

OPERATOR'S MANUAL

SERIES EL

ELECTRONIC LOAD

KEPCO INC.
An ISO 9001 Company.

MODEL Series EL ELECTRONIC LOAD

ORDER NO.

REV. NO

IMPORTANT NOTES:

- 1) This manual is valid for the following Firmware Versions:

FIRMWARE VERSION

UNIT REVISION NO.

NOTE

1.232

0 or 1

- 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 firmware version 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 firmware version number.
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Model EL 2K-200-200
Single Input Unit



Model EL 1K-200-100D
Dual Input Unit

FIGURE 1-1. SERIES EL LOAD

SECTION 1 - INTRODUCTION

1.1 SCOPE OF MANUAL

This manual contains instructions for the installation, operation and service of the Series EL Electronic loads manufactured by KEPCO, Inc., Flushing, New York, U.S.A.

WARNING



DANGEROUS AND LETHAL POTENTIALS AND CURRENTS ARE PRESENT, BOTH WITHIN THIS ELECTRONIC LOAD, AND AT THE OUTPUT!

Before proceeding to use the electronic load, read this manual very carefully. Caution must be used when working with, and making connections to, this load. Use only wires with the proper current rating and proper voltage rating for high voltage connections.

1.2 INTRODUCTION

The Series EL Electronic Loads (Figure 1-1) are modular, air-cooled, electronic loads. Typically these loads are used to test DC power sources, such as batteries, power supplies, generators, chargers, fuel cells etc.

Table 1-1 lists the rated power, voltage and current for Kepco's Series EL electronic loads. For example, Kepco Model 3K-600-90 Electronic Load uses 1000-volt devices allowing 600 volt operation and is rated at a maximum current capability of 90 amperes and a power rating of 3000 Watts.

Model numbers with a D suffix indicate a dual-channel load. These models are essentially comprised of two independent loads within a single chassis.

1.3 GENERAL DESCRIPTION

The Series EL load system is comprised of two elements—the load and a control source. The load dissipates power from the UUT—i.e. the source of electrical energy being tested by the load. The source of control is either the load front panel or an external computer or other device that can communicate using the interface protocols for which the Series EL is configured.

The load is rack-mountable. Local front panel control allows mode selection and provides: mode indications; display of load current, voltage and power measurements; control parameter adjustment; local/remote control status; fault indications; and power on/off control of the load.

The load has high-current rear panel LOAD Terminals used to connect the UUT to the load, analog control and monitoring terminals, master/slave communications connections, USB 2.0 and RS-232 connectors for remote control, and a mains power connector with fuse. The load can also be configured with optional Ethernet and GPIB interfaces.

Values of load current, voltage and power, as well as fault information can be reported to a computer for display and analysis. SCPI-compliant commands transmitted to the load set the load operating parameters. Special commands allow the user to configure the load measurement system and to perform diagnostic tests.

Series EL electronic loads are designed for future expandability to accommodate increased testing needs as user requirements grow. Any EL electronic load can be expanded to a full 5 kW

capability (with a commensurate increase in maximum current carrying capacity). Additionally, the Series EL system can be expanded above the power/current limits defined in Table 1-1 by adding additional loads. These slave loads act in concert with a master load to increase total power dissipation (and current handling).

TABLE 1-1. MODEL PARAMETERS

Model number	Operating Limits			Overload Protection ⁽¹⁾			Minimum On Resistance Short Mode (Ohms)
	Rated Power (Watts)	Rated Voltage ((Volts)	Rated Current Max (any Mode) (Amperes)	Power ⁽²⁾ (Watts)	Voltage ⁽³⁾ (Volts)	Current ⁽²⁾⁽⁴⁾ (Amps)	
EL 1K-50-100	1000	50	100	1050	52.5	105	0.008
EL 1K-200-100	1000	200	100	1050	210	105	0.014
EL 1K-400-70	1000	400	70	1050	420	73.5	0.046
EL 1K-600-30	1000	600	30	1050	630	31.5	0.017
EL 1K-50-100D	1000 ⁽⁵⁾	50 ⁽⁵⁾	100 ⁽⁵⁾	1050 ⁽⁵⁾	52.5 ⁽⁵⁾	105 ⁽⁵⁾	0.008 ⁽⁵⁾
EL 1K-200-100D	1000 ⁽⁵⁾	200 ⁽⁵⁾	100 ⁽⁵⁾	1050 ⁽⁵⁾	210 ⁽⁵⁾	105 ⁽⁵⁾	0.014 ⁽⁵⁾
EL 1K-400-70D	1000 ⁽⁵⁾	400 ⁽⁵⁾	70 ⁽⁵⁾	1050 ⁽⁵⁾	420 ⁽⁵⁾	73.5 ⁽⁵⁾	0.046 ⁽⁵⁾
EL 1K-600-30D	1000 ⁽⁵⁾	600 ⁽⁵⁾	30 ⁽⁵⁾	1050 ⁽⁵⁾	630 ⁽⁵⁾	31.5 ⁽⁵⁾	0.017 ⁽⁵⁾
EL 2K-50-200	2000	50	200	2100	52.5	210	0.004
EL 2K-200-200	2000	200	200	2100	210	210	0.007
EL 2K-400-140	2000	400	140	2100	420	147	0.023
EL 2K-600-60	2000	600	60	2100	630	63	0.083
EL 3K-50-300	3000	50	300	3150	52.5	315	0.005
EL 3K-200-300	3000	200	300	3150	210	315	0.005
EL 3K-400-210	3000	400	210	3150	420	220.5	0.015
EL 3K-600-90	3000	600	90	3150	630	94.5	0.056
EL 4K-50-500	4000	50	500	4200	52.5	525	0.002
EL 4K-200-500	4000	200	500	4200	210	525	0.003
EL 4K-400-350	4000	400	350	4200	420	367.5	0.009
EL 4K-600-150	4000	600	150	4200	630	157.5	0.033
EL 5K-50-600	5000	50	600	5250	52.5	630	0.001
EL 5K-200-600	5000	200	600	5250	210	630	0.002
EL 5K-400-420	5000	400	420	5250	420	441	0.008
EL 5K-600-200	5000	600	200	5250	630	210	0.028

NOTES:

- (1) Temperature protection: Per FET safe junction temperature.
- (2) Maximum operating power and current may be reduced if a) ambient temperature exceeds 25°C or b) operating conditions (ambient temperature, available air flow, etc.) cause internal load temperature to exceed safe operating conditions for FETs (temperature fault).
- (3) Maximum permissible voltage across ±LOAD terminals. This voltage should never be exceeded, regardless of load power or load on/off states. Applied voltage must always be positive: +LOAD with respect to –LOAD.
- (4) Each FET is individually fused. A blown fuse is reported as a Fault.
- (5) Per Channel.

1.4 OPERATING MODES

The load operates in one of six modes. Each mode is subject to independent limits for maximum load current, power, voltage and frequency. Current draw does not occur until the load is turned ON (engaged with) the Unit Under Test (UUT).

1.4.1 CI (CONSTANT CURRENT).

The current drawn by the load from the UUT remains at a constant value defined by the user.

1.4.2 CV (CONSTANT VOLTAGE)

The current drawn by the load from the UUT varies as required to cause the UUT voltage to decrease to the voltage defined by the user. Operation in CV mode requires sufficient source resistance in the UUT so voltage drops in the UUT allow the desired voltage control.

1.4.3 CP (CONSTANT POWER)

The current drawn by the load from the UUT varies as required to cause a constant amount of power defined by the user to be dissipated by the load, where power is defined as the product of UUT voltage and current drawn by the load.

1.4.4 CR (CONSTANT RESISTANCE)

The current drawn by the load from the UUT varies as required to cause a constant resistance (UUT voltage divided by load current) defined by the user.

1.4.5 CS (CONSTANT CONDUCTANCE)

The current drawn by the load from the UUT varies as required to cause a constant conductance (UUT current divided by load voltage) defined by the user.

1.4.6 SHORT

The current drawn by the load is the maximum possible by the load; load resistance is minimum ON (see Table 1-2). **CAUTION: There is no user adjustment of the current in the SHORT mode—use caution!**

1.4.7 OFF

No current is drawn by the load even when the load is turned ON.

1.5 FEATURES

1.5.1 LOCAL CONTROL

Three 4-digit, 7-segment LED displays and six individual LEDs on the front panel show operating status. A rotary encoder (CONTROL) allows the user to adjust the selected load parameter, define the resolution of the rotary encoder and to select the operating mode. An illuminated momentary pushbutton switch (LOAD) allows the user to alternately a) engage the load, allowing the source or Unit Under Test (UUT) to draw current and b) disengage the load, stopping current flow. An integral indicator within the LOAD switch changes color to show the load connection status and indicate a fault condition if one exists.

1.5.2 REMOTE CONTROL

Remote control of the Series EL Electronic Load is accomplished from a remote device using SCPI commands and either RS 232, USB, or optional GPIB/LAN protocols. The RS 232 and USB ports cannot be turned off, therefore the Series EL can always be controlled via these ports. Digital commands expand the control available from the front panel, and include damping when required for square wave or pulse type requirements, overvoltage, undervoltage, overcurrent and overpower protections.

1.5.3 ANALOG PROGRAMMING

An analog input is provided at the rear that allows the user to use a 10V analog signal to control the voltage, current or power, depending on the mode selected. See PAR 3.12 for details.

1.5.4 DIGITAL CALIBRATION

Internal adjustments of the Series EL Electronic Load are automatic. Calibration can be performed remotely via one of the remote interfaces.

1.5.5 DAMPING

Typical operation for an electronic load involves the flow of high currents. The combination of high, rapidly changing currents and the inductance associated with connections to the load via lead wires can cause unexpected results, such as very high voltage spikes, oscillation or severe ringing (damped oscillations) at the source. To help reduce these issues, the Series EL offers multiple forms and degrees of damping, allowing the best measurements possible. See PAR. 3.11 for details.

1.5.6 BUILT-IN PROTECTION

- **Overtemperature.** Thermal management of the EL Series is accomplished by continually monitoring the temperature of each individual power-dissipating MOSFET. If the temperature of a MOSFET begins to approach a dangerous level, then its power will be reduced and the other MOSFETs will naturally increase their share via the control loops. If the temperature of one or more of the MOSFETs exceeds safe operating limits, this may cause either a reduction of the load maximum current/power handling ability or a complete inability to use the load depending on the degree of overheating.
- The user can establish limits for overvoltage or undervoltage, overcurrent, or power which can not be exceeded at the input. If the limits are exceeded, the unit disengages from the UUT and a fault indication is displayed (see PAR. 3.3.1 for details).

1.5.7 MASTER/SLAVE CONTROL

For configurations that require power or current in excess of the maximum available from a single unit, additional units can be added to the system to increase power/current capability, up to a maximum of 15 units.

1.6 SPECIFICATIONS

Parameters unique to different models of Series EL loads are listed in Table 1-1. Specifications common to all Series EL models are listed in Table 1-2.

TABLE 1-2. SERIES EL SPECIFICATIONS

SPECIFICATION	RATING/DESCRIPTION	CONDITION/COMMENT	
MODE CHARACTERISTICS			
Linearity vs. programming command	See Table 1-3	5 – 100% of Full Scale	
Regulation ⁽¹⁾	See Table 1-3		
Resolution (via computer control)	14 Bits		
Current readback (Current mode)	Computer Accuracy:		±0.25%
	Computer Resolution:		±15 Bits
Parameter readback (Current and Voltage)	Accuracy:	±0.25%	
	Resolution:	±15 Bits	
	Temperature coefficient:	100 ppm/°C	
CONTROL CHARACTERISTICS			
USB Interface	Uses IEEE 488.2 and SCPI commands and queries.	Requires driver.	
RS 232 Interface	Uses IEEE 488.2 and SCPI commands and queries.	Baud rate: 38400 Parity: None Data Bits: 8 Stop Bits: 1 Flow Control: None	
GPIB Interface	Uses IEEE 488.2 and SCPI commands and queries.	Optional	
Ethernet Interface	Uses IEEE 488.2 and SCPI commands and queries.	Optional	
GENERAL CHARACTERISTICS			
a-c Line Power Input	120 VAC ±10%, 50/60 Hz or 240 VAC ±10%, 50/60 Hz	120V is factory default; 240V requires internal configuration (see PAR 2.3.1?)	
Operating Temperature	0°C to 40°C		
Dimensions (load)	19"W x 7"H x 24.5"D	See Figure 2-10.	
Weight (load)	88 lbs.		
Storage Requirements	-20 to +60°C, 15 to 80% RH	Relatively dust free environment	

NOTE:

(1) Regulation specified after 15 minutes of operation at set power level.

TABLE 1-3. MODE CHARACTERISTICS

MODE	Linearity Vs. Programming Command	Regulation ⁽¹⁾
Constant Current	±0.25%	±0.25%
Constant Power	±2%	±1%
Constant Voltage	±0.25%	±0.25%
Constant Resistance	±1%	±1%
Constant Conductance	±1%	±1%

(1) Regulation specified after 15 minutes of operation at set power level

1.7 EQUIPMENT SUPPLIED

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

TABLE 1-4. EQUIPMENT SUPPLIED

ITEM	PART NUMBER	QUANTITY
Source Power cable	118-1234 (Unicable 3850-761-BB/G)	1
Series EL Quick Start Guide *	228-1687	1
EL Series (except Dual models) \pm LOAD terminal hardware		
Screw, Cap, Hex, Silicon bronze, 3/8-16 (coarse thread) x 1 in.	101-0507	2
Nut, Hex, silicon bronze, 3/8-16	102-0182	2
Washer, split, silicon bronze, 3/8	103-0196	2
Washer, flat, silicon bronze, 3/8	103-0197	4
EL Series Dual models \pm LOAD terminal hardware		
Screw, Cap, Hex, Silicon bronze, 5/16-18 (coarse thread) x 1 in.	101-0065	4
Nut, Hex, silicon bronze, 5/16-18 (Dual load only)	102-0011	4
Washer, split, silicon bronze, 5/16 (Dual load only)	103-0005	4
Washer, flat, silicon bronze, 5/16 (Dual load only)	103-0212	8
Ground stud hardware		
Wingnut, 1/4-20, 18-8 stainless-steel	102-0190	1
Washer, Flat, 1/4 in., 18-8 stainless-steel	103-0201	2
Washer, split, 1/4 in., 18-8 stainless-steel	103-0204	1
Nut, 1/4-20, 18-8 stainless-steel	102-0188	1
Fuse 3A, SB	141-0129 (Littelfuse 0313003.HXP)	1
* Series EL USB Driver Manual and Series EL Operator Manual are available for free download from the Kepco website at www.kepcopower.com/support/opmanls.htm#e Series EL Drivers are available for free download at www.kepcopower.com/drivers/drivers-dl3.htm#el		

1.8 ACCESSORIES

Accessories for the Series EL Electronic Load are listed in Table 1-5.

1.9 OPTIONS

The following are options, and are not covered in this manual. Contact Kepco for further details about options listed.

- GPIB Interface
- Ethernet Interface



1.10 SAFETY

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

TABLE 1-5. ACCESSORIES

ITEM	FUNCTION	KEPCO PART NUMBER
RJ 22 Master/Slave cable, 1 ft. (See Note.)	Daisy chains Series EL loads with the same voltage for parallel configurations.	118-1245
Fuse 1.5A, SB	Required for units configured to run from 240V a-c source power.	141-0031 (Littelfuse 31301.5)
Slides	Allows the unit to slide out of a rack.	108-0474
Side Support bracket	Pair required. Used to provide side support for EL Load. Requires rear rail at 18-13/16 in. setback.	128-1775
NOTE: For units that use slide mounting, consult Kepco for longer cable lengths.		

TABLE 1-6. SAFETY SYMBOLS

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

SECTION 2 - INSTALLATION

2.1 UNPACKING AND INSPECTION

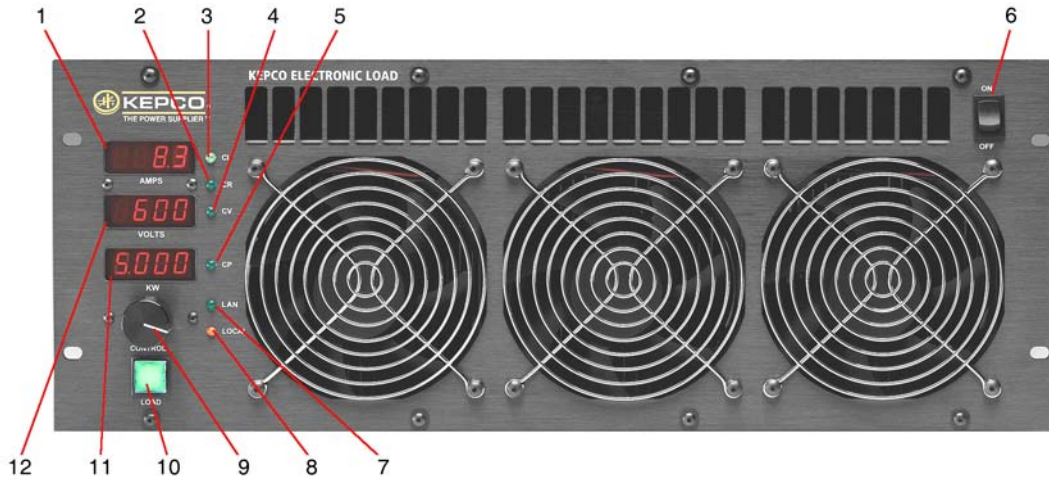
This instrument has been thoroughly inspected and tested prior to packing and is ready for operation. After careful unpacking, inspect for shipping damage before attempting to operate. Perform the preliminary operational check as outlined in PAR 2.5. If any indication of damage is found, file an immediate claim with the responsible transport service.

2.2 TERMINATIONS AND CONTROLS

2.2.1 FRONT PANEL CONTROLS AND INDICATORS. Three 4-digit, 7-segment LED displays and six individual LEDs on the front panel show operating status as shown in Figure 1. A rotary encoder (CONTROL) allows the user to: a) adjust the selected load parameter, b) define the resolution of the rotary encoder, c) select the operating mode. A momentary pushbutton switch (LOAD) with integral LED indicator allows the user to alternately a) engage the load, allowing the source or Unit Under Test (UUT) to draw current and b) disengage the load, stopping current flow. The LOAD LED indicator colors show the load connection status and indicate a fault condition if one exists.

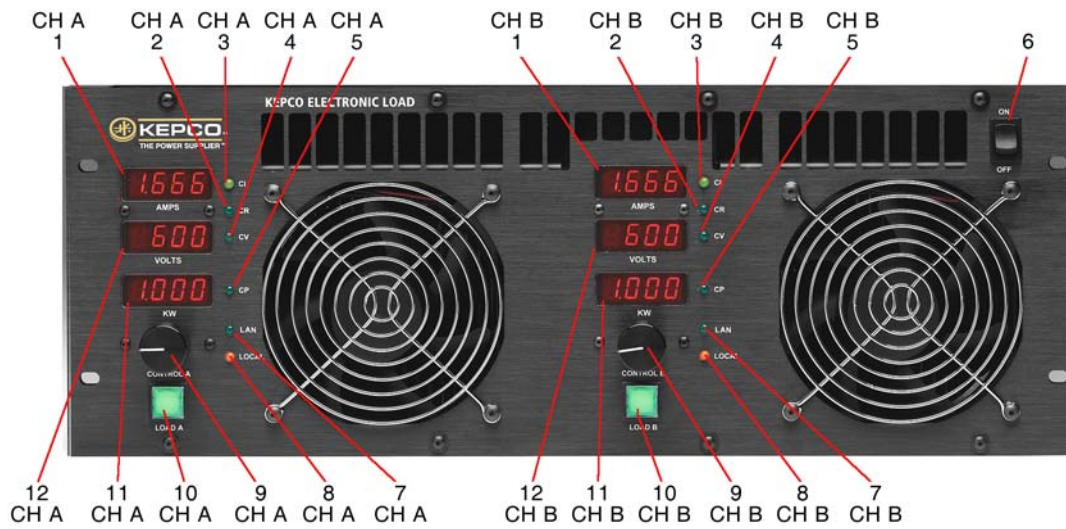
Figure 2-1 shows the front panel of standard units; Figure 2-2 shows the front panel of dual-channel units. Table 2-1 presents the functions of all front panel controls and indicators. Front panel controls listed in Table 2-1 are duplicated for identical (but independent) channels A and B of the dual-channel units, with the exception of the single POWER switch which applies to both channels.

2.2.2 REAR PANEL CONNECTIONS. Figure 2-3 shows the rear panel of standard units; figure 2-4 shows the rear panel of dual-channel units. Table 2-2 presents the functions of all rear panel connections. Rear panel connections listed in Table 2-2 are duplicated for identical (but independent) channels A and B of the dual-channel units, with the exception of the single power inlet connector and fuse which apply to both channels.



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FIGURE 2-1. SERIES EL, FRONT PANEL CONTROLS AND INDICATORS



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FIGURE 2-2. SERIES EL, DUAL MODEL FRONT PANEL CONTROLS AND INDICATORS

TABLE 2-1. FRONT PANEL FUNCTIONS

SEE FIG. 2-1 OR 2-2	COMPONENT	FUNCTION
1	AMPS display	Displays the load test current in Amps (factory default setpoint (see NOTE): 0 Amps) or test current setpoint in Amps.
CAUTION: Short mode is selected when CR, CI, CV and CP indicators all blink.		
2	CR indicator	On (solid) indicates Constant Resistance Mode; factory default setpoint (see NOTE): 1000 Ohms. On (blinking with other Mode indicators off) indicates Constant Conductance Mode; factory default setpoint: 1mS (0.001 siemens, I/E).
3	CI indicator	On to indicate Constant Current Mode.
4	CV indicator	On to indicate Constant Voltage Mode (factory default setpoint (see NOTE): maximum load voltage).
5	CP indicator	On to indicate Constant Power Mode (factory default setpoint (see NOTE): 0 kilowatts).
6	Power ON/OFF switch	Rocker switch: press top half to turn power on, bottom half to turn power off. NOTE: Cycling power switch from ON to OFF to ON resets fault conditions, but does not reset setpoints (see NOTE).
7	LAN indicator	Green LED on when Ethernet control is active.
8	LOCAL indicator	Red LED on when front panel controls are active.
9	CONTROL rotary encoder/pushbutton switch	When LOCAL is active, Four functions are available as follows: a. Select Mode: Press, hold (at least 3 seconds) and rotate knob to select mode indicated by the CI, CR, CV and CP indicators (see Table 3-1). LOAD indicator off while selecting mode; release to make selection. b. Set Value: Rotate knob to adjust the level of the controlled parameter: current, voltage, resistance, conductance or power (see Table 3-1). Rotate clockwise to increase, counterclockwise to decrease. Settings are stored and will be available at next power-up. c. Select Digit: Momentarily press knob to select one digit (blinks). Convenience function allows adjustment at desired resolution. d. Show settings: When Mode is set to OFF, rotating CONTROL while LOAD switch is blinking green and depressed displays Model number, Serial number, IP address, etc. (see PAR. 3.7).
10	LOAD momentary pushbutton switch/indicator	Switch used to alternately enable (load engaged) or disable (load disengaged) the ability of the load to draw current from the UUT. Indicator lights to show load status: Green (steady): Standby - Ready to operate; load does not draw current from the UUT. Parameter displays show voltage, current and power setpoints when CONTROL is momentarily depressed. Green (blinking): Modes set to off (CR, CI, CV, CP all off), Load can not be engaged. Load configuration information is displayed. Amber: Engaged - The load is able to draw current from the UUT, however current may or may not be flowing depending on the setpoint settings. Parameter displays show actual voltage, current and power. Red (blinking): Fault - The load does not draw current from the UUT. The nature of the fault is shown in the appropriate 7-segment display (see PAR.3.3.1) NOTE: The fault condition must be corrected before the load can be engaged; press LOAD switch to change indication to Standby (green) after fault is corrected. Off (not lit): Mode selection using CONTROL is in progress.
11	KW display	Displays the power (Amps x Volts) being dissipated by the load in kilowatts. Also indicates resistance (in Ohms) or conductance (in Siemens) settings.
12	VOLTS display	Displays test voltage from UUT applied to the load in Volts.
NOTES: Factory defaults refer to setpoints for the measurement displayed. These factory default setpoints are designed to ensure that no current is drawn from the UUT when the load is engaged without further adjustment of these parameters. The EL Series load maintains individual setpoints for each mode. These are stored in non-volatile memory, however the factory default setpoints can be restored by issuing *RST command over a remote interface.		

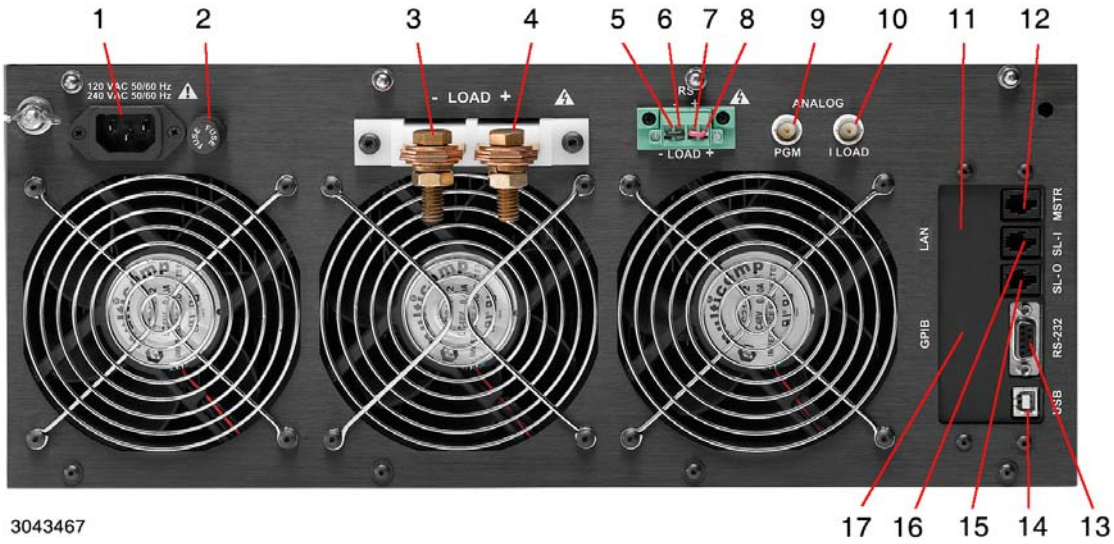


FIGURE 2-3. SERIES EL, REAR PANEL TERMINATIONS AND CONNECTORS

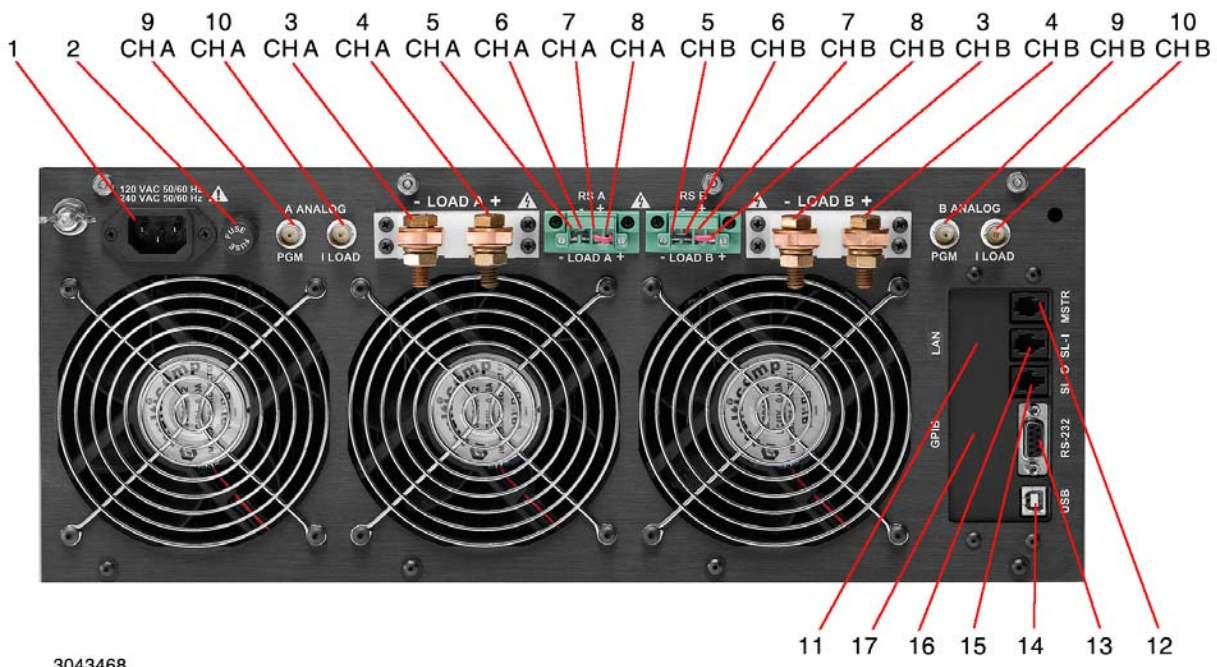


FIGURE 2-4. SERIES EL, DUAL MODELS, REAR PANEL TERMINATIONS AND CONNECTORS

TABLE 2-2. REAR PANEL CONNECTIONS

FIG. 2-3 or 2-4 INDEX NO.	NAME	DESCRIPTION
1	120VAC 50/60HZ/ 250VAC 50/60HZ/	POWER: IEC 60320-C13 line cord connector to connect mains power (either 120 VAC 50/60 Hz or optional 240V AC 50/60 Hz). NOTE: changing mains power voltage requires internal connector changes (see PAR. 2.3.1).
2	FUSE	FUSE: 120 V, 3AG, 3 Ampere Slo Blow (or 240V, 3AG, 1.5 Ampere Slo Blow)
3	LOAD (–) Bus bar	UUT Connections. (–) Negative and (+) Positive: High current connections to UUT. Connections to \pm LOAD are typically made using the supplied 3/8" low-resistance hardware (2 sets: bolt, nut and lockwasher).
4	LOAD (+) Bus bar	
5	LOAD (–) terminal	(–) Negative Load Voltage Monitor. (CAUTION: Do not attempt to pass load current through this connector—it is only for UUT voltage measurement)
6	RS (–) terminal	Remote Sense (voltage) Negative Connection (CAUTION: Do not attempt to pass load current through this connector—it is only for UUT sense connection)
7	RS (+) terminal	Remote Sense (voltage) Positive Connection (CAUTION: Do not attempt to pass load current through this connector—it is only for UUT sense connection)
8	LOAD (+) terminal	(+) Positive Load Voltage Monitor. (CAUTION: Do not attempt to pass load current through this connector—it is only for UUT voltage measurement)
9	ANALOG PGM Isolated BNC Connector	A 0 to 10V analog programming signal can alter the digital setpoint of the CONTROL parameter (depending on mode selection and digital setpoint) from 0 to full scale. See PAR. 3.12 for details and an example.
10	ANALOG I LOAD Isolated BNC Connector	This signal is 0 to 10V d-c corresponding to 0A to the configured/calibrated full scale current. Output at center pin when the load is drawing current from the UUT.
11	LAN	Not shown.
12	MSTR Master Out connector	Standard RS-522 connector. Connects from Master Out to Slave In (SL-I) for multiple units in parallel (see Figure 2-9). See PAR. 3.13 for master/slave configurations. See Table 1-5 to order RJ 22 master/slave cable.
13	RS-232 connector	Standard RS-232. Connects with a remote device using RS 232 protocols and SCPI commands (see Figure 2-3).
14	USB connector	Connection to remote device for command, monitoring or calibration. Use USB connector of master to communicate with multiple loads in a master/slave configuration. (see Figure 2-7).
15	SL-O Slave Out connector	Standard RS-522 connector. Connects Slave Out to SL-I (Slave In) of next slave if unit is a slave in a parallel configuration using more than two units. Only use Kepco cable (see Table 1-5) for master/slave connections (Figure 2-9).
16	SL-I Slave In connector	Standard RS-522 connector. Connects Slave Out to SL-I (Slave In) of next slave if unit is a slave in a parallel configuration using more than two units. Only use Kepco cable (see Table 1-5) for master/slave connections (Figure 2-9).
17	GPIB IEEE 488 connector	Not shown.

2.3 MAINS POWER REQUIREMENTS

The Electronic Load is delivered configured for operation from 120V a-c $\pm 10\%$, 50/60 Hz. If the load is to be operated from a 240V a-c $\pm 10\%$, 50/60 Hz power source, or the input power range needs to be changed from a previous selection, see PAR 2.3.1 to change mains power

CAUTION: The Series EL of electronic loads do not have 120/240V automatic line voltage switching. Applying 240V a-c to a load configured for 120V a-c will damage the load.

2.3.1 CHANGING MAINS POWER VOLTAGE

The load can be operated from either 120V a-c, $\pm 10\%$, 50/60 Hz or 240V a-c, $\pm 10\%$ 50/60 Hz. To change from one mains operating voltage to the other requires repositioning of line voltage selection jumpers located on the Master Control Board and must be done only by authorized personnel. NOTE: Carefully tag and retain all attaching hardware for use during reassembly.

1. Disconnect all line voltage sources and UUT sources.
2. Open the load cabinet by removing the top cover as described below:
 - a. Loosen and remove five screws holding the top cover to the load on each side.
 - b. Loosen and remove four nuts holding the top cover to the load rear panel. The top cover is held in place by four threaded studs.
 - c. Loosen and remove four screws holding the top cover to the load front panel. For ease of removal, use a non-metallic support tool through the front panel vertical ventilation slots to support the top cover as the screws are removed. With the screws removed, the tool can be used to elevate the top cover above the front panel so it can be grasped and removed from the load.
3. Refer to Figure 2-5 and remove the Master Control Board as follows:
 - a. Unplug 10-pin ribbon cable at top of Master Control Board.
 - b. Unplug 16-pin ribbon cable from Front Panel Display Board at top of chassis.
 - c. Unplug front and rear fan connectors from Master Control Board.
 - d. From outside of side panel, remove four Allen Head screws holding the Master Control Board mounting plate to the load side panel.
 - e. To allow the transformer on the Master Control Board clearance it is necessary to remove one Power FET Module (PFM) board (see Figure 2-5). Disconnect two PFM board interconnection cables, then remove four groups of four screws (each with one flat washer and one lockwasher) and two sets of brass nuts (each with one flat washer and one lockwasher).
 - f. Raise Master Control Board assembly until the two small black mains voltage selection jumpers are visible (see Figure 2-6). NOTE: It may be necessary to remove nut securing wire strap holding front fan connector wires to fully remove board.
4. Using long-nosed pliers, remove the jumpers and relocate them to the desired position (see Figure 2-6). NOTE: Two jumpers used for 120V a-c operation, only one jumper used for 240V a-c operation.

5. Reassemble the load by reversing the above steps. **CAUTION: When reinstalling the PFM Board, it is important to torque all screws and nuts to 1.5Nm (13.8 in-lb).**
6. Change the mains fuse to correspond to the type and rating suitable for the selected mains voltage operation (see Figure 2-3).

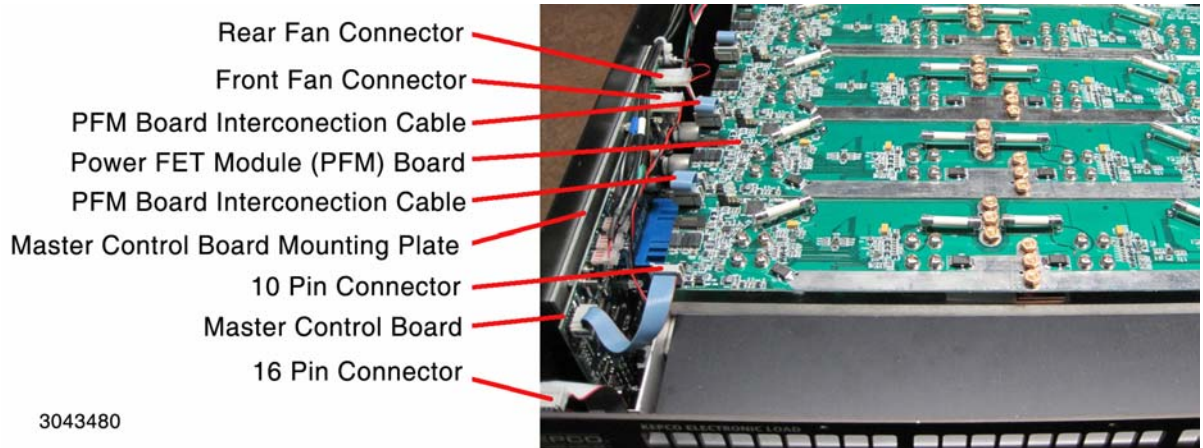


FIGURE 2-5. MASTER CONTROL BOARD REMOVAL, TOP VIEW

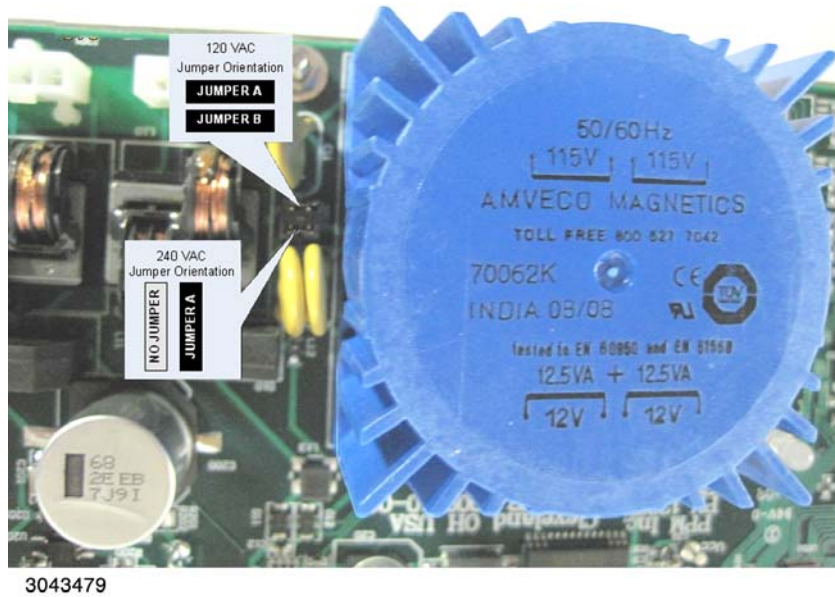


FIGURE 2-6. LINE VOLTAGE SELECTION JUMPER ORIENTATION

2.4 COOLING

The power devices used within the electronic load are maintained within their operating temperature range by means of internal heat sink assemblies cooled by six cooling fans.

ALL INLET AND EXHAUST OPENINGS AT THE FRONT AND REAR OF THE ELECTRONIC LOAD MUST BE KEPT CLEAR OF OBSTRUCTION TO ENSURE PROPER AIR ENTRY AND EXHAUST.

These units are zero-clearance stackable, i.e., no top or side ventilation is required when rack mounting. However, if the unit is rack mounted, or installed within a confined space, care must be taken that the ambient temperature, which is the temperature of the air immediately surrounding the load, does not rise above the specified limits (see Table 1-2).

2.5 INSTALLATION



WARNING!

The load is very heavy (80 - 90 pounds). Exercise care when lifting, mounting or otherwise handling this product. It is recommended that two or more persons handle the electronic load.

2.5.1 RACK MOUNTING

The unit is intended to be either used on a bench or mounted directly in a 19-inch wide rack. These units are zero-clearance stackable, i.e., no top or side ventilation is required when rack mounting (see cooling, PAR. 2.4). Optional slides (see Table 1-5) can be used.

Four front panel mounting holes are provided. When optional slides are not used, additional support is required.

When at least 1/2U space is available at the bottom, either a bottom support platform (shelf) or side support brackets can be used. Contact factory for proper bracket depending on rail set-back.

For zero-clearance stacking, support must be provided at the rear; contact factory for details.

2.6 WIRING INSTRUCTIONS

Interconnections between an a-c power source and the load, and between the load and the unit under test are as critical as the interface between other types of electronic equipment. Figure 2-7 illustrates connections for a typical test setup.

Series EL is provided with a three-terminal IEC appliance coupler for connection of the mains supply source, one terminal of which is dedicated for the protective earthing conductor; no other ground or earth connection is required, although the chassis may be separately connected to earth ground for noise or other reasons, such as user or site requirements.

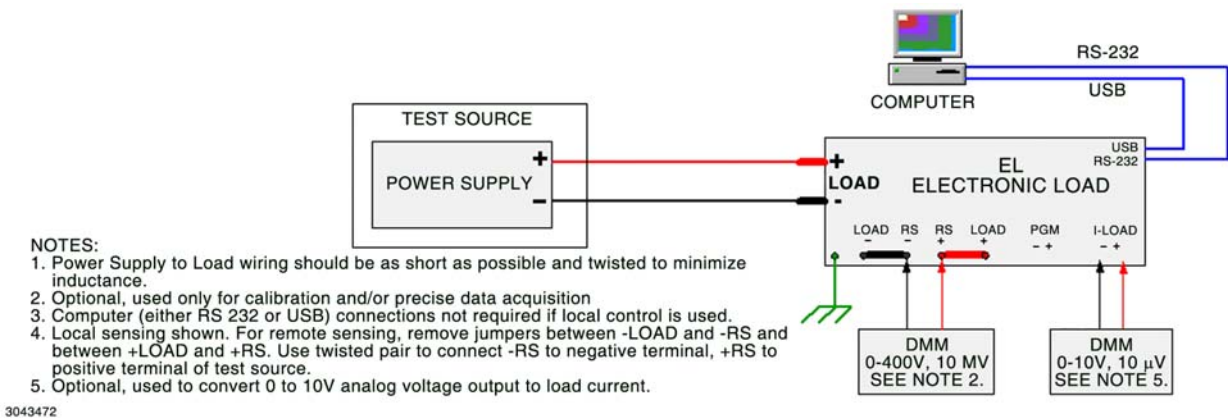


FIGURE 2-7. TYPICAL INTERCONNECTIONS

2.6.1 MAINS POWER

Mains power is connected at the rear panel of the Series EL Electronic Load (see Figure 2-3) via the IEC 320-style recessed power inlet connector, which provides interface to the three-wire safety line cord (supplied) via a polarized mating plug. (see PAR. 2.3 for mains power requirements).

It is recommended that the 1/4-inch bolt with wingnut and flat washers (supplied) at the top left of the rear panel be connected to earth ground.

2.6.2 UNIT UNDER TEST (UUT) TO LOAD CONNECTION



WARNING!

Loose test connections between the UUT and the Series EL load can lead to load instability, erratic operation and possible equipment damage. In addition, loose connections or insufficiently sized conductors can become very hot and cause burns.

2.6.2.1 POWER CONNECTIONS

Connections between the UUT and the Series EL Electronic Load are achieved via the (+) and (-) LOAD terminals located on the rear panel.

The load is capable of drawing very high currents. Connections between the UUT and the load should be of suitably large wire, sized to carry the maximum current. It is extremely important to ensure all connections are tight and corrosion free. Regular inspection of these connections is important. Inspection interval should be established based on frequency and type of use. Once per week is recommended, however where cable movement or vibration is likely, more frequent inspections are warranted.

Use two wrenches to tighten the 3/8 in. (5/16 in. for Dual models) Bolt/Nut on the bus bars. these hardware items are brass and could shear if overtightened: recommended maximum torque is 20 lb-ft for the 3/8 in. hardware, 10 lb-ft for the 5/16 in. hardware used on Dual models. The small resistance created by a loose joint can cause very destructive heating (e.g., a 1 milliohm joint with a current of 400 Amperes generates 160 watts).

WARNING



Reversing the polarity at the LOAD terminals will cause immediate and significant damage to the load and UUT!

2.6.2.2 SENSE CONNECTIONS

Remote Sensing terminals (\pm RS) are provided for connection to the UUT in order to compensate for voltage drops on the power cables connected to the \pm LOAD terminals. When remote sensing is used, the readings shown on the front panel accurately reflect the output of the UUT.

To use remote sensing first remove the local sense jumpers (NOTE: Local sense jumpers can be fabricated as needed using #18 AWG stranded wire) installed on the \pm RS Terminal block. Then connect wires (#24 AWG or 22 AWG) from +RS to the positive output of the UUT, and from -RS to the negative output of the UUT. Twisting of sense wires is recommended.

If remote sensing is not used, the pre-installed local sensing jumpers must remain in place as shown in Figure 2-3. Operating the unit with neither local or remote sensing in place will result in erroneous readings.

Connect the Series EL Electronic Load to the UUT using cabling appropriate for the current and voltage drawn during testing. Contact Kepco if assistance is needed in selecting the appropriate wire size, length and physical configuration. Ensure all connectors are suitable for the currents and that connections are tight. Connections should be re-checked on a regular basis (see PAR. 2.6) to ensure continued low-resistance connections.

CAUTION:When connecting the load to the UUT be very careful not to accidentally short the UUT output in the process of connecting the wiring. Best practice is to make the connection to the UUT Positive (+) output connector the last connection.

NOTE:

1. LOCAL SENSING SHOWN.
2. FOR REMOTE SENSING, REMOVE JUMPERS FROM \pm RS AND CONNECT \pm RS TERMINALS TO CORRESPONDING \pm OUTPUT TERMINALS AT THE UNIT UNDER TEST.

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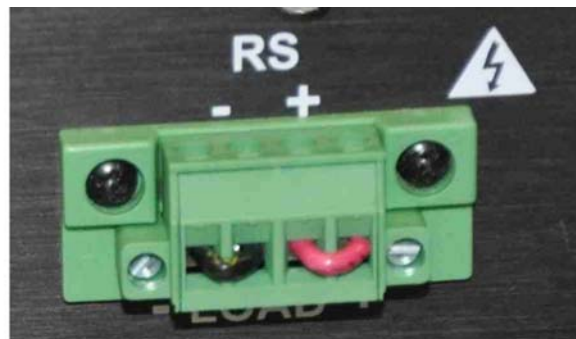


FIGURE 2-8. LOCAL SENSING JUMPERS

2.6.2.3 GROUNDING

It is recommended that the 1/4-inch bolt with wingnut and flat washers (supplied) at the top left of the rear panel be connected to earth ground.

The LOAD Bus bars are isolated from the chassis and from the control circuits well into the 100s of volts. The PGM (Program) input is isolated from the control circuits (and are therefore doubly isolated from the LOAD Bus) up into the 100s of volts. The I-Load output is independently isolated from the control circuits and therefore is double-isolated from all other external connections. Lastly, all of the Remote Interface inputs (RS-232, USB 2.0, RS-522) are optically isolated from the control circuits and are therefore doubly isolated from all other circuits.

2.6.3 PARALLEL MASTER/SLAVE CONFIGURATIONS

Up to 15 Series EL Electronic Loads may be paralleled for additional current and/or power handling capability. All units must have the same voltage rating. One load is designated as the Master, and the rest are designated as slaves. Master/slave communications are via proprietary protocols using special cable(s) connected to the MSTR (Master) and SL-I and SL-O (Slave In and Out) connectors on the rear panel. (see Table 1-5). Connections are from MSTR to SL-I, then for subsequent slaves, from SL-O to SL-I. Computer/load communications are via either the RS 232 or USB connections applied to the master only. Figure 2-9 illustrates connections for a typical master/slave system.

In a Master-Slave configuration, two or more Loads operate in parallel to increase the total current and power capacity.

CAUTION: Loads in Master-Slave configuration are always operated in PARALLEL, never in series. Each Load in the system must have exactly the same maximum voltage limit-otherwise the Load internal software will not allow the Loads to configure as a Master-Slave system. Paralleling two Loads of unequal voltage rating and applying a voltage greater than the limits of the Load with the lower voltage rating can result in the destruction of the Load, the connected source or both.

Typically Loads are stacked vertically to minimize the distance between the \pm LOAD terminals. It is essential to keep this cabling as short as possible due to the high currents flowing during operation. One of the Loads is designated as the Master and the other as the Slave. Any Load may be designated as the Master.

Master-Slave configuration is achieved by two interconnections at the Load rear panel (see Figure 2-9): First connect the \pm LOAD terminals of master and all slaves in parallel using sufficiently heavy cable to carry the maximum current expected to be drawn by any of the individual loads. Next connect the UUT (Unit Under Test) to the \pm LOAD terminals. Use of No. 6 (or larger) Welding Cable is recommended for flexibility, current carrying capacity and insulation.

For remote operation use the supplied RJ-22 Master-Slave communications bus cables (these use miniature modular connectors - do not try to use conventional modular telephone cables). Connect an RJ-22 bus cable from the MASTER (Master Out) which is the upper most RJ-22 Jack, to the SLAVE (Slave In) which is the lower RJ-22 Jack on the slave. For more than one slave, connect Slave Out to the next Slave in, and so on. No terminations are needed at the final slave in the daisy chain.

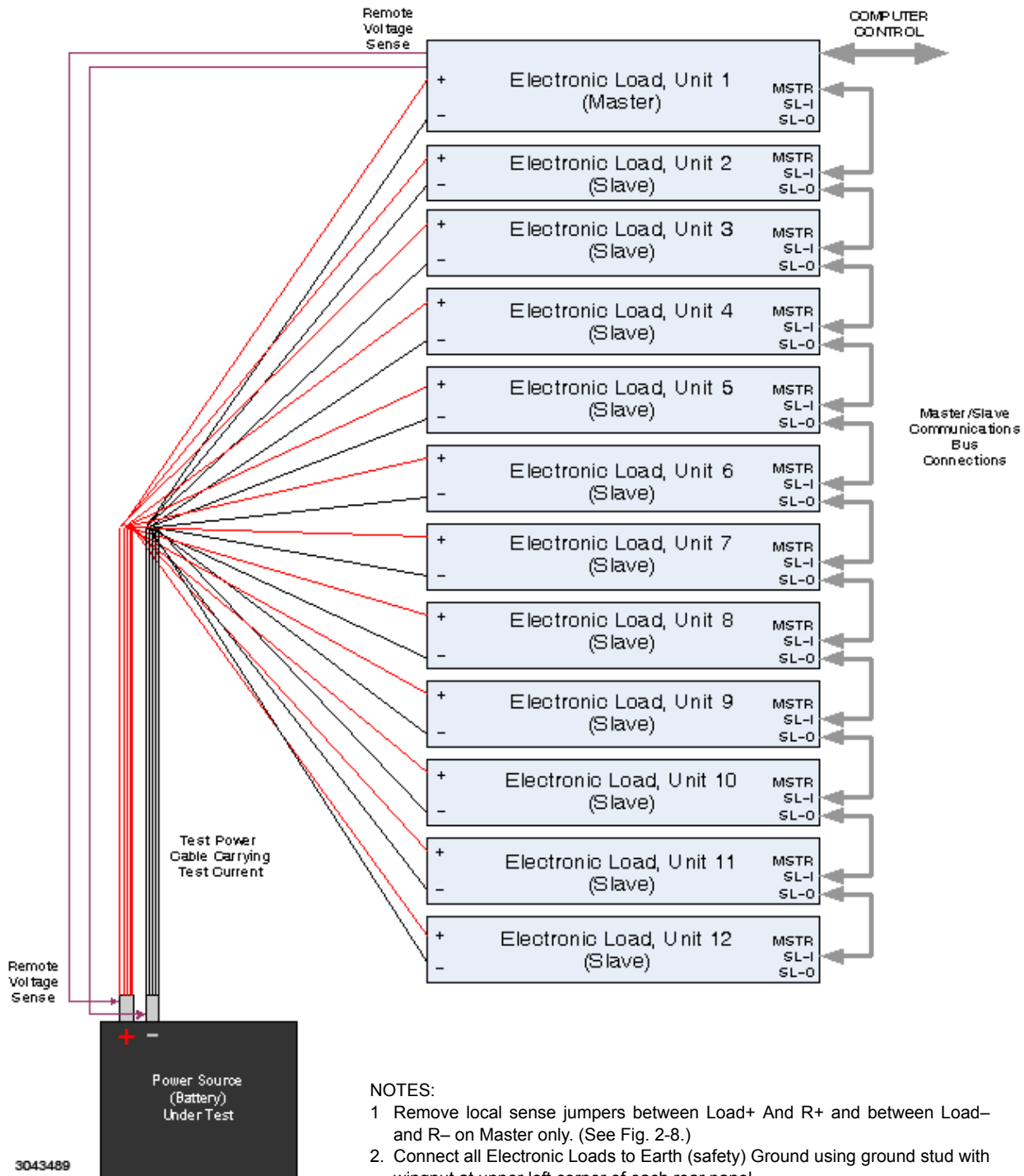


FIGURE 2-9. TYPICAL MASTER/SLAVE INTERCONNECTIONS

2.6.4 ANALOG PROGRAMMING CONNECTIONS

The ANALOG PGM input BNC connector is used for remote analog programming of the load. Applying 0 to 10V adjusts the controlled parameter (depending on mode selection) from 0 to full scale. See PAR. 3.12 for details. For Master/Slave configurations, the remote analog signal must be applied to all parallel-connected units.

2.6.5 CURRENT MONITOR CONNECTIONS

An output signal at the ILOAD BNC connector (see Figure 2-3 or 2-4) is 0 to 10V corresponding to 0 to full scale of the load's rated current. Connect voltmeter from shell to center pin when the load is drawing current from the UUT. For Master/Slave configurations, each ILOAD output reflects the current flowing in that individual load.

2.7 DIGITAL CONNECTIONS

The following paragraphs describe the connections required to use the RS 232 or USB ports for remote control of the unit.

If control via the computer interface is desired, the computer should be connected to the load via either the USB 2.0 type B connector or the RS-232 interface connector located at the rear panel.

The currently active interface takes precedence. That is, with no other direction, the Series EL communicates with the computer via the USB or RS-232 interface. The selection of the interface depends on the last interface used.

For simple communications a terminal emulator program such as HyperTerminal provides the necessary interface. No drivers are required when using the RS-232 interface, however If USB communications are used, a special driver must be installed (the USB interface is not *plug and play*). Refer to the Kepco website to download the Series EL USB Driver Installation Manual that describes how to download and install the driver, as well as how to establish communications between the Series EL load and the computer using a terminal emulator:

www.kepcopower.com/support/opmanls.com#e

NOTE: If using USB and HyperTerminal, it is advisable to first turn on the Series EL load and then launch HyperTerminal as HyperTerminal may become dysfunctional (hung up) if power is removed from the USB connection before HyperTerminal is closed or before the connection is closed.

When communicating with the Series EL via a computer interface, the Series EL responds to IEEE 488.2 and SCPI (Standard Commands for Programmable Instruments) commands and queries. Compatible IEEE 488.2 commands and queries are listed in Appendix A. The complete list of SCPI commands for designed for the Series EL Electronic Load are listed in Appendix B.

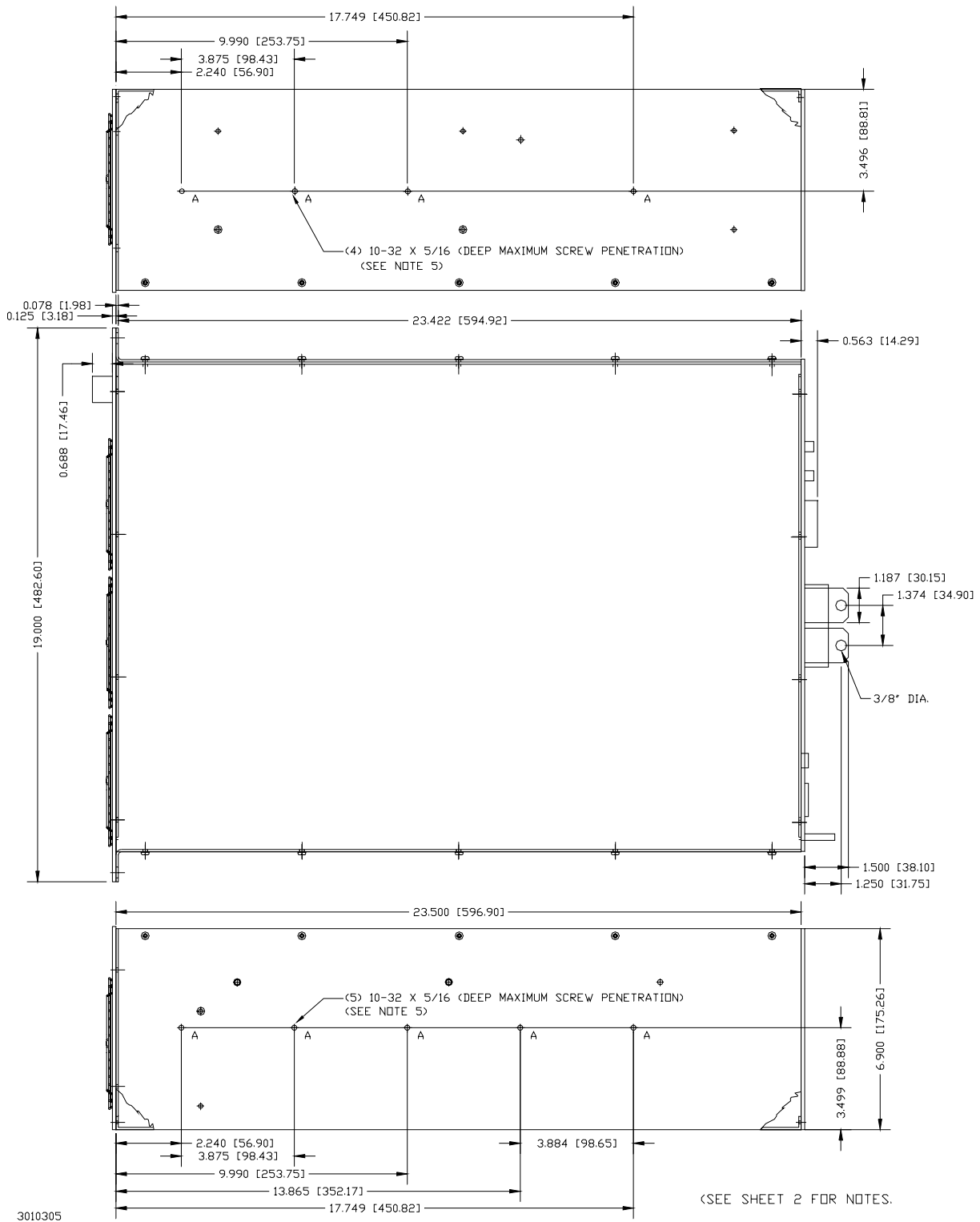
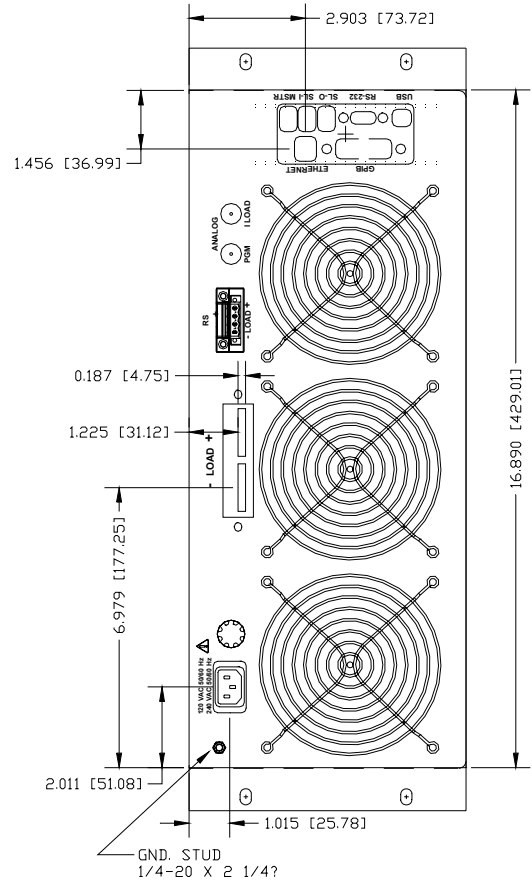
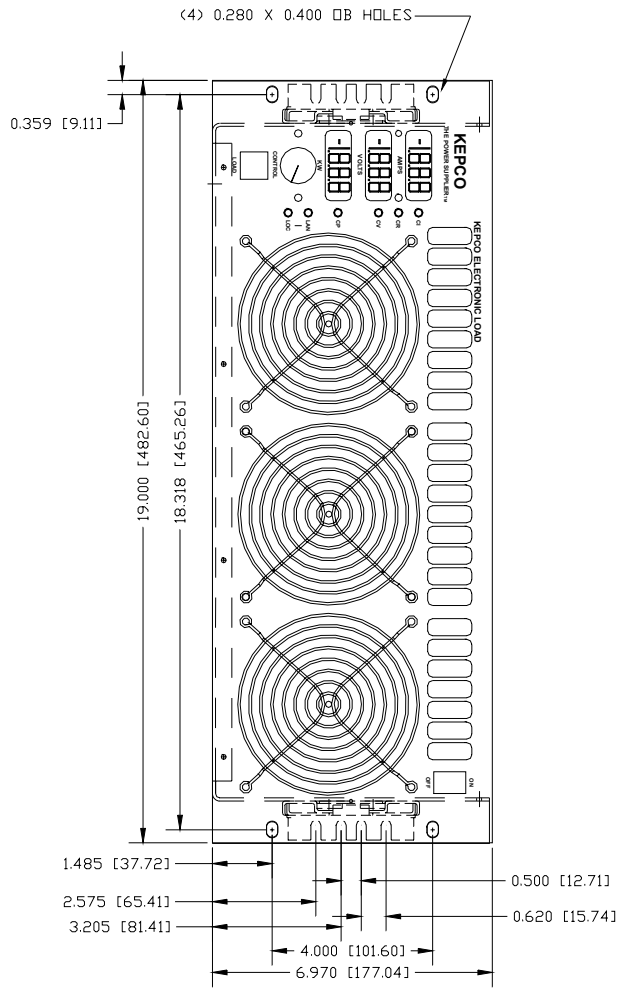


FIGURE 2-10. EL LOAD, OUTLINE DIMENSION DRAWING (SHEET 1 OF 2)



NOTES:

1. MATERIAL: A) CHASSIS & COVER: 0.078" MILD STEEL.
B) FRONT & REAR PANELS: 0.125" THICK 6061-T6 ALUMINUM.
2. FINISH: A) CHASSIS & COVER: BLACK CRINKLE PAINT.
B) FRONT PANEL: LIGHT FINE GRAINED FINISH WITH HARD COAT BLACK ANODIZE.
3. DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS.
4. TOLERANCES: A. BETWEEN MOUNTING HOLES: $\pm 1/64$ (0.4)
B. ALL OTHER DIMENSIONS $\pm 1/32$ (0.8), EXCEPT AS NOTED.
5. MOUNTING SLIDES ARE GENERAL DEVICE C230-S-124. USE NINE (9) MTG. HOLES (A).

3010305

FIGURE 2-10. EL LOAD, OUTLINE DIMENSION DRAWING (SHEET 2 OF 2)

SECTION 3 - OPERATION

3.1 GENERAL

This section contains general operating instructions for the Series EL Electronic Load. Refer to Section 2 for a description of the controls, display and terminals. When loading sources of electrical energy be sure to use appropriate precautions where high-currents and potentially high voltages may be present.



WARNING

An electronic load can present an extremely low resistance to a source of electrical energy. In some cases this may be the equivalent of placing a short circuit at the source output. This may have disastrous consequences if done unintentionally.

Be sure the load parameter settings are appropriate for the source being tested.

3.2 FACTORY DEFAULT SETTINGS

The unit is shipped with the following settings preset at the factory:

- Current set point 0 A
- Voltage set point Load maximum voltage
- Power set point 0 kWatts
- Overvoltage limit 5% above rated maximum
- Undervoltage limit 0V (deactivated)
- Overcurrent limit 5% above rated maximum
- Overpower limit 5% above rated maximum
- Resistance set point 1,000 ohms
- Conductance set point 1 mS (0.001 siemens)
- System damping 5
- Mode damping 3
- Local control Fully enabled
- Load ON/OFF OFF

3.3 TURNING THE UNIT ON

1. Connect the load to the UUT (Unit Under Test) (see PAR. 2.6.2)
2. Connect the load to mains power (see PAR. 2.6.1)
3. Connect the load to a computer system
4. Press the front panel POWER switch to ON. The LOAD switch lights green (steady). If it is illuminated Red a Fault condition exists that must be corrected prior to using the load (see PAR. 3.3.1).
5. Ensure the computer control system is turned on and communication with the Series EL Electronic Load is established. Current status of the Series EL Electronic Load modules is shown by front panel displays.
6. When the unit is first turned on, the LOAD setting and remote computer commands (INPUT/OUTPUT) are initialized for zero current draw. Setpoints, mode, limits, and other settings remain from prior work. The load is shipped in CI mode and set for 0 Amperes.
7. When first initiating a load, it is advisable to make a "Test run" at a nominal load level (e.g., 10% of the expected parameter setting). This allows the user to ensure all connections are properly made and results are as expected when engaging the load.

3.3.1 ERROR CONDITIONS

FALT blinking in the AMPS or KW display indicates the associated parameter (current or power) exceeded established limits.

- **HI:** Alternating with a voltage measurement in the VOLTS display indicates the established voltage limits were exceeded at the remote sense point. (Note: the voltage measurement continues to be displayed as long as the UUT is connected.)
- **LO:** Alternating with a voltage measurement in the VOLTS display indicates the UUT voltage (at the remote sense point) dropped below the internally set low voltage limit
- **HOT** Indicates that the temperature of one or more of the power dissipating Power MOS-FETs exceeded safe operating limits. (Note: this may cause either a reduction of the load maximum current/power handling ability or a complete inability to use the load depending on the degree of overheating)

3.4 SELECTING THE MODE AND SETPOINT

To select a mode and setpoint for the controlled parameter (current, power, voltage, resistance or conductance) prior to drawing current from the UUT, verify that the LOAD pushbutton indicator is green (steady) and proceed as follows:

1. Depress and hold the CONTROL knob for 3 seconds. The LOAD pushbutton indicator goes from green to off. Rotating the CONTROL knob sequentially selects the operating mode in the order: CV, CI, CP, CR, CS, SHORT and OFF (see Table 3-1). Release CONTROL to set mode.

2. After the operating mode is selected, set the CONTROL resolution by momentarily depressing the CONTROL knob (CONTROL knob must be depressed twice the first time it is used after a mode selection). This causes one digit in the selected mode parameter display (AMPS, VOLTS, KW) to blink while showing the setpoint. The blinking digit indicates the CONTROL resolution setting for one click of rotation. Momentarily depressing the CONTROL knob again shifts the resolution selection to the next digit.
3. Rotate the CONTROL (clockwise to increase or counterclockwise to decrease) to adjust the parameter setpoint. Once the setpoint is selected, the setpoint remains displayed momentarily and then the display returns to displaying the measured parameter value.

TABLE 3-1. MODE SELECTION AND ADJUSTMENTS

MODE INDICATOR	MODE SELECTED	ADJUSTMENT
Only CI on (solid)	CI mode (Constant Current).	CONTROL sets constant current level in Amperes as viewed on AMPS display.
Only CR on (solid)	CR mode (Resistance)	CONTROL sets resistance in Ohms as viewed on KW display.
Only CR on (blinking)	CS mode (Conductance)	CONTROL sets conductance in Siemens (= I in Amps / E in Volts) as viewed on KW display.
Only CV on (solid)	CV mode (Voltage)	CONTROL sets voltage in Volts as viewed on VOLTS display.
Only CP on (solid)	CP mode (Constant Power)	CONTROL sets constant power level in kilowatts as viewed on KW display.
CI, CR, CV and CP all blinking	Short mode (lowest ON resistance possible).	Short mode; maximum current, no adjustment. USE CAUTION before selecting this mode.
CI, CR, CV and CP all off	Off	Modes off, no adjustment. Load will not engage, no setpoints are active and load will not conduct current. When modes are off, pressing LOAD switch causes LOAD indicator to blink green, then rotate CONTROL to show model and serial number. on front panel displays (see PAR. 3.7).

3.5 ENGAGING THE LOAD

1. After selecting the mode and setpoint (PAR 3.4), momentarily press the LOAD pushbutton to engage the UUT, causing the load to draw current from the UUT at the level determined by the setpoint. LOAD pushbutton illumination changes to amber and the front panel displays show the measured parameters: voltage, current and power.
2. Rotating CONTROL with the load engaged (LOAD indicator amber) causes the controlled parameter to increase (clockwise) or decrease (counterclockwise) in steps at the resolution selected in PAR 3.4, step 2 above. The VOLTS, AMPS and KW displays show the measured parameters any time the load is engaged (LOAD indicator amber).

3.6 DISENGAGING THE LOAD

With the load engaged (LOAD indicator amber), disengage the load from the UUT by momentarily depressing the LOAD pushbutton (illumination changes to steady green) causing the load to stop drawing current from the UUT.

3.7 VIEWING MODEL INFORMATION

When the Mode is OFF (none of the mode LEDs are illuminated), momentarily depressing the LOAD pushbutton (illumination changes to blinking green) allows model information to be viewed. Rotating CONTROL sequences the VOLTS, AMPS and KW displays through Model Information (displayed as AMPS, VOLTS and KW in the respective display location) and Serial Number.

3.8 OPERATION OF MASTER/SLAVE CONFIGURATIONS.

3.8.1 POWER UP

When turning on Loads connected as Master/Slave, turn on the Slave Load(s) first, then after 10 - 20 seconds, turn on the Master Load.

- The LOAD button on each Slave Load turns green once the Load completes diagnostic tests.
- As the Master Load interrogates the Slave Load(s) via the Master-Slave communication bus, the VOLTS display on the Slave(s) changes to **SLAU** (Slave).
- The LOAD button on the Master Load turns green once the Master Load 1) completes its diagnostic routine, 2) interrogates the Slave(s) for Master-Slave connection eligibility and ratings, 3) establishes the overall Master-Slave Load configuration

3.8.2 LOCAL (FRONT PANEL) OPERATION

The Load can be operated from the Master front panel as described in the previous paragraphs for a single unit. Only the Master Load front panel is active

3.8.3 REMOTE (COMPUTER) OPERATION

If a computer is connected to the Master Load of a master/slave configuration in terminal display mode, the information shown in Figure 3-1 is displayed at startup (boot). The Master-Slave configuration responds to the SCPI command set described in the User's Manual

3.8.4 INDICATIONS DURING MASTER/SLAVE OPERATION

The Master Load displays:

- AMPS: Total Current drawn by the Master/Slave configuration
- VOLTS: Voltage applied to each of the Loads
- KW: Total power in kW drawn by the Master/Slave configuration

Slave Load(s) display:

- AMPS: Current drawn by the individual Slave
- VOLTS: reads **SLAU** showing unit is a slave connected to Master.
- KW: Power in kW drawn by the individual Slave.

3.8.5 MASTER/SLAVE CONTROLS AND INDICATORS

Controls and indicators function as described for a single unit, however controls are only active on the Master Load. Indicators on the Master Load are for Master/Slave configuration. Indicators on the Slave indicate individual Slave Load current and power and Slave status (VOLTS display reads **SLAU**). Slave LOAD switch indicators show engaged (amber) or disengaged (green) status of each slave. Fault indications are displayed on each slave as well as the master.

3.8.6 MASTER/SLAVE OPERATING NOTES/CAUTIONS/WARNINGS

Be sure to read and follow the operating instructions described for a single unit and observe all Cautions and Warnings. A Master/Slave Load configuration is capable of extremely high power and extremely high currents, thus suitable precautions should be taken when using the Load

- Use optimal damping (see PAR. 3.11) for setup instructions to optimize damping settings, otherwise use factory default settings.
- Interconnect UUT and Load with cabling designed to minimize inductance. Remember that rapidly-changing high-currents combined with inductance produces high-voltage spikes (spikes that can easily damage equipment including the EL Load).
- To minimize spiking and current surges when using computer-controlled remote operation, the best sequence is:
 1. Select Mode (e.g. MODE CURR).
 2. Select very low value set point (e.g. CURR 0.2).
 3. Engage Load (INPUT ON).
 4. Slew Load to desired operating set point (e.g. CURR 105).

4878 48780 38400 191 191 Baud OK

4878 4878

EEPROM Used: 287 bytes

```

78 48 45 4C:20 35 4B 2D:36 30 30 2D:32 30 30 20
30 33 2D 31:35 2D 32 30:31 30 00 00:00 00 00 00
00 00 00 00:00 00 00 00:00 00 00 41:31 30 34 35
30 33 00 00:00 00 00 00:00 00 00 00:00 00 00 00
00 FF 00 00:00 00 00 00:00 00 00 00:00 00 00 00
00 00 00 00:03 28 9A 01:00 50 34 03:00 3C 68 06
00 78 D0 0C:00 40 0D 03:00 05 03 18:31 0C 00 00
00 00 00 C0:27 09 00 80:8D 5B 00 20:12 0A 00 50
34 03 00 D0:1B 50 00 50:50 4D 33 32:30 30 00 00
00 00 00 00:00 00 00 00:00 00 00 00:00 00 00 00
00 00 00 00:00 00 00 00:00 00 00 00:00 00 00 00
02 20 12 0A:00 00 00 00:00 00 00 00:00 40 42 0F
00 01 00 00:00 C8 00 00:00 C8 00 00:00 B8 0B 00
00 94 2A 00:00 28 64 00:00 00 00 00:00 00 00 00
00 00 00 00:00 00 00 00:96 00 00 00:96 00 00 1A
04 00 00 E8:03 00 00 E8:03 00 00 2E:04 00 00 E8
03 00 00 D0:07 00 00 EC:FF 00 00 00:00 00 00 00
00 00 00 00:00 00 00 00:00 00 00 00:00 78 48

```

EL Load boot up diagnostic information verifying communications baud rate and memory check sums.

*IDN reply. See PAR. A.3 for details.

KEPCO, EL 5K-600-200 03-15-2010,A104503,MCB #234 1.219 \$ 2010/03/26 12:58:08 \$
 Compiled Mar 26 2010 07:58:52
 Copyright (C) 2010 PPM, Inc.

KEPCO, EL 5K-600-200 03-15-2010,A104503,MCB #234 1.219 \$ 2010/03/26 12:58:08 \$
 Compiled Mar 26 2010 07:58:52
 MEL (chassis) Serial Number: A104503

Calibration Settings
 Calibrated Fullscale Ranges
 100V 105000 mV
 200V 210000 mV
 400V 419900 mV
 800V 839800 mV
 Cutoffs
 Current : 0.200
 Voltage : 0.200
 Power : 0.003
 Max volt limit : 660.0
 Max curr limit : 210.0
 Max powr limit : 5.250
 Setpoint scaling factor: 10.90
 Setpoint Calibration Factors
 Voltage : 1.050
 Current : 1.000
 Power : 1.000
 Resistance : 1.070
 Conductance : 1.000
 Fan temperature limits (C)
 Lower : 40
 Upper : 100
 External FB Gain : 2.000
 Master Delay : -2000 uSec

Load Calibration Configuration Information
 Note: These are factory settings and are displayed should diagnostic information be required.

FIGURE 3-1. MASTER/SLAVE START-UP, COMPUTER DISPLAY (SHEET 1 OF 2)

KEPCO, EL 5K-600-200 03-15-2010,A104503,MCB #234 1.219 \$ 2010/03/26 12:58:08 \$

Compiled Mar 26 2010 07:58:52

Chassis Serial Number: A104503

Voltage range : 800V
 Current range : 200.0
 System damping : 5
 PFM damping : 3
 Overvoltage limit : 799.0
 Undrvoltage limit : 0.000
 Overcurrent limit : 600.0
 Overpower limit : 6.000
 System mode (startup): CURRent
 System mode (now) : CURRent

User protection settings (values shown are for no user protection).

Current EL Load User Settings
 Note: This same information can be displayed at any time by entering the SCPI command:
 SYST:SETTING?

Setpoints
 Voltage : 660.0
 Current : 0.000
 Power : 0.000
 Resistance : 1000.
 Conductance : 0.001
 IP Address : 0.0.0.0
 Sub Net : 0.0.0.0
 Gateway : 0.0.0.0
 DNS Addr : 0.0.0.0

User operating parameter settings (values shown are for no current draw at turn on). Note: Each parameter is retained by Mode and is stored in non-volatile memory.

Load Dialog During Process of recognizing Power FET Modules found By Master Control Board.

Querying Power FET Module 0 [FET Board # 257 in position 0< 0>]
 Found Ser# 257 at position 0 of 1
 Querying Power FET Module 1 [FET Board # 258 in position 1< 0>]
 Found Ser# 258 at position 1 of 2
 Querying Power FET Module 2 [FET Board # 259 in position 2< 0>]
 Found Ser# 259 at position 2 of 3
 Querying Power FET Module 3 [FET Board # 260 in position 3< 0>]
 Found Ser# 260 at position 3 of 4
 Querying Power FET Module 4 [FET Board # 261 in position 4< 0>]
 Found Ser# 261 at position 4 of 5
 Querying Power FET Module 5 [FET Board # 262 in position 5< 0>]
 Found Ser# 262 at position 5 of 6

Testing for additional Power FET Modules and seeking possible connections to slave Loads.

Querying Power FET Module 6
 Querying Power FET Module 6
 Querying Power FET Module 6 ZYX
 Discover Slaves
 9
 Setting serial # 222 as slave #0
 8
 Setting serial # 223 as slave #1
 7654321

Discovering Slave Loads found by Master Load

Load System overcurrent, overvoltage, under voltage, overpower Limits (mA, mV, mV, mW)

N	MCB-Serial	Amps	Volts	Kwatts	Ilast	Eng	Md	Setpt	Iover	Vover	Vundr	Pover
Master		630	660	15	0	0	2	0	600000	799000	0	6000000
0	222	210	660	5	0	0	0	0	0	0	0	0
1	223	210	660	5	0	0	0	0	0	0	0	0

46

Master boot time (Seconds)

Master Control Board Serial Nos.

Load System Current Voltage and Power Limits

FIGURE 3-1. MASTER/SLAVE START-UP, COMPUTER DISPLAY (SHEET 2 OF 2)

3.9 OPERATION VIA COMPUTER INTERFACE

The computer interface (either USB or RS 232) can be used to operate the load from a remote location using a computer using IEEE 488.2 and SCPI commands. Refer to Appendices A and B, respectively, for a complete list of applicable commands and queries. The commands INPut 1 (or ON) or OUTput 1 (or ON) are equivalent to using the LOAD switch on the front panel to engage the load; the commands INPut 0 (or OFF) or OUTput 0 (or OFF) are used to disengage the load. Figure 3-2 illustrates the commands used to set the load to operate at 100 Amperes from a 12.5-volt source in the Constant Current mode, engage the load, then disengage the load.

MODE CURR	Sets mode to current.
CURR 0.1	Sets current level to low level.
INPUT ON	Causes load to engage UUT and draw current. LOAD pushbutton illumination changes from green to amber and VOLTS, AMPS and KW displays show measured parameters.
CURR 100	Sets current level to 100 amperes.
MEAS:CURR?	Request that Series EL measure current. Unit responds with 100.0.
MEAS:VOLT?	Request that Series EL measure voltage. Unit responds with 12.5.
INPUT OFF	Causes load to disengage UUT and stop drawing current.

FIGURE 3-2. EXAMPLE OF REMOTE OPERATION

3.10 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 Series EL Electronic Load as ASCII output strings within the selected programming language (PASCAL, C, BASIC, LABVIEW, etc.) in accordance with the interface protocol used.

Different programming languages (e.g., BASIC, C, PASCAL, LABVIEW, etc.) have different ways of representing data that is to be put on the control bus. It is up to the programmer to determine how to output the character sequence required for the programming language used. If the optional IEEE 488.2 (GPIB) interface is used, address information (GPIB address) must be included before the command sequence.

3.10.1 SCPI MESSAGES

There are two kinds of SCPI messages: program messages from controller to electronic load, and response messages from the electronic load to the controller. Program messages consist of one or more properly formatted commands/queries and instruct the electronic load 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, electronic load state, status, or error conditions.

TABLE 3-2. REMOTE OPERATION COMMAND SUMMARY

Command	Function
CONTROL COMMANDS (Terminate command with ? to display established mode.)	
MODE CURRent	Enter Constant Current mode
MODE VOLTage	Enter Constant Voltage mode
MODE POWer	Enter Constant Power mode
MODE RESistance	Enter Constant Resistance mode
MODE CONDUCTance	Enter Constant Conductance mode
MODE SHORt	Enter Short mode
MODE OFF	Disengage load and enable viewing of Model data.
INPut 1 or INPut ON (alternatively OUT 1)	Engage load (load ON)
INPut 0 or INPut OFF (alternatively OUT 0)	Disengage load (load OFF)
SET PARAMETER LEVEL COMMANDS (Terminate command with ? to display parameter level.)	
CURRent <NR2>	Set Current level in Amperes
VOLTage <NR2>	Set Voltage level in Volts
POWer <NR2>	Set Power level in Watts
RESistance <NR2>	Set Resistance level in Ohms
CONDUCTance <NR2>	Set Conductance level in Siemens
MEASUREMENT QUERIES	
MEASure:CURRent?	Return Load current in Amperes
MEASure:VOLTage?	Return Load voltage in Volts
MEASure:POWer?	Return Load power in Kilowatts
MEASure:ALL?	Return Load Power, Current and Voltage
PROTECTION COMMANDS (Terminate command with ? to display the protection setting for that mode. Exceeding these user-defined protection levels disengages the UUT and displays fault indication (see PAR. 3.3.1.)	
CURRent:PROTection <NR2>	Set maximum Current level in Amperes
VOLTage:PROTection:OVer <NR2>	Set maximum Voltage level in volts
VOLTage:PROTection:UNDer <NR2>	Set minimum Voltage level in volts
POWer:PROTection <NR2>	Set maximum load Power in watts
VOLTMETER RANGE COMMANDS (Terminate command with ? to display the range setting. The voltmeter range is determined by the lower of: the range setting below and the lowest range that includes the current VOLT setting.)	
SYSTem:RANGe:VOLTage 100V	Set Voltage measurement range 0 – 100V
SYSTem:RANGe:VOLTage 200V	Set Voltage measurement range 0 – 200V
SYSTem:RANGe:VOLTage 400V	Set Voltage measurement range 0 – 400V
SYSTem:RANGe:VOLTage 800V	Set Voltage measurement range 0 – 800V
<NR2> = Numeric Values with or without a decimal point. Examples: 0.0156, 15.6, 156 or 1.56E+3 (scientific notation: digits with decimal point and exponent).	
NOTE: If commands that expect a boolean are entered without an argument, the argument is interpreted as 0.	

3.10.2 COMMON COMMANDS/QUERIES

Common commands and queries are defined by the IEEE 488.2 standard to perform overall electronic load functions (such as identification, status, or synchronization) unrelated to specific electronic load operation (such as setting voltage/current). Common commands and queries are preceded by an asterisk (*) and are defined and explained in Appendix A. Refer also to syntax considerations (PARs 3.10.3.9 through 3.10.6).

3.10.3 SCPI SUBSYSTEM COMMAND/QUERY STRUCTURE

Subsystem commands/queries are related to specific electronic load functions (such as setting voltage, current limit, etc.) Figure 3-4 is a tree diagram illustrating the structure of SCPI subsystem commands used in the EL Series Electronic Load 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.

3.10.3.1 CALIBRATION SUBSYSTEM

This subsystem is used for calibration and for LAN addressing.

3.10.3.2 DEBUG SUBSYSTEM

This subsystem is used to print the SCPI command set.

3.10.3.3 PROTECTION SUBSYSTEM

This subsystem establishes limits for voltage, current and power.

3.10.3.4 SENSE SUBSYSTEM

This subsystem controls the range of the front panel AMPS and VOLTS displays.

3.10.3.5 [SOURCE:]MEASURE SUBSYSTEM

This query subsystem returns the voltage, current and power measured at the LOAD terminals.

3.10.3.6 [SOURCE:]INPUT, [SOURCE:]OUTPUT SUBSYSTEMS

This subsystem controls whether the UUT is engaged (on) or disengaged (off) from the load.

3.10.3.7 [SOURCE:]VOLTAGE, [SOURCE:]CURRENT, [SOURCE:]POWER SUBSYSTEMS

These subsystems set the mode and establish setpoints for each mode. Also establish protection limits and the range of the front panel display (VOLTS, AMPS or KW, respectively) for each mode.

3.10.3.8 [SOURCE:]RESISTANCE, [SOURCE:]CONDUCTANCE SUBSYSTEMS

These subsystems set the mode and establish setpoints for each mode.

3.10.3.9 STATUS SUBSYSTEM

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

3.10.3.10 SYSTEM SUBSYSTEM

This subsystem controls various system functions.

3.10.4 PROGRAM MESSAGE STRUCTURE

SCPI program messages (commands from controller to load) 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” must be defined as CR (0D_H) followed by LF (0A_H). The message unit is a keyword consisting of a single command or query word followed by a message terminator (e.g., CURR?<newline> or INPut<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 3-3 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.

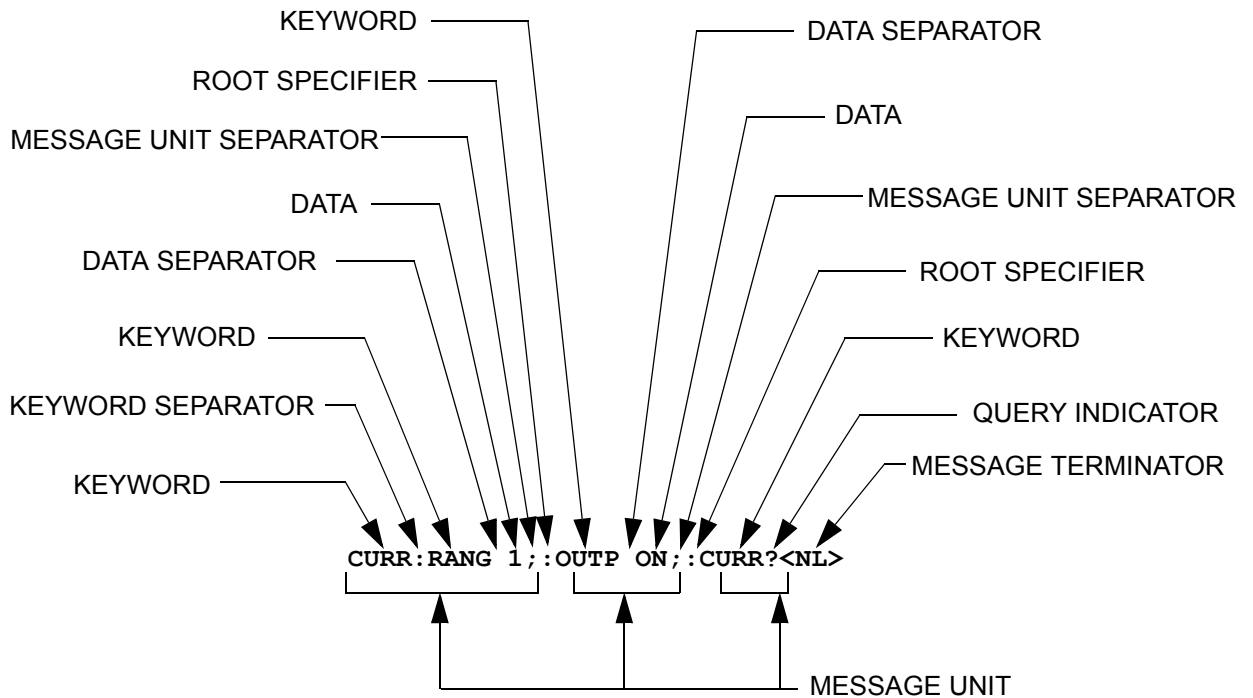


FIGURE 3-3. MESSAGE STRUCTURE

3.10.4.1 KEYWORD

Keywords are instructions recognized by a decoder within the EL Series, referred to as a “parser.” Each keyword describes a command function; all keywords used by the EL Series are listed in Figure 3-4.

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

You must use the rules above when using keywords. Using an arbitrary short form such as ENABL for ENAB (ENABLE) or PROTEC for PROT (PROTECTION) 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., PROTEction, CURRent, and OUTPut). The parser, however, is not sensitive to case (e.g., outp, OutP, OUTPUTt, ouTPut, or OUTp are all valid).

TABLE 3-3. 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

3.10.4.2 KEYWORDS FOR DUAL UNITS

Keywords sent to dual units must identify which load is to be controlled. This is done by adding a 1 (for unit A) or 2 (for unit B) to the **root keyword**. This means that the root keyword is required for dual units. For example, **SOUR1:MEAS:VOLT;SOUR2:MEAS:CURR** reports voltage from unit A and current from unit B. If the root keyword is not included, or the unit number is not specified, unit A is automatically selected.

3.10.4.3 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., SOUR:MEAS:VOLT). The colon can also act as a root specifier (paragraph).

3.10.4.4 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?).

3.10.4.5 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., SOUR:VOLT:LEV 100 or LOCK OFF).

3.10.4.6 DATA SEPARATOR

Data must be separated from the last keyword by a space (e.g., SOUR:VOLT:LEV 100 or LOCK OFF).

3.10.4.7 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 100;MEAS:VOLT?).

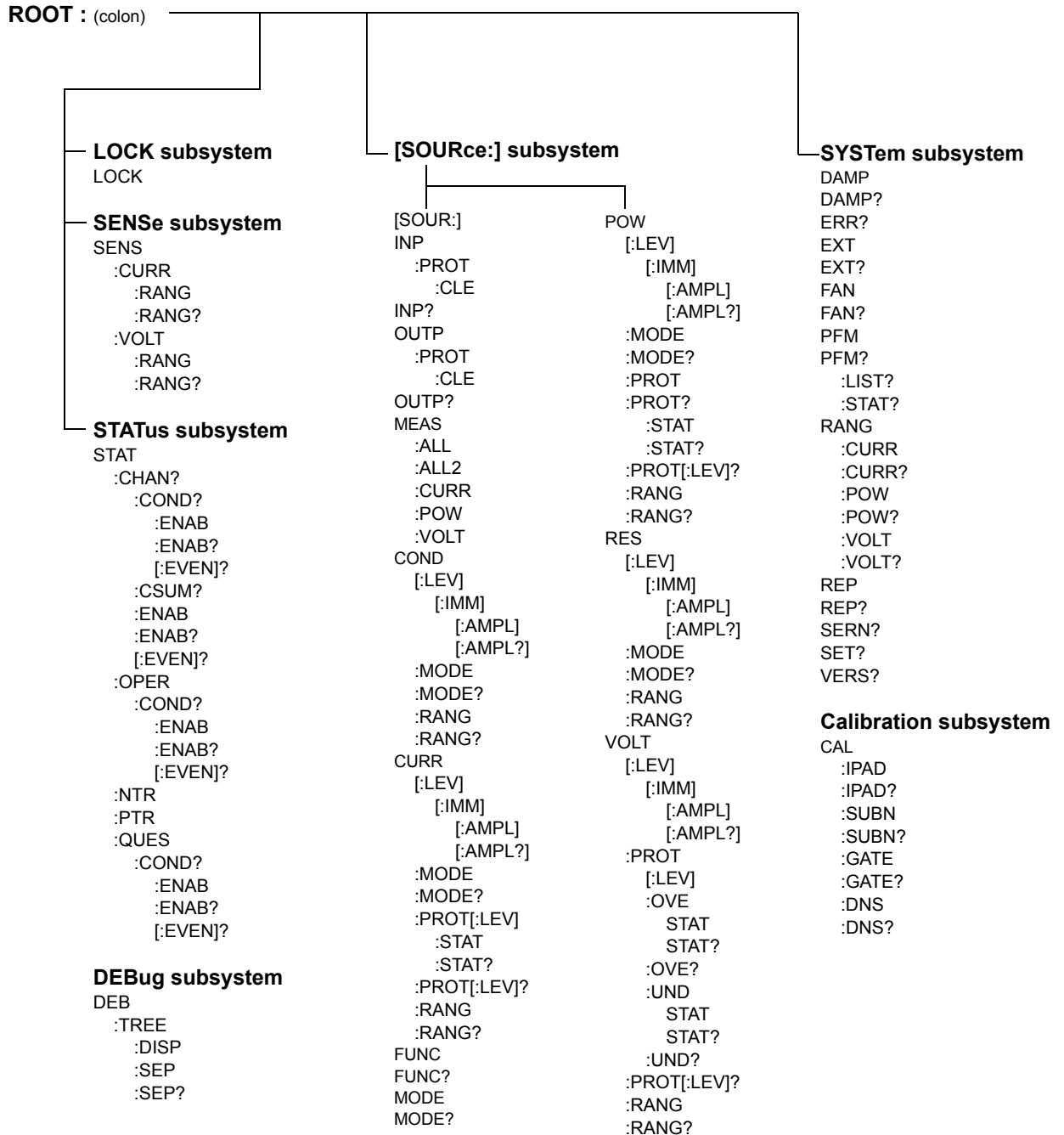


FIGURE 3-4. TREE DIAGRAM OF SCPI COMMANDS USED WITH SERIES EL ELECTRONIC LOAD

3.10.4.8 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 3-4) of the command tree. Note the difference between using the colon as a keyword separator and a root specifier in the following examples:

SYST:RANG:VOLT 100 Both colons are keyword separators.

:CURR:LEV:IMM 100 The first colon is the root specifier, the other two are keyword separators.

VOLT:LEV 60;:CURR:LEV 150 The second colon is the root specifier, the first and third are keyword separators

:INP ON;:LOCK OFF;:CURR 120;VOLT:LEV 60 The first three colons are root specifiers.

3.10.4.9 MESSAGE TERMINATOR

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

- new line (<NL>) is defined as CR (Carriage Return, 0D_H) followed by LF (Line Feed, 0A_H)

NOTE: 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> meaning CR (0D_H) followed by LF (0A_H).

3.10.5 UNDERSTANDING THE COMMAND STRUCTURE

Understanding the command structure requires an understanding of the subsystem command tree illustrated in Figure 3-4. 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 electronic load 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 EL Series are :MEASure, :INPut, :OUTPut, [:SOURce], :PROTection, :SENSe, :STATus, and :SYSTem. Because the [SOURce] keyword is optional, the parser moves the path to the next level, so that VOLTage, CURRent, and MEASure 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, CHANnel, and QUEStionable.

3.10.6 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., **PROTection** (long form) has the same effect as **PROT** (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][:AMPL]?` has the same effect as `:VOLT?`

3.10.7 STATUS REPORTING

The status reporting of the EL Series Electronic Load follows the SCPI and IEEE 488.2 requirements. The serial poll response of the EL provides summary bits of the status and error reporting system. The simplest status report is the command valid reporting and data availability. The 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 to a query.

3.10.7.1 STATUS REPORTING STRUCTURE

The status reporting of the EL uses multiple status register sets, illustrated in Figure 3-5. These register sets are Channel Status, Channel Summary, Questionable, Operation, Standard Event and Status Byte/Service Request registers. All registers are 16-bit registers except the Standard Event and Status Byte/Service Request registers which are 8 bits. The Channel Status, Operation Status and Questionable registers all have condition registers which are 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.

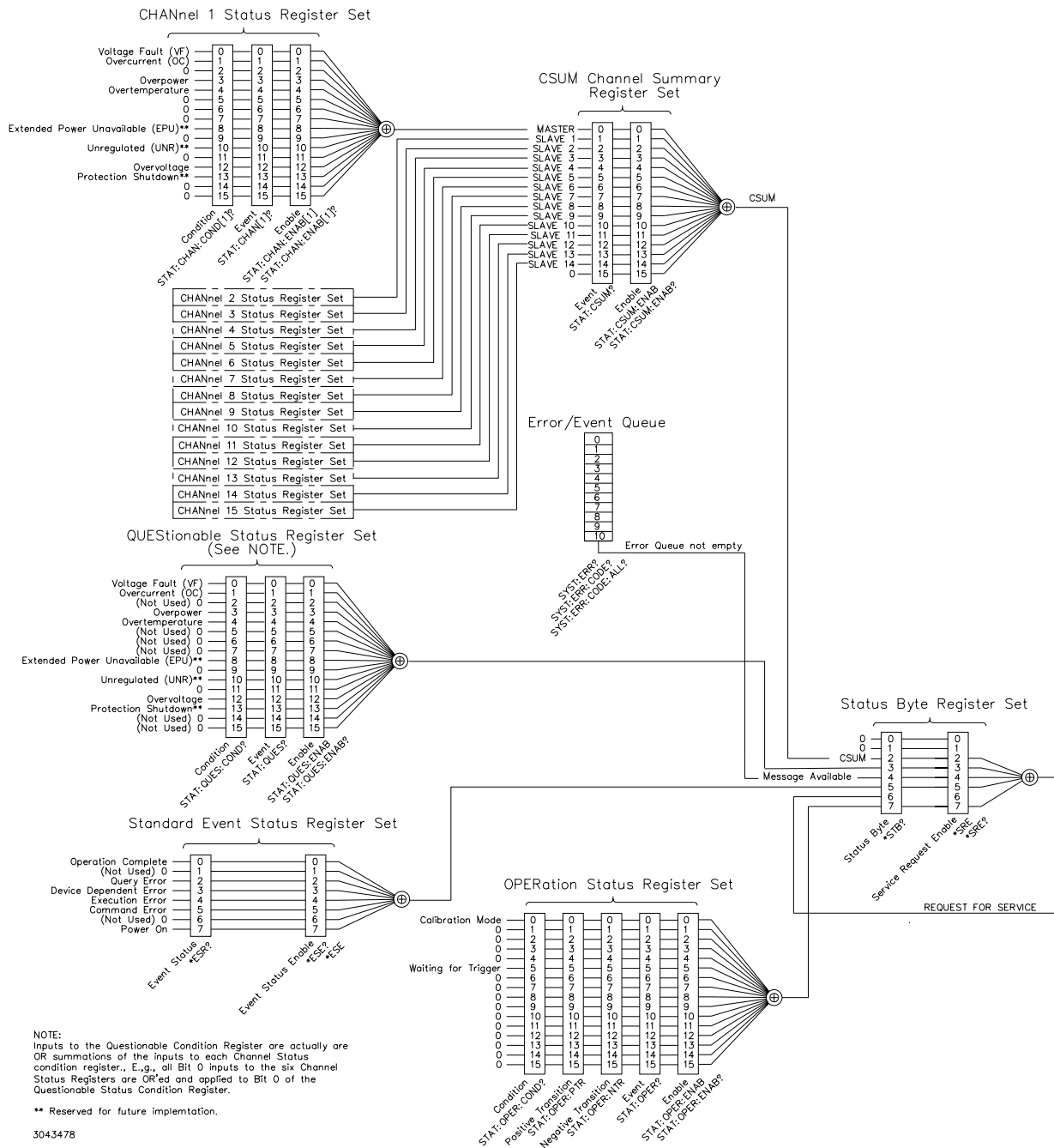


FIGURE 3-5. STATUS REPORTING STRUCTURE

A zero to one transition of a condition register is added to the event register. 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:ENAB (enable) register has bit 0 set and a voltage fault is detected, the event register 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 load to assert the SRQ line to the host controller.

Figure 3-5 also shows that if the error/event queue is not empty, bit 4 indicates that a message is available in the output buffer.

3.10.7.2 OPERATIONAL STATUS REGISTER

The OPERational condition register contains conditions which are a part of the instrument's normal operation. The PTR and NTR registers serve as masks between the Condition register and the Event register. Setting a bit in the PTR register allows positive-going transitions (0 to 1) in the Condition register to set the corresponding Event bit, while setting a bit in the NTR register enables negative going transitions (1 to 0). Corresponding bits can be set in both registers to enable latching of either transition type. The definition of each of these bits (condition register) is as follows:

- 0 - CAL — Calibration in progress
- 5 - WTG — Waiting for Trigger
- 6 - 7 - Not Used — always zero.

3.10.7.3 STANDARD EVENT STATUS REGISTER

The Standard Event registers contains bits (condition register) is as follows:

- 0 - OPC — Operation Complete
- 1 - Not Used — always zero.
- 2 - QYE — Query Error
- 3 - DDE — Device Dependent Error
- 4 - EXE — Execution Error
- 5 - CME — Command Error
- 6 - Not Used — always zero.
- 7 - PON — Power On since this bit last read

3.10.7.4 QUESTIONABLE STATUS REGISTER

The QUESTionable condition register (see Figure 3-5) contains status bits representing unusual operation such as inconsistent sensor readings or unusual but non-fault conditions.

- 0 - Voltage Fault (VF) — 1 indicates the Voltage Fault
- 1 - Overcurrent (OC) — 1 indicates overcurrent condition has been detected.
- 2 - Not Used — always zero.
- 3 - Overpower (OP) — 1 indicates power has exceeded the rated maximum.
- 4 - Overtemperature (OT) — 1 indicates overtemperature condition has been detected.
- 5 - 7 - Not Used — always zero.
- 8 - Extended Power Unavailable (EPU) — 1 indicates Extended Power Unavailable
- 9 - Not Used — always zero.

- 10 - Unregulated (UNR) — 1 indicates unregulated
- 11 - Not Used — always zero.
- 12 - Overvoltage (OV) — 1 indicates overvoltage condition has been detected.
- 13 - Protection Shutdown (PS) — 1 indicates protection shutdown has occurred
- 14 - 15 - Not Used — always zero.

3.10.7.5 CHANNEL STATUS REGISTER

The Channel Status registers (see Figure 3-5), one for each parallel-connected load, reflect the state of each load

- 0 - Voltage Fault (VF) — 1 indicates the Voltage Fault
- 1 - Overcurrent (OC) — 1 indicates overcurrent condition has been detected.
- 2 - Not Used — always zero.
- 3 - Overpower (OP) — 1 indicates power has exceeded the rated maximum.
- 4 - Overtemperature (OT) — 1 indicates overtemperature condition has been detected.
- 5 - 7 - Not Used — always zero.
- 8 - Extended Power Unavailable (EPU) — 1 indicates Extended Power Unavailable
- 9 - Not Used — always zero.
- 10 - Unregulated (UNR) — 1 indicates unregulated
- 11 - Not Used — always zero.
- 12 - Overvoltage (OV) — 1 indicates overvoltage condition has been detected.
- 13 - Protection Shutdown (PS) — 1 indicates protection shutdown has occurred
- 14 - 15 - Not Used — always zero.

3.10.7.6 CHANNEL SUMMARY REGISTER

The Channel Summary registers (see Figure 3-5), store the OR'ed output of each Channel status register.

- 0 - MASTER
- 1 - SLAVE 1
through
- 14 - SLAVE 14
- 15 - Not Used — always zero.

3.10.7.7 STATUS BYTE REGISTER

The Status Byte registers (see Figure 3-5), essentially determine which lower-level summary conditions can generate a Service Request.

- 0 - 1 - Not Used — always zero.
- 2 - CSUM — Channel Summary, logical OR of enabled channels in the Channel Summary registers.
- 3 - QUES — Questionable Status, logical OR of enabled conditions in the Questionable

Status registers

- 4 - MAV — Message Available, set if an error message is available in the Message Queue.
- 5 -ESB — Event Status Summary, set if an enabled standard event occurs.
- 6 - MSS — Master Status Summary.
- 7 - OPER — Operation Status Summary, set if an Operation event occurs.

3.11 DAMPING

Typical operation for an electronic load involves the flow of high currents. Often these currents flow through long interconnections. The combination of high, rapidly changing currents and the inductance associated with connections to the load can cause unexpected results, such as very high voltage spikes, oscillation or severe ringing (damped oscillations) at the source.

To help reduce these issues, the Series EL offers multiple forms and degrees of damping to allow the best measurements possible.

There are two forms of damping in the Series EL load: 1) System Damping, which dampens the response of the main control loop and 2) Mode Damping that dampens effects at the Power FET Modules by modifying the individual FET loop characteristics. Increased system damping reduces the tendency for oscillation and reduces response time to high speed transients. Increased Mode damping decreases the loop's response time to transients. These two damping functions have a great deal of interplay. For best results, follow the guidelines of PAR. 3.11.1.

3.11.1 DAMPING ADJUSTMENTS

The factory default settings for damping sets the overall system damping at maximum and the Power FET Module damping at mid-level. It should be noted that once changed, these damping settings are stored in non-volatile memory; the new values are retained until changed again. For most applications the factory settings should provide optimum damping, however, if you have a special situation, damping adjustments are best made using a test set up as shown in Figure 3-6.

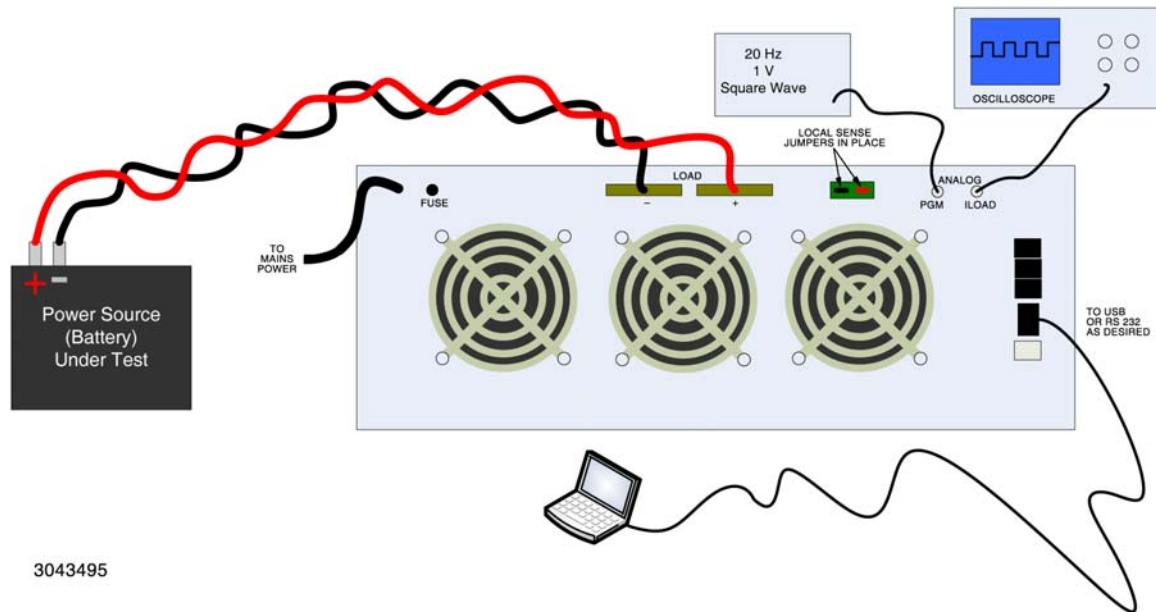


FIGURE 3-6. DAMPING MEASUREMENT SETUP

Figure 3-7 shows various waveforms that may appear at the current monitor output (I-Load) when the load is connected to a high current source and the current drawn from the source changes rapidly following a square wave (or pulse) source connected to the E-Load input. Figure 3-7 shows the effects of changing both the System Damping and the Mode Damping. The exact waveforms that will be seen are highly dependent on the nature of the source, the inter-connecting cables and the various damping setting.

Damping adjustments are made using the SCPI Commands found in Appendix B via either the RS 232 or USB remote interface.

- System Damping. Use SYST:DAMP command (see PAR. B.100).
- Mode Damping. Use SYST:PFM:DAMP (see PAR. B.107).

When modifying the damping settings, a good approach is to start with SYSTem:DAMPing 5 (the factory default) and adjust the Mode Damping from 3 to 2 or 4 while observing the results on an oscilloscope connected to the I-MON terminals (Figure 3-6). Once the impact of the Mode Damping adjustments are understood, a change in System Damping may be warranted.

A test plan should anticipate potential conditions that may cause an under-damped response to transitions. Some basic steps taken at setup may help minimize problems:

- Where possible, use short cables between the source (UUT) and the load.
- Maximize the size of the cables to minimize both resistance and inductance.
- Twist the positive and negative cables together to provide as much cancelation of inductance as possible.

- When using batteries, ensure they are fully charged when possible. Many styles of batteries (especially lead-acid batteries) have a tendency to oscillate when excited by fast rise-time transients. The sudden change in current causes the battery plates to warp slightly, thus changing capacitance which interacts with the inductance of the cables.

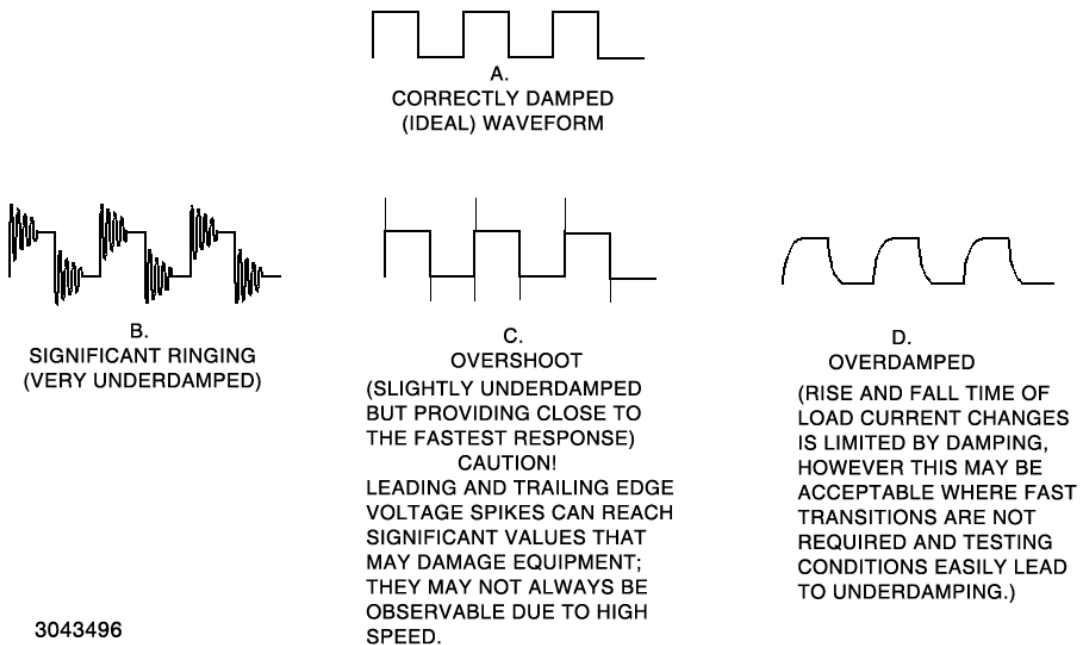


FIGURE 3-7. DAMPING WAVEFORMS

3.12 ANALOG PROGRAMMING

The Analog PGM input is summed with the digital setpoint value. Applying a positive voltage to the Analog PGM input increases the digitally determined setpoint, and applying a negative voltage to the Analog PGM input decreases the digitally determined setpoint.

Because the analog signal is summed with the digital setpoint, it must produce a result that is either 0 or positive, since the load can not control current in the negative direction.

For example, for the EL 5K-400-400 in CI Mode, if the digital setpoint is zero, a 0 to 10V signal applied to the PGM input adjusts the controlled parameter (current) from 0 to full scale (400A). However, if the digital setpoint is set to 200A, $\pm 5V$ applied to the Analog PGM input allows current from 0A (-5V) to 400A (+5V).

The effect of the analog signal varies depending on mode selected (limited to CI, CP or CV) and the range (see Table 3-4).

For Master/Slave configurations, the analog programming signal must be simultaneously applied to all parallel-connected units.

TABLE 3-4. ANALOG PROGRAMMING CONTROL VOLTAGE SCALE

MODE	RANGE (SEE NOTE)	ANALOG CONTROL
Constant Current (CI)	Not Applicable	60 Amperes/Volt
Constant Power (CP)	100 Volts	6 KWatts/Volt
	200 Volts	12 KWatts/Volt
	400 Volts	24 KWatts/Volt
	800 Volts	48 KWatts/Volt
Constant Voltage (CV)	100 Volts	10 Volts/Volt
	200 Volts	20 Volts/Volt
	400 Volts	40 Volts/Volt
	800 Volts	80 Volts/Volt

NOTE: Default voltage measurement setting for CP and CV mode is auto-range. Use SCPI commands to change ranges (see APPENDIX B).

3.13 MASTER/SLAVE CONFIGURATIONS

Up to 15 Series EL Electronic Loads may be paralleled for additional current handling capability. All units must have the same voltage rating. One load is designated as the Master, and the rest are designated as slaves. Refer to PAR. 2.6.3 for connections.

After the connections are complete, it is necessary to first turn on power to the slave(s), then turn on power to the master, so that the master will recognize that slave(s) are connected. If more than one slave is connected, power up the last slave in the chain first, then next to last, etc. until all slaves are powered up, then turn on the master.

A Master/Slave combination responds to an *IDN? query with the *IDN string from first the Master and then the Slave(s).

3.14 OPERATOR MAINTENANCE

No scheduled maintenance is required, other than to keep the high current connections tight and to ensure all airways are clear of obstructions that could cause the load to overheat during operation at higher power. Calibration Verification should be performed yearly or as required.

The exterior of the load should be cleaned periodically, as is necessary, using a soft cloth dampened with a mild, non-abrasive, water-soluble detergent, and then rinsed with a water-dampened soft cloth.

APPENDIX A - IEEE 488.2 COMMAND/QUERY DEFINITIONS

A.1 INTRODUCTION

This appendix defines the IEEE 488.2 commands and queries used with the Series EL Electronic Load. These commands and queries are preceded by an asterisk (*) and are defined and explained in PARs. A-1 through A.13, arranged in alphabetical order. Table A-1 provides a quick reference of all IEEE 488.2 commands and queries supported in the Series EL Electronic Load.

TABLE A-1. IEEE 488.2 COMMAND/QUERY INDEX

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

A.2 *CLS — CLEAR STATUS COMMAND

***CLS**

Syntax: *CLS

Description: **Clears status data.** Clears the following registers without affecting the corresponding Enable Registers: Standard Event Status Register (ESR), Operation Status Event Register, Questionable Status Event Register, and Status Byte Register (STB). Also clears the Error Queue.

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).

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

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

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

*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).

*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 load (see PAR. B.102).

- Any 1xx type error sets the Command error bit (5).
- Any 2xx type error sets the Execution error bit (4).
- Any 3xx type error sets the Device error bit (3).
- Any 4xx type error sets the Query error bit (2).

*IDN?

A.6 *IDN? — IDENTIFICATION QUERY

Syntax: *IDN?
Return value: Character string

Description: **Identifies the instrument.** This query requests identification. The electronic load returns a string (see example below) which contains the manufacturer name, the model, the serial number and the firmware level. The character string contains the following fields: <Manufacturer>, <Model> <Warranty Date>,<Serial Number>,MCB (Main Control Board) Serial number> <Firmware> \$ <Date> where: <Manufacturer> = KEPCO, <Model> =EL model (see Table 1-1), <Firmware = MCB Firmware revision no.> and <Date> = Date and Time of MCB Firmware compilation.

```
KEPCO, EL 5K-600-200 03-15-2010,A104503,MCB #234 1.219 $ 2010/03/26 12:58:08 $
```

*OPC

A.7 *OPC — OPERATION COMPLETE COMMAND

Syntax: *OPC

Description: **Causes load to set status bit 0 (Operation Complete) when pending operations are complete** This command sets Standard Event Status Register bit 0 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).

*OPC?

A.8 *OPC? — OPERATION COMPLETE QUERY

Syntax: *OPC?
Return value: <1> (ASCII) placed in output queue when load 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 Output Queue.

A.9 *RST — RESET COMMAND

*RST

Syntax: *RST

Description: **Resets load to the power on default state.** The load is programmed to the power on default settings listed in PAR. 3.2:

A.10 *SRE — SERVICE REQUEST ENABLE COMMAND

*SRE

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

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

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

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

ESB Event Status Byte summary
MAV Message available
MSS Master Status Summary
NU (Not Used)
OPER Operation Status Summary
QUES QUEStionable Status Summary
RQS Request for Service

A.11 *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?

A.12 *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.)

A.13 *TST? — SELF TEST QUERY

*TST?

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

Description: **Load test.** This query causes the load to do a self test and provide the controller with pass/fail results. A "1" is returned if there is an error.

A.14 *WAI — WAIT COMMAND

*WAI

Syntax: *WAI

Description: Causes the load 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, 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 Series EL Electronic Load. Subsystem commands are defined in PAR. B.11 through B.121, arranged Alphabetically in groups as they appear in the tree diagram, Figure 3-4. Table B-1 provides a quick reference of all SCPI subsystem commands and queries used in the Interface Card.

TABLE B-1. SCPI SUBSYSTEM COMMAND/QUERY INDEX

COMMAND	PAR.	COMMAND	PAR.
CAL:IPAD, ?	B.3, B.4	[SOUR:]POW:PROT, ?	B.57, B.58
CAL:SUBN, ?	B.5, B.6	[SOUR:]POW:PROT:STAT[:LEV], ?	B.59, B.60
CAL:GATE, ?	B.7, B.8	[SOUR:]POW:RANG, ?	B.61, B.62
CAL:DNS, ?	B.9, B.10	[SOUR:]RES[:LEV][:IMM][:AMP],	B.63, B.64
DEB:TREE:DISP	B.11	[SOUR:]RES:MODE, ?	B.65, B.66
DEB:TREE:SEP, ?	B.12, B.13	[SOUR:]RES:RANG, ?	B.67, B.68
LOCK, ?	B.14, B.15	[SOUR:]VOLT[:LEV][:IMM][:AMP], ?	B.69, B.70
SENS:CURR:RANG, ?	B.16, B.17	[SOUR:]VOLT:MODE, ?	B.71, B.72
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B.2 NUMERICAL VALUES AND DATA CONVENTIONS

The following conventions are used throughout this Appendix.

- < > Items in these brackets are parameter abbreviations. Parameters may be numbers or text
- <NR1> Simple numbers (without a decimal point) from 0 - 255. Examples: 156, 0 or 1
- <NR2 > Numeric Values with or without a decimal point. Examples: 0.0156, 15.6, 156 or 1.56E+3 (scientific notation: digits with decimal point and exponent)
- <txt> Text data indicating. For example, operating modes: CURRent, VOLTage, POWer, RESistance, CONDuctance, SHORT
- <bool> Boolean Data. Examples: 0, 1, OFF or ON. NOTE: If a command expecting a boolean argument is sent with no argument, the argument is assumed to be 0 (e.g., INPut and INPut 0 are identical).
- [] Optional keywords are shown in square brackets. For example [SOURce:]INPut:[STATE] <bool> means SOURce and STAtE: may be omitted thus the command is reduced to INP <bool>.

B.3 CALibrate:IPADdress COMMAND

CAL:IPAD

Syntax: Short Form: CAL:IPAD <a.b.c.d>
 Long Form: CALibrate:IPADdress <a.b.c.d>
 Where: <a, b, c, d> = numbers from 0 to 255 comprising the IP Address

Description: **Sets the IP address to be used during LAN communication.**

B.4 CALibrate:IPADdress? QUERY

CAL:IPAD?

Syntax: Short Form: CAL:IPAD? Long Form: CALibrate:IPADdress?
 Returns: <a.b.c.d> = numbers from 0 to 255 comprising the IP Address

Description: **Returns the IP Address used during LAN communication.**

B.5 CALibrate:SUBNetmask COMMAND

CAL:SUBN

Syntax: Short Form: CAL:SUBN <a.b.c.d>
 Long Form: CALibrate:SUBNetmask <a.b.c.d>
 Where: <a, b, c, d> = numbers from 0 to 255 comprising the Subnet Mask

Description: **Sets the Subnet Mask to be used during LAN communication.**

B.6 CALibrate:SUBNetmask? QUERY

CAL:SUBN?

Syntax: Short Form: CAL:SUBN? Long Form: CALibrate:SUBNetmask?
 Returns: <a.b.c.d> = numbers from 0 to 255 comprising the Subnet Mask

Description: **Returns the Subnet Mask used during LAN communication.**

B.7 CALibrate:GATEwayadd COMMAND

CAL:GATE

Syntax: Short Form: CAL:GATE <a.b.c.d>
Long Form: CALibrate:GATEwayadd <a.b.c.d>
Where: <a, b, c, d> = numbers from 0 to 255 comprising the Gateway Address.

Description: **Sets the Gateway Address to be used during LAN communication.**

B.8 CALibrate:GATEwayaddress? QUERY

CAL:GATE?

Syntax: Short Form: CAL:GATE? Long Form: CALibrate:GATEwayaddress?
Returns: <a.b.c.d> = numbers from 0 to 255 comprising the Gateway Address

Description: **Returns the Gateway Address used during LAN communication.**

B.9 CALibrate:DNSadd COMMAND

CAL:DNS

Syntax: Short Form: CAL:DNS <a.b.c.d>
Long Form: CALibrate:DNSadd <a.b.c.d>
Where: <a, b, c, d> = numbers from 0 to 255 comprising the DNS Address.

Description: **Sets the Gateway Address to be used during LAN communication.**

B.10 CALibrate:DNSadd? QUERY

CAL:DNS?

Syntax: Short Form: CAL:DNS? Long Form: CALibrate:DNSadd?
Returns: <a.b.c.d> = numbers from 0 to 255 comprising the DNS Address

Description: **Returns the DNS Address used during LAN communication.**

B.11 DEBug:TREE:DISPlay COMMAND

DEB:TREE:DISP

Syntax: Short Form: DEB:TREE:DISP Long Form: DEBug:TREE:DISPlay

Description: **Produces text file showing the SCPI command set accessible to the user.** The text file is arranged in columns and can be imported into a spreadsheet application such as Excel for easy viewing. The column separator is determined by DEB:TREE:SEP command

B.12 DEBug:TREE:SEParator COMMAND

DEB:TREE:SEP

Syntax: Short Form: DEB:TREE:SEP <NR1> Long Form: DEBug:TREE:SEParator <NR1>
where <NR1> defines the column separator

Description: **Defines the column separator used when producing a text file of the command set using DEB:TREE:DISP command.**

B.13 DEBug:TREE:SEParator? QUERY

DEB:TREE:SEP?

Syntax: Short Form: DEB:TREE:SEP? Long Form: DEBug:TREE:SEParator?
Returns <NR1> defines the column separator

Description: **Returns the number corresponding to the selected column separator when producing a text file of the command set using DEB:TREE:DISP command.**

B.14 LOCK COMMAND

LOCK

Syntax: Short Form: LOCK <lock state> Long Form: LOCK <lock state>
where <lock state> = OFF, EMERgency or LOCKed

Description: **Controls functionality of front panel controls.** When set to OFF, all front panel controls are fully functional. When set to EMER, the front panel LOAD switch can only turn the load to the off state; all other front panel controls except for the POWER switch are disabled. When set to LOCK, all front panel controls except for the POWER switch are disabled.

B.15 LOCK? QUERY

LOCK?

Syntax: Short Form: LOCK? Long Form: LOCK?
Returns: <lock state> = OFF, EMERgency or LOCKed

Description: **Indicates state of front panel controls.**

B.16 SENSE:CURRENT:RANGE COMMAND

SENS:CURR:RANG

Syntax: Short Form: SENS:CURR:RANG <NR1> Long Form: SENSE:CURRENT:RANGE <NR1>
Where: <NR1> = 0, 1, 2, 3 or 4

Description: **Controls the placement of the decimal point during remote interface readback of current and on the front panel AMPS display.**

Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.17 SENSE:CURRENT:RANGE? QUERY

SENS:CURR:RANG?

Syntax: Short Form: SENS:CURR:RANG? Long Form: SENSE:CURRENT:RANGE?
Returns: <NR1> = 0, 1, 2, 3 or 4

Description: **Indicates the placement of the decimal point during remote interface readback of current and on the front panel AMPS display.**

Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.18 SENSE:VOLTAGE:RANGE COMMAND

SENS:VOLT:RANG

Syntax: Short Form: SENS:VOLT:RANG <NR1> Long Form: SENSE:VOLTAGE:RANGE <NR1>
Where: <NR1> = 0, 1, 2, 3 or 4

Description: **Controls the placement of the decimal point during remote interface readback of voltage, and on the front panel VOLTS display.**

Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.19 SENSE:VOLTAGE:RANGE? QUERY

SENS:VOLT:RANG?

Syntax: Short Form: SENS:VOLT:RANG? Long Form: SENSE:VOLTAGE:RANGE?
Returns: <NR1> = 0, 1, 2, 3 or 4

Description: **Indicates the placement of the decimal point during remote interface readback of voltage, and on the front panel VOLTS display.**

Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.20 [SOURCE:]INPUT[:STATE] COMMAND

INP

Syntax: Short Form: [SOURCE:]INP[:STAT] <bool> Long Form: [SOURCE:]INPUT[:STATE] <bool>
where <bool> = 0 or OFF (load disengaged) or 1 or ON (load engaged)

Description: **Used to engage or disengage the load from the UUT.** When set to 1 the load engages at the programmed mode and corresponding setpoint value; when set to 0 the load disengages.

B.21 [SOURCE:]INPUT[:STATE]? QUERY

INP?

Syntax: Short Form: [SOURCE:]INP[:STAT]? Long Form: [SOURCE:]INPUT[:STATE]?
Returns <bool> = 0 or OFF (load disengaged) or 1 or ON (load engaged)

Description: **Indicates whether load is engaged or disengaged from the UUT.** When set to 1 the load is engaged, when set to 0 the load is disengaged.

B.22 [SOURCE:]INPUT:PROTECTION:CLEAR COMMAND

INP:PROT:CLE

Syntax: Short Form: [SOURCE:]INP:PROT:CLE Long Form: [SOURCE:]INPUT:PROTECTION:CLEAR

Description: **Resets protection from overcurrent, overpower, etc.**

B.23 [SOURCE:]INPut:PROTection:SHORt[:STATe] COMMAND**INP:PROT:SHOR**

Syntax: Short Form: [SOUR:]INP:PROT:SHOR[:STAT]
 Long Form: [SOURCE:]INPut:PROTection:SHORt[:STATe]

Description: **Applies maximum drive to FETs, effectively shorting the input.**

B.24 [SOURCE:]OUTPut[:STATe] COMMAND**OUTP**

Syntax: Short Form: [SOUR:]OUTP[:STAT] <bool> Long Form: [SOURCE:]OUTPut[:STATe] <bool>
 where <bool> = 0 or OFF (load disengaged) or 1 or ON (load engaged)

Description: **Used to engage or disengage the load from the UUT.** When set to 1 the load engages, when set to 0 the load disengages.

B.25 [SOURCE:]OUTPut[:STATe]? QUERY**OUTP?**

Syntax: Short Form: [SOUR:]OUTP[:STAT]? Long Form: [SOURCE:]OUTPut[:STATe]?
 Returns <bool> = 0 or OFF (load disengaged) or 1 or ON (load engaged)

Description: **Indicates whether load is engaged or disengaged from the UUT.** When set to 1 the load is engaged, when set to 0 the load is disengaged.

B.26 [SOURCE:]OUTPut:PROTection:CLEar COMMAND**OUTP:PROT:CLE**

Syntax: Short Form: [SOUR:]OUTP:PROT:CLE Long Form: [SOURCE:]OUTPut:PROTection:CLEar

Description: **Resets protection from overcurrent, overpower, etc.**

B.27 [SOURCE:]OUTPut:PROTection:SHORt[:STATe] COMMAND**OUTP:PROT:SHOR**

Syntax: Short Form: [SOUR:]INP:PROT:SHOR[:STAT]
 Long Form: [SOURCE:]INPut:PROTection:SHORt[:STATe]

Description: **Applies maximum drive to FETs, effectively shorting the output.**

B.28 [SOURCE:]MEASure:ALL? QUERY**MEAS:ALL?**

Syntax: Short Form: [SOUR:]MEAS:ALL? Long Form: [SOURCE:]MEASure:ALL?
 Returns: Measured values in the form 0.000 KW, 0.000 Amps, 0.000 Volts.

Description: Measures output power (Kilowatts), current (Amps), and voltage (Volts). Unit of measurement included in the reply.

B.29 [SOURCE:]MEASure:ALL2? QUERY**MEAS:ALL2?**

Syntax: Short Form: [SOUR:]MEAS:ALL2? Long Form: [SOURCE:]MEASure:ALL2?
 Returns: Measured values in the form 0.000 0.000 0.000 (Kilowatts Amps Volts).

Description: Measures output power (Kilowatts), current (Amps), and voltage (Volts). Unit of measurement is omitted from the reply.

B.30 [SOURCE:]MEASure[:SCALar]:CURRent[:DC]? QUERY**MEAS:CURR?**

Syntax: Short Form: [SOUR:]MEAS[:SCAL]:CURR[:DC]?
 Long Form: [SOURCE:]MEASure[:SCALar]:CURRent[:DC]?
 Returns: Measured values.

Description: **Measures current.** Measured returned as XXX Amps, where XXX is format determined by CURRent:RANGe command (see PAR. B.47)

B.31 [SOURce:]MEASure[:SCALar]:POWer[:DC]? QUERY**MEAS:POW?**

Syntax: Short Form: [SOUR:]MEAS[:SCAL]:POW[:DC]?
 Long Form: [SOURce:]MEASure[:SCALar]:POWer[:DC]?
 Returns: Measured values in the form 0.000 Kilowatts

Description: **Measures power.** Measured returned as XXX Kilowatts, where XXX is format determined by POWer:RANGe command (see PAR. B.61)

B.32 [SOURce:]MEASure[:SCALar]:VOLTage[:DC]? QUERY**MEAS:VOLT?**

Syntax: Short Form: [SOUR:]MEAS[:SCAL]:VOLT[:DC]?
 Long Form: [SOURce:]MEASure[:SCALar]:VOLTage[:DC]?
 Returns: Measured values in the form XXX Volts

Description: **Measures voltage.** Measured returned as XXX Volts, where XXX is format determined by VOLTage:RANGe command (see PAR. B.81)

B.33 [SOURce:]CONDuctance[:LEVel][:IMMediate][:AMPLitude] COMMAND**COND**

Syntax: Short Form:[SOUR:]CONDuctance[:LEVel][:IMMediate][:AMPLitude] <NR2>
 Long Form: [SOURce:]CONDuctance[:LEVel][:IMMediate][:AMPLitude] <NR2>
 Where <NR2> = conductance setpoint in Siemens

Description: **Establishes conductance setpoint.** Conductance setpoint is stored in non-volatile memory; value is restored upon power-up.

B.34 [SOURce:]CONDuctance[:LEVel][:IMMediate][:AMPLitude]? QUERY**COND?**

Syntax: Short Form:[SOUR:]CONDuctance[:LEVel][:IMMediate][:AMPLitude]?
 Long Form: [SOURce:]CONDuctance[:LEVel][:IMMediate][:AMPLitude]?
 Returns <NR2> = conductance setpoint in Siemens

Description: **Indicates conductance setpoint.**

B.35 [SOURce:]CONDuctance:MODE COMMAND**COND:MODE**

Syntax: Short Form: [SOUR:]COND:MOD Long Form: [SOURce:]CONDuctance:MODE

Description: **Selects conductance mode.**

B.36 [SOURce:]CONDuctance:MODE? QUERY**COND:MODE?**

Syntax: Short Form: [SOUR:]COND:MOD? Long Form: [SOURce:]CONDuctance:MODE?
 Returns: <txt> = CURR, POW, VOLT, RES, COND, OFF

Description: Returns the present mode: CURRent, POWer, VOLTage, RESistance, CONDuctance, OFF

B.37 [SOURce:]CONDuctance:RANGe COMMAND**COND:RANG**

Syntax: Short Form: [SOUR:]COND:RANG <NR1> Long Form: [SOURce:]CONDuctance:RANGe <NR1>
 Where <NR1> = 0, 1, 2, 3, or 4

Description: **Controls the placement of the decimal point during remote interface readback of conductance, and on the front panel KW display when showing conductance.**
 Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.38 [SOURce:]CONDuctance:RANGe? QUERY**COND:RANG?**

Syntax: Short Form: [SOUR:]COND:RANG? Long Form: [SOURce:]CONDuctance:RANGe?
 Returns <NR1> = 0, 1, 2, 3, or 4

Description: **Indicates the placement of the decimal point during remote interface readback of conductance, and on the front panel KW display when showing conductance.**
 Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.39 [SOURCE:]CURRENT[:LEVEL][:IMMEDIATE][:AMPLITUDE] COMMAND**CURR**

Syntax: Short Form: [SOUR:]CURR[:LEV][:IMM][:AMP] <NR2>
 Long Form: [SOURCE:]CURRENT[:LEVEL][:IMMEDIATE][:AMPLITUDE] <NR2>
 Where <NR2> = current setpoint

Description: **Current Setting.** Current setpoint is stored in non-volatile memory; value is restored upon power-up.

B.40 [SOURCE:]CURRENT[:LEVEL][:IMMEDIATE][:AMPLITUDE]? QUERY**CURR?**

Syntax: Short Form: [SOUR:]CURR[:LEV][:IMM][:AMP]?
 Long Form: [SOURCE:]CURRENT[:LEVEL][:IMMEDIATE][:AMPLITUDE]?
 Returns <NR2> = current setpoint

Description: **Indicates Current Setpoint.**

B.41 [SOURCE:]CURRENT:MODE COMMAND**CURR:MODE**

Syntax: Short Form: [SOUR:]CURR:MODE Long Form: [SOURCE:]CURRENT:MODE

Description: **Selects current mode.**

B.42 [SOURCE:]CURRENT:MODE? QUERY**CURR:MODE?**

Syntax: Short Form: [SOUR:]CURR:MODE? Long Form: [SOURCE:]CURRENT:MODE?
 Returns: <txt> = CURR, POW, VOLT, RES, COND, OFF

Description: **Returns the present mode:** CURRENT, POWER, VOLTage, RESistance, CONDuctance, OFF

B.43 [SOURCE:]CURRENT:PROTECTION[:LEVEL] COMMAND**CURR:PROT**

Syntax: Short Form: [SOUR:]CURR:PROT[:LEV] <NR2>
 Long Form: [SOURCE:]CURRENT:PROTECTION[:LEVEL] <NR2>
 where: <NR2> = current protection setpoint

Description: **Establishes current protection setpoint.** Current protection setpoint is stored in non-volatile memory; value is restored upon power-up. This is a user-defined value which, if exceeded during operation, causes a FAULT condition, forcing the load to disengage.

B.44 [SOURCE:]CURRENT:PROTECTION[:LEVEL]? QUERY**CURR:PROT?**

Syntax: Short Form: [SOUR:]CURR:PROT[:LEV]?
 Long Form: [SOURCE:]CURRENT:PROTECTION[:LEVEL]?
 Returns: <NR2> = current protection setpoint

Description: **Indicates current protection setpoint.**

B.45 [SOURCE:]CURRENT:PROTECTION:STATE COMMAND**CURR:PROT:STAT**

Syntax: Short Form: [SOUR:]CURR:PROT:STAT <bool>
 Long Form: [SOURCE:]CURRENT:PROTECTION:STATE <bool>
 where <bool> = 1 (enabled) or 0 (disabled)

Description: **Enables (1) or disables (0) the current protection level set using CURR:PROT.** This command saves having to change the protection level to some value outside of the operating range.

B.46 [SOURCE:]CURRENT:PROTECTION:STATE? QUERY**CURR:PROT:STAT?**

Syntax: Short Form: [SOUR:]CURR:PROT:STAT?
 Long Form: [SOURCE:]CURRENT:PROTECTION:STATE?
 Returns: <bool> = 1 (enabled) or 0 (disabled)

Description: **Indicates whether the current protection level set using CURR:PROT is enabled (1) or disabled (0).**

B.47 [SOURce:]CURRent:RANGe COMMAND**CURR:RANG**

Syntax: Short Form: [SOUR:]CURR:RANG <NR1> Long Form: [SOURce:]CURRent:RANGe <NR1>
 where: <NR1> = 0, 1, 2, 3 or 4

Description: **Controls the placement of the decimal point during remote interface readback of current, and on the front panel AMPS display when showing current.** Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.48 [SOURce:]CURRent:RANGe? QUERY**CURR:RANG?**

Syntax: Short Form: [SOUR:]CURR:RANG? Long Form: [SOURce:]CURRent:RANGe?
 Returns: <NR1> = 0, 1, 2, 3 or 4

Description: **Indicates the placement of the decimal point during remote interface readback of current, and on the front panel AMPS display when showing current.** Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.49 [SOURce:]FUNCtion COMMAND**FUNC**

Syntax: Short Form: [SOUR:]FUNC <txt> Long Form: [SOURce:]FUNCtion <txt>
 where: <txt> = CURR, POW, VOLT, RES, COND or OFF

Description: **Sets operating mode.**

B.50 [SOURce:]FUNCtion QUERY**FUNC?**

Syntax: Short Form: [SOUR:]FUNC?> Long Form: [SOURce:]FUNCtion?
 Returns: <txt> = CURR, POW, VOLT, RES, COND or OFF

Description: **Indicates operating mode.**

B.51 [SOURce:]MODE COMMAND**MODE**

Syntax: Short Form: [SOUR:]MODE <txt> Long Form: [SOURce:]MODE <txt>
 where: <txt> = CURR, POW, VOLT, RES, COND, SHORT or OFF

Description: **Sets operating mode:** CURRent, POWer, VOLTage, RESistance, CONDuctance, SHORT or OFF.

B.52 [SOURce:]MODE? QUERY**MODE?**

Syntax: Short Form: [SOUR:]MODE? Long Form: [SOURce:]MODE?
 Returns: <txt> = CURR, POW, VOLT, RES, COND, SHORT or OFF

Description: **Indicates the present mode:** CURRent, POWer, VOLTage, RESistance, CONDuctance, SHORT or OFF.

B.53 [SOURce:]POWer[:LEVel][:IMMEDIATE][:AMPLitude] COMMAND**POW**

Syntax: Short Form: [SOUR:]POW[:LEV][:IMM][:AMP] <NR2>
 Long Form: [SOURce:]POWer[:LEVel][:IMMEDIATE][:AMPLitude] <NR2>
 Where <NR2> = power setpoint

Description: **Establishes power setpoint.**

B.54 [SOURce:]POWer[:LEVel][:IMMEDIATE][:AMPLitude]? QUERY**POW?**

Syntax: Short Form: [SOUR:]POW[:LEV][:IMM][:AMP]?
 Long Form: [SOURce:]POWer[:LEVel][:IMMEDIATE][:AMPLitude]?
 Returns <NR2> = power setpoint

Description: **Indicates power setpoint.**

B.55 [SOURCE:]POWER:MODE COMMAND**POW:MODE**

Syntax: Short Form: [SOUR:]POW:MODE Long Form: [SOURCE:]POWER:MODE

Description: **Selects power mode.**

B.56 [SOURCE:]POWER:MODE? QUERY**POW:MODE?**

Syntax: Short Form: [SOUR:]POW:MODE? Long Form: [SOURCE:]POWER:MODE?
Returns: <txt> = CURR, POW, VOLT, RES, COND, OFF

Description: **Returns the present mode:** CURRrent, POWer, VOLTage, RESistance, CONDuctance, OFF

B.57 [SOURCE:]POWER:PROTECTION COMMAND**POW:PROT**

Syntax: Short Form: [SOUR:]POW:PROT <NR2> Long Form: [SOURCE:]POWER:PROTECTION <NR2>
where <NR2> = power protection setpoint

Description: **Selects power protection setpoint.** This is a user-defined value which, if exceeded during operation, causes a FAULT condition, forcing the load to disengage.

B.58 [SOURCE:]POWER:PROTECTION? QUERY**POW:PROT?**

Syntax: Short Form: [SOUR:]POW:PROT? Long Form: [SOURCE:]POWER:PROTECTION?
Returns <NR2> = power protection setpoint

Description: **Indicates power protection setpoint.**

B.59 [SOURCE:]POWER:PROTECTION:STATE[:LEVEL] COMMAND**POW:PROT:STAT**

Syntax: Short Form: [SOUR:]POW:PROT:STAT[:LEV] <bool>
Long Form: [SOURCE:]POWER:PROTECTION:STATE[:LEVEL] <bool>
where: <bool> = 1 (enabled) or 0 (disabled)

Description: **Clears or sets power protection trip.**

B.60 [SOURCE:]POWER:PROTECTION:STATE[:LEVEL]? QUERY**POW:PROT:STAT?**

Syntax: Short Form: [SOUR:]POW:PROT:STAT[:LEV]?
Long Form: [SOURCE:]POWER:PROTECTION:STATE[:LEVEL]?
where: <bool> = 1 (enabled) or 0 (disabled)

Description: **Indicates whether the power protection level set using POW:PROT is enabled (1) or disabled (0).**

B.61 [SOURCE:]POWER:RANGE COMMAND**POW:RANG**

Syntax: Short Form: [SOURCE:]POW:RANGE <NR1> Long Form: [SOURCE:]POWER:RANGE <NR1>
where: <NR1> = 0, 1, 2, 3 or 4

Description: **Controls the placement of the decimal point during remote interface readback of power, and on the front panel KW display when showing power.** Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.62 [SOURCE:]POWER:RANGE? QUERY**POW:RANG?**

Syntax: Short Form: [SOURCE:]POW:RANGE? Long Form: [SOURCE:]POWER:RANGE?
Returns: <NR1> = 0, 1, 2, 3 or 4

Description: **Indicates the placement of the decimal point during remote interface readback of power, and on the front panel KW display when showing power.** Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.63 [SOURce:]RESistance[:LEVel][:IMMEDIATE][:AMPLitude] COMMAND**RES**

Syntax: Short Form: [SOUR:]RES[:LEV][:IMM][:AMP] <NR2>
 Long Form: [SOURce:]RESistance[:LEVel][:IMMEDIATE][:AMPLitude] <NR2>
 Where: <NR2> = resistance setpoint

Description: **Establishes resistance setpoint.** Resistance setpoint is stored in non-volatile memory; value is restored upon power-up.

B.64 [SOURce:]RESistance[:LEVel][:IMMEDIATE][:AMPLitude]? QUERY**RES?**

Syntax: Short Form: [SOUR:]RES[:LEV][:IMM][:AMP]?
 Long Form: [SOURce:]RESistance[:LEVel][:IMMEDIATE][:AMPLitude]?
 Returns: <NR2> = resistance setpoint

Description: **Indicates resistance setpoint.**

B.65 [SOURce:]RESistance:MODE COMMAND**RES:MODE**

Syntax: Short Form: [SOUR:]RES:MODE Long Form: [SOURce:]RESistance:MODE

Description: **Selects resistance mode.**

B.66 [SOURce:]RESistance:MODE? QUERY**RES:MODE?**

Syntax: Short Form: [SOUR:]RES:MODE? Long Form: [SOURce:]RESistance:MODE?
 Returns: <txt> = CURR, POW, VOLT, RES, COND, OFF

Description: **Returns the present mode:** CURRent, POWer, VOLTage, RESistance, CONDuctance, OFF

B.67 [SOURce:]RESistance:RANGe COMMAND**RES:RANG**

Syntax: Short Form: [SOURce:]RES:RANGe <NR1> Long Form: [SOURce:]RESistance:RANGe <NR1>
 where: <NR1> = 0, 1, 2, 3 or 4

Description: **Controls the placement of the decimal point during remote interface readback of resistance, and on the front panel KW display when showing resistance.** Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.68 [SOURce:]RESistance:RANGe? QUERY**RES:RANG?**

Syntax: Short Form: [SOURce:]RES:RANGe? Long Form: [SOURce:]RESistance:RANGe?
 Returns: <NR1> = 0, 1, 2, 3 or 4

Description: **Indicates the placement of the decimal point during remote interface readback of resistance, and on the front panel KW display when showing resistance.** Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.69 [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] COMMAND**VOLT**

Syntax: Short Form: [SOUR:]VOLT[:LEV][:IMM][:AMP] <NR2>
 Long Form: [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] <NR2>
 where: <NR2> = voltage setpoint

Description: **Establishes voltage setpoint.** Voltage setpoint is stored in non-volatile memory; value is restored upon power-up.

B.70 [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude]? QUERY**VOLT?**

Syntax: Short Form: [SOUR:]VOLT[:LEV][:IMM][:AMP]?
 Long Form: [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude]?
 Returns: <NR2> = voltage setpoint

Description: **Indicates voltage setpoint.**

B.71 [SOURCE:]VOLTage:MODE COMMAND**VOLT:MODE**

Syntax: Short Form: [SOUR:]VOLT:MODE Long Form: [SOURCE:]VOLTage:MODE

Description: **Selects voltage mode.**

B.72 [SOURCE:]VOLTage:MODE? QUERY**VOLT:MODE?**

Syntax: Short Form: [SOUR:]VOLT:MODE? Long Form: [SOURCE:]VOLTage:MODE?
Returns: <txt> = CURR, POW, VOLT, RES, COND, OFF

Description: **Returns the present mode:** CURRent, POWer, VOLTage, RESistance, CONDuctance, OFF

B.73 [SOURCE:]VOLTage:PROTection:OVEr COMMAND**VOLT:PROT:OVE**

Syntax: Short Form: [SOUR:]VOLT:PROT:OVE <NR2>
Long Form: [SOURCE:]VOLTage:PROTection:OVEr <NR2>
where <NR2> = overvoltage protection limit

Description: **Sets overvoltage protection limit.** Overvoltage protection setpoint is stored in non-volatile memory; value is restored upon power-up.

B.74 [SOURCE:]VOLTage:PROTection:OVEr? QUERY**VOLT:PROT:OVE?**

Syntax: Short Form: [SOUR:]VOLT:PROT:OVE?
Long Form: [SOURCE:]VOLTage:PROTection:OVEr?
Returns <NR2> = overvoltage protection limit

Description: **Indicates overvoltage protection limit.**

B.75 [SOURCE:]VOLTage:PROTection:OVEr:STATe[:LEVe] COMMAND**VOLT:PROT:OVE:STAT**

Syntax: Short Form: [SOUR:]VOLT:PROT:OVE:STAT[:LEV] <bool>
Long Form: [SOURCE:]VOLTage:PROTection:OVEr:STATe[:LEVe] <bool>
where <bool> = 1 (enabled) or 0 (disabled)

Description: **Enables (1) or disables (0) the overvoltage protection level set using VOLT:PROT:OVE.** This command saves having to change the protection level to some value outside of the operating range.

B.76 [SOURCE:]VOLTage:PROTection:OVEr:STATe[:LEVe]? COMMAND**VOLT:PROT:OVE:STAT?**

Syntax: Short Form: [SOUR:]VOLT:PROT:OVE:STAT[:LEV]
Long Form: [SOURCE:]VOLTage:PROTection:OVEr:STATe[:LEVe]
where <bool> = 1 (enabled) or 0 (disabled)

Description: **Indicates whether the overvoltage protection level set using VOLT:PROT:OVE is enabled (1) or disabled (0).**

B.77 [SOURCE:]VOLTage:PROTection:UNDEr COMMAND**VOLT:PROT:UND**

Syntax: Short Form: [SOUR:]VOLT:PROT:UND <NR2>
Long Form: [SOURCE:]VOLTage:PROTection:UNDEr <NR2>
where <NR2> = undervoltage protection limit

Description: **Sets undervoltage protection limit.** Undervoltage protection setpoint is stored in non-volatile memory; value is restored upon power-up.

B.78 [SOURCE:]VOLTage:PROTection:UNDEr? QUERY**VOLT:PROT:UND?**

Syntax: Short Form: [SOUR:]VOLT:PROT:UND? Long Form: [SOURCE:]VOLTage:PROTection:UNDEr?
Returns: <NR2> = undervoltage protection limit

Description: **Indicates undervoltage protection limit.**

B.79 [SOURce:]VOLTage:PROTection:UNDer:STATE[:LEVe] COMMAND **VOLT:PROT:UND:STAT**

Syntax: Short Form: [SOUR:]VOLT:PROT:UND:STAT[:LEV] <bool>
 Long Form: [SOURce:]VOLTage:PROTection:UNDer:STATe[:LEVe] <bool>
 where <bool> = 1 (enabled) or 0 (disabled)

Description: **Enables (1) or disables (0) the undervoltage protection level set using VOLT:PROT:UND.** This command saves having to change the protection level to some value outside of the operating range.

B.80 [SOURce:]VOLTage:PROTection:UNDer:STATE[:LEVe]? QUERY **VOLT:PROT:UND:STAT?**

Syntax: Short Form: [SOUR:]VOLT:PROT:UND:STAT[:LEV]?
 Long Form: [SOURce:]VOLTage:PROTection:UNDer:STATe[:LEVe]?
 Returns: <bool> = 1 (enabled) or 0 (disabled)

Description: **Indicates whether the undervoltage protection level set using VOLT:PROT:UND is enabled (1) or disabled (0).**

B.81 [SOURce:]VOLTage:RANGe COMMAND **VOLT:RANG**

Syntax: Short Form: [SOURce:]VOLT:RANG <NR1> Long Form: [SOURce:]VOLTage:RANGe <NR1>
 Where <NR1> = 0, 1, 2, 3 or 4

Description: **Controls the placement of the decimal point during remote interface readback of voltage, and on the front panel VOLTS display when showing voltage.** Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.82 [SOURce:]VOLTage:RANGe? QUERY **VOLT:RANG?**

Syntax: Short Form: [SOURce:]VOLT:RANG? Long Form: [SOURce:]VOLTage:RANGe?
 Returns <NR1> = 0, 1, 2, 3 or 4

Description: **Indicates the placement of the decimal point during remote interface readback of voltage, and on the front panel VOLTS display when showing voltage.** Display Ranges: 0 - Auto, 1 - 0.000, 2 - 00.00, 3 - 000.0, 4 - 0000.

B.83 STATus:CHANnel[:EVENT]? QUERY **STAT:CHAN?**

Syntax: Short Form: STAT:CHAN[:EVENT]? Long Form: STATus:CHANnel[:EVENT]?
 Returns: <16 bits> = the value of the Channel event register.

Description: **Returns value of Channel event register.** Each PFM within a chassis has three Channel registers associated with it. Bits in the Event register are set whenever the associated condition occurs, and are cleared only upon an explicit command, thus latching any conditions that occur. See Table B-2 for bit assignments.

TABLE B-2. CHANNEL STATUS CONDITION, ENABLE, AND EVENT REGISTER BITS

CONDITION	NU	PS	OV	LRV	UNR	RRV	EPU	NU	OT	OP	NU	OC	VF
BIT	14-15	13	12	11	10	9	8	5-7	4	3	2	1	0
VALUE	16384-32768	8192	4096	2048	1024	512	256	32-128	16	8	4	2	1

EPU EXTENDED PWR UNAVAILABLE
 LRV LOCAL REVERSE VOLTAGE
 NU - NOT USED
 OC OVERCURRENT
 OP OVERPOWER
 OT OVERTEMPERATURE
 OV OVERVOLTAGE
 PS PROTECTION SHUTDOWN
 RRV REMOTE REVERSE VOLTAGE
 UNR UNREGULATED
 VF VOLTAGE FAULT

B.84 STATus:CHANnel:CONDition? QUERY **STAT:CHAN:COND?**

Syntax: Short Form: STAT:CHAN:COND? Long Form: STATus:CHANnel:CONDition?
 Returns: <16 bits> = the value of the Channel condition register.

Description: **Returns the value of the Channel Condition Register.** Each PFM within a chassis has three Channel registers associated with it. The Condition register reflects the instantaneous state of that PFM. Bits in the Event register are set whenever the associated condition occurs, and are cleared only upon an explicit command, thus latching any conditions that occur. See Table B-2 for bit assignments.

B.85 STATus:CHANnel:ENABle COMMAND**STAT:CHAN:ENAB**

Syntax: Short Form: STAT:CHAN:ENAB <NR1> Long Form: STATus:CHANnel:ENABle <NR1>
 Where <NR1> = 16 bits = the value of the Channel enable register.

Description: **Sets the Channel Enable Register to determine which bits are allowed to set the channel event register.** Each PFM within a chassis has three Channel registers associated with it. The Enable register selects which of the latched bits in the Event register can propagate to higher-level indicators. See Table B-2 for bit assignments.

B.86 STATus:CHANnel:ENABle? QUERY**STAT:CHAN:ENAB?**

Syntax: Short Form: STAT:CHAN:ENAB? Long Form: STATus:CHANnel:ENABle?
 Returns: <16 bits> = the value of the Channel enable register.

Description: **Returns the value of the Channel Enable Register.** See Table B-2 for bit assignments.

B.87 STATus:CSUMmary[:EVENT]? QUERY**STAT:CSUM?**

Syntax: Short Form: STAT:CSUM[:EVENT]? Long Form: STATus:CSUMmary[:EVENT]?
 Returns: <16 bits> = the value of the Channel summary register.

Description: **Returns the value of the Channel Summary Register.** The Channel Summary Group contains an Event and Enable register which sums the

TABLE B-3. CHANNEL SUMMARY ENABLE AND EVENT REGISTER BITS

CONDITION	NU	SL14	SL13	SL12	SL11	SL10	SL9	SL8	SL7	SL6	SL5	SL4	SL3	SL2	SL1	MSTR
BIT	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
VALUE	32768	16384	8192	4096	2048	1024	512	256	128	64	32	16	8	4	2	1

MSTR MASTER
 NU NOT USED
 SL1 SLAVE 1
 through
 SL14 SLAVE 14

B.88 STATus:CSUMmary:ENABle COMMAND**STAT:CSUM:ENAB**

Syntax: Short Form: STAT:CSUM:ENAB <NR1> Long Form: STATus:CSUMmary:ENABle <NR1>
 Where: <NR1> = 16 bits = the value of the Channel summary enable register.

Description: **Sets the value of the Channel Summary Enable Register to determine which bits are allowed to set the Channel Summary Register.**

B.89 STATus:CSUMmary:ENABle? QUERY**STAT:CSUM:ENAB?**

Syntax: Short Form: STAT:CSUM:ENAB? Long Form: STATus:CSUMmary:ENABle?
 Returns: <16 bits> = the value of the Channel summary enable register.

Description: **Returns the value of the Channel Summary Enable Register.**

B.90 STATus:OPERation[:EVENT]? QUERY**STAT:OPER?**

Syntax: Short Form: STAT:OPER[:EVENT]? Long Form: STATus:OPERation[:EVENT]?
 Return Value:

Description: **Indicates changes in conditions monitored by Operational Event Register.** Returns the value of the Operation Event register. The Operation Event register is a read-only register which holds (latches) all events that occur. Reading the Operation Event register clears it.

TABLE B-4. OPERATION CONDITION REGISTER, OPERATION ENABLE REGISTER, AND OPERATION EVENT REGISTER BITS

CONDITION	NU	PON	NU	CME	EXE	DDE	QYE	NU	OPC
BIT	8 - 15	7	6	5	4	3	2	1	0
VALUE	256 - 32,768	128	64	32	16	8	4	2	1

CME COMMAND ERROR
DDE DEVID DEPENDENT ERROR
EXE EXECUTION ERROR
NU - NOT USED
OPC OPERATION COMPLETE
PON POWER ON SINCE THIS BIT LAST READ
QYE QUERY ERROR

B.91 STATus:OPERation:CONDition? QUERY

STAT:OPER:COND?

Syntax: Short Form: STAT:OPER:COND? Long Form: STATus:OPERation:CONDition?
Return Value:

Description: **Returns the value of the Operation Condition Register.** The Operation Condition Register contains unlatched real-time information about the operating conditions of the load. Bit set to 1 = function enabled (active, true); bit reset to 0 = function disabled (inactive, false).

B.92 STATus:OPERation:ENABLE COMMAND

STAT:OPER:ENAB

Syntax: Short Form: STAT:OPER:ENAB <int_value>
Long Form: STATus:OPERation:ENABLE <int_value>

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.

B.93 STATus:OPERation:ENABLE? QUERY

STAT:OPER:ENAB?

Syntax: Short Form: STAT:OPER:ENAB? Long Form: STATus:OPERation:ENABLE?
Return Value: <int_value>

Description: **Reads Operation Enable Register.** Returns value of Operation Enable Register bits. Bit set to 1 = function enabled (active, true); bit reset to 0 = function disabled (inactive, false).

B.94 STATus:OPERation:NTRansition COMMAND

STAT:OPER:NTR

Syntax: Short Form: STAT:OPER:NTR Long Form: STATus:OPERation:NTRansition

Description: **Negative transition enable register.**

B.95 STATus:OPERation:PTRansition COMMAND

STAT:OPER:PTR

Syntax: Short Form: STATus:OPERation:PTRansition Long Form: STATus:OPERation:PTRansition

Description: **Positive transition enable register.**

B.96 STATus:QUESTIONable[:EVENT]? QUERY

STAT:QUES?

Syntax: Short Form: STAT:QUES[EVENT]? Long Form: STATus:QUESTIONable[EVENT]?
Return Value: <NR1> =16 bits = actual Questionable register value

Description: **Indicates questionable events that occurred since previous STAT:QUES? query.** Returns the value of the Questionable Event register. The Questionable Event register is a read-only register which holds (latches) all events. Reading the Questionable Event register clears it.

B.97 CONDition:QUEStionable:CONDition? QUERY**STAT:QUES:COND?**

Syntax: Short Form: STAT:QUES:COND? Long Form: STATus:QUEStionable:CONDition?
Return Value: <NR1> =16 bits = actual Questionable condition register value

Description: **Returns the value of the Questionable Condition Register.** The Questionable Condition Register contains unlatched real-time information about questionable conditions of the electronic load. Bit set to 1 = condition (active, true); bit reset to 0 = condition (inactive, false). (See example, Figure B.93.)

B.98 STATus:QUEStionable:ENABle COMMAND**STAT:QUES:ENAB**

Syntax: Short Form: STAT:QUES:ENAB <NR1> Long Form: STATus:QUEStionable:ENABle <int_value>

Description: **Programs Questionable Condition Enable Register.** 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).

B.99 STATus:QUEStionable:ENABle? QUERY**STAT:QUES:ENAB?**

Syntax: Short Form: STAT:QUES:ENAB? Long Form: STATus:QUEStionable:ENABle?
Return Value: <NR1> =16 bits = actual Questionable enable register value

Description: **Reads Questionable Condition Enable Register.** Electronic load 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).

B.100 SYSTem:DAMPing COMMAND**SYST:DAMP**

Syntax: Short Form: SYST:DAMP x Long Form: SYSTem:DAMPing x
Where x = integer from 0 (minimum damping) to 5 (maximum damping)

Description: **Inserts capacitance required to damp oscillation.** Increased damping reduces the tendency for oscillation and reduces response time to high speed transients. Factory default setting is 5. See PAR. 3.11 for details.

B.101 SYSTem:DAMPing? QUERY**SYST:DAMP?**

Syntax: Short Form: SYST:DAMP? Long Form: SYSTem:DAMPing?
Returns x where x = integer from 0 (minimum damping) to 5 (maximum damping)

Description: **Inserts capacitance required to damp oscillation.** Factory default setting is 5. See PAR. 3.11

B.102 SYSTem:ERRor? QUERY**SYST:ERR?**

Syntax: Short Form: SYST:ERR? Long Form: SYSTem:ERRor?

Description: **Returns next entry from the error message queue.** Responds with the most recent error message in a queue of up to 10 possible messages and clears each error message as it is sent. Issuing *CLS clears all error messages in the queue.

<u>Error Message</u>	<u>Code</u>
Command Error Generic	-100
Invalid Separator	-103
Illegal Parameter Value	-224
Invalid Unit Number	-241
Queue Overflow	-350
No Error	-0

B.103 SYSTem:EXTernal COMMAND

SYST:EXT

Syntax: Short Form: SYST:EXT <x> Long Form: SYSTem:EXTernal <x>
where <bool> = 0 or OFF for disable, 1 or ON for enable

Description: **Enables or disables external analog programming.**

B.104 SYSTem:EXTernal? QUERY

SYST:EXT?

Syntax: Short Form: SYST:EXT? Long Form: SYSTem:EXTernal?
Returns: <bool> = 0 (disabled) or 1 (enabled)

Description: **Indicates whether external analog programming is enabled or disabled.**

B.105 SYSTem:FAN COMMAND

SYST:FAN

Syntax: Short Form: SYST:FAN <NR1> Long Form: SYSTem:FAN <NR1>
Where <NR1> = integer from 0 to 100 indicating fan speed

Description: **Sets minimum fan speed as a percent.**

B.106 SYSTem:FAN? QUERY

SYST:FAN?

Syntax: Short Form: SYST:FAN? Long Form: SYSTem:FAN?
Returns <NR1> = integer from 0 to 100 indicating fan speed

Description: **Indicates minimum fan speed setting as a percent.**

B.107 SYSTem:PFModule:DAMPing COMMAND

SYST:PFM:DAMP

Syntax: Short Form: SYST:PFM:DAMP <x> Long Form: SYSTem:PFModule:DAMPing <x>
Where <x> = integer from 0 (minimum damping) to 5 (maximum damping)

Description: **Establishes damping settings for Power FET Modules.** Increased damping decreases the loop's response time to transients. Factory default setting is 3.
Damping Settings: 0 - 1nF, 1 - 4.3nF, 2 - 11nF, 3 - 34nF, 4 - 101nF, 5 - 147.3nF. See PAR. 3.11 for details.

B.108 SYSTem:PFModule:DAMPing? QUERY

SYST:PFM:DAMP?

Syntax: Short Form: SYST:PFM:DAMP? Long Form: SYSTem:PFModule:DAMPing?
Returns <x> = integer from 0 (minimum damping) to 5 (maximum damping)

Description: **Indicating damping settings for Power FET Modules.** See PAR. 3.11 for details.

B.109 SYSTem:PFModule:LIST? QUERY

SYST:PFM:LIST?

Syntax: Short Form: SYST:PFM:LIST? Long Form: SYSTem:PFModule:LIST?

Description: **List Power FET Modules within chassis (see below for example).**

```

SYST:PFM:LIST?
KEPCO, EL 5K-200-600 01-18-2010,A999104,MCB #200 1.176 $ 2010/01/18 22:27:06 $
Compiled Jan 18 2010 17:28:28
6 Power FET Modules Installed
Pos Serial
0 230
1 231
2 228
3 229
4 227
5 226

```

B.110 SYSTem:PFModule:STATus? QUERY

SYST:PFM:STAT?

Syntax: Short Form: SYST:PFM:STAT?

Long Form: SYSTem:PFModule:STATus?

Description: **Show FET channel temperature and fuse status (see below for example).**

```

SYST:PFM:STAT?
KEPCO, EL 5K-200-600 01-18-2010,A999104,MCB #200 1.176 $ 2010/01/18 22:27:06 $
Compiled Jan 18 2010 17:28:28
0.000 100 26C 0.000 100 24C 0.020 100 24C 0.000 100 21C
0.000 100 26C 0.000 100 25C 0.000 100 23C 0.000 100 21C
0.000 100 26C 0.000 100 25C 0.000 100 24C 0.000 100 22C
0.000 100 27C 0.020 100 25C 0.000 100 24C 0.020 100 23C
0.000 100 27C 0.000 100 25C 0.000 100 24C 0.000 100 21C
0.000 100 27C 0.000 100 25C 0.000 100 24C 0.000 100 21C

      26 C      24 C      24 C      21 C
      26 C      25 C      23 C      21 C
      26 C      25 C      24 C      22 C
      27 C      25 C      24 C      23 C
      27 C      25 C      24 C      21 C
      27 C      25 C      24 C      21 C

```

Below is a response to SYST:PFM:STAT? for a 2 PFM Load when the load is drawing 52 Amperes. Note that these are not highly accurate current measurements but rather are intended to show system status such as the distribution of current (and therefore power) between the FETs. In the example below, the top row is the second set of FETs and the bottom row is the first row of FETs. The Currents are for FETs in each of the four positions as viewed from the front.

```

KEPCO, EL XK-VVV-AAA,12345,MCB #205 1.195 $ 2010/02/22 12:48:37 $ Compiled
Feb
22 2010 07:50:04
6.590 100 21C 6.590 100 20C 6.590 100 19C 6.615 100 19C
6.565 100 23C 6.565 100 21C 6.590 100 20C 6.590 100 19C

      21 C      20 C      19 C      19 C
      23 C      21 C      20 C      19 C

```

Below is an example showing illustrating a Fuse blows on the PFM.

```

KEPCO, EL 5K-200-600 01-18-2010,A999101,MCB #205 1.176 $ 2010/01/18
22:27:06 $
Compiled Jan 18 2010 17:28:28
1.585 100 119C 1.535 100 117C 1.610 100 113C 1.585 100 97C
1.535 100 104C 1.585 100 114C 1.535 100 110C 1.610 100 104C
1.560 100 98C 1.585 100 106C 1.585 100 100C 1.585 100 101C
1.610 100 94C 1.560 100 93C 1.585 100 100C 1.610 255 91C
1.535 100 87C 1.535 100 82C 1.560 100 86C 1.585 100 82C
1.560 100 74C 1.535 100 76C 1.560 100 76C 1.535 100 71C

      119 C      117 C      113 C      97 C
      104 C      114 C      110 C      104 C
      98 C      106 C      100 C      101 C
      94 C      93 C      100 C      FUSE 91 C
      87 C      82 C      86 C      82 C
      74 C      76 C      76 C      71 C

```

B.111 SYSTem:RANGe:CURRent COMMAND**SYST:RANG:CURR**

Syntax: Short Form: SYST:RANG:CURR <txt> Long Form: SYSTem:RANGe:CURRent <txt>
Where <txt> = HIGH (HIGH = factory default) or LOW

Description: **Establishes range for remote interface current readback and front panel AMPS display.** LOW changes the current range to 1/10 of full scale. If the unit is 200A at full scale, entering SYST:RANG:LO, changes the ammeter range to 0 - 20A full scale.

B.112 SYSTem:RANGe:CURRent? QUERY**SYST:RANG:CURR?**

Syntax: Short Form: SYST:RANG:CURR? Long Form: SYSTem:RANGe:CURRent?
Returns: <txt> = HIGH or LOW

Description: **Indicates the range for remote interface current readback and front panel AMPS display.**

B.113 SYSTem:RANGe:POWer COMMAND**SYST:RANG:POW**

Syntax: Short Form: SYST:RANG:POW <txt> Long Form: SYSTem:RANGe:POWer <txt>
Where <txt> = HIGH or LOW (LOW = factory default)

Description: **Selects one of two power ranges, low (default) or high for remote interface power readback and KW meter on front panel.** The power ranges are a function of the full scale ammeter range. For example, for a 5 kW load (600A, 50V), the instrument inherently has a 600A full scale range. So at, for example, the 100V voltmeter range, the dynamic range of power measurement is: (0 - 100V) x 600A = 0 - 60,000 Watts, much higher than needed. Therefore, when the voltage is high and the current is low, SYST:RANG:POW LOW restricts the ammeter to 1/10th of full scale and thus, in this example, limits the maximum power reading to 6,000 Watts.

B.114 SYSTem:RANGe:POWer? QUERY**SYST:RANG:POW?**

Syntax: Short Form: SYST:RANG:POW? Long Form: SYSTem:RANGe:POWer?
Returns: <txt> = HIGH or LOW (LOW = factory default)

Description: **Indicates one of two power ranges, low (1/10 full scale) or high for remote interface power readback and KW meter on front panel.**

B.115 SYSTem:RANGe:VOLTage COMMAND**SYST:RANG:VOLT**

Syntax: Short Form: SYST:RANG:VOLT <Vrange> Long Form: SYSTem:RANGe:VOLTage <Vrange>
where <Vrange> = 100V, 200V, 400V or 800V

Description: **Establishes full scale voltage range of remote interface voltage readback and VOLTS display on front panel.** This setting is saved in non-volatile memory and is retained for subsequent power-up.

B.116 SYSTem:RANGe:VOLTage? QUERY**SYST:RANG:VOLT?**

Syntax: Short Form: SYST:RANG:VOLT? Long Form: SYSTem:RANGe:VOLTage?
Returns: <Vrange> = 100V, 200V, 400V or 800V

Description: **Indicates full scale voltage range for remote interface voltage readback and VOLTS display on front panel.**

B.117 SYSTem:REPLy COMMAND**SYST:REP**

Syntax: Short Form: SYST:REP <bool> Long Form: SYSTem:REPLy <bool>
Where <bool> = 0 or OFF = replies off or 1 (or ON) = replies ON

Description: **Turns reporting of error messages on (1) or off (0).** Turns on/off reporting of error messages generated when SCPI parser analyses SCPI commands. When set to 0, If command is understood, the EL load provides the normal or expected response. When set to 1, if command is understood, the EL load provides the normal or expected response, followed by OK. If the command is not understood, the EL Load responds with "???" and the appropriate error message is added to the error queue. (see PAR. B.102 for details).

B.118 SYSTem:REPlY? QUERY

SYST:REP?

Syntax: Short Form: SYST:REP? Long Form: SYSTem:REPlY?
Returns: <bool> = 0 or 1

Description: **Indicates whether error message reporting is on (1) or off (0).**

B.119 SYSTem:SERNumber? QUERY

SYST:SERN?

Syntax: Short Form: SYST:SERN? Long Form: SYSTem:SERNumber?
Returns: <NR3> where <NR3> = unit serial number

Description: **Returns unit serial number.**

B.120 SYSTem:SETTings? QUERY

SYST:SET?

Syntax: Short Form: SYST:SETT? Long Form: SYSTem:SETTings?
Returns: <txt> where <txt> = system settings (see below).

Description: **Display system settings (see sample response shown below).**

```
SYST:SETT?
KEPCO, EL 5K-200-600 01-18-2010,A999104,MCB #200 1.176 $ 2010/01/18 22:27:06 $
Compiled Jan 18 2010 17:28:28
Chassis Serial Number: A999104
Voltage range: 400V
Current range: 595.5
System damping: 5
PFM damping: 3
Overvoltage limit: 799.0
Undrvoltage limit: 0.000
Overcurrent limit: 600.0
Overpower limit: 6.000
Max volt limit: 220.0
Max curr limit: 630.0
Max powr limit: 5.250
System mode (startup): CURRent
System mode (now): CURRent
Setpoints
Voltage : 220.0
Current : 0.000
Power : 0.000
Resistance : 1000.
Conductance : 0.255
Fan temperature limits (C)
Lower: 40
Upper: 70
IP Address: 0.0.0.0
Sub Net : 0.0.0.0
Gateway : 0.0.0.0
DNS Addr : 0.0.0.0
```

B.121 SYSTem:VERSion? QUERY

SYST:VERS?

Syntax: Short Form: SYST:VERS? Long Form: SYSTem:VERSion?
Returns:

Description: **Identify unit and firmware version.**

```
syst:vers?
KEPCO, EL 5K-200-600 01-18-2010,A999104,MCB #200 1.176 $ 2010/01/18 22:27:06 $
Compiled Jan 18 2010 17:28:28
```

