
- 12 - Voltage Error — 1 indicates an error has been detected in Voltage mode.
- 13 - Current Error — 1 indicates an error has been detected in Current mode.
- 14 - 15 Not Used — always zero.

### 3.8.8 SCPI PROGRAM EXAMPLES

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

Figure 3-12 is an example of a program using SCPI commands to program the BOP 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.

### 3.9 ANALOG REMOTE MODE PROGRAMMING

The BOP can be programmed remotely using analog signals applied to the remote Analog I/O port at the rear panel (see Figure 2-1 and Table 2-10). Analog remote programming allows the

user to 1) establish voltage or current mode (PAR. 3.9.1), 2) control the main channel using the BOP as a power amplifier (PAR. 3.9.2) and 3) establish the protection limits (PAR. 3.9.3). An output signal proportional to output current is also provided for external use (PAR. 3.9.4)

```

/*****
/* 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 3-12. TYPICAL EXAMPLE OF BOP POWER SUPPLY PROGRAM USING SCPI COMMANDS**

### 3.9.1 VOLTAGE/CURRENT MODE CONTROL

The mode of operation, voltage or current, can be programmed externally by applying a signal at pin 2, referenced to pin 9, of the Analog I/O port. Applying a TTL logic 1 (or open circuit) programs the unit to voltage mode. Applying a TTL logic 0 (or short) programs the unit to current mode.

To be functional this feature must first be configured from the front panel (see PAR. 3.3.5.4.4).

1. From the main screen (Figure 3-3) press **F5** - SETTINGS, **F4** - PROTECTED SETTINGS then enter the password (see PAR. 3.2.4.1) to access the Protected Settings Menu (see Table 3-8).

2. Highlight (V/I) MODE CONTROL - EXTERNAL and press  - SAVE. **Note that this configuration is temporary and can not be saved when the unit is powered down.**

Each time (V/I) MODE CONTROL is toggled between KEYPAD and EXTERNAL or vice versa, the unit generates an internal \*RST reset command (see PAR. A.11) requiring the BOP output to be reprogrammed.

### 3.9.2 CONTROLLING THE OUTPUT USING THE BOP AS A POWER AMPLIFIER

The BOP can function as a power amplifier by means of the External Reference input at the Analog I/O port. This signal controls the main channel of the BOP. To use the BOP as a power amplifier see the following instructions for using the external reference: PAR. 3.9.2.1 for fixed gain, PAR. 3.9.2.2 for variable gain by establishing the maximum full scale output.

#### 3.9.2.1 FIXED GAIN USING EXTERNAL REFERENCE CONTROL

The main channel of the BOP, voltage in voltage mode, and current in current mode, can be controlled by an external reference voltage, 0 to  $\pm 10V$  applied at pin 11, referenced to pin 4, of the Analog I/O port. The input impedance for this signal is 20K ohms.

When the external reference is used, the BOP functions as a power amplifier, amplifying the external reference at pin 11 to produce the output. So for an external reference of  $\pm 10V$ , the nominal voltage gain (see PAR. 3.9.2.1.1) ( $G_{NOM-V}$ ) of a BOP 36-28MG is  $36/10 = 3.6$ , the nominal current gain ( $G_{NOM-I}$ ) is  $28/10 = 2.8$ .

##### 3.9.2.1.1 NOMINAL (INHERENT) GAIN



The nominal (inherent) voltage gain of each model is calculated by  $(G_{NOM-V}) = E_{Onom} / E_{REF}$  and nominal (inherent) current gain is  $(G_{NOM-I}) = I_{Onom} / E_{REF}$ . Thus the nominal gain is the ratio between the nominal (rated) voltage or current ( $E_{Onom}$  or  $I_{Onom}$ ), and the external reference ( $E_{REF}$ ) used to produce that output.

##### 3.9.2.1.2 EXTERNAL REFERENCE VOLTAGE

The external reference voltage controls the output voltage or current between zero and  $\pm$ Full Scale and may be d-c, a-c, or a combination of a-c plus d-c. The maximum frequency of an a-c signal should be below the inherent frequency response of the BOP (2KHz for voltage, 800Hz for current (see Table 1-2). For parallel or series combinations, the frequency response is reduced as specified in the instruction manual included with the cable kit. A frequency that exceeds the bandwidth of the BOP will cause the output to be distorted.

For linear response (input vs. output) the software limit (see 3.2.6.1) should be set to nominal and the maximum peak value (d-c plus a-c) must not exceed  $\pm 10V$ . If the input signal exceeds the limit value (either  $\pm 10V$  if the limit is set to nominal, or a lesser voltage for a user-determined software limit) clipping of the output voltage or current to 1% above the limit will occur.

To be functional this feature must first be configured from the front panel (see PAR. 3.3.6.1.2).

1. From the main screen (Figure 3-3) press  - REFERENCE to access the Reference Menu (see Table 3-10).
2. Highlight REFERENCE - EXTERNAL and press  - SAVE. Each time REFERENCE setting is changed, the unit generates an internal \*RST reset command (see PAR. A.11) which may require the BOP output and/or protection limits to be reprogrammed.


### 3.9.2.2 VARIABLE GAIN USING EXTERNAL REFERENCE LEVEL

The BOP can function as a variable gain power amplifier similar to the fixed (inherent or nominal) gain amplifier as described in PAR. 3.9.2.1. The user can determine a new (lower) full scale output value that the  $\pm 10V$  reference level (applied at pin 11, referenced to pin 4, of the Analog I/O port) will produce by selecting REFERENCE - EXTL REF LVL at the Reference Menu (see Table 3-10). Refer to PAR. 3.9.2.1.2 for details regarding the external reference characteristics.

For an external reference of  $\pm 10V$ , the nominal voltage gain ( $G_{NOM-V}$ ) of a BOP 36-28MG is  $36/10 = 3.6$ . If the new full scale voltage for 10V is set to 29V, the voltage gain is changed from 3.6 to  $29/10 = 2.9$ . The range for the new full scale value is between zero and the rated (nominal) output of each model.

New Gain = New Full scale set at front panel / External reference that produces Full scale output. This means that the External reference voltage, from +10V to -10V, can control the full scale output voltage from +29V to -29V.

To be functional this feature must first be configured from the front panel (see also PAR. 3.3.6.1.3).

1. From the main screen (Figure 3-3) press \$ - REFERENCE to access the Reference Menu (see Table 3-10).
2. Highlight REFERENCE - EXTL REF LVL and press  - SAVE. Each time REFERENCE setting is changed, the unit generates an internal \*RST reset command (see PAR. A.11) which may require the BOP output and/or protection limits to be reprogrammed.
3. Once the feature is configured, the new full scale value is entered by changing the active setting value of the main channel (see Figure 3-3 and PAR. 3.3.2).

### 3.9.3 EXTERNAL PROTECTION LIMITS

In addition to programming the main channel using the external reference (see PAR. 3.9.2) the protection limits can be controlled by an external voltage, 0 to +10V applied to the Analog I/O port, reference to pin 12, as follows:

- pin 13 for +current protection in voltage mode
- pin 5 for -current protection in voltage mode
- pin 14 for +voltage protection in current mode.
- pin 6 for -voltage protection in current mode.


A voltage between 0 and +10V at the above pins will control the corresponding protection parameter between minimum (box) value (see Figure 1-2) and the corresponding positive or negative full scale value. Even though all four signals may be present, only the complementary protection limits are active: external current protection in voltage mode, and external voltage protection in current mode.

The maximum frequency of an a-c signal used for the external protection limit must be at least 100 times lower than the sampling rate of the external signal (100Hz), resulting in a bandwidth of 1Hz.

The external programming circuit must be able to sink 0.15mA maximum provided by the BOP. When the input is an open circuit, the corresponding input signal automatically goes to 20% above the nominal protection limit.



To be functional this feature must first be configured from the front panel (see also PAR. 3.3.6.2).

1. From the main screen (Figure 3-3) press \$ - REFERENCE to access the Reference Menu (see Table 3-10).
2. Highlight LIMIT CONTROL - EXTERNAL and press  - SAVE.

NOTE: If LIMIT CONTROL - LESSER LIMIT is highlighted and saved in step 2 above, the lesser value between the internal and external protection limits is automatically applied.

Each time LIMIT CONTROL setting is changed, the unit generates an internal \*RST reset command (see PAR. A.11) requiring the BOP output to be reprogrammed.

### **3.9.4 CURRENT MONITOR**

The BOP provides an output analog signal, 0 to  $\pm 10V$ , that is proportional to the output current. For the master of a parallel or series configuration this signal is proportional to the output current of the parallel or series combination. This signal is available at pin 3, referenced to pin 10, of the Analog I/O port. To protect the BOP circuitry this signal is provided via a series 2K ohm resistor, thus requiring a high impedance monitoring device or instrument.



## 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 zero, max and min, and protection limit calibration. In addition, the control signals required for series and parallel operation of multiple units are also calibrated.

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

Calibration of the BOP is performed in one of three ways: locally using the front panel keys (PAR. 4.4), remotely by sending commands through either the GPIB or RS 232 bus (PAR. 4.3), or remotely using the graphical interface supplied with the instrument driver available at [www.kepcopower.com/drivers.htm](http://www.kepcopower.com/drivers.htm) (PAR. 4.4.3). This VISA compliant driver works with many GPIB cards from suppliers like National Instruments and Hewlett-Packard. These three ways cannot be combined. Separate calibration procedures are provided for units connected in series or parallel.

NOTE: During calibration, various circuits of the BOP are verified. If an error occurs during the verification process, the unit will beep and an error 24(x), Hardware, (see PAR. B.124) will be placed in the error queue.

### 4.2 TEST EQUIPMENT REQUIREMENTS

Table 4-1 lists sense resistors recommended for measuring current and includes Kepco and Manufacturer's part numbers. The thermal coefficient of the sense resistor chosen should be known with 0.001% accuracy. If other than a recommended sense resistor is to be used, it must be rated for at least 100W power dissipation (actual power dissipation will be approximately 10W).

The digital voltmeter (DVM) used to measure output voltage and the voltage across the current sensing resistor should have at least six digits, multiple ranges, the smallest resolution must be at least one microvolt and the accuracy must be at least 0.0001%.

**TABLE 4-1. SUGGESTED SENSE RESISTORS**

MODEL	VALUE	KEPCO PART NO.	MANUFACTURER	MANUFACTURER PART NO.
BOP 10-75MG BOP 20-50MG	0.001 OHM	115-3033	ISOTEK	RUG-Z-R001-0.1 TK10
BOP 36-28MG BOP 50-20MG	0.01 OHM	115-2997	ISOTEK	RUG-Z-R010-0.1 TK10
BOP 72-14MG BOP 100-10MG	0.1 OHM	115-2995	ISOTEK	RUG-Z-R100-0.1 TK10
NOTE: ALL SENSE RESISTORS MUST BE MOUNTED ON A HEATSINK WITH A MINIMUM SURFACE AREA OF 36 SQUARE INCHES TO MAINTAIN THERMAL STABILITY DURING CALIBRATION; FORCED COOLING IS RECOMMENDED.				

**TABLE 4-2. VOLTAGE CALIBRATION MEASUREMENTS AND TOLERANCES**

MODEL	VOLTAGE ZERO	±FULL SCALE VOLTAGE	±FULL SCALE VPR LIMIT
BOP 10-75MG	0V ±0.0001V	10V (MAX) -10V (MIN) ±0.001V	10V (MAX) -10V (MIN) ±0.003V
BOP 20-50MG	0V ±0.0002V	20V (MAX) -20V (MIN) ±0.002V	20V (MAX) -20V (MIN) ±0.006V
BOP 36-28MG	0V ±0.0036V	36V (MAX) -36V (MIN) ±0.0036V	36V (MAX) -36V (MIN) ±0.01V
BOP 50-20MG	0V ±0.005V	50V (MAX) -50V (MIN) ±0.005V	50V (MAX) -50V (MIN) ±0.015V
BOP 72-14MG	0V ±0.0072V	72V (MAX) -72V (MIN) ±0.0072V	72V (MAX) -72V (MIN) ±0.022V
BOP 100-10MG	0V ±0.01V	100V (MAX) -100V (MIN) ±0.01V	100V (MAX) -100V (MIN) ±0.03V

### 4.3 CALIBRATION USING REMOTE SCPI COMMANDS VIA GPIB OR RS 232 INTERFACE

The primary means of adjustment are the **CAL:DATA** commands. Basically these commands are fine and coarse adjustments, however there are slight differences in how they work for different types of calibrations.

a. **ZERO Calibrations (always done first).** The only means of adjustment is the **CAL:DATA <VALUE>** command which provides a total of 4095 increments of adjustment starting at 0, with 2047 increments in either direction to achieve maximum output levels of ± 0.5V. Adjust the output to obtain the closest value to zero.

b. **MAX and MIN Calibrations.** The primary means of adjustment is the **CAL:DATA <VALUE>** command to either increase (**CAL:DATA 1**) or decrease (**CAL:DATA -1**) the output value. Adjustment can be done in larger increments by increasing the numeric value, e.g.,

**CAL:DATA +10** or **CAL:DATA -10**. Adjust the output to obtain the closest value above the full scale value.

c. **VPR and CPR Calibrations.** The only means of adjustment is the **CAL:DATA <VALUE>** command which provides a total of 4095 increments of adjustment from zero to maximum. Adjust the output to obtain the closest value above the full scale value.

**TABLE 4-3. CURRENT CALIBRATION MEASUREMENTS AND TOLERANCES**

MODEL	SENSE RESISTOR VALUE (SEE NOTE AND TABLE 4-1)	CURRENT ZERO	±FULL SCALE CURRENT	±FULL SCALE CPR LIMIT
BOP 10-75MG	0.001 Ohm	0V ±0.008mV	0.075V (MAX) -0.075V (MIN) ±0.008mV	0.075V (MAX) -0.075V (MIN) ±0.022mV
BOP 20-50MG	0.001 Ohm	0V ±0.005mV	0.05V (MAX) -0.05V (MIN) ±0.005mV	0.05V (MAX) -0.05V (MIN) ±0.015mV
BOP 36-28MG	0.01 Ohm	0V ±0.03mV	0.28V (MAX) -0.28V (MIN) ±0.03mV	0.28V (MAX) -0.28V (MIN) ±0.08mV
BOP 50-20MG	0.01 Ohm	0V ±0.02mV	0.2V (MAX) -0.2V (MIN) ±0.02mV	0.2V (MAX) -0.2V (MIN) ±0.06mV
BOP 72-14MG	0.1 Ohm	0V ±0.14mV	1.4V (MAX) -1.4V (MIN) ±0.14mV	1.4V (MAX) -1.4V (MIN) ±0.42mV
BOP 100-10MG	0.1 Ohm	0V ±0.1mV	1.0V (MAX) -1.0V (MIN) ±0.1mV	1.0V (MAX) -1.0V (MIN) ±0.3mV
REFER TO NOTES FOR SENSE RESISTOR VALUE OTHER THAN LISTED HERE	R <sub>SENSE</sub> SEE NOTE.	SEE NOTE A.	SEE NOTE B.	SEE NOTE C.
USE SPACE PROVIDED AT RIGHT FOR CALCULATED VALUES.				

**NOTES:** The following formulas are used to calculate proper calibration values for Sense Resistors other than those recommended.

**R<sub>SENSE</sub>** = the measured value of the sense resistor in ohms (0.001% accuracy).

**I<sub>Onom</sub>** = Nominal (rated) current output of BOP in Amperes (e.g., for BOP 50-20M, I = 20A)

**A. 0V, Tolerance = ±(R<sub>SENSE</sub>) × (0.1) × (I<sub>Onom</sub>)-- result in mV.**

**B. (R<sub>SENSE</sub>) × (I<sub>Onom</sub>)--result in V, Tolerance = ±(R<sub>SENSE</sub>) × (0.1) × (I<sub>Onom</sub>)--result in mV.**

**B. (R<sub>SENSE</sub>) × (I<sub>Onom</sub>)--result in V, Tolerance = ±(R<sub>SENSE</sub>) × (0.3) × (I<sub>Onom</sub>)--result in mV.**

### 4.3.1 CALIBRATION PROCEDURE USING SCPI COMMANDS

The following procedure provides a complete calibration of the unit. Steps 15 and 16 calibrate the control signal used when the unit is a slave in series configurations. Steps 31 and 32 calibrate the control signal used when the unit is a master in parallel configurations. Steps 33 and 34 calibrate the control signal used when the unit is a slave in parallel configurations. There is no need for a special calibration step when the unit is used as a master in series configurations since the BOP output voltage (which is calibrated by this procedure) is used to control the next unit in series.

- NOTES:
1. For ZERO calibration, adjust output to obtain value closest to zero.
  2. For FULL SCALE calibration adjust the output to obtain the closest value above the nominal full scale value.
  3. Set the unit for local sensing with GND Network in (see Figure 4-1) and disconnect load from BOP output.

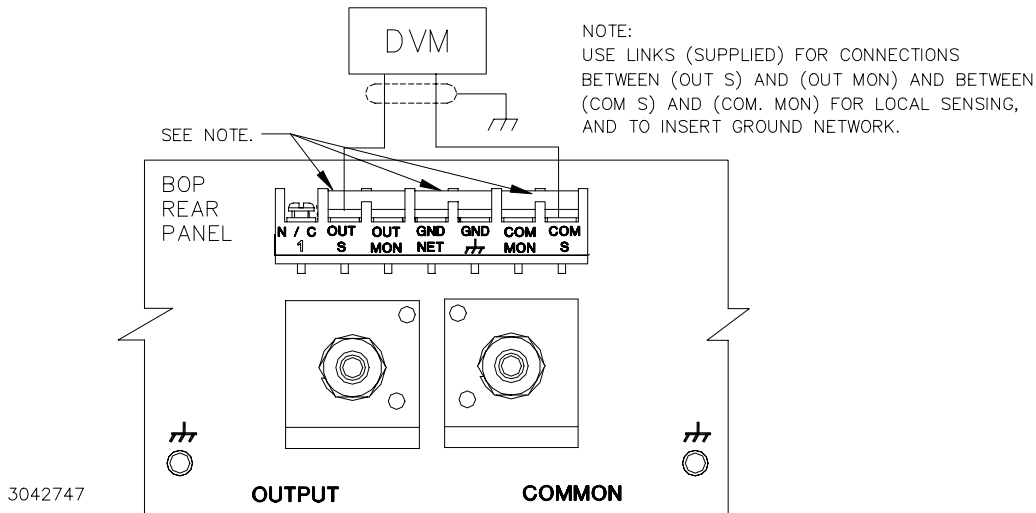


FIGURE 4-1. CALIBRATION SETUP

1. Initiate calibration by sending the SCPI command **SYSTEM:PASSWORD:CENable DEFAULT** and then send **CAL:STATE 1**. The password **DEFAULT** has been set at the factory. If the password has been changed from **DEFAULT**, substitute the correct password for the unit in the **SYST:PASS:CEN** command. If the password has been lost, consult factory.
2. Set the BOP to zero volts output by sending **CAL:VOLT ZERO**. Connect a Digital Voltmeter (DVM) to the BOP OUT S and COM S terminals to measure the output voltage. Send **CAL:DATA** commands as needed (see PAR. 4.3c) to adjust the BOP output until the DVM reads as close to zero as possible within tolerance specified in Table 4-2 for VOLTAGE ZERO.
3. Set the BOP to maximum positive output voltage by sending **CAL:VOLT MAX**. Measure the voltage output using the DVM. To adjust, send **CAL:DATA** commands as needed (see PAR. 4.3b) until the DVM reading is as close as possible above the nominal full scale value within the tolerance specified in Table 4-2 for +FULL SCALE VOLTAGE.
4. Set the BOP to maximum negative output voltage by sending **CAL:VOLT MIN**. To adjust, send the **CAL:DATA** and **CAL:DPOT** commands as needed (see PAR. 4.3b) until the reading

is as close as possible above the nominal full scale value within the limits specified in Table 4-2 for –FULL SCALE VOLTAGE.

5. Send **CAL:VPR MAX** to adjust the maximum positive voltage protection limit of the power supply. Send the **CAL:DATA** commands as needed (see PAR. 4.3c) until the reading is as close as possible above the nominal full scale value within the limits specified in Table 4-2 for +FULL SCALE VPR LIMIT.
6. Send **CAL:VPR MIN** to adjust the maximum negative protection limit of the power supply. Send the **CAL:DATA** commands as needed (see PAR. 4.3c) until the reading is as close as possible above the nominal full scale value within the limits specified in Table 4-2 for –FULL SCALE VPR LIMIT.
7. Connect a  $0V \pm 0.1mV$  d-c reference to pin 11 (EXT\_REF) referenced to pin 4 (SGND) of the Analog I/O Port connector (A2A5J6). Set the BOP to zero volts output by sending **CAL:VEXT ZERO**. Connect the DVM to the BOP output and send **CAL:DATA** commands as needed (see PAR. 4.3c) to adjust the BOP output until the DVM reads as close to zero as possible within tolerance specified in Table 4-2 for VOLTAGE ZERO.

NOTE: Accuracy of the 10V d-c reference must be  $\pm 0.1mV$  in order for the calibrated unit to meet published specifications.

8. Replace 0V reference at pin 11 (EXT\_REF) of the Analog I/O Port connector (A2A5J6) with a +10V d-c reference. Set the BOP to maximum positive output voltage by sending **CAL:VEXT MAX**. Measure the voltage output using the DVM. To adjust, send **CAL:DATA** commands as needed (see PAR. 4.3b) until the DVM reading is as close as possible above the nominal full scale value within the tolerance specified in Table 4-2 for +FULL SCALE VOLTAGE.
9. Replace +10V reference at pin 11 (EXT\_REF) of the Analog I/O Port connector (A2A5J6) with a  $0V \pm 0.1mV$  d-c reference. Set the BOP to zero volts output by sending **CAL:VGA ZERO**. Connect DVM to the BOP OUT S and OUT COM terminals to measure the output voltage. Send **CAL:DATA** commands as needed (see PAR. 4.3c) to adjust the BOP output until the DVM reads as close to zero as possible within tolerance specified in Table 4-2 for VOLTAGE ZERO.
10. Replace 0V reference at pin 11 (EXT\_REF) of the Analog I/O Port connector (A2A5J6) with a +10V d-c reference. Set the BOP to maximum positive output voltage by sending **CAL:VGA MAX**. Measure the output voltage using the DVM. To adjust, send **CAL:DATA** commands as needed (see PAR. 4.3b) until the DVM reading is as close to zero as possible within tolerance specified in Table 4-2 for VOLTAGE ZERO.
11. Replace +10V reference at pin 11 (EXT\_REF) of the Analog I/O Port connector (A2A5J6) with a –10V d-c reference. Set the BOP to maximum negative output voltage by sending **CAL:VGA MIN**. To adjust, send the **CAL:DATA** commands as needed (see PAR. 4.3b) until the reading is as close as close to zero as possible within tolerance specified in Table 4-2 for VOLTAGE ZERO.
12. Set the BOP to zero volts output by sending **CAL:VLIM ZERO**. Disconnect the -10V d-c reference voltage from the analog I/O port external reference pin (A2A5J6 pin 11) of the BOP, then connect  $0V \pm 0.1mV$  d-c reference voltage from the external voltage source to VLIM+ \_EXTERNAL and VLIM– \_EXTERNAL (pins 14 and 6) referenced to pin 12 (GND1) of the BOP analog I/O connector (A2A5J6), then send the **CAL:ZERO** command. This enables the BOP to recognize that the voltage at the VLIM \_EXTERNAL pins is 0V.

13. Connect  $+10.0V \pm 0.1mV$  d-c reference voltage from the external voltage source to VLIM+\_EXTERNAL and VLIM-\_EXTERNAL (pins 14 and 6) referenced to pin 12 (GND1) of the BOP analog I/O connector (A2A5J6), then send **CAL:VLIM MAX**, then **CAL:ZERO** commands. This enables the BOP to recognize that the voltage at the VLIM+\_EXTERNAL pin is 10.0V.
14. Set the BOP to minimum (maximum negative) output by sending **CAL:VLIM MIN**, then send the **CAL:ZERO** command. This enables the BOP to recognize that the voltage at the VLIM-\_EXTERNAL pin is 10.0V.
15. Connect a  $0V \pm 0.1mV$  d-c reference to pin 8 (S\_IN\_SERIAL) of the PAR/SER CONTROL IN connector (A2A5J3) referenced to COM S terminal at the rear panel. Set the BOP to zero volts output by sending **CAL:SER ZERO**. Connect the DVM to the BOP OUT S and OUT COM terminals and send **CAL:DATA** commands as needed (see PAR. 4.3b) to adjust the BOP output until the DVM reads as close to zero as possible within tolerance specified in Table 4-2 for VOLTAGE ZERO.

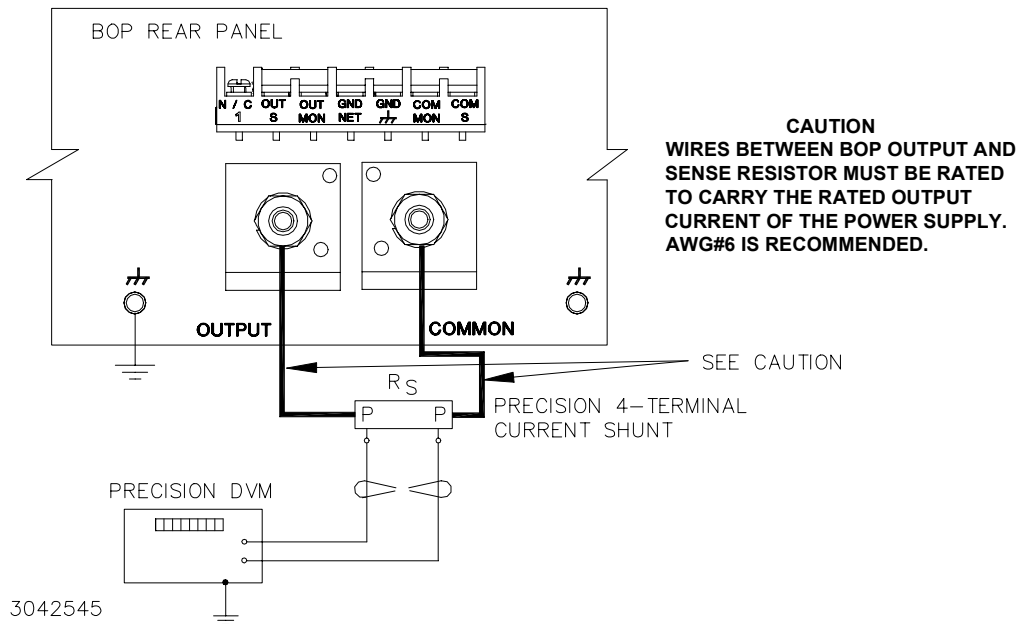
NOTE: Accuracy of the 10V d-c reference must be  $\pm 0.1mV$  in order for the calibrated unit to meet published specifications.

16. Connect a  $+10V \pm 0.1mV$  d-c reference to pin 8 (S\_IN\_SERIAL) of the PAR/SER CONTROL IN connector (A2A5J3) referenced to COM S terminal at the rear panel. Set the BOP to maximum positive output voltage by sending **CAL:SER MAX**. Measure the voltage output using the DVM. Send **CAL:DATA** commands as needed (see PAR. 4.3a) until the DVM reading is as close as possible to  $-10V$ .
17. Send **CAL:ZERO** to prepare for current calibration. After sending the command, the BOP output will be set to zero volts. Connect the Kelvin type sense resistor to the BOP output. Connect the DVM to the sensing terminals of the Kelvin type sense resistor as shown in Figure 4-2. Table 4-3 provides recommended sense resistor values for various BOP current outputs, as well as the formula for calculating expected measured values and tolerances for any sense resistor other than those recommended. Table 4-1 lists Kepco and Manufacturer part numbers for those sense resistors recommended.



**The sense resistor will be dissipating full rated current of the BOP. If it is hot to the touch, the sense resistor value, power rating and/or cooling are incorrect; refer to PAR. 4.3 and Table 4-1.**





**FIGURE 4-2. CURRENT SHUNT CONNECTIONS**

18. Set the BOP to zero volts across the sense resistor (corresponding to zero current) by sending **CAL:CURR ZERO**. Send **CAL:DATA** commands as needed (see PAR. 4.3a) until the reading is as close to zero as possible within the limits specified in Table 4-3 for CURRENT ZERO.
19. Set the BOP to maximum positive output current by sending **CAL:CURR MAX**. Measure the current by reading the voltage across the sense resistor. To adjust, send **CAL:DATA** commands as needed (see PAR. 4.3b) to adjust the BOP output until the DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-3 for +FULL SCALE CURRENT.
20. Set the BOP to maximum negative output current by sending **CAL:CURR MIN**. Continue to measure the output current of the supply using the DVM connected to the sense resistor. To adjust, send **CAL:DATA** commands as needed (see PAR. 4.3b) to adjust the BOP output until the DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-3 for -FULL SCALE CURRENT.
21. Send **CAL:CPR MAX** to adjust the maximum positive current protection limit of the power supply. To adjust, send **CAL:DATA** commands as needed (see PAR. 4.3c) to adjust the BOP output until the DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-3 for +FULL SCALE CPR LIMIT.
22. Send **CAL:CPR MIN** to adjust the minimum (maximum negative) current protection limit of the power supply. To adjust, send **CAL:DATA** commands as needed (see PAR. 4.3c) to adjust the BOP output until the DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-3 for -FULL SCALE CPR LIMIT.
23. Send **CAL:ZERO** to set the BOP output to zero. Connect  $0V \pm 0.1mV$  d-c reference voltage to external reference pin 11 referenced to pin 4 (SGND) of the BOP analog I/O port (A2A5J6). Set the BOP to zero volts across the sense resistor (corresponding to zero current) by send-

- ing **CAL:CEXT ZERO**. Send **CAL:DATA** commands as needed (see PAR. 4.3a) until the reading is as close to zero as possible within the limits specified in Table 4-3 for CURRENT ZERO.
24. Replace the 0V d-c reference applied to analog I/O port A2A5J6 pin 11 with a +10V  $\pm 0.1\text{mV}$  d-c reference voltage. Set the BOP to maximum positive output current by sending **CAL:CEXT MAX**. Measure the current by reading the voltage across the sense resistor. To adjust, send **CAL:DATA** commands as needed (see PAR. 4.3b) to adjust the BOP output until the DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-3 for +FULL SCALE CURRENT.
  25. Replace the +10V d-c reference applied to analog I/O port A2A5J6 pin 11 with a 0V  $\pm 0.1\text{mV}$  d-c reference voltage. Set the BOP to zero volts across the sense resistor (corresponding to zero current) by sending **CAL:CGA ZERO**. Send **CAL:DATA** commands as needed (see PAR. 4.3a) until the reading is as close to zero as possible within the limits specified in Table 4-3 for CURRENT ZERO.
  26. Replace the 0V d-c reference applied to analog I/O port A2A5J6 pin 11 with a +10V  $\pm 0.1\text{mV}$  d-c reference voltage. Set the BOP to maximum positive output current by sending **CAL:CGA MAX**. Measure the current by reading the voltage across the sense resistor. To adjust, send **CAL:DATA** commands as needed (see PAR. 4.3b) to adjust the BOP output until the DVM reads as close as close to zero as possible within the limits specified in Table 4-3 for CURRENT ZERO.
  27. Replace the +10V d-c reference applied to analog I/O port A2A5J6 pin 11 with a -10V  $\pm 0.1\text{mV}$  d-c reference voltage. Set the BOP to maximum negative output current by sending **CAL:CGA MIN**. Continue to measure the output of the supply using the DVM connected to the sense resistor. To adjust, send **CAL:DATA** commands as needed (see PAR. 4.3b) to adjust the BOP output until the DVM reads as close to zero as possible within the limits specified in Table 4-3 for CURRENT ZERO.
  28. Set the BOP to zero amperes output by sending **CAL:CLIM ZERO**., then connect 0V  $\pm 0.1\text{mV}$  d-c reference voltage from the external voltage source to ILIM+\_EXTERNAL and ILIM-\_EXTERNAL pins, pins 5 and 13, referenced to pin 12 (GND1) of the BOP analog I/O connector (A2A5J6). Then send the **CAL:ZERO** command. This enables the BOP to recognize that the voltage at the ILIM-\_EXTERNAL pins is 0V.
  29. Connect +10.0V  $\pm 0.1\text{mV}$  d-c reference voltage from the external voltage source to ILIM+\_EXTERNAL and ILIM-\_EXTERNAL, pins 5 and 13, referenced to pin 12 (GND1) of the BOP analog I/O connector (A2A5J6). Then send **CAL:CLIM MAX**, then **CAL:ZERO** commands. This enables the BOP to recognize that the voltage at the ILIM+\_EXTERNAL pin is 10.0V.
  30. Set the BOP to minimum (maximum negative) output by sending **CAL:VLIM MIN**, then send the **CAL:ZERO** command. This enables the BOP to recognize that the voltage at the VLIM-\_EXTERNAL pin is 10.0V.
  31. Send **CAL:ZERO** to prepare for calibration of IOUT\_M\_UNIT (master output) control signal. Connect the DVM to pin 6 (IOUT\_M\_UNIT) referenced to pin 1 (SGND) of the PAR/SER CONTROL IN connector (A2A5J3). Set the BOP to zero output current by sending **CAL:IOUT ZERO**. Send **CAL:DATA** commands as needed (see PAR. 4.3b) to adjust the BOP output until the DVM reads 0V  $\pm 1\text{mV}$ .

32. Set the BOP to maximum positive output current by sending **CAL:IOUT MAX**. With the DVM still connected to pin 6 (IOUT\_M\_UNIT) referenced to pin 1 (SGND) of the PAR/SER CONTROL IN connector measure the voltage output using the DVM. Send **CAL:DATA** commands as needed (see PAR. 4.2.1a) until the DVM reading is +10V ±1.0mV.

33. Send **CAL:ZERO** to prepare for calibration of S\_IN\_PARALLEL (slave input) control signal. Connect a 0V ±0.1mV d-c reference to pin 3 (S\_IN\_PARALLEL) referenced to pin 1 (SGND) of the PAR/SER CONTROL IN connector (A2A5J3). Set the BOP to zero output current by sending **CAL:PAR ZERO**. Connect the DVM across the sense resistor to measure the BOP output current and send **CAL:DATA** commands as needed (see PAR. 4.3b) to adjust the BOP output current until the DVM reads as close to zero as possible within tolerance specified in Table 4-3 for CURRENT ZERO.

NOTE: Accuracy of the 10V d-c reference must be ±0.1mV in order for the calibrated unit to meet published specifications.

34. Connect a +10V ±0.1mV d-c reference to pin 3 (S\_IN\_PARALLEL) referenced to pin 1 (SGND) of the PAR/SER CONTROL IN connector (A2A5J3). Set the BOP to maximum positive output current by sending **CAL:PAR MAX**. Measure the output current using the DVM. Send **CAL:DATA** commands as needed (see PAR. 4.3a) until the DVM reading is as specified in Table 4-3 for +FULL SCALE CURRENT.









35. Save the calibration levels by sending **CAL:SAVE 12/21/2003**. The characters at the end are optional and represent the calibration date of the power supply. The date entered in this manner is reported in the \*idn? query.

#### 4.4 CALIBRATION USING FRONT PANEL KEYPAD IN LOCAL MODE

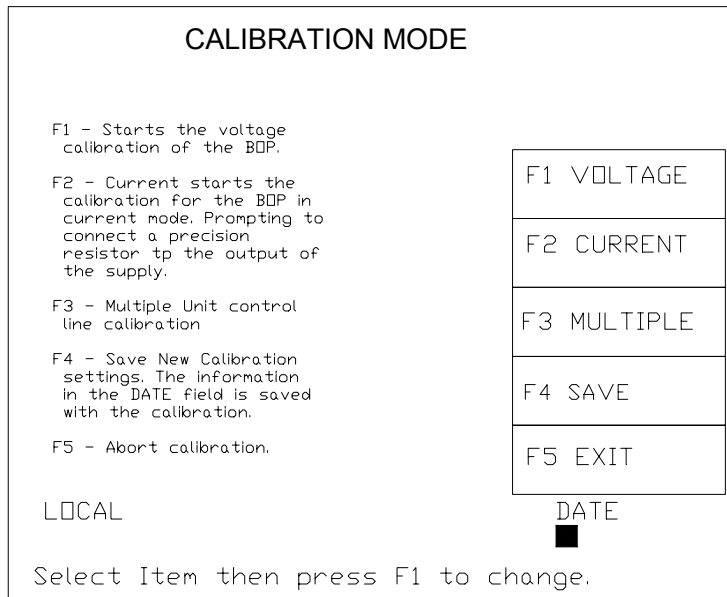
The following paragraphs describe the screens and keys used in the calibration process.

##### 4.4.1 UNDERSTANDING THE CALIBRATION PROCESS

The following steps describe the calibration screens, and associated keys active during the calibration process. Refer to PAR. 4.4.2 for full calibration procedure.

1. From the top menu, press  to enter the Protected Settings menu
2. Refer to PAR. 3.2.4.1 and enter the password, then press , then  to begin calibration. The LCD shows main calibration screen (Figure 4-30 which includes explanations for the following function keys:
  -  - VOLTAGE - Selects the voltage calibration of the BOP. This places the unit in voltage mode with the voltage at zero output.
  -  - CURRENT - Starts the calibration for the BOP in current mode.
  -  - MULTIPLE - Selects multiple unit control signal calibration.
  -  - SAVE - Save New Calibration Setting. The information in the DATE field is saved with the Calibration.
  -  or **ENTER** - EXIT

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**FIGURE 4-3. MAIN CALIBRATION SCREEN**














3. Press either or to initiate Voltage or Current calibration, respectively. To calibrate multiple units refer to the Instruction Manual Included with the associated parallel or series connection cable kit. The LCD shows the explanations for the following function keys:
  - - INTERNAL - Selects the voltage calibration of the BOP.
  - - GAIN - Starts the calibration of the external gain mode of the power supply.
  - - EXTERNAL - Starts the external reference calibration.
  - - PROTECT - Starts the protection limits calibration of the power supply.
  - or **ENTER** - EXIT - Exit Voltage or Current Calibration
4. Pressing , , , or displays following explanations for the function keys:

**CAUTION: IF THE CALIBRATE ZERO FUNCTION IS AVAILABLE, PERFORM THIS FUNCTION FIRST, AS IT AFFECTS ALL OTHER OUTPUT CALIBRATIONS.**

- - Calibrate the Zero adjustment for this operational mode. IF THIS FUNCTION IS AVAILABLE, PERFORM THIS FUNCTION FIRST, AS IT AFFECTS ALL OTHER OUTPUT calibrations.
- - Adjust the MAXIMUM (Positive) OUTPUT of the supply.
- - Adjusts the MINIMUM (Negative) OUTPUT of the Supply
- - PROTECT - Adjusts External Protection limits. (Active for EXTERNAL screen only.)
- or **ENTER** to exit this menu.

5. Selecting one of the above options begins calibrating the output. The screen describes the function of the active keys:
  -  - Adjust the output by approximately 100 increments in the positive direction.
  -  - or clockwise rotation of the **ADJUST** control adjusts the output by 10 increments in the positive direction.
  -  - or counterclockwise rotation of the **ADJUST** control adjusts the output by 10 increments in the negative direction.
  -  - Exits the active calibration and allows you to select other calibrations that are required.
  -  - or clockwise rotation of the depressed **ADJUST** control increments the output D to A by 1 causing the output to increase.
  -  - or counterclockwise rotation of the depressed **ADJUST** control decrements the output D to A by 1 causing the output to decrease.
  -  through  - Number keys allow for quick setting of the output to the bottom of the range () to top of the range(.

#### 4.4.2 CALIBRATION PROCEDURE USING LOCAL MODE


- NOTES:
1. For ZERO calibration, adjust output to obtain value closest to zero.
  2. For FULL SCALE calibration adjust the output to obtain the closest value above the nominal full scale value.
  3. Set the unit for local sensing with GND Network in (see Figure 4-1) and disconnect load from BOP output.
  4. When adjustment is needed refer to PAR. 4.4.1, step 5.
1. From the top menu, press  to enter the Protected Settings menu. Refer to PAR. 3.2.4.1 and enter the password, then press , then  to begin calibration.
  2. Press  - VOLTAGE,  - INTERNAL,  - ZERO to set the BOP to zero volts output. Connect a Digital Voltmeter (DVM) to the BOP OUT S and OUT COM terminals to measure the output voltage. Adjust the BOP output as needed until the DVM reads as close to zero as possible within tolerance specified in Table 4-2 for VOLTAGE ZERO.
  3. Press ,  - MAXIMUM. Measure the voltage output using the DVM. Adjust as needed until the DVM reading is as close as possible above the nominal full scale value within the tolerance specified in Table 4-2 for +FULL SCALE VOLTAGE.
  4. Press ,  - MINIMUM to set the BOP to maximum negative output voltage and adjust as needed until the reading is as close as possible above the nominal full scale value within the limits specified in Table 4-2 for -FULL SCALE VOLTAGE.
  5. Press  twice, then  - PROTECT,  - MAXIMUM to adjust the maximum positive voltage protection limit of the power supply. Adjust as needed until the reading is as close as


possible above the nominal full scale value within the limits specified in Table 4-2 for +FULL SCALE VPR LIMIT.

6. Press **F5**, **F3** - MINIMUM to adjust the maximum negative protection limit of the power supply. Adjust as needed until the reading is as close as possible above the nominal full scale value within the limits specified in Table 4-2 for –FULL SCALE VPR LIMIT.
7. Press **F5** three times, **F3** - EXTRL CONTROLS, **F4** - EXTERN PROTECT, **F1** - ZERO to set the BOP to zero volts output. Connect 0V  $\pm$ 0.1mV d-c reference voltage from the external voltage source to the following pins of analog I/O connector (A2A5J6) referenced to pin 12 (GND1): VLIM+\_EXTERNAL (pin 14), VLIM-\_EXTERNAL (pin 6), ILIM+\_EXTERNAL (pin 13), ILIM-\_EXTERNAL (pin 5). Then press **F5**. This enables the BOP to recognize that the voltage at the four \_EXTERNAL pins (14, 6, 13, and 5) is 0V.

NOTE: Accuracy of the 10V d-c reference must be  $\pm$ 0.1mV in order for the calibrated unit to meet published specifications.



















8. Replace 0V  $\pm$ 0.1mV d-c reference voltage at pins 14, 6, 13, and 5 with +10.0V  $\pm$ 0.1mV d-c reference voltage from the external voltage source referenced to pin 12 (GND1) of the analog I/O connector (A2A5J6), then press **F2** - MAXIMUM. Then press **F5**. This enables the BOP to recognize that the voltage at the four \_EXTERNAL pins (14, 6, 13, and 5) is 10.0V.
9. Press **F5** three times to set the BOP output to zero. Disconnect +10.0V d-c reference voltage from pins 14, 6, 13 and 6 of analog I/O connector (A2A5J6). Connect a +0V  $\pm$ 0.1mV d-c reference voltage to EXT\_REF, pin 11, referenced to pin 12 (GND1), of the BOP analog I/O port (A2A5J6).
10. Press **F5** twice, **F3** - EXTERNAL, **F1** - ZERO to set the BOP to zero volts output. Adjust as needed until the DVM reads as close to zero as possible within the limits specified in Table 4-3 for VOLTAGE ZERO.
11. Press **F5** twice, **F2** - GAIN, **F1** - ZERO to set the BOP to zero volts output. Adjust as needed until the DVM reads as close to zero as possible within the limits specified in Table 4-3 for VOLTAGE ZERO.
12. Connect +10.0V  $\pm$ 0.1mV d-c reference voltage from the external voltage source to EXT\_REF, pin 11, referenced to pin 4 (SGND) of Analog I/O Port connector (A2A5J6), Press **F5** twice, **F2** - GAIN, **F2** - MAXIMUM to set the BOP to maximum positive output voltage. Adjust as needed until the DVM reads as close to zero as possible within the limits specified in Table 4-2 for VOLTAGE ZERO.
13. Press **F5** twice, **F3** - EXTERNAL, **F2** - MAXIMUM. Adjust as needed until the DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-2 for +FULL SCALE VOLTAGE.
14. Connect a 0V  $\pm$ 0.1mV d-c reference to pin 8 (S\_IN\_SERIAL) of the PAR/SER CONTROL IN connector (A2A5J3) referenced to COM S terminal at rear panel. Press **F2** - SERIES, and **F1** - ZERO to set the BOP output to zero volts. Connect DVM to OUT S and OUT COM terminals of BOP and adjust as needed until DVM reads within tolerance specified in Table 4-2 for VOLTAGE ZERO. Press **F5** - EXIT when done.
15. Connect a +10.0V  $\pm$ 0.1mV d-c reference to pin 8 (S\_IN\_SERIAL) of the PAR/SER CONTROL IN connector (A2A5J3) referenced to COM S terminal at rear panel. Press **F2** - POS-

ITIVE to set the BOP to maximum output. With DVM still connected to BOP output, adjust as needed until DVM reads as close as possible to  $-10V$ . Press  - EXIT when done.

16. Press  to set the BOP output to zero volts. Connect the Kelvin type sense resistor to the BOP (see Figure 4-2). Connect the DVM to the sensing terminals of the Kelvin type sense resistor. Table 4-3 provides recommended sense resistor values for various BOP current outputs, as well as the formula for calculating expected measured values and tolerances for any sense resistor other than those recommended. Table 4-1 lists Kepeco and Manufacturer part numbers for those sense resistors recommended.



**The sense resistor will be dissipating full rated current of the BOP. If it is hot to the touch, the sense resistor value, power rating and/or cooling are incorrect; refer to PAR. 4.4 and Table 4-1.**

17. Press  - CURRENT,  - ZERO to set the BOP to zero volts across the sense resistor (corresponding to zero current). Adjust as needed until the reading is as close to zero as possible within the limits specified in Table 4-3 for CURRENT ZERO.
18. Press  ,  - MAXIMUM to set the BOP to maximum positive output current. Measure the current by reading the voltage across the sense resistor. Adjust as needed until the DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-3 for +FULL SCALE CURRENT.
19. Press  ,  - MINIMUM to set the BOP to maximum negative output current. Continue to measure the output current of the supply using the DVM connected to the sense resistor. Adjust as needed until the DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-3 for -FULL SCALE CURRENT.
20. Press  twice,  - PROTECT,  - MAXIMUM to set to adjust the maximum positive current protection limit of the power supply. Adjust as needed until the DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-3 for +FULL SCALE CPR LIMIT.
21. Press  ,  - MINIMUM to adjust the minimum (maximum negative) current protection limit of the power supply. Adjust as needed until the DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-3 for -FULL SCALE CPR LIMIT.
22. Press  three times to set the BOP output to zero. Connect a  $+0V \pm 0.1mV$  d-c reference voltage to external reference, A2A5J6 pin 11, referenced to pin 12 (GND1) of the BOP analog I/O port.
23. Press  twice,  - EXTERNAL,  - ZERO to set the BOP to zero volts across the sense resistor (corresponding to zero current). Adjust as needed until the DVM reads as close to zero as possible within the limits specified in Table 4-3 for CURRENT ZERO.
24. Press  twice,  - GAIN,  - ZERO to set the BOP to zero volts across the sense resistor (corresponding to zero current). Adjust as needed until the DVM reads as close to zero as possible within the limits specified in Table 4-3 for CURRENT ZERO.

25. Connect +10.0V  $\pm$ 0.1mV d-c reference voltage from the external voltage source to External reference, pin 11, referenced to pin 4 (SGND) of the BOP Analog I/O Port connector (A2A5J6), Press **F5** twice, **F2** - GAIN, **F2** - MAXIMUM to set the BOP to maximum positive output current. Measure the current by reading the voltage across the sense resistor. Adjust as needed until the DVM reads as close to zero as possible within the limits specified in Table 4-3 for CURRENT ZERO.
  26. Press **F5** twice, **F3** - EXTERNAL, **F2** - MAXIMUM. Measure the current by reading the voltage across the sense resistor. Adjust as needed until the DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-3 for +FULL SCALE CURRENT.
  27. Connect the DVM to pin 6 (IOUT\_M\_UNIT) referenced to pin 1 (SGND) of the PAR/SER CONTROL IN connector (A2A5J3). Press **F5** three times, **F3** - EXTRN CONTROLS, **F1** - IOUT, and **F1** - ZERO to set the BOP output current to zero. Adjust as needed until DVM reads 0V  $\pm$ 1mV d-c.
  28. Press **F5** - EXIT, **F2** - POSITIVE. With DVM still connected to pin 6 (IOUT\_M\_UNIT) referenced to pin 1 (SGND) of the PAR/SER CONTROL IN connector, adjust as needed until DVM reads +10V  $\pm$ 1mV d-c. Press **F5** - EXIT when done.
  29. Connect a 0V  $\pm$ 0.1mV reference to pin 3 (S\_IN\_PARALLEL) referenced to pin 1 (SGND) of the PAR/SER CONTROL IN connector (A2A5J3). Press **F2** - PARALLEL, and **F1** - ZERO to set the BOP output current to zero. Adjust as needed until DVM reads as close to zero as possible within tolerance specified in Table 4-3 for CURRENT ZERO. Press **F5** - EXIT when done.
- NOTE: Accuracy of the 10V d-c reference must be  $\pm$ 0.1mV d-c in order for the calibrated unit to meet published specifications.
30. Connect a 10.0V  $\pm$ 0.1mV d-c reference to pin 3 (S\_IN\_PARALLEL) of the PAR/SER CONTROL IN connector (A2A5J3). Press **F2** - POSITIVE to set the BOP to maximum output current. Adjust as needed until DVM reads as close as possible above the nominal full scale value within tolerance specified in Table 4-3 for +FULL SCALE CURRENT. Press **F5** - EXIT when done.
  31. Save the calibration levels by first using the **ADJUST** control to enter data such as the calibration date, e.g., 12/21/2003 in the ASCII area of the display. The date entered in this manner is reported in the \*idn? query. Then press **F4** - SAVE.

#### 4.4.3 CALIBRATION USING VISA DRIVER SOFT PANEL

Refer to help text included with VISA Driver. Calibration of series-connected or parallel-connected configurations is not supported by the demonstration program supplied with the VISA Driver soft panel, stand-alone calibrations may be performed using the VISA driver soft panel.



## APPENDIX A - SCPI COMMON COMMAND/QUERY DEFINITIONS

### A.1 INTRODUCTION

This appendix defines the SCPI common commands and queries used with the BOP power supply. Common commands and queries are preceded by an asterisk (\*) and are defined and explained in paragraphs A.2 through A.18, arranged in alphabetical order. Table A-1 provides a quick reference of all SCPI common commands and queries used in the Interface Card.

**TABLE A-1. IEEE 488.2 COMMAND/QUERY INDEX**

COMMAND	PAR.	COMMAND	PAR.
*CLS	A.2	*RST	A.11
*ESE, ?	A.3, A.4	*SAV	A.12
*ESR?	A.5	*SRE, ?	A.13, A.14
*IDN?	A.6	*STB?	A.15
*OPC, ?	A.7, A.8	*TRG	A.16
*OPT?	A.9	*TST?	A.17
*RCL	A.10	*WAI	A.18

### A.2 \*CLS — CLEAR STATUS COMMAND

**\*CLS**

Syntax: \*CLS

Description: **Clears status data.** Clears the error queue of the instrument. Forces power supply to “operation complete idle” and “operation complete query” state. Clears all Event Registers summarized in Status Byte Register without affecting the corresponding Enable Registers: Standard Event Status Register (ESR), Operation Status Event Register, Questionable Status Event Register, and Status Byte Register (STB). 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	NU	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

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

## \*ESE?

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

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.)

## \*ESR?

### A.5 \*ESR? — EVENT STATUS REGISTER QUERY

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

Description: **Causes the power supply to return the contents of the Standard Event Status register. After it has been read, the register is cleared.** 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.124)

- Any 1xx type error sets the Command error bit (5) see.
- Any 2xx type error sets the Execution error bit (4).
- Any 3xx type error sets the Device error bit (3). The Device error bit will be set when Current Error or Voltage Error is detected and the corresponding Status Questionable bit is set (see PAR. B.28).
- Any 4xx type error sets the Query error bit (2).

Related Commands: \*CLS, \*ESE, \*OPC. (See example, Figure A-1.)

## \*IDN?

### A.6 \*IDN? — IDENTIFICATION QUERY

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>, <Serial Number>, <Main revision>-<Flash revision> where: <Manufacturer> = KEPCO, <Model> = BOP 1000W, <Serial Number> = SSSSSS <date> = (see CAL:SAVE DATE, PAR. B.12) <Main revision>=n.m, e.g, 1.0) > (See example, Figure A-1.)

## \*OPC

### A.7 \*OPC — OPERATION COMPLETE COMMAND

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.)

# \*OPC?

## A.8 \*OPC? — OPERATION COMPLETE QUERY

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.)

*CLS	Power supply clears status data.
*ESE 60	Power supply enables bits 5, 4, 3 and 2, allowing command error, execution error, device dependent error and query error to set the Event Status Summary bit when an STB command is executed.
*ESE?	Returns 60, (value of the mask) verifying that bits 5, 4, 3 and 2 are enabled.
*ES	Unknown command will set command error (Bit 5).
*ESR?	Returns 32 (bit 5 set), indicating Command Error has occurred since the last time the register was read.
*IDN?	Power supply returns: KEPCO, BOP 1000W 36-28 123456 1.43
*OPC	Allows status bit 0 to be set when pending operations complete
VOLT 21;CURR 3	Sets output voltage to 21V, output current to 3A
*ESR	Returns 129 (128 + 1, power on, bit 7 = 1, operation complete, bit 1 = 1)
*ESR	Returns 0 (event status register cleared by prior *ESR?)
VOLT 15;CURR 5;*OPC?	Sets output voltage to 15V, output current to 5A, puts "1" on output bus when command operations are complete.
*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 25	Power supply voltage commanded to 25V.
VOLT:TRIG 12	Programs power supply voltage to 12V when *TRG received.
INIT	Trigger event is initialized.
*TRG	Power supply reverts to commanded output voltage of 12V. ** LOAD DISCONNECTED
*TST?	Power supply executes self test and responds with 0 if test completed successfully, with 1 if test failed.

FIGURE A-1. GPIB COMMANDS

# \*OPT?

## A.9 \*OPT? — OPTIONS QUERY

Syntax: \*OPT?  
Returns string determined by power supply model.

Description: **Causes the power supply to return an ASCII string which defines the functionality of the power supply.** The functionality is defined as follows:

STRING DATA	MEANING
CAL	Support for CALibrate is present.
RL1	Commands sent over GPIB cause unit to enter remote mode.
MEM	Indicates the number of memory steps supported.(200)
LST	Indicates the number of LIST steps supported (2000).

# \*RCL

## A.10 \*RCL — RECALL COMMAND

Syntax: \*RCL <integer> (1 to 99)

Description: **Restores power supply to previously defined levels of output voltage, output current and triggers.** This command selects one of the 99 power supply memory locations, each of which stores values for output current, and output voltage and trigger levels. Executing a \*RCL recalls the previously defined trigger settings from memory and places them in the trigger control section of the BOP. Executing a second \*RCL will cause the values in the trigger control section to be moved to the BOP output channel, allowing the power supply to operate with the recalled trigger information. The following parameters are affected by \*RCL: VOLT:TRIG, CURR:TRIG, and FUNC:MODE:TRIG.

# \*RST

## A.11 \*RST — RESET COMMAND

Syntax: \*RST

Description: **Resets power supply to the power on default state.** The power supply output set to off and the power supply is programmed to the power on values of the following parameters: CURR[:LEV][:IMM] = 0, VOLT[:LEV][:IMM] = 0, MODE = VOLT. If the power supply is in either an overvoltage or overcurrent state, this condition is reset by \*RST. After sending \*RST it is necessary to send OUTPUT on for programmed values to appear at the output. The \*RST command always returns the mode to Voltage and the range to automatic.(See example, Figure A-1.)

# \*SAV

## A.12 \*SAV — SAVE COMMAND

Syntax: \*SAV <integer> (1 to 99)

Description: **Saves the present state of output voltage, output current and trigger values, to the specified memory location.** This command stores the present state of the power supply to one of 99 memory locations in Flash Memory (see PAR. 3.8.3.7), including the state of Keyboard lockout (see PAR. B.127) Executing \*SAV with SYST:KEYB set to DIS (disabled) prevents that location from being changed using the front panel The following parameters are stored by \*SAV: VOLT:TRIG, CURR:TRIG, FUNC:MODE:TRIG, and SYST:KEYB. The stored values can be restored by the \*RCL command. See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

# \*SRE

## A.13 \*SRE — SERVICE REQUEST ENABLE COMMAND

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.124)  
NU      (Not Used)

**A.14 \*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.15 \*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.16 \*TRG — TRIGGER COMMAND**

**\*TRG**

Syntax:      \*TRG

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

# \*TST?

## A.17 \*TST? — SELF TEST QUERY

Syntax: \*WAI                      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 0 is returned if the unit passes the test. If the unit fails, a number from 1 through 1023 is returned to indicate the cause of the error. The test executes each of the subtests even when any one fails. If any test fails an error code bit is set which is returned to the user. The error codes returned are listed in Table A-4

**TABLE A-4. BUILT-IN TEST ERROR CODES**

TEST ACTIVE		ERROR CODES		MEANING
*tst?	DIAG:TST?	BIT	VALUE	
Yes	Yes		0	Pass (No error)
Yes	Yes	0	1	ROM error
Yes	Yes	1	2	RAM error
Yes	Yes	2	4	FLASH error -- Perform calibration to correct
Yes	Yes	3	8	Optical Buffer Error'
Yes	Yes	4	16	Digital Pot error
No	Yes	5	32	Loop Back Test error
No	Yes	6	64	Max Voltage Output error
No	Yes	7	128	Min Voltage Output error

## A.18 \*WAI — WAIT-TO-CONTINUE COMMAND

# \*WAI

Syntax: \*WAI                      Response:

Description: **Causes the power supply to wait until all previously issued commands and queries are complete before executing subsequent commands or queries.** This command can be used to guarantee sequential execution of commands and queries. When all pending operations are complete (all previous commands have been executed, changes in output level have been completed), the WAI command is completed and execution of subsequent commands can continue.

## APPENDIX B - SCPI COMMAND/QUERY DEFINITIONS

### B.1 INTRODUCTION

This appendix defines the SCPI subsystem commands and queries used with the BOP power supply. Subsystem commands are defined in PAR. B.3 through B.136, arranged in groups as they appear in the tree diagram, Figure 3-9. Table B-1 provides a quick reference of all SCPI subsystem commands and queries used in the BOP.

**TABLE B-1. SCPI SUBSYSTEM COMMAND/QUERY INDEX**

COMMAND	PAR.	COMMAND	PAR.
CAL:[STAT], ?	B.3, B.4	[SOUR:]FUNC:MODE:TRIG, ?	B.44, B.45
CAL:CEXT	B.5	[SOUR:]LIST:CLE	B.46
CAL:CGA	B.6	[SOUR:]LIST:COUN, ?	B.47, B.48
CAL:CLIM	B.7	[SOUR:]LIST:COUN:SKIP, ?	B.49, B.50
CAL:CPR	B.8	[SOUR:]LIST:CURR, ?	B.51, B.52
CAL:CURR	B.9	[SOUR:]LIST:POIN?	B.53
CAL:DATA	B.10	[SOUR:]LIST:DIR, ?	B.54, B.55
CAL:DPOT	B.11	[SOUR:]LIST:DWEL, ?	B.56, B.57
CAL:SAVE	B.12	[SOUR:]LIST:DWEL:POIN?	B.58
CAL:VEXT	B.13	[SOUR:]LIST:QUER, ?	B.59, B.60
CAL:VOLT	B.14	[SOUR:]LIST:VOLT, ?	B.61, B.62
CAL:VGA	B.15	[SOUR:]LIST:VOLT:POIN?	B.63
CAL:VLIM	B.16	[SOUR:]CURR, ?	B.64, B.65
CAL:VPR	B.17	[SOUR:]CURR:LIM[:BOTH], ?	B.66, B.67
CAL:ZERO	B.18	[SOUR:]CURR:LIM:NEG	B.68
DISP:COL, ?	B.19, B.20	[SOUR:]CURR:LIM:POS	B.69
DISP:CONT, ?	B.21, B.22	[SOUR:]CURR:MODE, ?	B.70, B.71
DISP:LLE ?	B.23, B.24	[SOUR:]CURR:PROT[:BOTH], ?	B.72, B.73
DISP:TEXT, ?	B.25, B.26	[SOUR:]CURR:PROT:NEG	B.74
DISP:URIG, ?	B.27, B.28	[SOUR:]CURR:PROT:POS	B.75
INIT[:IMM]	B.29	[SOUR:]CURR:PROT:LIM[:BOTH], ?	B.76, B.77
INIT:CONT, ?	B.30, B.31	[SOUR:]CURR:PROT:LIM:NEG	B.78
MEAS:CURR?	B.32	[SOUR:]CURR:PROT:LIM:POS	B.79
MEAS:VOLT?	B.33	[SOUR:]CURR:TRIG?	B.80, B.81
MEM:PACK, ?	B.34, B.35	[SOUR:]VOLT	B.82, B.83
MEM:REL	B.36	[SOUR:]VOLT:LIM[:BOTH], ?	B.84, B.85
MEM:UPD	B.37	[SOUR:]VOLT:LIM:NEG	B.86
OUTP[:STAT], ?	B.38, B.39	[SOUR:]VOLT:LIM:POS	B.87
OUTP:MODE, ?	B.40, B.41	[SOUR:]VOLT:MODE, ?	B.88, B.89
[SOUR:]FUNC:MODE, ?	B.42, B.43	[SOUR:]VOLT:PROT[:BOTH], ?	B.90, B.91

NOTE: Commands listed above that are followed by ", ?" have a related query.

**TABLE B-1. SCPI SUBSYSTEM COMMAND/QUERY INDEX (CONTINUED)**

COMMAND	PAR.	COMMAND	PAR.
[SOUR:]VOLT:PROT:NEG	B.92	SYST:COMM:SER:BAUD, ?	B.114, B.115
[SOUR:]VOLT:PROT:POS	B.93	SYST:COMM:SER:ECHO, ?	B.116, B.117
[SOUR:]VOLT:PROT:LIM:[BOTH], ?	B.94, B.95	SYST:COMM:SER:PACE, ?	B.118, B.119
[SOUR:]VOLT:PROT:LIM:NEG	B.96	SYST:COMM:SER:PROM, ?	B.120, B.121
[SOUR:]VOLT:PROT:LIM:POS	B.97	SYST:ERR?	B.122
[SOUR:]VOLT:TRIG	B.98, B.99	SYST:ERR:CODE?	B.123, B.124
STAT:OPER:COND?	B.100	SYST:KEYB	B.125
STAT:OPER:ENAB, ?	B.101, B.102	SYST:LANG	B.126
STAT:OPER:[EVEN]?	B.103	SYST:PASS:CEN	B.127
STAT:PRES	B.104	SYST:PASS:CDIS	B.128
STAT:QUES:[EVEN]?	B.105	SYST:PASS:NEW	B.129
STAT:QUES:COND?	B.106	SYST:PASS:STAT	B.130
STAT:QUES:ENAB, ?	B.107, B.108	SYST:REM, ?	B.131, B.132
SYST:DISP:BACK	B.109	SYST:SEC	B.133
SYST:DISP:CONT	B.110	SYST:SET, ?	B.134, B.135
SYST:BEEP	B.111	SYST:VERS?	B.136
SYST:COMM:GPIB:ADDR, ?	B.112, B.113	TRIG:SOUR	B.137

NOTE: Commands listed above that are followed by “, ?” have a related query.

## B.2 NUMERICAL VALUES

The SCPI data parser on the BOP supports a maximum of 8 digits after the decimal point and a maximum integer of  $4 \times 10^8$ . 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 BOP 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 BOP. 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 CALibrate:STATe COMMAND

## CAL:STAT

Syntax: Short Form: CAL:STAT <boolean>  
 Long Form: CALibrate:STATe <boolean>  
 where boolean = 0 or OFF, 1 or ON

Description: **Sets the power supply to Calibrate state.** <boolean> 1 or ON causes power supply to enter Calibrate state. <boolean> 0 or OFF causes power supply to exit Calibrate state. If the wrong password was used, or the password was not enabled, error message -224 is posted to the queue. **Related Commands:** CAL:STAT, CAL:VOLT, CAL:CURR, CAL:ZERO, CAL:DATA, CAL:DPOT, CAL:SAVE. (See example, Figure B-1.)

## B.4 CALibrate[:]STATus]? QUERY

## CAL[:]STAT]?

Syntax: Short Form: CAL:STAT? Long Form: CALibrate:STATus?  
**Return Value:** <DATA>

where DATA = ZERO-ZERO, VOLTAGE-ZERO, VOLTAGE-MAX, VOLTAGE-MIN, VEXTERNAL-ZERO, VEXTERNAL-MAX, VEXTERNAL-MIN, VGAIN-ZERO, VGAIN-MAX, VGAIN-MIN, VLIMIT-ZERO, VLIMIT-MAX, VLIMIT-MIN, VPROTECT-ZERO, VPROTECT-MAX, VPROTECT-MIN, LVGAIN-ZERO, LVGAIN-MAX, LVGAIN-MIN, LVOLTAGE-ZERO, LVOLTAGE-MAX, LVOLTAGE-MIN, CURRENT-ZERO, CURRENT-MAX, CURRENT-MIN, CEXTERNAL-ZERO, CEXTERNAL-MAX,



CEXTERNAL-MIN, CGAIN-ZERO, CGAIN-MAX, CGAIN-MIN, CLIMIT-ZERO, CLIMIT-MAX, CLIMIT-MIN, CPROTECT-ZERO, CPROTECT-MAX, CPROTECT-MIN, CVGAIN-ZERO, CVGAIN-MAX, LCGAIN-MIN, LCURRENT-ZERO, LCURRENT-MAX, LCURRENT-MIN, DISABLED or ENABLED.

Description: **Identifies whether the power supply is in Calibrate status and indicates which calibration step is active Returns the long form of the calibration command being executed followed by the output condition (maximum, minimum or zero).** OFF indicates power supply is not in Calibrate state. ZERO-ZERO indicates power supply is at 0V, 0A, waiting for connection of load resistor. The following explanations are for typical return values: VOLTAGE-ZERO indicates full scale zero offset voltage adjustment is active. VOLTAGE-MAXIMUM indicates full scale maximum (positive) voltage adjustment is active. VOLTAGE-MINIMUM indicates full scale minimum (negative) voltage adjustment is active. CURRENT-ZERO indicates full scale zero offset current adjustment is active. CURRENT-MAXIMUM indicates full scale maximum (positive) current adjustment is active. CURRENT-MINIMUM indicates full scale minimum (negative) current adjustment is active. **Related Commands:** CAL:STAT, CAL:VOLT, CAL:CURR, CAL:ZERO, CAL:DATA, CAL:DPOT, CAL:SAVE, CAL:VGA, CAL:VEXT, CAL:VLIM, CAL:VPR, CAL:LVG, CAL:LVOLT, CAL:CGA, CAL:CEXT, CAL:CLIM, CAL:CPR, CAL:CVG, CAL:LCURR. (See example, Figure B-1.)

## B.5 CALibrate:CEXTernal COMMAND

## CAL:CEXT

Syntax: Short Form: CAL:CEXT {MAX | ZERO}  
Long Form: CALibrate:CEXTernal {MAX | ZERO}

Description: **Selects External Reference full scale current calibration, only effective with power supply in Calibrate status.** CAL:CEXT MAX selects maximum positive external reference full scale current calibration. CAL:CEXT ZERO selects external zero reference current calibration. **Related Commands:** CAL:DATA, CAL:DPOT, CAL:ZERO. (See example, Figure B-1.)

SYST:PASS:CEN 1234	If password set to 1234, enables commands requiring password.
CAL:STAT 1	Power supply enters Calibrate status.
CAL:STAT?	Returns ZERO-ZERO indicating power supply in Calibrate status.
CAL:VOLT ZERO	Voltage Zero Calibration selected.
CAL:VOLT MAX	Voltage positive Calibration selected.
CAL:DPOT 1	Output voltage increased by 63 LSB.
CAL:VOLT MIN	Voltage negative Calibration selected.
CAL:DATA -2	Output voltage decreased by 2 LSBs.
CAL:ZERO	Output voltage and current set to zero.
---	* User connects shunt and connects DVM to output.
CAL:CURR ZERO	Current Zero Calibration selected.
CAL:DATA -10	Output current decreased by 10 LSB.
CAL:CURR MIN	Current negative Calibration selected.
CAL:DATA 10	Output current increased by 10 LSB.
CAL:CURR MAX	Current positive Calibration selected.
CAL:DATA -1	Output current decreased by 1 LSB.
CAL:SAVE	Calibration values saved.
CAL:STAT?	Returns DISABLED indicating power supply not in Calibrate status
---	* User disconnects shunt and DVM.

FIGURE B-1. USING CALIBRATION COMMANDS AND QUERIES

## B.6 CALibrate:CGAin COMMAND

## CAL:CGA

Syntax: Short Form: CAL:CGA {MIN | MAX | ZERO}  
Long Form: CALibrate:CGAin {MIN | MAX | ZERO}

Description: **Selects External Reference full scale current calibration, only effective with power supply in Calibrate status.** CAL:CGA MAX selects maximum positive external reference current calibration. CAL:CGA MIN selects maximum negative external reference current calibration. **Related Commands:** CAL:STAT, CAL:VOLT, CAL:CURR, CAL:ZERO, CAL:DATA, CAL:DPOT, CAL:SAVE. (See example, Figure B-1.)

## B.7 CALibrate:CLIMit COMMAND

## CAL:CLIM

Syntax: Short Form: CAL:CLIM {MIN | MAX}  
Long Form: CALibrate:CLIMit {MIN | MAX}

Description: **Selects External Reference Current Protection Limit calibration, only effective with power supply in Calibrate status.** CAL:CLIM MAX selects maximum positive external reference current protection limit calibration. CAL:CLIM MIN selects maximum negative external reference current protection limit calibration. **Related Commands:** CAL:STAT, CAL:ZERO, CAL:DATA, CAL:DPOT, CAL:SAVE. (See example, Figure B-1.)

## B.8 CALibrate:CPRotect COMMAND

## CAL:CPR

Syntax: Short Form: CAL:CPR {MIN | MAX}  
Long Form: CALibrate:CPRotect {MIN | MAX}

Description: **Selects Current Protection limit calibration, only effective with power supply in Calibrate status.** CAL:CPR MAX selects maximum positive current protection limit calibration. CAL:CPR MIN selects maximum negative current protection limit calibration. **Related Commands:** CAL:STAT, CAL:ZERO, CAL:DATA, CAL:SAVE. (See example, Figure B-1.)

## B.9 CALibrate:CURREnt COMMAND

## CAL:CURR

Syntax: Short Form: CAL:CURR {MIN | MAX}  
Long Form: CALibrate:CURREnt {MIN | MAX}

Description: **Selects Current calibration, only effective with power supply in Calibrate status.** CAL:CURR MIN selects Current Full Scale Negative Calibration. CAL:CURR MAX selects Current Full Scale Positive Calibration. Normally Current Zero is done first, then Current Full Scale Positive Calibration. **Related Commands:** CAL:STAT, CAL:ZERO, CAL:DATA, CAL:DPOT, CAL:SAVE. (See example, Figure B-1.)

## B.10 CALibrate:DATA COMMAND

## CAL:DATA

Syntax: Short Form: CAL:DATA {N} Long Form: CALibrate:DATA {N}  
N = integer

Description: **Provides fine adjustment of output during calibration only; Increases or decreases output by N LSB's.** CAL:CURR -N decreases output by N LSBs. CAL:CURR N increases output by N LSBs. This command is used during calibration to adjust the output for zero calibration as well as full scale calibration. This command is only effective if Calibration status is active. **Related Commands:** CAL:STAT, CAL:VOLT, CAL:LVOLT, CAL:LCURR, CAL:CEXT, CAL:CGA, CAL:CLIM, CAL:CPR, CAL:LCG, CAL:LCURR, CAL:LVG, CAL:VEXT, CAL:VGA, CAL:VLIM, CAL:VPR, CAL:CURR, CAL:DPOT. (See example, Figure B-1.)

## B.11 CALibrate:DPOT COMMAND

## CAL:DPOT

Syntax: Short Form: CAL:DPOT {N} Long Form: CALibrate:DPOT {N}  
N = integer

Description: **Provides coarse adjustment of the output during calibration to within 5% of maximum and 2% of nominal; increases or decreases output by 50 LSB increments.** Acceptable values of N are within  $\pm 32$ , corresponding to  $\pm 1600$  ( $50 \times 32$ ) LSB's. CAL:DPOT -N decreases output voltage by N LSBs. CAL:VOLT N increases output voltage by N LSBs. This command is used during calibration to adjust the output for Zero calibration as well as Full Scale Positive calibration. Output voltage is monitored on a calibrated digital multimeter and increased or decreased as required using this command. Output current is monitored on a calibrated digital multimeter (reading voltage at the sense terminals of the shunt resistor) and increased or decreased as required using this command. This command is only effective if Calibration status and either Voltage Zero, Voltage Maximum, Current Zero or Current Maximum calibration are active. CAL:STAT, CAL:VOLT, CAL:LVOL, CAL:VOLT, CAL:CURR, CAL:CGA, CAL:CLIM, CAL:CPR, CAL:LCG, CAL:LCURR, CAL:LVG, CAL:VGA, CAL:VLIM, CAL:VPR. (See example, Figure B-1.)

## B.12 CALibrate:SAVE COMMAND

## CAL:SAVE

Syntax: Short Form: CAL:SAVE Long Form: CALibrate:SAVE  
Short Form: CAL:SAVE DATE <string> Long Form: CALibrate:SAVE DATE <string>  
where DATE is optional allowing <string> of up to 12 contiguous characters identifying calibrations date to be saved. Active DATE <string > is returned by \*IDN? query.

Description: **Saves computed calibration values in non-volatile memory.** This command saves only the calibration values computed after entering Calibration status. If, for example, only Voltage calibration was performed, these are the only values saved. These values are stored in Flash Memory (see PAR. 3.8.3.7). Previous values are not lost, and can be restored. This command should be the last command before exiting Calibrate status. **Related Commands:** CAL:STAT, CAL:DATA, CAL:DPOT, CAL:VOLT, CAL:CURR, CAL:ZERO. (See example, Figure B-1.) See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

### B.13 CALibrate:VEXternal COMMAND

## CAL:VEXT

Syntax: Short Form: CAL:VEXT {MAX | ZERO}  
Long Form: CALibrate:VEXternal {MAX | ZERO}

Description: **Selects External Reference full scale voltage calibration, only effective with power supply in Calibrate status.** CAL:VEXT MAX selects external reference full scale voltage calibration. CAL:VEXT ZERO selects external zero reference voltage calibration. **Related Commands:** CAL:STAT, CAL:ZERO, CAL:DATA, CAL:SAVE. (See example, Figure B-1.)

### B.14 CALibrate:VOLTAge COMMAND

## CAL:VOLT

Syntax: Short Form: CAL:VOLT {MIN | MAX}  
Long Form: CALibrate:VOLT {MIN | MAX}

Description: **Selects Voltage calibration, only effective with power supply in Calibrate status.** CAL:VOLT MIN selects Voltage Full Scale Negative Calibration. CAL:VOLT MAX selects Voltage Full Scale Positive Calibration. Normally Voltage Zero is done first, then Voltage Full Scale Positive Calibration. **Related Commands:** CAL:STAT, CAL:ZERO, CAL:DATA, CAL:DPOT, CAL:SAVE. (See example, Figure B-1.)

### B.15 CALibrate:VGAin COMMAND

## CAL:VGA

Syntax: Short Form: CAL:VGA {MIN | MAX}  
Long Form: CALibrate:VGAin {MIN | MAX}

Description: **Selects External Reference full scale voltage calibration, only effective with power supply in Calibrate status.** CAL:VGA MAX selects maximum positive external reference voltage calibration. CAL:VGA MIN selects maximum negative external reference voltage calibration. **Related Commands:** CAL:STAT, CAL:VOLT, CAL:CURR, CAL:ZERO, CAL:DATA, CAL:DPOT, CAL:SAVE. (See example, Figure B-1.)

### B.16 CALibrate:CLIMit COMMAND

## CAL:VLIM

Syntax: Short Form: CAL:VLIM {MIN | MAX | ZERO}  
Long Form: CALibrate:VLIMit {MIN | MAX | ZERO}

Description: **Selects External Reference Voltage Protection Limit calibration, only effective with power supply in Calibrate status.** CAL:VLIM MAX selects maximum positive external reference voltage protection limit calibration. CAL:VLIM MIN selects maximum negative external reference voltage protection limit calibration. **Related Commands:** CAL:STAT, CAL:ZERO, CAL:DATA, CAL:SAVE. (See example, Figure B-1.)

### B.17 CALibrate:VPRotect COMMAND

## CAL:VPR

Syntax: Short Form: CAL:VPR {MIN | MAX}  
Long Form: CALibrate:VPRotect {MIN | MAX}

Description: **Selects Voltage Protection Limit calibration, only effective with power supply in Calibrate status.** CAL:VPR MAX selects maximum positive voltage protection limit calibration. CAL:VPR MIN selects maximum negative voltage protection limit calibration. **Related Commands:** CAL:STAT, CAL:VOLT, CAL:CURR, CAL:ZERO, CAL:DATA, CAL:DPOT, CAL:SAVE. (See example, Figure B-1.)

### B.18 CALibrate:ZERO COMMAND

## CAL:ZERO

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

Description: **Sets output to zero while calibration equipment connections are changed.** This command is used when changing from Voltage to Current calibration or vice-versa. CAL:ZERO sets output voltage and current to zero. The user then connects or disconnects the shunt resistor or the digital voltmeter from the output terminals of the power supply as required for the subsequent Voltage or Current calibration. The next command should select the new parameter to be calibrated. **Related Commands:** CAL:STAT, CAL:VOLT, CAL:CURR, CAL:SAVE. (See example, Figure B-1.)

## B.19 DISPlay[:WINDow]:COLor COMMAND DISP:COL

Syntax: Short Form: DISP[:WIND]:COL {1 | 0} Long Form: DISPlay[:WINDow]:COLor {1 | 0}  
Description: **Selects display to show normal (0) or reverse (1).**

## B.20 DISPlay[:WINDow]:COLor? QUERY DISP:COL?

Syntax: Short Form: DISP[:WIND]:COL? Long Form: DISPlay[:WINDow]:COLor?  
Description: **Returns 0 (normal) or 1 (reverse) to indicate display color.**

## B.21 DISPlay[:WINDow]:CONTrast COMMAND DISP:CONT

Syntax: Short Form: DISP[:WIND]:CONT value Long Form: DISPlay[:WINDow]:CONTrast value  
where value = 0.00 to 1.00

Description: **Updates the contrast level for the selected display color.**

## B.22 DISPlay[:WINDow]:CONTrast? QUERY DISP:CONT?

Syntax: Short Form: DISP[:WIND]:CONT? Long Form: DISPlay[:WINDow]:CONTrast?  
Returns value from 0.00 to 1.00

Description: **Returns the contrast level for the selected display color.**

## B.23 DISPlay[:WINDow]:LLEft COMMAND DISP:LLE

Syntax: Short Form: DISP[:WIND]:LLE xx,yy Long Form: DISPlay[:WINDow]:LLEft xx,yy  
where xx = starting column, yy = ending row

Description: **Establishes the starting column (xx) and ending row (yy) where characters from the DISP:TEXT command are to be displayed. Default = 01,26. Related Commands: DISP:TEXT, DISP:LLE, DISP:URIG.**

## B.24 DISPlay[:WINDow]:LLEft? QUERY DISP:LLE?

Syntax: Short Form: DISP[:WIND]:LLE? Long Form: DISPlay[:WINDow]:LLEft?  
Returns xx,yy where xx = starting column, yy = ending row

Description: **Returns the starting column (xx) and ending row (yy) where characters from the DISP:TEXT command are to be displayed. Related Commands: DISP:TEXT, DISP:LLE, DISP:URIG.**

## B.25 DISPlay[:WINDow]:TEXT COMMAND DISP:TEXT

Syntax: Short Form: DISP[:WIND]:TEXT abcdefg,hijklmn,  
Long Form: DISPlay[:WINDow]:TEXT abcdefg,hijklmn,  
where abcdefg,hijklmn, = any ASCII character, from 20<sub>H</sub> (space) to 7A<sub>H</sub> (z)

Description: **Displays text within the starting and ending locations established by DISP:LLE and DISP:URIG.** Text is ASCII characters. Each line can be up to 40 characters long, and there can be up to 29 lines. New lines are indicated by commas (.). Characters are displayed within the boundaries established by DISP:LLE and DISP:URIG. Characters that exceed the ending line and ending row established by DISP:LLE and DISP:URIG are not displayed. **Related Commands: DISP:TEXT, DISP:LLE, DISP:URIG.**

## B.26 DISPlay[:WINDow]:TEXT? QUERY DISP:TEXT?

Syntax: Short Form: DISP[:WIND]:TEXT? Long Form: DISPlay[:WINDow]:TEXT?  
Returns character arrays starting at xx (established by DISP:LLE), ww (established by DISP:URIG) and ending at uu (established by DISP:LLE), yy (established by DISP:URIG).

Description: **Returns the character arrays as defined above, each line separated by a comma. Related Commands: DISP:TEXT, DISP:LLE, DISP:URIG.**

## B.27 DISPlay[:WINDow]:URIGht COMMAND DISP:URIG

Syntax: Short Form: DISP[:WIND]:URIG uu,ww Long Form: DISPlay[:WINDow]:URIGht uu,ww  
where uu = ending column, ww = starting row

Description: **Establishes the ending column (uu) and starting row (ww) where characters from the DISP:TEXT command are to be displayed. Default = 29,26. Related Commands: DISP:TEXT, DISP:LLE, DISP:URIG.**

## B.28 DISPlay[:WINDow]:URIGht? QUERY DISP:URIG?

Syntax: Short Form: DISP[:WIND]:URIG? Long Form: DISPlay[:WINDow]:URIGht?  
Returns uu,ww where uu = ending column, ww = starting row

Description: **Returns the ending column (uu) and starting row (ww) where characters from the DISP:TEXT command are to be displayed. Related Commands: DISP:TEXT, DISP:LLE, DISP:URIG.**

### B.29 INITiate[:IMMEDIATE] COMMAND

## INIT[:IMM]

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

Description: **Enables a single trigger.** This command enables a single trigger. A \*TRG command completes the sequence. Upon receipt of the \*TRG command, the power supply will return to the commanded values of voltage and current established by the VOLT:TRIG and CURR:TRIG commands. After a \*TRG command has been received, subsequent \*TRG commands have no effect unless preceded by INIT or INIT:CONT ON. Related Commands: \*TRG, TRIG. (See example, Figure B-2.)

### B.30 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] arms the trigger system for a single trigger. If INIT:CONT is ON, then the trigger system is continuously armed and INIT[:IMM] is redundant. Executing \*RST command sets INIT:CONT to ON. (See example, Figure B-2.)

### B.31 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-2.)

### B.32 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. During calibration this command returns the measurement tolerance (See example, Figure B-2.)

### B.33 MEASure[:VOLTage][:SCALar][:DC]? QUERY

## MEAS:VOLT?

Syntax: Short Form: MEAS[:SCAL]:VOLT[:DC]?  
Long Form: MEASure[:SCALar]:VOLTage[:DC]?  
Return Value: <num\_value> (digits with decimal point and Exponent)

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. During calibration MEAS:VOLT? returns measured value followed by ,VOLT (See example, Figure B-2.)

### B.34 MEMory:PACK COMMAND

## MEM:PACK

Syntax: Short Form: MEM:PACK Long Form: MEMory:PACK

Description: **Compresses the flash memory contained on the Flash EEPROM.** Refer to PAR. 3.8.3.7 for details. See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

### B.35 MEMory:PACK QUERY

## MEM:PACK?

Syntax: Short Form: MEM:PACK? Long Form: MEMory:PACK?  
Returns INT 0-99

Description: **Returns integer representing percent of Flash memory that has been filled.**

### B.36 MEMory:RELoad COMMAND

## MEM:REL

Syntax: Short Form: MEM:REL Long Form: MEMory:RELoad

Description: **Restores variables to power-up state by reloading all saved variables with data from non-volatile RAM.**

- NOTES: 1. The power supply is assumed to be operating in constant voltage mode.  
 2. Examples below are intended only to illustrate command functions. Refer to PAR. 3.4.2 for programming techniques to optimize performance.

OUTP ON	Turns the output on.
VOLT 21; CURR 1.5	Power supply output programmed to go to 21V, current limit 1.5A
INIT:CONT ON	Continuous triggers enabled.
INIT:CONT?	Power supply returns "1."
VOLT:TRIG 15;CURR:TRIG 3	Power supply output programmed to return to 15V, current limit 3A upon receipt of trigger.
*TRG	Power supply output returns to 15V,current limit 3A.
VOLT 21; CURR 5E-2	Power supply output programmed to go to 21V, current limit 0.05A
MEAS:VOLT?	If actual value of output voltage is 20.9V, power supply returns 2.09E1.
MEAS:CURR?	If actual value of output current is 0.0483A, power supply returns 4.83E-2.
FUNC:MODE CURR	Establishes constant current mode as power supply operating mode.
VOLT 21; CURR 1.1	Power supply programmed to voltage limit 21V, 1.1A.
CURR?	Returns 1.1.
FUNC:MODE VOLT	Establishes constant voltage mode as power supply operating mode.
CURR:TRIG?	Returns 3 (current value established by CURR:TRIG).
VOLT:TRIG?	Returns 15 (voltage value established by VOLT:TRIG).
TRIG	Power supply output returns to 15V, current limit 3A.
INIT:CONT 0	Triggers disabled.
INIT:CONT?	Power supply returns "0."
VOLT 0	Power supply output programmed to go to 0V.
MEAS:VOLT?	Returns 0. (measured output voltage).
VOLT?	Returns 0.(programmed output voltage).
CURR?	Returns 1.5 (programmed current).
MEAS:CURR?	Returns 0. (measured output current).
CURR .3	Selecting a range greater than 0.25 results in no change of output current.
CURR .2	Sets power supply to deliver 0.2 ampere at 0.024% accuracy.
CURR .5	Sets the output to be 1/2 ampere in the high range.
CURR:RANG?	Unit returns a 1 indicating unit range.is full scale.

FIGURE B-2. PROGRAMMING THE OUTPUT

### B.37 MEMory:UPDate COMMAND

## MEM:UPD

Syntax: Short Form: MEM:UPD {INT | REF | LIM | SER | CONT}

Long Form: MEMory:UPDate {INTerface | SERIAL | LIMits | REFerence | CONTrast}

Description: **Saves selected variables.** MEM:UPD INT saves GPIB address, Language (SCPI or CILL) and all SYST:SET (PAR. B.134) variables. MEM:UPD REF saves Main reference state (Fixed, External, or Ext Ref Lvl) and the Limit reference state (Fixed, External or Lesser) described in Table 3-10. MEM:UPD LIM saves limits for voltage and current and the maximum allowable protection values for voltage and current. MEM:UPD CONT saves the display contrast and color settings for the next power-up cycle. Related commands: SYST:COMM:GPIB:ADDR, SYST:LANG, SYST:SET, VOLT:LIM, CURR:LIM, CURR:PROT:LIM, VOLT:PROT:LIM, DISP:COL, DISP:CONT. See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

### B.38 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.** Upon power up the power supply is in Local mode: the output is always on and the front panel controls affect the unit's operation. Upon entering Remote mode, the default state is OUTP OFF; OUTP ON must be executed to enable the output.

For passive loads, when OUTP OFF is executed, the programmed values of voltage and current are saved, then voltage and current are programmed as follows: when the unit is operating as a volt-

age source, voltage is programmed to zero and current protect is programmed to a low value; when operating as a current source, current is programmed to zero and voltage protect is programmed to a low value. 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.

For active loads, instead of using OUTP OFF, program the unit to current mode using the FUNC:MODE command, then program output current to zero.

Related Commands: FUNC:MODE, OUTP?.

### B.39 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.

### B.40 OUTPut:MODE COMMAND

## OUTP:MODE

Syntax: Short Form: OUTP:MODE {ACTIVE | RESISTIVE | BATTERY}  
Long Form: OUTPut:MODE {ACTIVE | RESISTIVE | BATTERY}

Description: **Determines how the unit functions when output is turned off depending on the type of load in use: active, resistive or battery.** See PAR. 3.3.5.4.2 for description of ACTIVE, RESISTIVE and BATTERY modes.

### B.41 OUTPutMODE? QUERY

## OUTP:MODE?

Syntax: Short Form: OUTP:MODE? Long Form: OUTPut:MODE]?  
Return Value: ACTIVE | RESISTIVE | BATTERY

Description: **Indicates whether power supply is configured for ACTIVE, RESISTIVE or BATTERY type loads.** See PAR. 3.3.5.4.2 for description of ACTIVE, RESISTIVE and BATTERY modes. Related Commands: OUTP:MODE.

### B.42 [SOURce:]FUNCTION:MODE COMMAND

## FUNC:MODE

Syntax: Short Form: FUNC:MODE {VOLT | CURR} Long Form: [SOURce:]FUNCTION:MODE {VOLT | CURR}

Description: **Establishes the operating mode of the power supply.** VOLT = Constant Voltage mode (CV). CURR = Constant Current mode (CC). FUNC:MODE VOLT commands power supply to Voltage mode, FUNC:MODE CURR commands power supply to Current mode. Commanded mode establishes parameters (voltage or current) monitored for error conditions. Actual mode depends upon load conditions. When commanded to Voltage mode, if load conditions cause the power supply to try to exceed the current limit, the unit will flag an error condition. When commanded to Current mode, if load conditions cause the power supply to try to exceed the voltage limit, the unit will flag an error condition. If VOLT:MODE or CURR:MODE is set to TRANS or LIMIT, the FUNC:MODE command automatically changes the mode to FIXed. (See example, Figure B-2.)

### B.43 [SOURce:]FUNCTION:MODE? QUERY

## FUNC:MODE?

Syntax: Short Form: FUNC:MODE? Long Form: [SOURce:]FUNCTION:MODE?  
**Return value:** 0 (voltage mode) or 1 (current mode)

Description: **Returns the operating mode of the power supply.** 0 = Constant Voltage mode (CV). 1 = Constant Current mode (CC).

### B.44 [SOURce:]FUNCTION:MODE:TRIGger

## FUNC:MODE:TRIG

Syntax: Short Form: FUNC:MODE:TRIG {VOLT | CURR}  
Long Form: [SOURce:]FUNCTION:MODE:TRIGger {VOLT | CURR}

Description: **Establishes the operating mode of the power supply when a TRIGger command is sent.** VOLT = Constant Voltage mode (CV). CURR = Constant Current mode (CC). This command establishes the operating mode for triggers which is be saved or recalled using \*SAV or \*RCL command. FUNC:MODE:TRIG VOLT commands power supply to Voltage mode when a TRIGger command is sent, FUNC:MODE:TRIG CURR commands power supply to Current mode when a TRIGger command is sent. If VOLT:MODE or CURR:MODE is set to TRANS, FUNC:MODE:TRIG command automatically changes the mode to FIXed. (See example, Figure B-5.)

**B.45 [SOURCE:]FUNCTION:MODE:TRIGGER? QUERY****FUNC:MODE:TRIG?**

Syntax: Short Form: FUNC:MODE:TRIG? Long Form: [SOURCE:]FUNCTION:MODE:TRIGGER?  
**Return value:** 0 = voltage mode or 1 = current mode

Description: **Returns the operating mode which the power supply will enter when a trigger command is sent.** VOLT = Constant Voltage mode (CV). CURR = Constant Current mode (CC). (See example, Figure B-5.)

**B.46 [SOURCE:]LIST:CLEAR COMMAND****LIST:CLEAR**

Syntax: Short Form: LIST:CLEAR Long Form: LIST:CLEAR>

Description: **Clears all list entries by setting all pointers to 0.** Also sets LIST:DIR to UP, LIST:GEN to DSEQ, Related Commands: All LIST commands (See example, Figure B-3.)

**B.47 [SOURCE:]LIST:COUNT COMMAND****LIST:COUN**

Syntax: Short Form: LIST:COUN<int\_value 0 to 255> Long Form: LIST:COUN> <int\_value 0 to 255>

Description: **Establishes how many times the list is executed.** Allows user to establish how many times the list (established by LIST:GEN DSEQ or LIST:GEN SEQ and LIST:SEQ) 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 either a VOLT:MODE FIXED, or PROG:STOP command is received. Commands: LIST:GEN, LIST:SEQ, LIST:DIR. (See example, Figure B-3.)

**B.48 [SOURCE:]LIST:COUNT? QUERY****LIST:COUN?**

Syntax: Short Form: LIST:COUNT? Long Form: LIST:COUNT?  
 Return Value: <int\_value>

Description: **Identifies how many times the list will be executed.** Returns value set by LIST:COUN command. (See example, Figure B-3.)

**B.49 [SOURCE:]LIST:COUNT:SKIP COMMAND****LIST:COUN:SKIP**

Syntax: Short Form: LIST:COUN:SKIP nn Long Form: LIST:COUN:SKIP nn  
 nn = <int\_value 0 to 255>

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:SEQ, LIST:DIR, LIST:CLEAR. (See example, Figure B-3.)

**B.50 [SOURCE:]LIST:COUNT:SKIP? QUERY****LIST:COUN:SKIP?**

Syntax: Short Form: LIST:COUN:SKIP? Long Form: LIST:COUN:SKIP?  
 Return Value: <int\_value>

Description: **Identifies how many steps will be skipped the first time the list is executed.** Returns value set by LIST:COUN:SKIP command. (See example, Figure B-3.)

**B.51 [SOURCE:]LIST:CURRENT COMMAND****LIST:CURRE**

Syntax: Short Form: LIST:CURRE <exp\_value>, <exp\_value>, . . . (to max of 1002 data points)  
 Long Form: LIST:CURREnt <exp\_value>, <exp\_value>, . . . (to max of 1002 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 locations illustrated in Table B-2. Starting location is indicated by LIST:CURRE:POIN? These locations correspond to the default sequence (LIST:GEN DESQ). The maximum number of entries is 1002. Since the input buffer of the BOP has a limit of 253 characters, multiple commands are necessary to complete the full 1002 entries of the list. If LIST:VOLT has any entries, an error message: -221, "Settings conflict" is posted in the error queue. Related Commands: LIST:CURRE:POIN?. (See example, Figure B-3.)



NOTES:	Examples below are intended only to illustrate command functions. Refer to PAR. 3.4.2 for programming techniques to optimize performance.
FUNC:MODE VOLT	Initializes the power supply mode to be voltage.
LIST:CLEAR	Initializes the list processor to add entries, clears main channel (LIST:CURR or LIST:VOLT) and LIST:DWEL data tables (Table B-2).
LIST:dwel .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 -20,-18,-16,-14,-12,-10,-8,-6,-4,-2,0	Starting at location 0 (-20), up to location 10 (0), 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 2,4,6,8,10,12,14,16,18,20	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 -20,-18,-16,-14,-12,-10,-8,-6,-4,-2,0,2,4,6,8 (the contents of locations 0 through 15).
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 (-20V) will last 10 milliseconds.
CURR 1;VOLT -20	initializes the BOP output
OUTPUT ON	Turns the output on (BOP now provides -20 volts)
VOLT:MODE LIST	Executes the list. For 40 milliseconds the BOP outputs -20V, then output a staircase triangle wave from -20V to +20V and back down to -20V. This staircase will have a uniform spacing between voltage changes of 10 milliseconds and will repeat 100 times.
VOLT?	Returns -20 (the last step in the list set the unit to -20V).
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 -20V to +20V and repeats 10 times. There is an abrupt change from +20V to -20V each time the list transitions from location 20 to location 0.
VOLT?	Returns 20, (the last step in the list set the unit to 20V).
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 20V then decreases to -20V in 2V steps and repeats 10 times. The sawtooth is similar to the previous sawtooth, except the waveform is inverted and the abrupt change from -20 to +20 is executed in three steps of 10 volts.

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

VOLT:MODE:LIST	The original list of 20 points will be executed (without the three new steps.)
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,.1,.1,.1	Dwell times are entered in locations 11 through 23.
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 16,18,20,10,0,-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.
LIST:DWEL?	Returns error -221,Settings Error because a LIST command cannot be executed while the LIST is still being executed.
VOLT:MODE FIX	Stops execution of the list
VOLT?	VOLT?Returns -20 (the last step in the list set the unit to -20V.
VOLT: -4	Programs output to -4V
VOLT:MODE TRAN .05	Prepares for a voltage transient lasting 0.05 seconds.
VOLT: 3	Output goes to +3V for 0.05 second, then returns to -4V.

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

**TABLE B-2. List Data Table**

Location (DSEQ)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	.....	1001
Main Channel (commanded mode) LIST:CURREnt or LIST:VOLTage																			.....	
LIST:DWELI																			.....	

NOTE: FUNC:MODE determines whether main channel is for voltage or current. FUNC:MODE CURR must precede LIST:CURRE commands, FUNC:MODE VOLT must precede LIST:VOLT commands

**B.52 [SOURce:]LIST:CURREnt? QUERY**

**LIST:CURREnt?**

Syntax: Short Form: LIST:CURREnt? 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 locations of Table B-2. Related Commands: LIST: CURREnt, LIST:QUERy. If LIST:VOLT has any entries, an error message: -221,"Settings conflict" is posted in the error queue. (See example, Figure B-3.)

**B.53 [SOURCE:]LIST:CURRENT:POINTS? QUERY****LIST:CURR:POIN?**

Syntax: Short Form: LIST:CURR:POIN? Long Form: LIST:CURRENT:POINTS?  
Return Value: <value> (0 to 1001)

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:CLEAR. For each data point entered by a LIST:CURR command the list pointer is incremented. If LIST:CURR:POIN? returns 5, the LIST:CURR pointer is at 5 indicating there are 6 data points comprising the list. If LIST:VOLT has any entries, an error message: -221, "Settings conflict" is posted in the error queue. Related Commands: LIST:CURR. (See example, Figure B-3.)

**B.54 [SOURCE:]LIST:DIRrection COMMAND****LIST:DIR**

Syntax: Short Form: LIST:DIR (UP|DOWN) Long Form: LIST:DIRrection (UP|DOWN)

Description: **Allows the list to be executed from beginning to end (UP) or from end to the beginning (DOWN).** \*RST or LIST:CLEAR sets the list to the UP direction (beginning to end). Works with both LIST:GEN DSEQ and LIST:GEN SEQ commands. Related Commands: LIST:GEN. LIST:SEQ, LIST:DWEL?. (See example, Figure B-3.)

**B.55 [SOURCE:]LIST:DIRrection? QUERY****LIST:DIR?**

Syntax: Short Form: LIST:DIR? Long Form: LIST:DIRrection?  
Return Value: <value> (UP or DOWN)

Description: **Identifies the for executing the list established by LIST:DIR.** Related Commands: LIST: DIR. (See example, Figure B-3.)

**B.56 [SOURCE:]LIST:DWELI COMMAND****LIST:DWEL**

Syntax: Short Form: LIST:DWEL <value> (0.0005 to 10), <value>, <value>, . . . to maximum of 1002 values  
Long Form: LIST:DWELI <value> (0.0005 to 10), <value>, <value>, . . . to maximum of 1002 values

Description: **Determines how long the main channel parameters will be active.** Sets time value (from 0.0005 to 10) in seconds for List:Dwell locations illustrated in Table B-2. These locations are associated with the corresponding main channel locations illustrated in Table B-2. The main channel is determined by FUNC:MODE, either current (FUNC:MODE CURR) or voltage (FUNC:MODE VOLT) 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, FUNC:MODE, LIST:CURR, LIST:VOLT, LIST:DWEL?, LIST:SEQ. (See example, Figure B-3.)

**B.57 [SOURCE:]LIST:DWELI? QUERY****LIST:DWEL?**

Syntax: Short Form: LIST:DWEL? Long Form: LIST:DWELI?  
Return Value: <value>

Description: **Identifies the dwell times entered for the list.** Starting at location established by LIST:QUERY, returns comma-separated list of up to 16 values indicating the dwell time parameters entered. i.e., the contents of LIST:DWEL locations of Table B-2. Related Commands: LIST: DWEL, LIST:QUERY. (See example, Figure B-3.)

**B.58 [SOURCE:]LIST:DWELI:POINTS? QUERY****LIST:DWEL:POIN?**

Syntax: Short Form: LIST:DWEL:POIN? Long Form: LIST:DWELI:POINTS?  
Return Value: <value> (0 to 1001)

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.59 [SOURCE:]LIST:QUERY COMMAND****LIST:QUER**

Syntax: Short Form: LIST:QUER <int\_value>  
Long Form: LIST:QUERY <int\_value>  
int\_value = 0 to 1001

Description: **Determines first location to be queried by LIST:SEQ? query.** Related Commands: LIST:SEQ?. LIST:QUER?. (See example, Figure B-3.)

## B.60 [SOURCE:]LIST:QUERY? QUERY

## LIST:QUER?

Syntax: Short Form: LIST:SEQ? Long Form: LIST:SEQUence?  
Return Value: <int\_value>

Description: **Identifies first location to be queried by LIST:SEQ?, LIST:VOLT?, LIST:CURR?, LIST:DWEL? queries.** Related Commands: LIST:QUER, LIST:SEQ. (See example, Figure B-3.)

## B.61 [SOURCE:]LIST:VOLTage COMMAND

## LIST:VOLT

Short Form: LIST:VOLT[:LEV] <exp\_value>, <exp\_value>, . . . (to max of 1002 data points)  
Long Form: LIST:VOLTage[:LEVel] <exp\_value>, <exp\_value>, . . . (to max of 1002 data points)  
<exp\_value> = digits with decimal point and Exponent, e.g., 2.71E1 for 27.1

Description: **Adds the voltage value (in Amps) to list.** This command sequentially adds LIST:VOLTage values to the main channel List Data Table locations illustrated in Table B-2. LIST:CLE sets starting location to 0. Next location indicated by LIST:VOLT:POIN? These locations correspond to the default sequence (LIST:GEN DESQ) The maximum number of entries is 1002. Since the input buffer of the BOP has a limit of 253 characters, multiple commands are necessary to complete the full 1002 entries of the list. If LIST:CURR has any entries, an error message: -221, "Settings conflict" is posted in the error queue. Related Commands: LIST:VOLT:POIN?, FUNC:MODE, LIST:CLE, \*RST. (See example, Figure B-3.)

## B.62 [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 locations of Table B-2. Related Commands: LIST:VOLT, LIST:QUERY. If LIST:CURR has any entries, an error message: -221, "Settings conflict" is posted in the error queue. (See example, Figure B-3.)

## B.63 [SOURCE:]LIST:VOLTage:POINTs? QUERY

## LIST:VOLT:POIN?

Syntax: Short Form: LIST:VOLT:POIN? Long Form: LIST:VOLTage:POINTs?  
Return Value: <value> (0 to 1001)

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 through 4) and location 5 is the next to be filled. If LIST:CURR has any entries, an error message: -221, "Settings conflict" is posted in the error queue. Related Commands: LIST:VOLT. (See example, Figure B-3.)

## B.64 [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., 2.71E1 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 CURR:RANG is set to 4, any data that exceeds 1/4 of  $I_{MAX}$  causes error message -222 "data out range" to be posted to the error queue (See example, Figure B-2.)

## B.65 [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., 2.71E1 for 27.1

Description: **Returns either the programmed value, maximum value, or minimum value of current.** The CURR? query returns the programmed value of current. Actual output current will depend on load conditions. The CURR?MAX query returns the maximum current allowed for a particular model. CURR? Returns programmed current value. CURR? MAX returns maximum current allowed for power supply. CURR? MIN returns minimum current allowed for power supply (always negative). **Related Commands:** CURR. (See example, Figure B-2.)

**B.66 [SOURCE:]CURRENT[:LEVEL]:LIM[:BOTH] COMMAND****CURR:LIM[:BOTH]**

Syntax: Short Form: [SOUR:]CURR[:LEV]:LIM[:BOTH] <value>  
 Long Form: [SOURCE:]CURRENT[:LEVEL]:LIMit[:BOTH] <value>

Description: Reduces the rated output current that the unit can both source and sink to the <value> specified. See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

**B.67 [SOURCE:]CURRENT[:LEVEL]:LIM[:BOTH]? QUERY****CURR:LIM[:BOTH]?**

Syntax: Short Form: [SOUR:]CURR[:LEV]:LIM[:BOTH]?  
 Long Form: [SOURCE:]CURRENT[:LEVEL]:LIMit[:BOTH]?  
 Returns <value>, <value>

Description: Identifies the value of output current that the unit can sink, followed by the value of output current that the unit can source.

**B.68 [SOURCE:]CURRENT[:LEVEL]:LIM:NEG COMMAND****CURR:LIM:NEG**

Syntax: Short Form: [SOUR:]CURR[:LEV]:LIM:NEG <value>  
 Long Form: [SOURCE:]CURRENT[:LEVEL]:LIMit:NEGative <value>  
 <value> =

Description: Reduces the rated output current that the unit can source to the value specified by the user. See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

**B.69 [SOURCE:]CURRENT[:LEVEL]:LIM:POS COMMAND****CURR:LIM:POS**

Syntax: Short Form: [SOUR:]CURR[:LEV]:LIM:POS <value>  
 Long Form: [SOURCE:]CURRENT[:LEVEL]:LIMit:POSitive <value>  
 <value> =

Description: Reduces the rated output current that the unit can sink to the value specified by the user. See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

**B.70 [SOURCE:]CURRENT:MODE COMMAND****CURR:MODE**

Syntax: Short Form: [SOUR:]CURR:MODE (FIX | LIST | TRAN | EXT | GAIN |PROT) nn  
 Long Form: [SOURCE:]CURRENT:MODE (FIXed | LIST | TRANSient | EXTernal | GAIN |PROTect) nn  
 nn = <value> = time in seconds for transient

Description: **Allows the user to execute or stop a list, or to execute a transient.** The default mode is FIXed: 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.

CURR:MODE TRAN nn causes the next CURR: command to produce a transient pulse of nn seconds duration, after which the current reverts back to the previous setting (Similar to VOLT:MODE TRAN (see PAR. B.88 for examples).If the time nn exceeds 10 seconds, error message -222 “data out range” is posted to the error queue.

CURR:MODE EXT Configures the unit to use an external reference to change the output current.

CURR:MODE GAIN Configures the unit to use an external reference to provide a proportional output current

CURR:MODE PROT Configures the current protection limits to be 3% to 5% higher than the rated output current.

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

**B.71 [SOURCE:]CURRENT:MODE? QUERY****CURR:MODE?**

Syntax: Short Form: [SOUR:]CURR[:LEV]:MOD?  
 Long Form: [SOURCE:]CURRENT[:LEVEL]:MODE?  
**Return value:** FIXED, LIST, TRANSIENT, EXTERNAL, GAIN or PROTECT

Description: **Identifies active current mode.** Returns LIST while list is being executed. Returns TRANSIENT after CURR:MODE:TRAN command has been issued, but before CURR: or \*TRG command executes the transient. Returns FIXED while in fixed (default) mode of operation. **Related Commands:** LIST commands. (Similar to VOLT:MODE?, see Figure B-3.)

## **B.72 [SOURCE:]CURRENT[:LEVEL]:PROTECT[:BOTH] COMMAND      CURR:PROT[:BOTH]**

Syntax:      Short Form: [SOURCE:]CURRENT[:LEVEL]:PROT:BOTH <value>  
              Long Form: [SOURCE:]CURRENT[:LEVEL]:PROTECT:BOTH <value>  
              <value> =

Description: Establishes both the positive and negative protection limits for current, the maximum current the unit is set up to source and sink; maximum is 3 to 5% greater than rated output current.

## **B.73 [SOURCE:]CURRENT[:LEVEL]:PROT[:BOTH] QUERY      CURR:PROT[:BOTH]?**

Syntax:      Short Form: [SOURCE:]CURRENT[:LEVEL]:PROT[:BOTH]?  
              Long Form: [SOURCE:]CURRENT[:LEVEL]:PROTECT[:BOTH]?  
              Returns <value>, <value>

Description: Identifies the protection limits for current (source, sink), the maximum current the unit will source or sink

## **B.74 [SOURCE:]CURRENT[:LEVEL]:PROTECT:NEGATIVE COMMAND      CURR:PROT:NEG**

Syntax:      Short Form: [SOURCE:]CURRENT[:LEVEL]:PROT:NEG <value>  
              Long Form: [SOURCE:]CURRENT[:LEVEL]:PROTECT:NEGATIVE <value>  
              <value> =

Description: Establishes the negative limit for current, the maximum current the unit is set up to sink; maximum is 3 to 5% greater than rated output current.

## **B.75 [SOURCE:]CURRENT[:LEVEL]:PROTECT:POSITIVE COMMAND      CURR:PROT:POS**

Syntax:      Short Form: [SOURCE:]CURRENT[:LEVEL]:PROT:POS <value>  
              Long Form: [SOURCE:]CURRENT[:LEVEL]:PROTECT:POSITIVE <value>  
              <value> =

Description: Establishes the positive protection limit for current, the maximum current the unit will source; maximum is 3% to 5% greater than rated output current.

## **B.76 [SOURCE:]CURRENT[:LEVEL]:PROTECT:LIMIT:BOTH COMMAND      CURR:PROT:LIM[:BOTH]**

Syntax:      Short Form: [SOURCE:]CURRENT[:LEVEL]:PROT:LIM[:BOTH] <value>  
              Long Form: [SOURCE:]CURRENT[:LEVEL]:PROTECT:LIMIT[:BOTH] <value>  
              <value> =

Description: Establishes the maximum value possible for both the positive and negative protection limits for current. See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

## **B.77 [SOURCE:]CURRENT[:LEVEL]:PROTECT:LIMIT[:BOTH]? QUERY      CURR:PROT:LIM[:BOTH]?**

Syntax:      Short Form: [SOURCE:]CURRENT[:LEVEL]:PROT:LIM[:BOTH]?  
              Long Form: [SOURCE:]CURRENT[:LEVEL]:PROTECT:LIMIT[:BOTH]?  
              Returns <exp\_value>, <exp\_value>

Description: Identifies the maximum value possible for protection limits for current (positive, negative); maximum is 1% greater than rated output current.

## **B.78 [SOURCE:]CURRENT[:LEVEL]:PROTECT:LIMIT:NEGATIVE COMMAND      CURR:PROT:LIM:NEG**

Syntax:      Short Form: [SOURCE:]CURRENT[:LEVEL]:PROT:LIM:NEG <exp\_value>  
              Long Form: [SOURCE:]CURRENT[:LEVEL]:PROTECT:LIMIT:NEGATIVE <exp\_value>

Description: Establishes the minimum (maximum negative) value possible for the negative protection limit for current. This may be set up to 1% greater than rated current. See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

## **B.79 [SOURCE:]CURRENT[:LEVEL]:PROTECT:LIMIT:POSITIVE COMMAND      CURR:PROT:LIM:POS**

Syntax:      Short Form: [SOURCE:]CURRENT[:LEVEL]:PROT:LIM:POS <exp\_value>  
              Long Form: [SOURCE:]CURRENT[:LEVEL]:PROTECT:LIMIT:POSITIVE <exp\_value>

Description: Establishes the maximum value possible for the positive protection limit for current. This may be set up to 1% greater than rated current. See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

- NOTES: 1. This example assumes a BOP 36-28MG power supply is operating in constant current (CC) mode.  
 2. Examples below are intended only to illustrate command functions. Refer to PAR. 3.4.2 for programming techniques to optimize performance.

CURR:LIM?	Returns 28.3,28.3 (positive and negative defaults for max current).
CURR:LIMIT:POS 10;NEG 2	Establishes the maximum positive and negative current values that can be set; automatically sets positive and negative maximum protection levels to be 3% higher.
func:mode volt volt 15;curr 2	Sets power supply in voltage mode. Allows the power supply to provide 15 volts positive with the ability to sink up to 2 amperes or source up to 2 amperes. The display shows: 15.000 2.000 2.000.
CURR 10	Since BOP is operating in voltage mode, sets the source capability (current protect) to 10 amperes (sink capability remains at 2 amperes. The display shows: 15.000 10.000 2.000
curr:prot?	Returns 10,2 (since BOP is operating in voltage mode, actual values of positive and negative current are returned).
CURR:prot:neg 1 CURR:PROT:MAX:NEG 5	Limits the current sinking capability to 1 ampere. Prevents CURR:PROT:NEG setting from exceeding 5 amperes
CURR 10	Sets the source capability to 10 amperes. Changing a limit does not effect the unit output except if the limit is less than the current
curr:prot?	setting value. Returns 10,5 (the actual positive (10) and negative (5) protection levels for the current channel
---- Turn BOP POWER off and then on. curr:lim?	Returns 28.3,28.3 the factory default levels (all the above changes have been lost). To lock in the changed limits, the user must send :MEMORY:UPDATE LIMITS.
CURR:MODE PROTECT CURR:PROT:MAX:POS 28.3;neg 28 CURR 28.3	Sets the current protection to be at the max value Establishes new max current protect limits. Establishes the positive protect to be 28.3 amperes and the negative protection to 28 amperes.
curr:prot? func:mode curr curr?	returns 28.3,28 changes the output mode of the power supply to current mode. returns 28 - the max current.

FIGURE B-4. SETTING LIMITS

**B.80 [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., 2.71E1 for 27.1

Description: **Programs current value to be transferred to output by \*TRG or TRIG commands.** This command can be used to reset many power supplies to preselected parameters by issuing a single \*TRG or TRIG command. Actual output current will depend on load conditions. If the value exceeds the maximum for the model being programmed, error message -222,"Data out of range" is posted in output queue. **Related Commands:** CURR, \*TRG, TRIG (See example, Figure B-5.)

**B.81 [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., 2.71E1 for 27.1

Description: **Returns the current value established by CURR:TRIG command.** (See example, Figure B-5.)

## VOLT

### B.82 [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] COMMAND

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., 2.71E1 for 27.1

Description: **Sets programmed voltage level at power supply output.** This command programs output voltage to a specific value; actual output voltage will depend on load conditions. If the value exceeds the maximum for the model being programmed, error message -222, "Data out of range" is posted in output queue. (See example, Figure B-2.)

### B.83 [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. VOLT? MIN returns minimum voltage allowed for power supply (always negative). **Related Commands:** VOLT. (See example, Figure B-2.)

### B.84 B-2.[SOURce:]VOLTage[:LEVel]:LIM[:BOTH] COMMAND

## VOLT:LIM[:BOTH]

Syntax: Short Form: [SOUR:]VOLT[:LEV]:LIM[:BOTH] <value>  
 Long Form: [SOURce:]VOLTage[:LEVel]:LIMit[:BOTH] <value>

Description: Reduces both the positive and negative rated output voltage to the <value> specified.

### B.85 [SOURce:]VOLTage[:LEVel]:LIM[:BOTH] ? QUERY

## VOLT:LIM[:BOTH]?

Syntax: Short Form: [SOUR:]VOLT[:LEV]:LIM[:BOTH] ?  
 Long Form: [SOURce:]VOLTage[:LEVel]:LIMit[:BOTH] ?  
 Returns <value>

Description: Identifies the value (positive, negative) of reduced output voltage specified by the user.

### B.86 [SOURce:]VOLTage[:LEVel]:LIMit COMMAND

## VOLT:LIM:NEG

Syntax: Short Form: [SOUR:]VOLT[:LEV]:LIM:NEG <value>  
 Long Form: [SOURce:]VOLTage[:LEVel]:LIMit:NEGative <value>  
 <value> =

Description: Reduces the rated maximum negative voltage to the value specified by the user.

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. 3.4.2 for programming techniques to optimize performance.

*RST	BOP goes to 0 volts, 0 amperes, Voltage mode
VOLT 10;CURR 1	The voltage is placed in memory of the BOP.
	No Output Changes
OUTP ON	Turns on Output, 10 Volts up to 1 ampere will be delivered.
VOLT:TRIG 1;CURR:TRIG 2	Trigger is placed in RAM
*SAV 6	Volt 1, Current 2 and Volt mode stored in Memory location 6
*TRG	No action - Trigger control not send
VOLT:TRIG 3;FUNC:MODE:TRIG CURR	No action -trigger placed in RAM
*SAV 7	volt 3, curr 2, current mode saved in location 7
*RCL 6;VOLT:TRIG?	BOP returns 1 (= 1V) (saved value of memory 6)
FUNC:MODE:TRIG?	BOP returns 0 (= trigger will command voltage mode)
*RCL 6;VOLT?	BOP returns 1 (output voltage now set to 1V.).
*RCL 7;:INIT;:VOLT:TRIG?	Enables the trigger capability, unit returns 3 (= 3V)
*TRG	The voltage is set to 3, and the unit mode changes to Current
FUNC:MODE:TRIG?::FUNC MODE VOLT	Unit switches to voltage mode. Returns 1 (= trigger will command current mode.
FUNC:MODE:TRIG?	Unit returns 0 indicating Voltage mode trigger in effect.

FIGURE B-5. USING RECALL AND TRIGGER FUNCTIONS



**B.87 [SOURce:]VOLTage[:LEVel]:LIMit COMMAND****VOLT:LIM:POS**

Syntax: Short Form: [SOUR:]VOLT[:LEV]:LIM:POS <value>  
 Long Form: [SOURce:]VOLTage[:LEVel]:LIMit:POSitive <value>  
 <value> =

Description: Reduces the rated maximum positive voltage to the value specified by the user.

**B.88 [SOURce:]VOLTage:MODE COMMAND****VOLT:MODE**

Syntax: Short Form: [SOUR:]VOLT:MODE (FIX | LIST | TRAN | EXT | GAIN |PROT) nn  
 Long Form: [SOURce:]VOLTage:MODE (FIXed | LIST | TRANsient | EXTernal | GAIN |PROTect) nn  
 nn = <value> = time in seconds for transient

Description: **Allows the user to execute or stop a list, or to execute a transient.** The default mode is FIXed: 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.

VOLT:MODE TRAN nn causes the next VOLT: command to produce a transient pulse of nn seconds duration, after which the voltage reverts back to the previous setting. E.g., VOLT:25 sets the output to 25 volts, and VOLT:MODE TRAN .02 primes the unit for a transient of 0.02 seconds. When VOLT:10 is issued, the power supply output goes to 10V for 0.02 seconds, then reverts to 25V. Similarly, sending VOLT:TRIG 14, VOLT:MODE TRAN .05 and \*TRG causes the output to go to 14V for 0.05 seconds, then revert to 25V.

VOLT:MODE EXT Configures the unit to use an external reference to change the output voltage;  $\pm 10V$  reference produces output =  $\pm E_o$  (rated) (Fixed gain =  $E_o$  (rated)/10).

VOLT:MODE GAIN Configures the unit to use an external reference to provide a proportional output voltage.

VOLT:MODE PROT Configures the voltage protection limits to be 3% to 5% higher than the rated output voltage.

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

**B.89 [SOURce:]VOLTage:MODE? QUERY****VOLT:MOD?**

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

Description: **Identifies active voltage mode.** Returns LIST while list is being executed. Returns TRANSIENT after VOLT:MODE TRAN nn command has been issued, but before VOLT: or \*TRG command executes the transient. Returns FIXED while in fixed (default) mode of operation. **Related Commands:** LIST commands. (See example, Figure B-3.)

**B.90 [SOURce:]VOLTage[:LEVel]:PROTect:BOTH COMMAND****VOLT:PROT[:BOTH]**

Syntax: Short Form: [SOUR:]VOLT[:LEV]:PROT[:BOTH] <value>  
 Long Form: [SOURce:]VOLTage[:LEVel]:PROTect[:BOTH] <value>  
 <value> =

Description: Establishes the both the positive and negative protection limits for voltage.

**B.91 [SOURce:]VOLTage[:LEVel]:PROTect[:BOTH]? QUERY****VOLT:PROT[:BOTH]?**

Syntax: Short Form: [SOUR:]VOLT[:LEV]:PROT[:BOTH]?  
 Long Form: [SOURce:]VOLTage[:LEVel]:PROTect[:BOTH]?  
 Returns <exp\_value>,<exp\_value>

Description: Identifies the protection limits for voltage (positive, negative); maximum is 3% to 5% greater than rated output voltage.

**B.92 [SOURCE:]VOLTage[:LEVel]:PROTect:NEGative COMMAND VOLT:PROT:NEG**

Syntax: Short Form: [SOUR:]VOLT[:LEV]:PROT:NEG <exp\_value>  
Long Form: [SOURCE:]VOLTage[:LEVel]:PROTect:NEGative <exp\_value>

Description: Establishes the negative protection limit for voltage; maximum is 3% to 5% greater than rated output voltage.

**B.93 [SOURCE:]VOLTage[:LEVel]:PROTect:POSitive COMMAND VOLT:PROT:POS**

Syntax: Short Form: [SOUR:]VOLT[:LEV]:PROT:POS <exp\_value>  
Long Form: [SOURCE:]VOLTage[:LEVel]:PROTect:POSitive <exp\_value>

Description: Establishes the positive protection limit for voltage; maximum is 10% greater than rated output voltage.

**B.94 [SOURCE:]VOLTage[:LEVel]:PROTect:LIMit:BOTH COMMAND VOLT:PROT:LIM[:BOTH]**

Syntax: Short Form: [SOUR:]VOLT[:LEV]:PROT:LIMit[:BOTH] <value>  
Long Form: [SOURCE:]VOLTage[:LEVel]:PROTect:LIMit[:BOTH] <value>  
<value> =

Description: Establishes the maximum value possible for both the positive and negative protection limits for voltage.

**B.95 [SOURCE:]VOLTage[:LEVel]:PROTect:LIMit[:BOTH]? QUERY VOLT:PROT:LIM[:BOTH]?**

Syntax: Short Form: [SOUR:]VOLT[:LEV]:PROT:LIMit[:BOTH]?  
Long Form: [SOURCE:]VOLTage[:LEVel]:PROTect:LIMit[:BOTH]?  
Returns <exp\_value>, <exp\_value>

Description: Identifies the maximum value possible for protection limits for voltage (positive, negative); maximum is 3% to 5% greater than rated output voltage.

**B.96 [SOURCE:]VOLTage[:LEVel]:PROTect:LIMit:NEGative COMMAND VOLT:PROT:LIM:NEG**

Syntax: Short Form: [SOUR:]VOLT[:LEV]:PROT:LIM:NEG <exp\_value>  
Long Form: [SOURCE:]VOLTage[:LEVel]:PROTect:LIMit:NEGative <exp\_value>

Description: Establishes the minimum (maximum negative) value possible for the negative protection limit for voltage. This may be set up to 3% greater than rated voltage

**B.97 [SOURCE:]VOLTage[:LEVel]:PROTect:LIMit:POSitive COMMAND VOLT:PROT:LIM:POS**

Syntax: Short Form: [SOUR:]VOLT[:LEV]:PROT:LIM:POS <exp\_value>  
Long Form: [SOURCE:]VOLTage[:LEVel]:PROTect:LIMit:POSitive <exp\_value>

Description: Establishes the maximum value possible for the positive protection limit for voltage. This may be set up to 3% greater than rated voltage

**B.98 [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., 2.71E1 for 27.1

Description: **Programs voltage value to be transferred to output by \*TRG or TRIG commands.** Actual output voltage will depend on load conditions. If the value exceeds the maximum for the model being programmed, error message -222, "Data out of range" is posted in output queue. If value exceeds VOLT:LIM:HIGH value, a value corresponding to the voltage limit will be programmed. (See example, Figure B-5.)

**B.99 [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., 2.71E1 for 27.1

Description: **Returns value representing voltage value to be programmed by \*TRG or TRIG command established by VOLT:TRIG command).** (See example, Figure B-5.)

**B.100 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-3).** 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-3. OPERATION CONDITION REGISTER, OPERATION ENABLE REGISTER, AND OPERATION EVENT REGISTER BITS**

CONDITION	NU	CC	NU	CV	NU	NU	NU	NU
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

CC - POWER SUPPLY IN CONSTANT CURRENT MODE  
 CV - POWER SUPPLY IN CONSTANT VOLTAGE MODE  
 NU - NOT USED

**B.101 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.)

**B.102 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-3).** 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.103 STATus:OPERation[:EVENT] QUERY**

**STAT:OPER?**

Syntax: Short Form: STAT:OPER[:EVENT]? 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 (see Table B-3).** 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.104 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-3) and Questionable Condition Registers to 0, preventing all status events from being reported. (See example, Figure B-6.)

**B.105 STATus:QUESTIONable[:EVENT]? QUERY**

**STAT:QUES?**

Syntax: Short Form: STAT:QUES[EVENT]? Long Form: STATus:QUESTIONable[EVENT]?

**Return Value:** <int\_value> actual register value

Description: **Indicates the latched condition of the Questionable Event register.** Returns the value of the Questionable Event register (see Table B-4). The Questionable Event register is a read-only register which holds (latches) all events. Only bits 13 and 12 are latched in the Status Questionable Event register. Bits 0 and 1 of the Status Questionable Condition Register are not latched in the power supply. Reading the Questionable Event register clears it. (See example, Figure B-6.)

**TABLE B-4. QUESTIONABLE EVENT REGISTER, QUESTIONABLE CONDITION REGISTER AND QUESTIONABLE CONDITION ENABLE REGISTER BITS**

CONDITION	NU	CE	VE	NU	TE	NU	CM	VM	
BIT	15-14	13	12	11 - 4	3	2	1	0	
VALUE	32,768 -16,359	8192	4096	2048 - 16	8	4	2	1	

CE CURRENT ERROR  
VE VOLTAGE ERROR  
CM CURRENT MODE  
TE THERMAL ERROR  
VM VOLTAGE MODE  
NU NOT USED

**B.106 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-4).** 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). Bits 1 or 0 may be both be set, indicating the power supply is settling after a voltage change. (See example, Figure B-6.)

**B.107 STATus:QUESTIONable:ENABLE COMMAND**

**STAT:QUES:ENAB**

Syntax: Short Form: STAT:QUES:ENAB <int\_value> Long Form: STATus:QUESTIONable:ENABLE <int\_value>

Description: **Programs Questionable Condition Enable Register (see Table B-4).**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.108 STATus:QUESTIONable:ENABLE? QUERY**

**STAT:QUES:ENAB?**

Syntax: Short Form: STAT:QUES:ENAB? Long Form: STATus:QUESTIONable:ENABLE?

**Return Value:** <int\_value> actual register value

Description: **Reads Questionable Condition Enable Register (see Table B-4).** 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.109 SYSTem:DISPlay:BACK COMMAND**

**SYST:DISP:BACK**

Syntax: Short Form: SYST:DISP:BACK<value> Long Form: SYSTem:DISPlay:BACK<value>

Description: Establishes front panel LCD backlight.

**B.110 SYSTem:DISPlay:CONT COMMAND**

**SYST:DISP:CONT**

Syntax: Short Form: SYST:DISP:CONT<value> Long Form: SYSTem:DISPlay:CONT<value>

Description: Establishes front panel LCD contrast.

**B.111 SYSTem:BEEP COMMAND**

**SYST:BEEP**

Syntax: Short Form: SYST:BEEP Long Form: SYSTem:BEEP [ON | OFF]

Description: Causes the unit to emit a brief audible tone each time a key is presses when ON. Disables audible tines when OFF.

**B.112 SYSTem:COMMunication:GPIB:ADDRess COMMAND**

**SYST:COMM:GPIB:ADDR**

Syntax: Short Form: SYST:COMM:GPIB:ADDR<INT VAL> 0 to 30  
Long Form: SYSTem:COMMunication:GPIB:ADDRess<INT VAL> 0 to 30

Description: **Sets selected power supply GPIB address.**

**B.113 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> 0 to 30

Description: **Identifies selected power supply GPIB address.**

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. 3.4.2 for programming techniques to optimize performance.

STAT:PRES	Operation Condition and Questionable Condition registers are reset.
STAT:QUES:ENAB 12228	Allows latching of CE and VE bits
STAT:OPER:ENAB 1280	Mask enabled for CC and CV bits.
STAT:OPER:ENAB?	Returns 1280 (256 + 1024) (CC and CV bits set).
INIT:CONT ON	Continuous triggers enabled.
STAT:OPER:COND?	Power supply returns 256 to indicate that power supply is in constant voltage mode.
STAT:OPER?	Returns 256, indicating that since the last reading of the Operation Event Register the power supply has entered Constant Voltage mode.
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
	--- OVERCURRENT CONDITION OCCURS
SYST:ERR?	Power supply returns 0, "No error" message.
*RST::VOLT 5;CURR 1;OUTP ON	The BOP is in Voltage mode and delivering 5 Volts
*ESR?	Bop returns a 0 - all functions are normal
FUNC:MODE CURR	BOP is in Current mode but Limit Light is on
*ESR?;STAT:QUES:COND?	BOP returns 8;4097 - Current error.
*ESR?;STAT:QUES?	BOP returns 0;4096 - no new errors, Current Error
*ESR?;STAT:QUES?	BOP returns 0;0 - no new errors
MEAS:CURR?;VOLT?	BOP returns 1.0E-4;5.00003E0 - Voltage is 5 volts
STAT:QUES:COND?	BOP returns 4097 - error still in effect
	Short is applied to the BOP
*ESR?:STAT:QUES:COND?	BOP returns 0;1 - Current mode is selected
MEAS:VOLT?;CURR?	BOP returns 1E-4;1.00003E0 - Current is 1 amperes
FUNC:MODE VOLT;*ESR?	BOP switches mode, returns 3 - settling
*ESR?::STAT:QUES?	BOP returns 8;8194
	Short is removed from the BOP output
STAT:QUES:COND?	BOP returns 2, voltage mode operation OK.

**FIGURE B-6. USING STATUS COMMANDS AND QUERIES**

**B.114 SYSTem:COMMunication:SERial:BAUDrate COMMAND SYST:COMM:SER:BAUD**

Syntax: Short Form: SYST:COMM:SER:BAUD {19200 | 9600}  
Long Form: SYSTem:COMMunication:SERial:BAUDrate {19200 | 9600}

Description: **Sets the unit to operate at the specified baud rate.**

**B.115 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 | DISABLED}

Description: **Returns operating baud rate.**

**B.116 SYSTem:COMMunication:SERial:ECHO COMMAND SYST:COMM:SER:ECHO**

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

Description: **Enables (ON) or disables (OFF) echo mode** (see PAR. 3.7.2.1) Sending ON causes all subsequent characters to be echoed back. Sending OFF turns off the character echo after the nest line terminator character. The \*RST command has no effect on echo status



Description: Locks (DIS) or unlocks (ENAB) the front panel keypad. If set to DIS when a memory location is saved by \*SAV, the memory location will no longer be able to be changed from the front panel. To be able to change it from the front panel, SYST:KEYB ENAB must be executed prior to saving the location using \*SAV.

**B.126 SYSTem:LANG COMMAND**

**SYST:LANG**

Syntax: Short Form: SYST:LANG[SCPI | CIIL | SNR | SND]  
Long Form: SYSTem:LANGuage [SCPI | CIIL | SNR | SND]

Description: Establishes which protocol the unit will respond to. SCPI selects the SCPI commands described in this appendix. CIIL selects the CIIL command set compatible with older MATE compatible equipment. SNR or SND selects 12 bit protocol compatible with Kepco's SN programmers; SNR selects hex mode, SND selects BCD (binary-coded decimal) mode. These SN modes provide the ability to talk over the bus and support the IEEE 488.2 commands listed in Appendix A as well as the SYSTem, STATus, CALibration, and MEASure commands from the SCPI interface.

**B.127 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 DIAG:SAV and CALibrate to operate.

**B.128 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.129 SYSTem:PASSword:NEW COMMAND**

**SYST:PASS:NEW**

Syntax: Short Form: SYST:PASS:NEW <old password>,<new password>  
Long Form: SYSTem:PASSword:NEW <old password>,<new password>

Description: **Establishes new password.** The old (current) password is checked, then the replaced by the new password. (See example, Figure B-8.) See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

**B.130 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.131 SYSTem:REMOte COMMAND**

**SYST:REM**

Syntax: Short Form: SYST:REM {ON | OFF} or {1 | 0}  
Long Form: SYSTem:REMOte {ON | OFF} or {1 | 0}

Description: **Sets the unit to remote (1 or ON) or local (0 or OFF) mode.** This command must be issued prior to commands that affect the power supply output (e.g., VOLT 10:OUTP ON) to ensure the unit is in remote mode. See PAR. 3.7.3 and Figure B-7.

**B.132 SYSTem:REMOte? QUERY**

**SYST:REM?**

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

Description: **Identifies whether unit is in remote mode (1) or local mode (0).** See PAR. 3.7.3 and Figure B-7.

*IDN?	Unit responds with KEPCO,BOP 50-20,E1234,1.66 (typical).
outp?	Unit responds with 0 indicating output is off
sys:rem?	Unit responds with 0 indicating unit is in local mode.
outp on	
outp?	Unit responds with 0 (output off). Unit was under local control so the output was not changed.
sys:rem 1	Unit set to remote mode.
outp on	Unit commanded to turn output on.
outp?	Unit responds with 1 (output on) unit is in remote so changes have an immediate effect.
sys:rem?	Unit responds with 1 indicating unit is in remote mode.

FIGURE B-7. SETTING THE UNIT TO REMOTE MODE

### B.133 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.** Empties all memory locations. See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

### B.134 SYSTem:SET COMMAND

## SYST:SET

Syntax: Short Form: SYSTem:SET {CM0 | CM1 | DC0 | DC1 | LF0 | LF1 | RO0 | RO1}

Long Form: SYSTem:SET {CM0 | CM1 | DC0 | DC1 | LF0 | LF1 | RO0 | RO1}

Description: **Establishes Device Clear, Line Feed, and Reset functions. Sending SYST:SEC:IMM sets LF1, DC0, and RO0 (as if CM0 was sent).** See PAR. 3.4.2.2 and Figure 3-7 for special programming considerations.

DC0	Device Clear functions per IEEE 488.2 Standard. (No effect on the device (power supply), only clears internal status registers.)
DC1	Device Clear functions identical to *RST (Output set to 0V, voltage mode and output set to OFF except if RO1 (see below) is set.)
LF0	Line Feed not provided upon empty buffer condition
LF1	Line Feed provided if buffer is empty and a read is performed.
RO0	*RST and power up set output to OFF, 0V, 0A, voltage mode.
RO1	*RST sets output to ON, 0V, 0A, voltage mode. Subsequent VOLT and CURR commands are immediately present at the output without sending OUTP ON (OUTP OFF and OUTP ON function normally to turn the output off or on.)
CM0	Establishes DC0, LF0, RO0 conditions described above. (SCPI 1997 Standard compliance)
CM1	Establishes DC1, LF1, RO1 conditions described above. (Compatible with software versions 1.2 and earlier) (See example, Figure B-8.)



**TABLE B-5. ERROR MESSAGES**

ERROR MESSAGE	ESR ERROR BIT SET (SEE PAR. A.5)	EXPLANATION
0,"No error"	None	No error
1,"Interprocessor communications error"	Device Error bit 3 <sup>(1)</sup>	Interprocessor communications error
2,"Configuration error"	Device Error bit 3 <sup>(1)</sup>	Configuration error
10,"Program Error"	Device Error bit 3 <sup>(1)</sup>	Program error
1xx01,"A3 Output Temperature Error" 1xx02,"A2 Output Temperature Error" 1xx03,"Output Overcurrent" 1xx04,"Output Overvoltage" 1xx05," A2 Instant Overcurrent" 1xx06,"A2 (+)15V BUS Missing" 1xx07,"A3 Overcurrent" 1xx08,"A4 Module Temperature Error" 1xx09,"A4 Output Voltage Error" 1xx10,"A4 Input Section Error" 1xx11,"A2 Input Over Current Error" 1xx12,"A4 (-)15VS Missing	Device Error bit 3 <sup>(1)</sup>	Indicates the power supply or one of the connected power supplies has detected an error. These errors are an indication of a hardware problem in either the BOP or the BOP system consisting of a master and up to four slave BOPs to create additional current or voltage. The last two digits of the error code indicate the type of error and its source; xx indicates the position of the unit on the BITBUS: xx = 1: Device 1 (Master) xx = 2: Device 1 (Slave 1) xx = 3: Device 1 (Slave 2) xx = 4: Device 1 (Slave 3) xx = 5: Device 1 (Slave 4)
2yy01,"OVER TEMPERATURE" 2yy02,"CROWBAR ACTIVE" 2yy03,"DEVICE TURNED OFF" 2yy04,"CURRENT FAULT" 2yy05,"POWER LOSS" 2yy06,"VOLTAGE FAULT" 2yy07,"RELAY OPEN" 2yy08,"POLARITY ERROR" 2yy09,"OVERLOAD"	Device Error bit 3 <sup>(1)</sup>	Indicates a hardware problem has been detected in either the BOP power supply or an auxiliary power supply, such as Kepco's MST, MAT, MBT or low power (under 1KW) BOP, connected to the BITBUS. The last two digits of the error code indicate the type of error detected,; yy indicates the position of the unit on the BITBUS yy = 2: Device 2 through yy = 15: Device 15
-100,"Command error"	Command Error bit 5	Command and data understood, but more information included which is not recognized.
-120,"Numeric data error"	Command Error bit 5	Expected number but other characters were detected
-203,"Command Protected"	Execution error bit 4	Password must be CENabled
-221,"Settings Conflict"	Execution error bit 4	Calibration state not enabled but CALibrate command received
-222,"Current, Voltage or Data out of range"	Execution error bit 4	Value (current or voltage) exceeds power supply rating or (data) exceeds acceptable command parameters
-223,"Too Much Data"	Execution error bit 4	During a LIST command, the list became full, preventing all the data from being added to the list
-226,"Lists not same length"	Execution error bit 4	During a LIST command, number of DWEL list entries was not equal to 1 and did not match number of LIST:VOLT or LIST:CURR entries.
-240,"Hardware error"	Execution error bit 4	Power supply did not respond to command.
-249,"Master Not Found"	Execution error bit 4	The slave controller for a multiple unit configuration has not detected a master unit. - this is an operator error as the slave should not be operated over the GPIB interface.
-311,"Memory Error"	Device Error bit 3 <sup>(1)</sup>	*SAV (save), *RCL (recall), MEMory:SAVE, MEMory:UPDAte or CALibrate:STORe error
-314,"Save/recall Memory Lost"	Device Error bit 3 <sup>(1)</sup>	A memory location that was saved earlier was lost due to a flash error in ether the Display or Analog processor memory.
(1) The Device error bit may be set when the status monitoring functions of the power supply detect an overvoltage/under-voltage condition.		

**TABLE B-5. ERROR MESSAGES**

ERROR MESSAGE	ESR ERROR BIT SET (SEE PAR. A.5)	EXPLANATION
-340,"Calibration Failed"	Device Error bit 3 <sup>(1)</sup>	The calibration results were invalid. This normally indicates an incorrect calibration caused by operator error such as performing a current calibration without a load, or a voltage calibration with a load.
-350,"Queue Overflow"	Device Error bit 3 <sup>(1)</sup>	Error queue was full, error events have been lost.
-363,"Input buffer overrun"	Device Error bit 3 <sup>(1)</sup>	The input from the controlling computer was longer than 253 characters in length.
-400,"QueryError"	Query Error bit 2	Data requested was lost due to 253 character limit or BIT 4886 output buffer
-420,"Query Unterminated"	Query Error bit 2	Controller sent query but did not accept data from power supply. See VOLT? (PAR. B.83), CAL:SAVE (PAR. B.83) commands
(1) The Device error bit may be set when the status monitoring functions of the power supply detect an overvoltage/under-voltage condition.		

**B.135 SYSTem:SET? QUERY**

**SYST:SET?**

Syntax: Short Form: SYST:SET? Long Form: SYSTem:SET?  
Return Value: DC<n>,LF<n>,RO<n> where n = 0 or 1

Description: **Identifies functions established by SYST:SET command.** (See example, Figure B-8.)

**B.136 SYSTem:VERSion? QUERY**

**SYST:VERS?**

Syntax: Short Form: SYST:VERS? Long Form: SYSTem:VERSion?  
Return Value: <int\_value>.<int\_value> (YYYY.V)

Description: **Identifies SCPI Version implemented.** Returns SCPI Version number:  
YYYY = year, V = Revision number for specified year. (See example, Figure B-8.)

SYST:VERS?	Unit returns 1997
SYST:SET?	Unit returns DC0,LF0,RL0
SYST:PASS:NEW DEFAULT,OKAY	Unit changes password to be OKAY
SYST:SET LF1,RL1,DC1	Configures Device Clear, Line Feed and Reset (see PAR. B.134).
DIAG:SAV;:SYST:ERR:CODE?	BOP returns -231 indicating command is protected
SYST:PASS:CEN OKAY	Password enabled commands are accepted
DIAG:SAV	Unit saves the LF1 state for next power on cycle.

**FIGURE B-8. USING SYSTEM COMMANDS AND QUERIES**

**B.137 TRIGger:SOURce COMMAND**

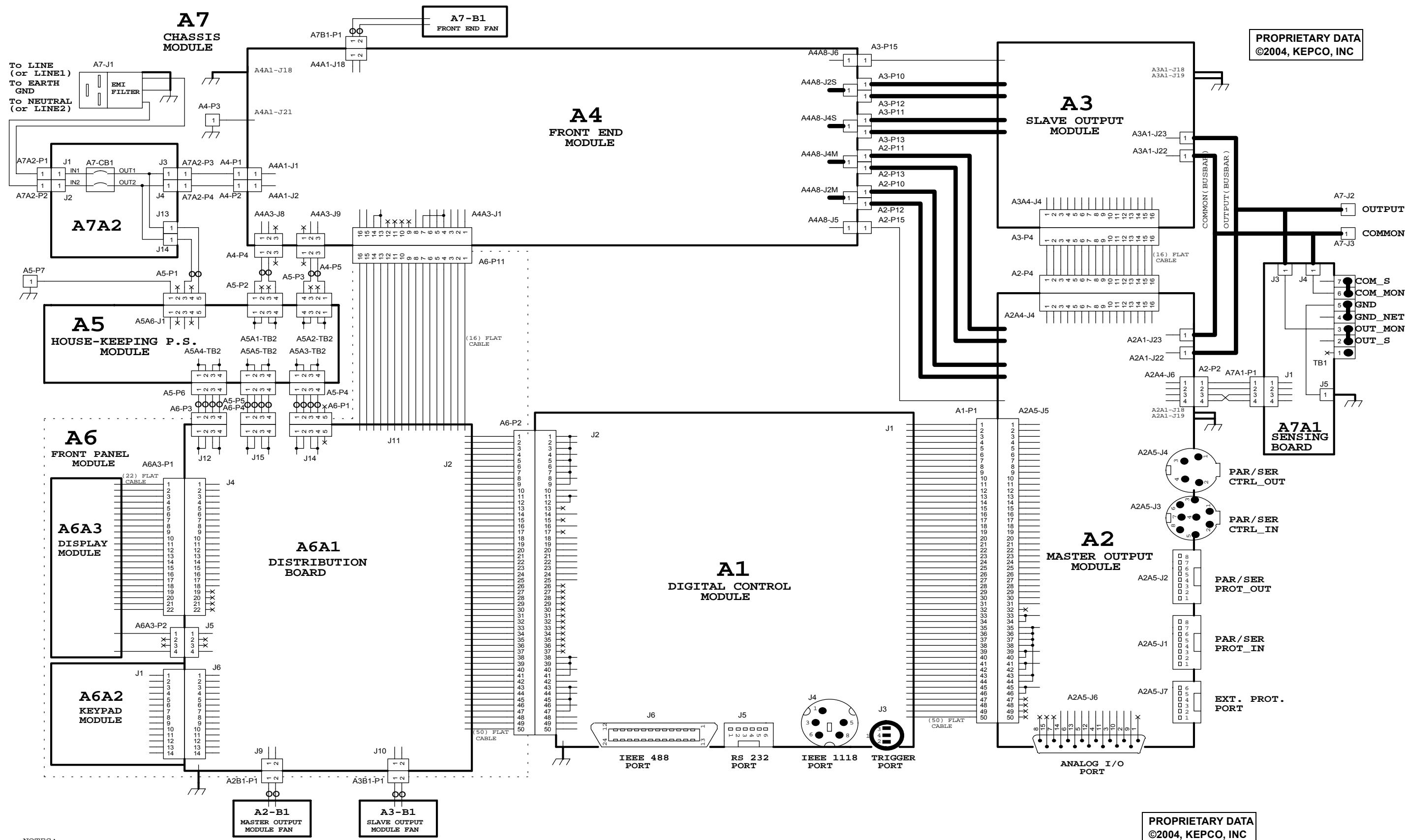
**TRIG:SOUR**

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

APPENDIX C - DIAGRAMS



PROPRIETARY DATA  
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- NOTES:
- 1) THE P.S. IS REPRESENTED IN LOCAL SENSING CONFIGURATION. SEE MANUAL FOR REMOTE SENSING CONNECTION.
  - 2) A3 MODULE AND A3B1 ARE NOT INSTALL FOR 1kw UNITS.
  - 3) A6A2 AND A6A3 ARE NOT INSTALLED FOR SLAVE UNITS.
  - 4) A1 FOR SLAVE UNITS HAS IEEE 1118 PORT ONLY.

FIGURE C-1. BOP POWER SUPPLY, MAIN SCHEMATIC DIAGRAM

