RBL488 Series Electronic Loads

Operation & Programming Manual

TDI-Dynaload® Division

Document Number 402825 — Revision B V3

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The contents of this document, including all specifications, are subject to change without notice.

Mandatory Customer Information
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NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy; and, if not installed and used in accordance with the instruction manual, may cause interference to radio communications. Operation of this equipment in a residential area may cause harmful interference in which case the user will be required to correct the interference at their expense.

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TDI-Dynaload Division
36A Newburgh Road
Hackettstown, NJ 07840
Telephone: (908) 850-5088
Facsimile: (908) 850-0679

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Customer Service and Repairs

Dynaload Customer Service Department
Telephone: (908) 850-5088
Facsimile: (908) 850-3645

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Chapter 1. — Overview

Introduction

The RBL488 series single channel loads are ideal for testing power supplies, fuel cells, large batteries, and other related DC power equipment. The high range current capability and constant power feature facilitate battery testing and analysis. The ultra-fast slew rate provides unmatched power supply transient testing capabilities. The ultra-low voltage, high current capability makes the RBL and RBL488 series an ideal solution for most fuel cell requirements.

Standard Features for the RBL488 Series include the following:

- Ratings from 0-1000 Volts (RBL 1000V only), 0-1000 Amps, up to 4000 watts in a single unit
- Units available include:
  - 400 Watt (8 inches W x 5.25 inches H x 13 inches D)
  - 800 Watt (8 inches W x 5.25 inches H x 22 inches D)
  - 2000 Watt (19 inches W x 5.25 inches H x 22 inches D)
  - 4000 Watt (19 inches W x 8.75 inches H x 22 inches D).
- Variable speed fans minimize fan noise (standard on 2000W and 4000W only)
- Operation below 0.5 volts at 1000 Amps
- Five modes of operation: Constant Current, Constant Resistance, Constant Power, Constant Voltage, Pulse Mode
- Full Scale Range Switching: for increased resolution and accuracy
- Synchronized paralleling to create larger systems that are controlled simultaneously
- Internal pulse generator with variable slew adjust for transient testing
- Lab View drivers are available for IEEE-488 or RS232 computer control.

The Dynaload modes of operation are described in the sections that follow and are thoroughly detailed in *Chapter 2. — Operating Instructions*.

Modes of Operation

The Dynaload is a precision instrument that simulates DC loads to test power supplies, generators, servo systems, batteries and similar DC sources.

The RBL488 series provides four basic modes of operation: Constant Current, Constant Resistance, Constant Voltage, Constant Power and Pulse Mode. Complete control is available through the full feature front panel, IEEE-488 bus or optional RS232 interface. A 0-10V analog programming input is also available in all of the four modes of operation. The connections for IEEE-488 and analog programming are located at the rear of the unit. Refer to Figure 1 through Figure 4 and the four modes of operation explanations that follow.

❑ Constant Current Mode

Referring to Figure 1, the Dynaload will sink the set current regardless of the input voltage.

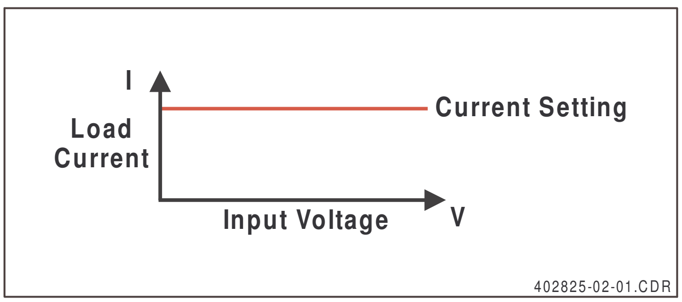


Figure 1. Constant Current Mode

❑ Constant Resistance Mode

Referring to Figure 2, the Dynaload will sink current linearly proportional to the input voltage. This is set in Amps/Volt, (1/R), or ohms.

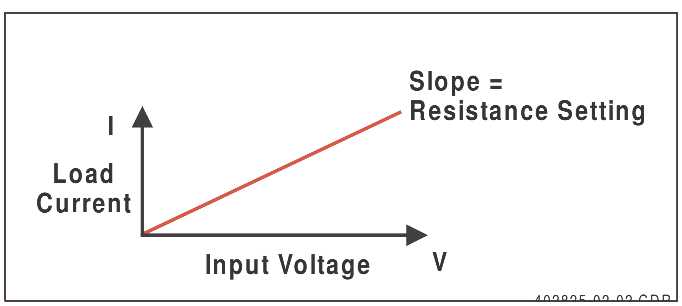


Figure 2. Constant Resistance Mode

❑ Constant Voltage Mode

Referring to Figure 3, the Dynaload will sink the current required to maintain the voltage of the source connected to it.

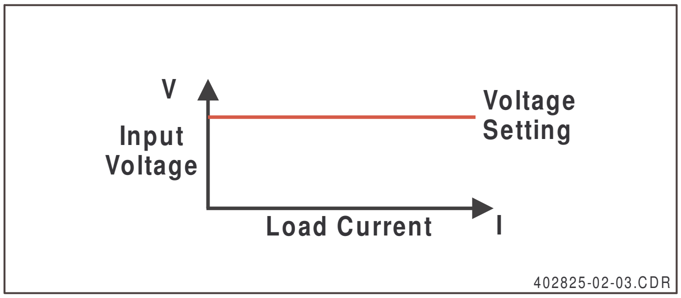


Figure 3. Constant Voltage Mode

❑ Constant Power Mode

Referring to Figure 4, the Dynaload will sink the current required at its present input voltage to maintain the desired power level.

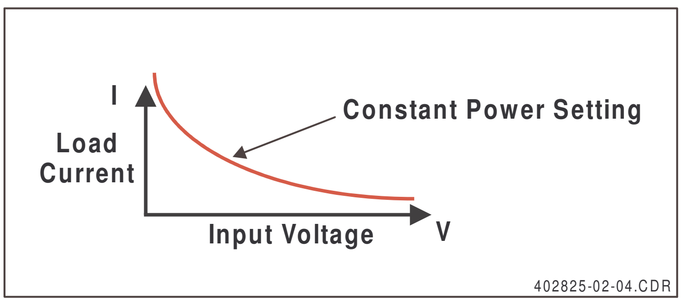


Figure 4. Constant Power Mode

❑ Pulse Mode

This mode can be used with any of the four preceding modes. Pulse mode is an enhancement that allows for operation between two predefined levels of current, resistance, voltage or power.

Front Panel Features and Controls

To better understand the features and controls of the front panel, refer to Figure 5 and Table A. The item numbers in the figure directly correspond to the item numbers in the table.

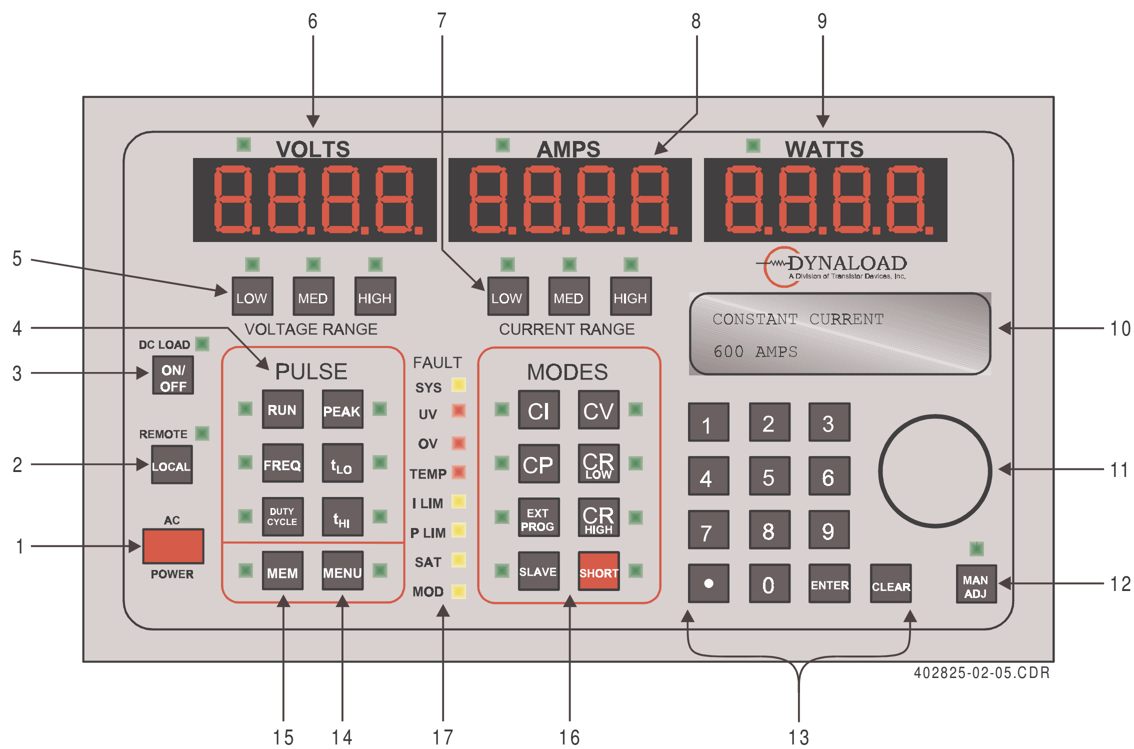


Figure 5. Front Panel Features and Controls

Table A. Front Panel Features and Controls

Item Number	Description
1	AC Power (Power On, Power Off)
2	IEEE-488 Local Select
3	DC Load (On, Off)
4	Pulse Mode Controls RUN: Pulse Mode On/Off PEAK: Sets peak amplitude of pulse FREQ: Sets frequency of pulse DUTY CYCLE: Sets duty cycle of pulse ^{t}LO: Sets duration of the low portion of pulse ^{t}HI: Sets duration of the high portion of pulse

Item Number	Description
5	Voltmeter/Voltage Full Scale Range Selection*
6	Voltmeter - 4 digit
7	Ammeter/Current Full Scale Range Selection*
8	Ammeter - 4 digit
9	Watt meter - 4 digit
10	Backlit Alpha-Numeric Display This display indicates data input from the front panel controls (range, mode, and setpoint as entered by the user). This will also display other data as selected through the menu selector.
11	Manual Adjust Knob
12	Manual Adjust Enable
13	Keypad (for numerical entry)
14	Menu Select
15	MEM Preset (up to 10 configurations)
16	Mode Select CI: Constant Current Mode Select CV: Constant Voltage Mode Select CP: Constant Power Mode Select CR LOW: Constant Resistance (Low Ohm) Mode Select CR HIGH: Constant Resistance (High Ohm) Mode Select EXT PROG: Remote Programming Mode Select SLAVE: Slave Mode Select SHORT: Short Circuit (momentary action)
17	Fault And Warning Status Indicators SYS: System Fault Indicator UV: Undervoltage Fault Indicator OV: Overvoltage Fault Indicator TEMP: Over Temperature Fault Indicator I LIM: Current Limit Warning Indicator P LIM: Power Limit Warning Indicator SAT: Saturation Warning Indicator MOD: Module Fault Warning Indicator

* The RBL488 Series offers the selectable full-scale ranges for current and voltage. When a full scale is selected it changes the full scale of the meter, the current sample, the front panel adjustments, IEEE controlled adjustments and the analog programming input. This provides an increase in accuracy and resolution. There are three standard full-scale current ranges and three standard full-scale voltage ranges.

Chapter 2. — Operating Instructions

Operator Safety Instructions and Symbols

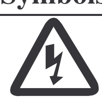
It is very important that these safety instructions and operation instructions are read and understood prior to the installation and use of this electronic load. Failure to follow these basic guidelines could result in serious injury or death.

This electronic load is inherently safe by design. It cannot produce any hazardous voltages or currents; however, when in use it may expose the operator to the hazards of the DC source to which the load is connected. This equipment is intended for use by trained personnel and there are no operator serviceable parts inside. All service and calibration must be performed by authorized personnel. Table B describes the safety symbols and their definitions. Safety symbols are placed to ensure the safety of Dynaload operators and should never be covered or removed from the equipment.

WARNING:
Ensure that all AC and DC power for both the load, the test source, and any peripheral equipment is OFF prior to making any connections to the load. Also ensure that the proper AC input range is selected before attaching the line cord; and that the load selected is properly rated for the voltage and current generated by the DC source; and that all connections are correct and secure, and that all safety covers are in place before applying power.

If the unit is to be mounted, please consider the weight and position of the equipment to prevent the rack from becoming top heavy. A top-heavy rack can create a tip over hazard. All air intake and exhaust ports should be kept clear of obstructions.

Table B. Equipment Safety Symbols

Symbols	Definitions	Publication Numbers
	**CAUTION, RISK OF ELECTRIC SHOCK**	ISO 3864, No. B.3.6
	**CAUTION, REFER TO INSTRUCTION MANUAL**	ISO 3864, No. B.3.1
	**EASILY TOUCHED HIGHER TEMPERATURE PARTS**	ISO 3864

Rear Panel Description and Electrical Connections

Electrical connections are made on the rear panel of the unit. Typical rear panel connections are detailed in Figure 6. The rear panel also has terminal block connections that are detailed later in this section as is an optional equipment wiring diagram using the terminal block connections.

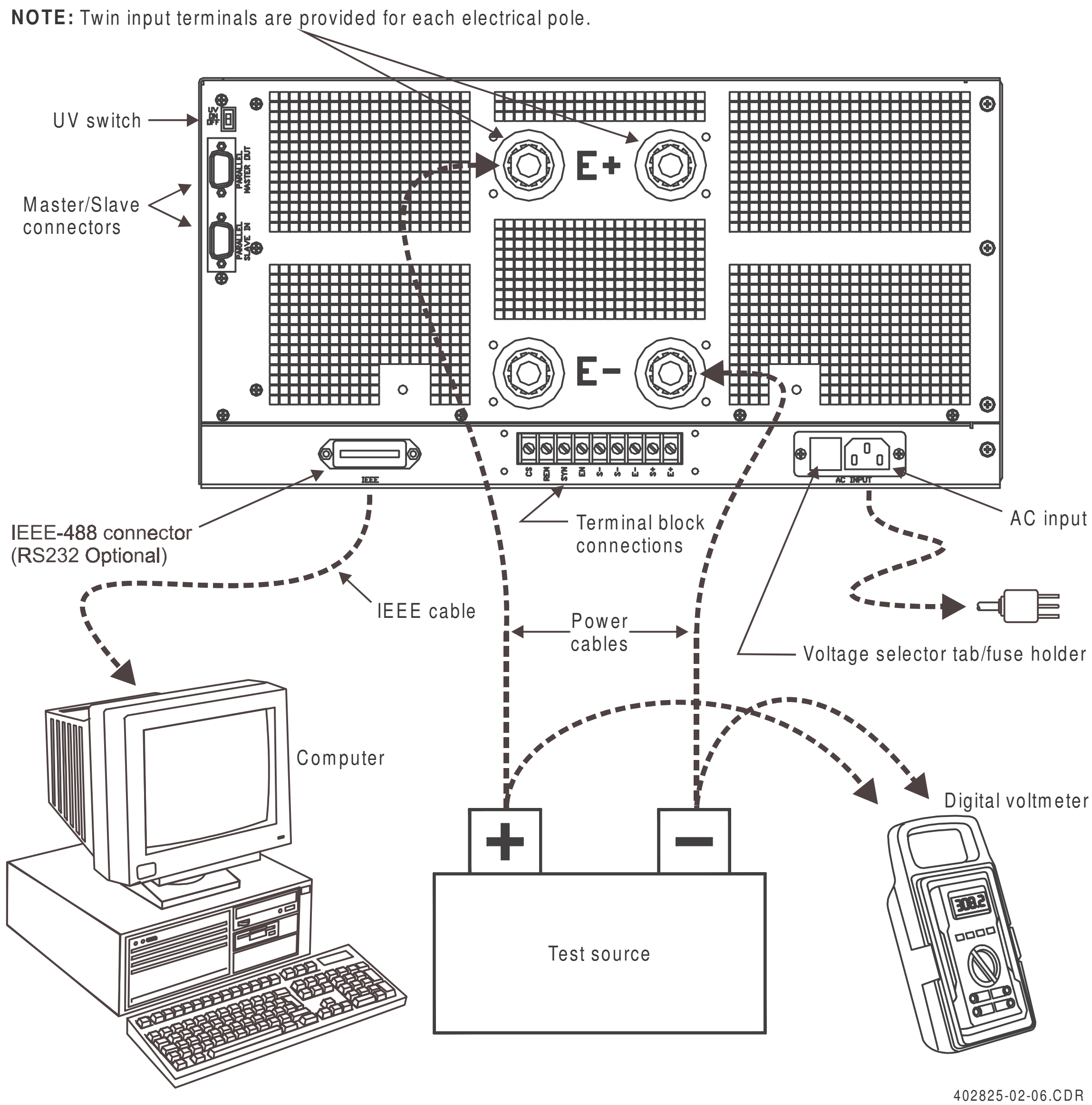


Figure 6. Typical Rear Panel Connections

❑ E– and E+ Power Input Terminals

Referring to Figure 6, E– and E+ are the power inputs for connecting the power source to be monitored or tested. The E– and E+ power inputs are the large studs on the rear of the unit.

E+ and *E*– (Power Input Studs) Wiring Tips

Use the shortest cables that are large enough in cross-section to handle the power source's current output. Twist and/or bundle the E+, E– cable(s) as a means of reducing self-inductance. Also, use lugs to secure the E+, E– cables to the studs. Connect only the power source to load cables to these studs; all other connections must be made via the terminal strip located below the studs.

CAUTION:
Only the power source-to-load connections are to be made to these studs.

❑ The "IEEE-488" Connector (RS232 Optional)

This is used for computer control and uses a standard IEEE-488 cable (refer to Figure 6).

❑ AC Input

This connection provides the Dynaload with its operating power and its safety ground. Power requirements are user selectable as follows:

100V, 1.8A / 120V, 1.5A
200V, 0.9A / 220V, 0.8A
47Hz – 63Hz

Input Voltage Selector

WARNING:
Ensure that the power cord is removed before making changes to the voltage selector tab.

The AC input module on the rear of the Dynaload will have one of two possible selectors. Only the labeling on the selector is different, the applicable ranges are identical. The selector will be labeled as follows: *[100,120,200,240]*...or...*[115,125,230,250]*. Use Table C to set the voltage selector position for your input voltage. The selected voltage should be positioned adjacent to the molded arrow on the top of the input module.

Table C. Voltage Selector Tab Setting Guide

AC Input Voltage	**Selector Marked 100, 120, 200, 240**	**Selector Marked 115, 125, 230, 250**
90V – 110V	(N/A)	(N/A)
108V – 132V	120	125
180V – 220V	200	230
216V – 264V	240	250

AC Input Wiring Tips

A standard U.S. three-prong cord is provided with your Dynaload. The voltage selector tab is mounted to the left of the three-prong AC connector (see Figure 6 and refer to the *Input Voltage Selector* section and Table C).

WARNING:

The power cord provides a chassis ground through a third conductor. Make sure that your power outlet is of the 3-conductor type with the correct pin connected to earth ground. Always Connect the AC cord first to your Dynaload and THEN to the utility outlet.

Fuse Replacement

The AC input fuse is located inside the voltage selector tab. The fuse replacement part numbers for the Dynaload are MDA-3 (3 Amp, 250 Volt, slow blow, 1-1/2 inch American version) or equivalent **OR** GDC-3.15A-250V (3.15 Amp, 250 Volt, slow blow, 20 mm European version) or equivalent.

❑ The Master/Slave Connectors

These two DB9 “D” connectors are used for synchronized parallel Dynaload operation. The two connectors are labeled “Parallel Master Out” and “Parallel Slave In” (see Figure 7).

Master/Slave Connector Wiring

The two 9-pin “D” connectors are used to link the master unit to slave units. This is a standard RS232 cable that is necessary in master/slave systems. If you are purchasing this cable, be sure the PIN configuration is always 1 to 1. Not all RS232 cables are provided this way and a crossover of PINS will cause erroneous operation. Install this cable starting with the master unit (“Master Out”) connected to “Slave In” on the slave unit. Additional slave units would be connected from “Master Out” of the first slave to “Slave In” on the next unit. This configuration can be extended to multiple units. Refer to the *Master/Slave Parallel Operation* section later in this chapter.

❑ UV (Undervoltage Lockout) Switch

Referring to Figure 7, the UV switch has two positions, ON and OFF. This switch is described in detail in the Operating Instructions chapter of this manual. Refer to the *Undervoltage Lockout* section later in this chapter.

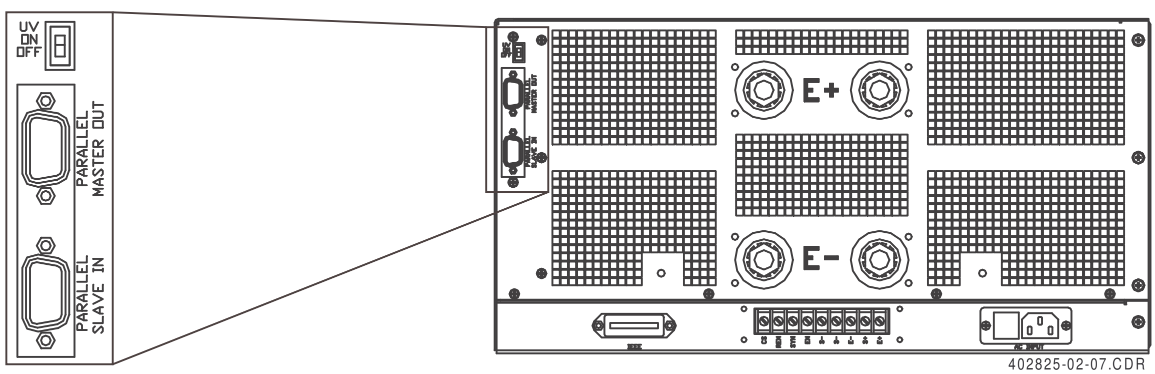


Figure 7. “D” Connectors and UV Switch Detail

❑ The Terminal Block and Terminal Block Connections

Refer to Figure 8 through Figure 11, and the sections that follow to better understand the wiring connections that can be made to the terminal block.

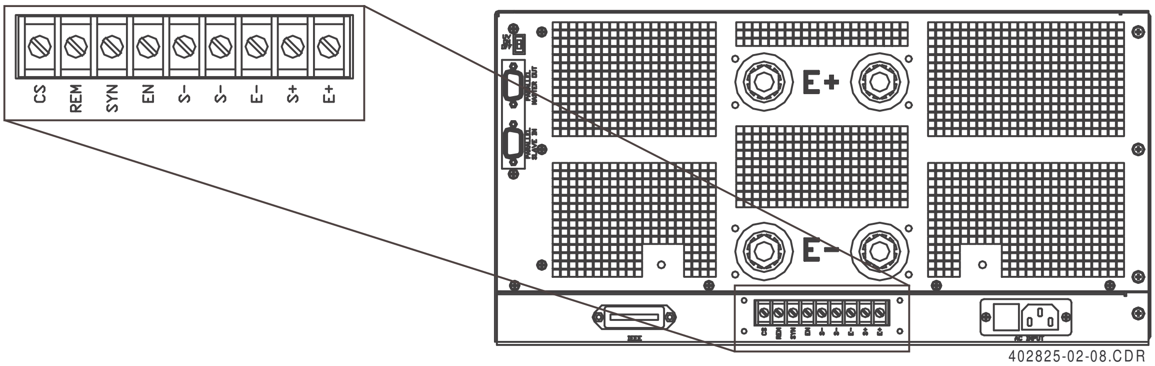


Figure 8. Terminal Block Detail

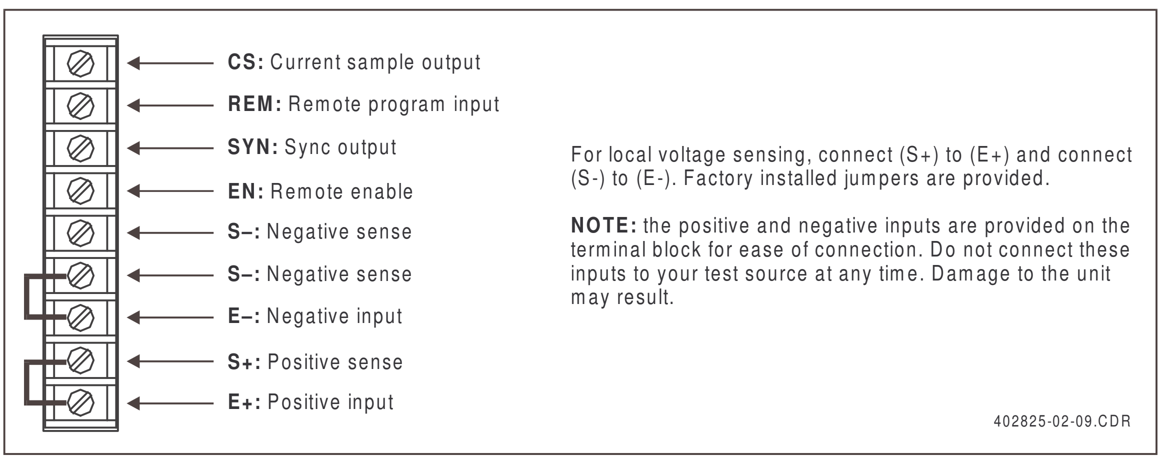


Figure 9. Terminal Block Connections

CS (Current Sample)

The CS (Current Sample Output) terminal is provided for the current sample output signal. The current sample output should be referenced to the (S–) terminal.

A 0-10V signal representing 0-full scale current in each of the selected current ranges is generated. This signal is a true representation of the current level and waveform being generated by the load. Connect an oscilloscope or other external instruments to this terminal as monitoring devices. The instruments should be referenced to terminal S–. Shielded wire is recommended.

REM (Remote or External Programming)

The REM (Remote Program Input [External Modulation]) terminal is the connecting point for remote programming from an external programming source. This input is referenced to (S–).

This is the remote control input signal. 0 to 10 volts in yields 0 to full scale loading in whatever mode and range is selected. When a signal or waveform is presented at this input it will translated directly into your current level and waveform. The signal source should be referenced to S–.

SYN (Synchronized Output Signal)

The SYN (Synchronized Output) terminal supplies a 15V sync signal for triggering external instrumentation. For instrumentation triggering purposes a 15V square wave synchronous to the internal pulse generator is supplied. This signal is incorporated on the rear panel terminal block on RBL488 IEEE models. On non-IEEE models this signal is provided on the front panel. As with all signals in or out, it is referenced to S (–). The signal is generated with a 10Kohm pull-up resistor to 15V, and an open collector pull-down to S–. The amplitude of the square wave may be externally limited without damage to the load. When not in pulse mode, this output remains high until a current change is executed. At this time, the output is pulsed low for scope triggering.

EN (Remote Enable)

The EN (Remote Enable) terminal is the remote DC enable. Connection between (EN) and (S–) will turn the DC on.

This input is used for remote operation of the DC on/off function. This input is TTL negative true in order for the load to operate. This input operates in parallel with the front panel control. If the front panel is in the OFF position the enable can toggle the DC on and off. If the front panel is in the ON position, the enable will **NOT** function to turn the DC off.

S– and S+ (Voltage Sense)

There are two S– terminals and one S+ terminal. The S– and S+ (Sense Negative and Sense Positive) terminals are used to sense the load voltage. The connection of a remote voltage sense device to the S– and S+ terminals is illustrated in Figure 10.

CAUTION:
Do not attempt to connect these inputs as the load inputs, internal damage may occur.

S– and S+ (Voltage Sense) Wiring Tips

The S– and S+ terminals may be connected at the back of the Dynaload, or remotely at the source. In addition, all input and output signals are referenced to S–. In any single or multiple load system, S– should be connected to E– (or the negative of the source) ***at one and ONLY one point***.

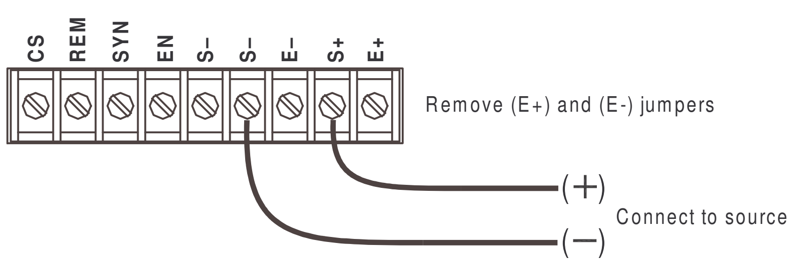
CAUTION:
Damaging current loops could result from multiple connections to E–.

The Dynaload is supplied with two (2) metal straps between the S–, E– terminals and between the S+, E+ terminals on the terminal strip. These are to facilitate voltage sense wiring when sensing locally.

The S– and S+ external sense leads can be connected any where between the power source and the Dynaload. However, it is recommended that the voltage sense wires are connected to the power source terminals. This will eliminate potential errors due to voltage drop in the cable. It is also recommended to use shielded wire for remote voltage sense leads to prevent external noise from being introduced into the system.

In a master/slave (parallel) configuration, (S–) must only be connected to the E– source at the master Dynaload. The D connector cable(s) between master and slave(s) provides the S– loop to the slave(s).

IMPORTANT:
When using units in a Master/Slave configuration the S– and E– jumper MUST be removed from all slave units.



NOTE: For improved voltage readback, use the remote voltage sensing capabilities.
1. Remove the jumpers from (E+) to (S+) and (E-) to (S-).
2. Connect the (S+) terminal to the positive output on the test source.
3. Connect the (S-) terminal to the negative output on the test source.

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Figure 10. Remote Voltage Sense

E– and E+ (Input)

E– and E+ are connected internally to the power input studs. They are to be used only as a convenient connection point for the sense terminals when sensing the voltage locally.

Terminal Block Connections Optional Equipment Wiring

The terminal block may also be used to include various optional equipment to the Dynaload. In the example shown in Figure 11 an oscilloscope, function generator and remote DC ON/OFF switch are shown installed to the Dynaload.

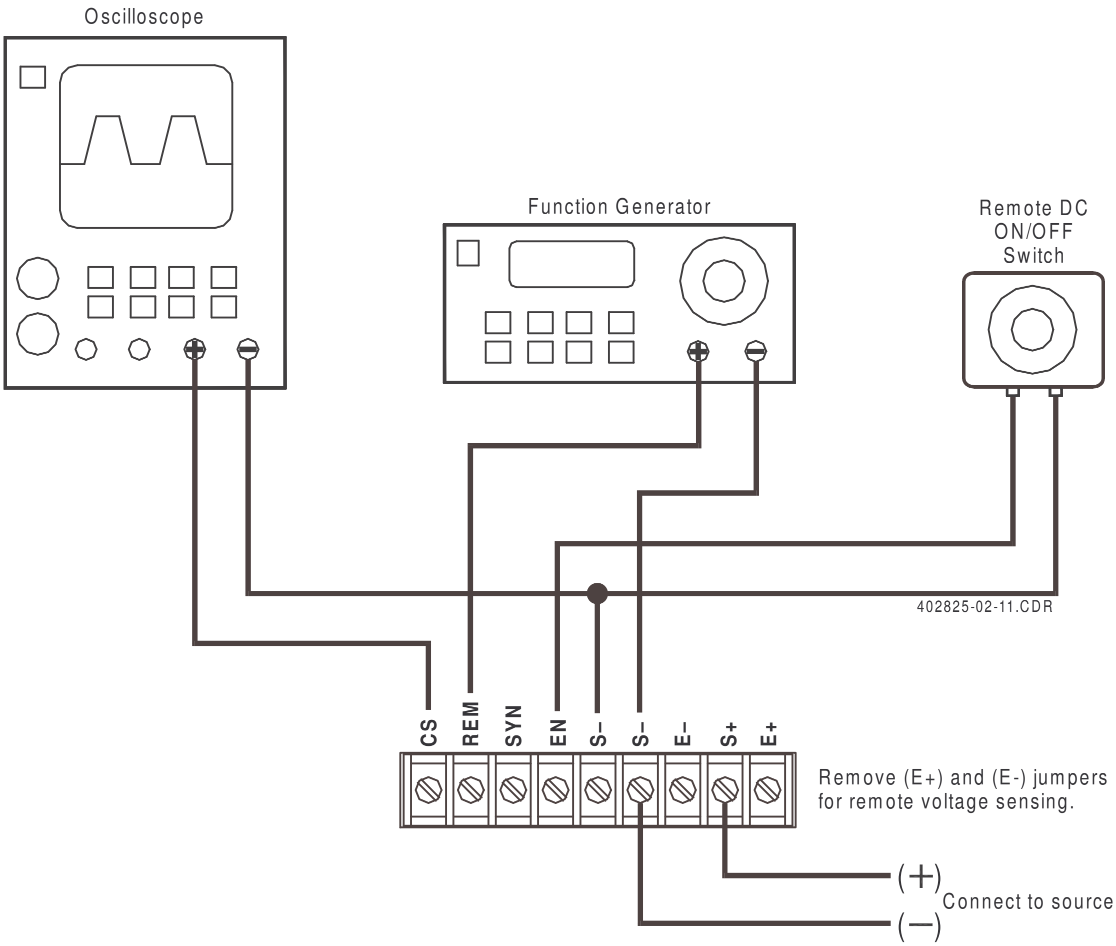

Figure 11. Terminal Block Connections Optional Equipment Wiring

Effects Of Cable Length

Current Oscillation

The Dynaload regulation loop is designed to operate at a maximum response time of 10μS. This is not affected by manipulating the slew rate. When operating in any of the constant DC modes, the external cable length can effect the performance of the load. If the total inductance of the power cables is excessive, a parasitic oscillation could occur. It is always recommended to monitor the current sample output to verify that the load is operating without current oscillation. If this situation occurs refer to the section on effects of cable inductance on pulse loading for recommended solutions in *Chapter 2. — Operating Instructions*.

Line Loss

If the Dynaload is not configured for remote voltage sensing, the voltage display and voltage readback will reflect what may appear to be an erroneous number. The voltage display will indicate the voltage present at the input terminals. This number will be affected by the current level. Wire is a resistor, and will lose voltage as the current is increased. A general rule of thumb is to size your wire at 500 circular mils per amp of load current. This will allow a maximum of 10 degrees centigrade rise in temperature of the wire. The resistance of wire is approximately 107 ohms per 1000 feet for 100 circular mils of cross-sectional area. You can use Ohm's law (E = I x R) to calculate the line losses for your particular application. For detailed information about the maximum current capacity of conductors refer to Table D.

Table D. Wire Gauge/Ampere Rating Reference Table

Size AWG	MIL-W-5088				NEC[1]	UL[2]		AIA[3]	500 c mils/A
	Copper		Aluminum						
	Single wire	Wire bundled	Single wire	Wire bundled		60°C	80°C		
30	—	—	—	—	—	0.2	0.4	—	0.20
28	—	—	—	—	—	0.4	0.6	—	0.32
26	—	—	—	—	—	0.6	1.0	—	0.51
24	—	—	—	—	—	1.0	1.6	—	0.81
22	9	5	—	—	—	1.6	2.5	—	1.28
20	11	7.5	—	—	—	2.5	4.0	3	2.04
18	16	10	—	—	6	4.0	6.0	5	3.24
16	22	13	—	—	10	6.0	10.0	7	5.16
14	32	17	—	—	20	10.0	16.0	15	8.22
12	41	23	—	—	30	16.0	26.0	20	13.05
10	55	33	—	—	35	—	—	25	20.8
8	73	46	58	36	50	—	—	35	33.0
6	101	60	86	51	70	—	—	50	52.6
4	135	80	108	64	90	—	—	70	83.4
2	181	100	149	82	125	—	—	90	132.8
1	211	125	177	105	150	—	—	100	167.5
0	245	150	204	125	200	—	—	125	212.0
00	283	175	237	146	225	—	—	150	266.0
000	328	200	—	—	275	—	—	175	336.0
0000	380	225	—	—	325	—	—	225	424.0

[1] National Electrical Code
[2] Underwriters Laboratory
[3] American Insurance Association

Recommended Operating Procedure

The following procedure is the recommended procedure for Dynaload operation:

(1) AC switch should be turned off.

(2) Connect DC source to E+ and E–. Always watch for correct polarity.

(3) If external analog programming is to be used, connect signal source. If IEEE-488 or RS232 (optional) is to be used, connect the cable.

(4) Connect AC power. Be sure you have selected the correct AC input position on the load.

(5) Be sure ALL electrical connections, including peripheral equipment, are secure and in the correct polarity before applying AC or DC voltages to the load.

(6) Turn on AC power; meters should come on and fan should run.

(7) Step through the Menu settings to be sure the set points are appropriate to the application. Check to see that the voltage and current ranges selected are correct.

(8) Press the DC-ON button, or send the LOAD ON command via the IEEE controller. This will close the relays and connect the source to the power dissipating circuitry. The DC on LED will illuminate.

(9) Turn on the power source to be tested.

(10) Press the mode select button for the mode you wish to operate in. The LCD display will prompt you for a numeric value. Enter an appropriate number for the level desired then press ENTER. The load will now be operating at the set level.

NOTE:
For computer controlled operation, Begin sending the appropriate commands. (See IEEE-488 syntax for command listing.)

Operating Mode Guidelines

❑ CI — Constant Current Mode (Basic Mode)

This mode of operation allows the user to set a fixed current. This set level will not change regardless of changes in the source voltage. Some power sources such as variable power supplies are rated at a fixed maximum load current and adjustable over a predetermined voltage range. For example, 5-30V @ 20A. If the resistive load characteristic were used for this type of a test, it would be necessary to reset the load each time the power supply voltage was changed in order to maintain desired load current. However, if the load is in the constant current mode, the current is constant regardless of input voltage fluctuations.

It should be noted that many power supplies are designed for short circuit protection by internal current limiting and foldback; therefore, the supply may not start up into a constant current load. Accordingly, it is suggested that the Constant Resistance mode be used as a load when simulating short circuit protection and recovery of most power supplies, unless otherwise specified by the manufacturer.

> **NOTE:**
> The constant current mode should never be used to test a constant current source. The regulation of the two units will fight for control of the current and an unstable oscillation will result.

❑ CR — Constant Resistance Mode (Basic Mode)

The constant resistance mode regulates the load current in direct proportion to the load voltage. There are eighteen different resistance ranges available. These are derived from the nine different voltage and current combinations available, and the two different resistance modes (HIGH and LOW). The actual resistance values, expressed in Ohms, are outlined in the specification section of this manual. In general, select the appropriate voltage and current range for the source, and then determine if the high resistance range or the low resistance range is required. Other ranges may be selected to tailor the response to a particular application.

> **EXAMPLE:**
> Given a 48V source capable of 60A, select the 200V, and 200A ranges. If the high resistance mode is selected, the maximum current capability is 0.5 Amps/Volt X 48 Volts = 24 Amps MAX. — Too Low!
>
> Select the low resistance mode: 5 Amps/Volt X 48 Volts = 240 Amps MAX. — sufficient current capability.
>
> The resolution of the load may be improved by selecting the 400V range. This yields:
> 2.5 Amps/Volt X 48 Volts = 120 Amps MAX. This provides double the resolution, but it reduces voltage sensitivity.
>
> **NOTE:**
> The resistance may be entered in Ohms or Amps/Volt (1/R). This option is selected through the front panel menus.

❑ CV — Constant Voltage Mode (Basic Mode)

The constant voltage mode can best be described as a shunt regulator or a zener diode. The load will not conduct any current until the source voltage tries to exceed the voltage set point. Once the source voltage is high enough the load will shunt current in order to regulate the voltage. The regulating voltage is adjustable from full scale of the range selected to approximately zero. The constant voltage mode is used to simulate a battery to a battery charger or for special applications, such as a shunt regulator.

> **NOTE:**
> Never use the constant voltage mode for testing a constant voltage source. The regulators of the two devices will buck each other trying to gain control of the voltage, which in turn will lead to an unstable condition.

❑ CP — Constant Power Mode (Basic Mode)

In constant power mode, the Dynaload will dissipate a set wattage anywhere up to the maximum power rating of the unit. The Dynaload will automatically adjust the current level inversely in response to a change in voltage. The constant power mode in NOT affected by changes of the voltage or current range.

> **CAUTION:**
> ***If the source voltage decays to zero volts the load will attempt to draw infinite current.***

❑ Full Scale Range Switching

The RBL488 series provides selection of one of three full scale input voltage ranges and one of three full scale input current ranges. The full scale voltage and current ranges may be selected in any combination resulting in nine operational ranges per unit. These are selectable over the bus as ranges (1 thru 9 refers to IEEE-488 syntax section).

The selectable ranges provide increased resolution. For example: Setting 10 amps may be difficult using the 1000 amp full scale. By selecting a lower full scale, 100 amps, the resolution of the meters, IEEE-488 control, programming input and the current sample output are greatly increased.

❑ Master/Slave Parallel Operation

The synchronized paralleling function allows the user to connect two or more loads in parallel. One unit is controlled through normal operation, the master. The additional units, the slaves, are connected via a nine-pin serial cable and respond to the control signals sent by the master. In all operating modes, the slave units act as a “mimic” to the master.

> **EXAMPLE:**
> With two units connected in a master/slave configuration, operating in constant current, if the master is programmed to 100 Amps, the slave will also go to 100 Amps for a total of 200 Amps load current.

Operating two or more RBL Dynaload units in parallel requires a number of control signals to be shared among the units. These signals are present on two 9-pin "D" connectors on the rear of the RBL. Other than the analog programming signal, all signals are active low- when active, they are pulled to Sense (–), when inactive, they float to +15 Volts. The analog programming signals, MASTER OUT and REMOTE IN, are 0 to 10 Volts for 0 to Selected Full Scale. MASTER OUT is available on the top connector, and REMOTE IN is available on the bottom connector. All other signals are present on both connectors. The pin assignments are detailed in Table E.

Table E. Master/Slave Parallel Operation Pin Assignments

Pin Number	Function
1	Current Control Signal (0-10 Volts)
2	Low Current Range Select
3	Medium Current Range Select
4	DC ON/OFF (slave) Select
5	Short Circuit
6	Current Average Out
7	Fault, Critical Alarm
8	Fault, Warning Alarm
9	Sense (–) (used for signal return)

IMPORTANT:
When using units in a Master/Slave configuration the S– and E– jumper MUST be removed from all slave units.

The REMOTE IN signal is also present on the terminal block (the "REM" terminal block connection).

Other than DC ON/OFF, all the other signals are independent of the slave mode, and may be used in any mode. Only DC ON/OFF is linked through the slave mode.

NOTE:
Slave mode selects the remote constant current mode of operation. The master unit provides the appropriate control input with respect to mode and amplitude.

IMPORTANT:
Master/slave operation is intended as an extension of the current and power capabilities when testing a single output power source. The slave units cannot be connected to a second source or output. This will cause damage to any or all of the loads in the system.

In systems with parallel loads, the system fault indicator will illuminate if any load in the system has a fault. The DC-ON indicator illuminates when the load is active. If a load is in the slave mode, the indicator will illuminate yellow when the slave is enabled and the master is off. When the master is turned on, the slave DC-ON will illuminate green.

❑ Short Circuit Feature

In order to test current limited power sources that require short circuit testing, the RBL488 provides a Short Circuit feature. When this feature is activated it applies a simulated short circuit across the device being tested.

The load simulates a short circuit by driving all of its power semiconductors hard into a saturated on state. Caution must be exercised to only use this feature when testing current limited sources as the Power Limit and Current Limit are disabled while it is activated. A Saturation fault will indicate while the short is activated.

The Under Voltage and Programmable Under Voltage both remain active while the Short Circuit feature is used. These will disconnect the load from the device under test if they are not turned off or set to zero first..

This feature is activated momentary while the “Short” button on the front panel is depressed. It can also be remotely programmed using the SHORT ON/OFF command. Since a short circuit could cause damage to the load or the device under test in many applications, front panel use of this feature is normally locked out. This feature must first be enabled through the menu to use it from the front panel.

CAUTION:
This function is intended for use only when testing current limited power sources. Use of the Short Circuit feature with power sources which do not limit their current to values within the load’s ratings could result in damage to the load, damage to the device under test, FIRE or EXPLOSION.

❑ MEM — Memory Recall Locations

The configuration of the load may be stored in 10 settable memory locations labeled 0 thru 9. To recall a memory location, press the MEM key on the front panel. Enter the numeric location number, then press ENTER. When using the IEEE-488 bus the setup can be stored with the MS command and recalled with the MR command.

> **NOTE:**
> Memory location "0" is reserved for initialization of the Dynaload.

❑ Manual Adjust

The round knob above the MAN ADJ key is used to manually adjust all settable features within the Dynaload. This knob can be activated by pressing the MAN ADJ key. The resolution of the knob is set through the menu.

❑ Remote Programming

The RBL series is analog programmable in all four modes of operation. The loading in a particular voltage or current range is directly proportional to the 0-10 volt programming input. For example: If the constant current mode is selected and the 200A range is selected, a programming voltage of 5 volts is required to program the load to 100A. Waveforms can be programmed with the remote programming input as long as they do not exceed the capability of the load. The slew rate setting is set at the factory for 100 microseconds for a 0 to selected full scale transition, but is adjustable from the front panel by the menus, or through the IEEE-488 bus.

❑ Local Control

The local button on the front panel will allow the user to resume front panel control of the load when operating through the IEEE-488 bus. Pressing this button will enable all the front panel controls (until any instruction is given by the controlling computer). By pressing the LOCAL button a second time, the unit will return to IEEE control. This key will not function if password lockout is enabled. (See section on password protection, *Password Change*, later in this chapter.

> **NOTE:**
> A controlling computer program must be stopped before local control will function. Computer control is always selected over local control by the Dynaload. Any command or query issued by the computer will clear the local control functions.

❑ Fault Indicators

The Dynaload fault indications include both major and minor faults.

Major faults are an alarm and are displayed in red. If they occur, the Dynaload will shut down, however, the fan will continue to run.

Minor faults are a warning and are displayed in yellow. If they occur, the Dynaload may continue to operate, however, it may be out of regulation.

Refer to Table F for additional information about fault indicators.

Table F. Major and Minor Fault Indicators

Fault Category	Fault Indicator	Description
Major Faults	**UV** — Undervoltage	DC ON will not function until voltage is greater than 0.4 Volts (override switch provided on rear panel). See the *Undervoltage Lockout* section below.
	OV — Overvoltage	Unit will disconnect from source.
	OT - Overtemperature	Unit will shut down.
Minor Faults	**OC** — Overcurrent	Unit has reached the set current limit or the current limit of the selected range.
	OP — Overpower	Unit has reached the set power limit.
	SAT — Saturation	Saturation condition whereby one or more of the electronic power components are completely saturated. This may be due to insufficient source voltage, inadequate wiring, or excessive line loss. This may also indicate an open power device.
	MOD — Module	Indicates that there is an abnormal operating condition at the module level.

❑ Undervoltage Lockout

The UV switch on the rear panel has two positions, ON and OFF. When the switch is ON, the DC relay will not engage and the SYS and UV fault indicators will be on until there is greater than 0.4 volts applied to the DC inputs. Anytime the voltage drops below 0.4 volts the relays will disengage and the UV alarm will be latched. Please note that the DC relays will re-engage and the SYS fault LED will extinguish when the input voltage goes over 0.4 volts, but the UV fault indication remains until cleared with the LOAD ON command over the IEEE bus or by depressing the DC ON button on the front panel. When the UV switch is in the OFF position this action is inhibited allowing for load operation under 0.4 volts.

This function is separate and distinct from the programmable undervoltage function.

❑ Programmable Under Voltage

In addition to the Undervoltage Lockout, the load also has a Programmable Under Voltage feature. This feature provides a means to have the load automatically stop loading when the input voltage from the device under test drops below the defined threshold.

Unlike the Undervoltage Lockout, the Programmable Under Voltage can be set to generate a fault when the Voltage drops below its defined Voltage. The Voltage level can be programmed through menu item #18 or the through the IEEE 488 (or RS232) interface using the UV command. Like the hardware Undervoltage Lockout, this will open the load connect relay and generate a UV fault. Other than its programmability, it differs from the Undervoltage Lockout in that once the input voltage has dropped below the Programmable Under Voltage threshold causing a UV fault, the load will not re-connect until a DC LOAD ON is commanded. For this reason the input Voltage must be above the Programmable Under Voltage setting before performing a DC LOAD ON. Otherwise a UV fault will occur immediately and the DC LOAD ON will be cancelled. Setting the Programmable Under Voltage to zero disables this feature and does not affect the hardware Undervoltage Lockout.

❑ Menu Commands

The menu commands are accessible through the front panel by pressing the MENU key. Continue to press the MENU key to toggle through the menu selections. Table G lists the menu commands and their relative number in appearance. The subsections in this section detail each of the menu commands. Referring to Table G, the menu features are as follows:

Table G. Menu Commands

Number	Menu Command
1	Current Limit Setting
2	Voltage Limit Setting
3	Power Limit Setting
4	Slew Rate Adjust
5	Short Lock
6	Encoder Resolution Setting
7	Front Panel Configuration Memory Set
8	Front Panel Lock
9	IEEE Address Setting
10	Password Change
11	SF/SS (Fast Slew/Slow Slew)
12	Number of Pulses
13	Terminator (CR/CR-LF)
14	LCD Contrast Adjustment
15	Select AMPS/VOLT or OHMS
16	Sound ON/OFF
17	Check Firmware Revision
18	Programmable UV level

Current Limit Setting

The current limit function acts as a "brick wall". The load will not permit the current to exceed the numeric set point. When prompted, press ENTER to select this as a function. Then simply enter the value using the numeric keypad and press ENTER. If the limit is achieved by the load, an alarm will be indicated and the load will continue at the limit point. This is considered a MINOR FAULT.

Voltage Limit Setting

The voltage limit function acts as a protection to both the load and the source under test. If the voltage limit point is achieved, the load will disconnect from the source. An alarm condition will be indicated and will be a MAJOR FAULT. The load will not reconnect until the input voltage is below the limit set point. When prompted, press ENTER to select the function, then enter the numeric value using the keypad and press ENTER.

Power Limit Setting

The power limit function acts as a "brick wall". The load will not permit the power level to exceed the numeric set point. If the voltage continued to rise once in power limit the load will respond by continually reducing the current to meet the prescribed set point. If the set point is achieved an alarm will be indicated and will be a MINOR FAULT. When prompted, press ENTER to select the function, enter the numeric value using the keypad and press ENTER.

Slew Rate Adjustment

The slew rate adjustment sets both the rise and fall in time microseconds for a full-scale transition within the selected range. This is utilized to compensate for the inductance in long load input cables that could cause oscillation and/or overshoot. The slew rate setting is set at the factory for 100us and can be programmed from 10us and 4,000us when Fast Slew is selected (default). When Slow Slew is selected the slew rate can be set between 1,000us (1ms) and 400,000us (400ms). See Slew Fast/Slew Slow. When prompted press ENTER. Then enter the desired slew value in microseconds. Finish by pressing ENTER.

Short Lock

In some applications, such as battery testing, the short circuit feature could be detrimental to the unit under test. As a protection the short circuit function can be "Locked" to prevent use of this function.

Encoder Resolution Setting

The rotary digital encoder used for manual adjust can be set to different resolution settings. This will allow the user to set for a fine or coarse knob control. This function is active in all modes of operation, but depending on the mode, a setting that seems good in the constant current mode may be coarse in the constant resistance mode. It is up to the users discretion to decide what setting is appropriate.

Front Panel Configuration Memory Set

The Dynaload has the provision for memory presets. When a memory location is selected, the load will store the exact configuration and state that it currently is operating at. Items such as DC on, voltage range, current range, mode of operation, slew setting, limit settings and set current level will all be held in memory. To set a memory location, scroll through the menu to the memory set window. Press ENTER to select this function. Enter a location number (0 thru 9), and press ENTER.

> **NOTE:**
> Memory location zero (0) is the start up location of the load. Each time the AC power is applied memory location (0) is executed.

Front Panel Lock

The Dynaload will allow the user to "lock out" the front panel controls. When locked, the front panel controls become inactive and can only be restored by entering a password.

IEEE Address Setting

The IEEE-488 primary address must be set through the front panel numeric keypad. When prompted, press ENTER to select this function, enter the numeric address you wish the load to respond to and press ENTER.

Password Change

Through this screen the user can enter a password. When prompted, press ENTER. Then enter the new password. This is a numeric entry. Then press ENTER. The maximum number of characters is seven (7). The factory default is 1234.

SF/SS (Slew Range)

The Dynaload provides for two different slew ranges. SF stands for Slew Fast and will allow slew settings from 10us to 4000μs. SS stands for Slew Slow and will allow slew settings from 1000μs (1ms) to 400,000μs (400ms). When prompted press ENTER. Enter either a 1 for Slew Fast or 2 for Slew Slow. Finish by pressing ENTER.

Number Of Pulses

When operating in the pulse mode, the user has the option of setting a prescribed number of pulses. When prompted, simply enter the number of pulses to be executed and press ENTER. The maximum set number is 9,999,999. For continuous operation enter (0).

Terminator (CR/CR-LF)

When operating using the IEEE-488 control input the user must select the line terminator. You must choose either CR (carriage return) or CR/LF (carriage return/line).

LCD Contrast Adjust

The user has the ability to set the contrast on the alpha-numeric display. When prompted, press the ENTER button repeatedly until the contrast of the display is ideal. Then press the CLEAR button to exit this function.

Select Amps/Volt Or Ohms

This function refers to the constant resistance mode of operation. It allows the user to enter the resistance setting as a proportional ratio based on the input voltage (Amps/Volt) or to enter a numeric value directly in Ohms. When prompted, press ENTER to select this function. Enter the number (1) to select operation as a ratio of AMPS/VOLT or select (2) to operate in OHMS. Finish by pressing ENTER.

Sound ON/OFF

The load has an audio beeper to indicate if an error was entered using the front panel controls. This function can be silenced by choosing sound off.

Check Firmware Revision

This displays the installed version of Dynaload firmware.

Programmable UV Level

The Programmable Under Voltage provides a means for having the load automatically stop loading when the input Voltage drops below a specified threshold. If the input Voltage level drops below the UV setting the load will disconnect from the source. A UV and MAJOR FAULT will be indicated. The load will not reconnect until a DC LOAD ON command is issued. When prompted, press ENTER to select the function. Then enter the numeric value using ht keypad and press ENTER.

❑ Pulse Mode

Pulse mode loading is available in all four basic modes of operation (Constant Current, Constant Resistance, Constant Voltage and Constant Power). Use the following steps when operating in pulse mode:

Manual Operation

To manually operate the Dynaload, use the following procedure:

(1) Use the CI, CP, CV or CR button to set the baseline current, power, voltage, or resistance respectively.

(2) Use the FREQ button to set the frequency.

(3) Use the DUTY CYCLE button to set the duty cycle. For applications that require the period to be set, the ^{t}HI and ^{t}LO functions should be used. The ^{t}HI function will set the time that the pulse remains at the peak setting. The ^{t}LO function will set the time that the pulse remains at the baseline setting.

(4) Use the PEAK button to set the amplitude of the pulse.

NOTE:
The peak setting is added to the baseline setting.

(5) Use the menu button to scroll through the menu's to set the slew rate. This is set from the factory at 100 microseconds.

(6) Use the RUN button to initiate pulse loading. Press RUN a second time to turn pulse off.

(7) Use the SW command to initiate pulse loading.

The slew rate setting is set at the factory for 100 microseconds, but is adjustable through the front panel menu commands or the IEEE-488 bus.

It is recommended to monitor the current sample output with an oscilloscope to observe the actual current amplitude and waveform. If waveforms other than square waves are required, this can be accomplished by programming the loads using an external analog program source (refer to the *Remote Programming* section that follows).

NOTE:
In constant voltage mode the load current is increased by lowering the voltage. Therefore, in constant voltage pulse mode, the baseline voltage is higher than the peak setting. In constant resistance pulse mode, the baseline resistance is added in parallel with the peak resistance.

IEEE-488 Programming

This section covers basic operation only. For detailed information on pulse loading with the IEEE-488 commands, refer to the *IEEE-488 Commands and Programming* section and the *Language Elements* chapter later in this manual.

❑ Effects of Cable Inductance On Pulse Loading

When the Dynaload is used for high current pulse loading, the effects of cable inductance must be considered. The critical parameters are the rise time and the minimum compliance specifications. If the inductance of the cables from the voltage source is great enough to cause the voltage at the Dynaload to go below the minimum compliance level, then excessive current wave form distortion will occur. This is the result of the power devices driving into saturation. They attempt to reach the programmed current, however they cannot because of the low drain voltage. Once in a saturated state, the response time is much slower. The result is a significant overshoot on the rising edge of the pulse.

In order to prevent this from occurring, it should be noted that:

- 1 microhenry = 2.4 feet of wire (total)
- 50A @ 50 microseconds rise time = 1 volt drop with 1 microhenry
- The inductive drop cannot exceed the difference between the source voltage and the minimum compliance.

  EXAMPLE:
  Referring to Equation 1 that follows, to test a 10V source with a 100A pulse, and assuming a 3 Volt minimum compliance, the maximum cable length would be:

E Max drop = 7V

$$E = L\left(\frac{di}{dt}\right) \qquad 7V = L\left(\frac{100A}{50\mu s}\right)$$

L = 3.5 microhenries maximum

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Equation 1. Establishing Maximum Cable Length

In the example above, the maximum cable length is equal to 8.4 feet total or 4.2 feet per cable from the source to the Dynaload.

If the distance from the load to the source must be greater than this, there are several methods to increase the maximum distance. One way is to use several insulated conductors. This cuts the inductance in half if 4 are used instead of 2, or by 1/3 if 6 are used. This double or triples the maximum length, respectively.

Another method is to slow down the rise time of the pulse generator before applying it to the regulation loop. Increasing the slew rate to 100 microseconds will double the maximum cable length.

The third method is to use a large electrolytic capacitor at the Dynaload studs that can supply current necessary to counteract the inductive drop of the cable.

EXAMPLE:
If the previous example required 15 feet of total cable length or 6.25 microhenries, which would be 12.5V of inductive drop, then the capacitor would have to supply 5.5V @ 100A for 50 microseconds. The capacitance of this capacitor is computed using Equation 2 below:

$$C = \frac{I\,T}{E}$$

Where:
I is current in Amps (A)
T is time in microseconds (µs)
E is Voltage in Volts (V)
C is capacitance in microfarads (µF)

Substituting the values from the example into this equation results in:

$$C = \frac{100A \times 50\mu s}{5.5V} = 910\mu F$$

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Equation 2. Formula to Establish Capacitor Requirements

❑ Transconductance

One characteristic of power MOSFET'S is called transconductance. Today's MOSFET'S are designed for high speed switch mode operation where the operation is full ON or full OFF. The Dynaload uses these FET's in their linear region where the transconductance effect becomes apparent. When the gate of a FET is pulsed, the drive circuitry must overcome the inherent miller capacitance to reach the desired gate voltage. When the pulsed gate signal is very small the transconductance of the component will limit the rise time of the FET.

When operating the Dynaload at pulsed currents less than 10% of full scale, the rise time of the current waveform will be much slower than expected. Since this roll off in response is dependent on the number of FET's used in the power tray and the actual current pulse desired, it is very difficult to provide exact equations to define the effect. It is suggested to select a load that will provide the desired pulse level while operating at current levels greater than 10% of the full current rating of the load. If the baseline current is greater than 10% of full scale current and the pulsed waveform is added above this baseline the effects of transconductance will be eliminated. The greatest distortion occurs when pulsing from a zero current baseline.

> **NOTE:**
> Range switching will have no effect on operation in the transconductance region.

❑ Location, Airflow, Maintenance

The figures shown in *Appendix D — Outline Drawings by Model* are the dimensions of your Dynaload. In addition to the rack mounting ears, the use of slides or shelf type supports is required. The RBL chassis is equipped with mounting holes that match Jonathan 110QD-24-2 slides. The slide mounting screws ***must*** be #10 - 32 x 5/16 truss head.

The internal fan cools the unit by drawing in air from the front and exhausting it out the back. Keeping the airflow inlet and outlet screens open and free of dust and other airflow inhibitors will help keep your Dynaload unit's operating temperature within the intended design limits. We suggest that the loads be cleaned and free of dust build-up at least once a year.

The load can operate without performance derating over the temperature range of 0 to 40°C and with derated power dissipation capability up to 50°C.

Troubleshooting Guide

Table H includes a brief description of fault conditions and indicators while Table I addresses symptoms, possible causes, and explanations and corrective actions.

Table H. Troubleshooting Fault Conditions and Indicators

"SYS" (System) Fault LED	■ Lights red for a major fault. A major fault means the load will not draw current and will not connect to the source under test. Major faults include "OV", "UV", "OT" and AC fail. ■ Lights yellow for a minor fault. A minor fault will allow the unit to continue operating but may not be at the programmed setpoint due to a limit protection circuit. Minor faults include "I LIM", "P LIM", "SAT", and "MOD" fault.
"OV" (Overvoltage) Fault LED	■ Lights red when the loads input voltage exceeds the voltage limit setpoint menu item number 2. The DC load relay will not close until the input voltage is less than the setpoint.
"UV" (Undervoltage) Fault LED	■ Lights red when the input voltage is between zero and 0.6 volts and the "UV" switch on the rear panel is on. The DC load relay will not close in a "UV" condition.
"TEMP" (Temperature) Fault LED	■ Lights red when one or more internal power modules overheat. This will disconnect the load and reset once allowed to cool.
"I LIM" (Current Limit) Fault LED	■ Lights yellow when the loads current reaches the current limit setpoint menu item number 1. This is a "minor" fault.
"P LIM" (Power Limit) Fault LED	■ Lights yellow when the loads power reaches the power limit setpoint menu item number 3. This is a "minor" fault.
"SAT" (Saturation) LED	■ Lights yellow when there is insufficient source voltage to support the programmed current.* ■ May also indicate one or more component failures in the loads power section. This is a "minor" fault.
"MOD" (Module) Fault LED	■ 4000 watt load only — Lights yellow when there is an abnormal operating condition at the module level. ■ 2000 watt and 800 watt loads only — Lights yellow whenever the "SAT" LED lights. If the "SAT" LED is off, the "MOD" LED lights when there is an abnormal operating condition at the module level. This is a "minor" fault.

* Compliance Voltage: The minimum input voltage at which the load can sink its maximum rated current. Loads can operate below the minimum compliance voltage but will not be able to achieve full rated current.

Table I. Troubleshooting (Symptoms/Possible Causes/Explanations and Corrective Actions)

Symptom	Possible Cause	Explanation/Corrective Action
AC power button does not function.	AC input fuse on the rear panel has blown.	Check fuse and replace as necessary.
	AC power cord is loose or not connected.	Secure AC power cord.
	AC select on the rear panel is not set properly.	*2-Position Switch Models Positions:* Low switch position 110 volts AC High switch position 220 volts AC *4-Position Switch Models Positions:* Lowest switch position 100 volts AC Next switch position 120 volts AC Next switch position 200 volts AC Highest switch position 240 volts AC Select the AC voltage you are using.
Load powers up but the red SYS fault LED lights and the DC LOAD LED will not come on.	AC line voltage may be too low.	The load detects low incoming AC voltage (88% or less) and turns the load off for self-protection. Measure the AC input and correct or change the AC switch position as above.
Load powers up and the “SAT” LED lights before a “Load On” is initiated.	There are one or more defective components in the load.	The “SAT” LED should never come on during a load off condition. Send the unit in for service.
Load will not “Load On” with a green LED indicator. The indicator lights yellow.	The “Slave” button may have been pressed.	The load is in the slave mode, press any mode select button to clear from the slave mode.

Symptom	Possible Cause	Explanation/Corrective Action
Load powers up but, the “SYS” and “UV” LEDs light red. The “DC Load” LED will not come on.	The under voltage switch on the rear panel is on and the voltage applied the loads input is less than 0.6 volts DC.	With the “UV” switch in the on position, the load will “Load Off” whenever the input voltage falls below 0.6 volts DC. Switch the “UV” switch to the off position.
	The voltage applied to the input of the load may be reversed and greater than 0.6 volts DC.	Correct the polarity of the load’s input DC connection.
Unit “Loads Off” by itself. The “OV” and “SYS” LEDs light red.	The voltage applied to the loads input has exceeded the voltage limit setpoint, menu item number 2.	The load detects DC input voltage above its over voltage setpoint and “Loads Off” for self-protection. Measure the DC input voltage and reduce as necessary. Check the loads voltage limit setpoint by pressing the menu button until item 2 “Voltage Limit” appears. This voltage limit can set for zero to 105% of the voltage range selected.
Unit “Loads Off” by itself with no fault lights.	The voltage applied to the loads input has exceeded the maximum voltage of the load for its present range and then reduced to within range, as with a voltage spike.	The loads voltage detection circuit is very fast and will “Load Off” when a voltage spike above it’s over voltage setpoint appears. The fault lights do not latch they are self-resetting. Measure for voltage spikes at the loads input and correct as necessary. Once the input voltage is within range, manually press the load on button to resume operation.

Symptom	Possible Cause	Explanation/Corrective Action
Load powers up, “Loads On” but will not draw current.	The “EXT PROG” button or a range button has been pressed after setting the current (CI 5 for example).	Pressing the “EXT PROG” or a range button will reset the current to zero.
	In the constant resistance mode, the voltage sense leads may be improperly wired.	Repeat your required current entry. If the voltage sense read zero applied voltage, the load will calculate infinite resistance (zero current). Units are shipped with internal voltage sense lead jumpers installed on the rear terminal strip. These can be removed and remote sense leads can be installed. Refer to the voltage sense-related sections of Chapter 1.
Unit powers up, “Loads On” “SYS” and “SAT” LEDs are yellow and will not draw current.	There is little or no DC voltage applied to the loads input.	The “SAT” LED indicates the loads inability to draw the proper set point current, due to lack of input voltage. Measure the input voltage; it must exceed the compliance voltage specification for your model.
With the unit in a “Load On” condition, the “SYS” and “SAT” LEDs are light yellow. The load is set for “CI 0” and has no input DC voltage connected to it.	The “SYS” fault LED will light whenever the “SAT” LED lights. Both these LED’s under these conditions can be on or off. This is normal.	At “CI 0” the load may normally leak a small amount of current (30 milli amps for example). When the loads input voltage is zero, it can’t even provide the 30ma leakage current and the “SAT” LED lights. Connect an input voltage to the load and these LEDs will turn off.

Symptom	Possible Cause	Explanation/Corrective Action
Load is set to draw a current. The current is correct but the "SYS" and "SAT" LEDs light yellow.	DC voltage applied to the load is too low.	Raise the input voltage.
	If the voltage is above the compliance voltage specification, one or more components in the power section may be defective.	Send the unit in for service.
Load draws current when it is not programmed for current.	Loads rear terminal strip has a programming (0 to 10 VDC) signal applied to "REM" (positive) and S– (return) and the "EXT PROG" button has been pressed.	The load is in the external programming mode. Press the "EXT PROG" button to clear the unit to the constant current mode.
	Peak button has been set for a current other than zero and the pulse "RUN" button has been pushed.	The load is in the pulse mode. Press the "RUN" button to clear the unit to the constant current mode.
	In the constant power mode, the voltage sense leads may be improperly wired.	If the voltage sense leads read zero applied voltage, the load will try to draw to draw infinite current to achieve the proper power. Units are shipped with internal voltage sense lead jumpers installed on the rear terminal strip. These can be removed and remote sense leads can be installed. Refer to the voltage sense-related sections of Chapter 1.
	Loads power section may have one or more defective components.	Send the unit in for service.
Loads voltmeter reading does not match the voltage sense leads measured on the rear terminal strip.	The voltage sense leads may be improperly wired.	Units are shipped with internal voltage sense lead jumpers installed on the rear terminal strip. These can be removed and remote sense leads can be installed. Refer to the voltage sense-related sections of Chapter 1.

Symptom	Possible Cause	Explanation/Corrective Action
During normal operation the loads red "SYS", "TEMP" and "MOD" LEDs light.	One or more power modules in the power tray are overheating.	Check that there is nothing blocking the airflow through the unit.
	One of the loads cooling fans may be defective.	Send the unit in for service.
Load is set in the constant current mode, constant power mode or the constant resistance mode, and the expected current differs from the actual current. An audible sound may also be heard.	System (includes the load, power source, metering, etc.) may be oscillating. Prolonged use of the load while the system is oscillating may cause damage to the load.	To check for oscillation, connect an oscilloscope to the "CS" (current sample) with respect to the S– on the rear terminal strip. Oscillation is usually caused by the inductance of the cabling between the DC source and the load. This cabling should be as short as possible and the positive and negative wires should be twisted, to reduce the cable inductance. Also connecting a capacitor across the loads inputs can squelch the oscillation.
Load does not communicate over the IEEE bus.	IEEE address of the load is not matched with the computer program being used to communicate.	Change the IEEE address using menu item 9 to match the computer program being used.
	IEEE interconnect cable maybe loose or defective	Tighten or replace the cable.
Load communicates commands over the IEEE bus but not queries.	The terminator in the load may not be matched to the terminator of the computer program being used.	Change the terminator in the load, "CR" (carriage return) or "CR-LF" (carriage return, line feed) using the menu item 13 to match the computer program being used.
Load does not communicate over the RS 232 bus	Computer program used to run the RS 232 is not properly set up.	The computer program should be set to 9600 Baud N8+1 (8 Bit, 1 Stop Bit, no parity).
	RS 232 interconnect cable may be loose or defective.	Tighten or replace the cable.

Chapter 3. — IEEE-488 Commands and Programming

Introduction

The purpose of this section is to describe the IEEE-488 commands for operating your programmable Dynaload. This section assumes that your RBL488 has been installed, is operating properly, and that an IEEE-488 bus controller has been attached to it. It is also assumed that the IEEE-488 address and terminator has been set through the front panel menu selections. Be sure to read *Chapter 2. — Operating Instructions*, especially the *Operator Safety Instructions* section, before proceeding.

IEEE-488 Bus Subsets

The programmable Dynaload has the IEEE-488 bus subset capabilities indicated in Table J.

Table J. Bus Subset Capabilities

Subset	Category	Response
Acceptor Handshake	AH1	Full capability - the load can generate the handshake for receiving data.
Source Handshake	SH1	Full capability - the load can generate the handshake for transmitting data
Talker	T6	The load can: A. Transmit data B. Not be a talker and a listener at the same time. C. Respond to a bus serial poll with status information.
Listener	L1	The load can: A. Receive data B. Not be a talker and a listener at the same time.
Service Request	SR1	The load will set the SRQ line if there is an enabled service request condition.
Remote Local	RL1	The load can be switched to local operation.
Parallel Poll	PPO	No capability.
Device Clear	DC1	The Dynaload responds to device clear (DCL) and selected device clear (SDC) commands according to IEEE-488.2 specifications.
Device Trigger	DTO	No capability.

IEEE-488.2 Compliance

❑ Command Subsets

The Dynaload supports the following IEEE 488.2 commands including all the required command subsets as listed below in Table K. All 488.2 defined commands are prefixed by an asterisk (*). Further information can be found in the *Detail Language Elements* section of this chapter.

Table K. IEEE-488.2 Commands

Command	Description
***CLS**	Clear Status
***IDN?**	Read 488.2 Identification string
***ESE <NR1>**	Set Event Status Enable register
***ESE?**	Read Event Status Enable register
***ESR?**	Read Event Status Register
***OPC**	Operation Complete
***OPC?**	Operation Complete query
***RST**	Reset
***SRE <NR1>**	Set Service Request Enable register
***SRE?**	Read Service Request Enable register
***STB?**	Read Status Byte
***TST?**	Self Test
***WAI**	Wait

❑ Command Execution and Synchronization

All the commands in the Dynaload are immediate commands with the exception of the SW <NR1> and WF <NR1> form of the SW and WF commands. Immediate means they execute and complete at the time the command is processed. The SW <NR1> and WF <NR1> commands define a specific number of pulses after which the command completes and pulsing is turned off. Therefore the IEEE 488.2 synchronization commands *OPC and *OPC? will indicate function complete immediately except when used with the SW <NR1> and WF <NR1>. In this case they will indicate complete after the defined number of pulses has been generated. Likewise the *WAI command will have no effect except when used with the SW <NR1> and WF <NR1> commands. This does not apply to the simple SW and WF commands since they turn on pulsing for an indefinite period. In this case, once pulsing is on (which is immediate) the command is considered to have completed execution.

❑ Status Structure

The Dynaload supports the IEEE 488.2 defined status structure. In addition to the IEEE 488.2 defined registers the device specific CON (Condition) and SBE (Summary Bit Enable) registers provide additional status information. Additionally the LAT (Latch) and SDN (Shutdown) registers provide some control as to how the load responds to a change in condition. STATXT OFF is recommended so numeric responses are returned for the device specific status register queries. Refer to the CON, SBE, LAT, SDN and STATXT in the *Detail Language Elements* and *Status and Event Register* sections of this chapter for more information.

❑ Reading Data

An attempt to read data when the message queue is empty and the load is not in an Operation Complete query (*OPC?) or a Wait (*WAI) state will return the loads Identification (*IDN?) string and cause a query error. During an Operation Complete query or a Wait state, an attempt to read data will result in a hold-off condition until the pending functions complete.

Data Separators

It is not necessary to separate numerical data from the previous command by any character. White space is ignored. The use of a space is recommended, however, as it aids in command string legibility.

Program Line Terminators

The terminator instructs the Dynaload that the end of an incoming command line has been reached and that command decoding can begin. In a like manner, the Dynaload terminates each of its outgoing response strings with a terminator.

Normally the terminator for command strings is appended automatically by the IEEE-488 bus controller in the system computer. The terminator must be established as both a carriage return and a line feed, or as a carriage return only by following the IEEE-488 bus configuration procedure.

Numerical Data Formats

The programmable Dynaload accepts the two numerical data formats listed below (see Table L). These are described in more detail in IEEE Standard 488.2 — *Standard Digital Interface for Programmable Instruments*.

Table L. Numerical Data Formats

Symbol	Data Form(s)
NR1	Digits with no decimal point. The decimal point is assumed to be to the right of the least significant digit. For example: 314, 0314.
NR2	Digits with a decimal point. For example: 314.0, 31.41, 0.0314

Numerical Data Units

The numerical units in which the RBL488 receives and transmits quantities are fixed. They are listed in Table M.

Incoming commands must not have any units transmitted with them, as this will cause an “unrecognized command” error.

Responses to queries in the TEXT ON (long format) mode are followed by the unit transmission format indicated in the table. In the TEXT OFF (short format) only the numbers are transmitted.

Table M. Numerical Data Units

Item	Description	Unit	Format
AV1	First resistance value (A/V mode)	Amps/Volt	Amps/Volt
AV2	Second resistance value (A/V mode)	Amps/Volt	Amps/Volt
AVH	Constant resistance setpoint	(High A/V) Amps/Volt	Amps/Volt
AVL	Constant resistance setpoint	(Low A/V) Amps/Volt	Amps/Volt
CI	Constant current setpoint	Amperes	Amps
CP	Constant power setpoint	Watts	Watts
CRH	Constant resistance setpoint	(High Ω) ohms	Ohms
CRL	Constant resistance setpoint	(Low Ω) ohms	Ohms
CV	Constant voltage setpoint	Volts	Volts
DU	Square wave duty cycle	Percent	%
ET	Elapsed time	Hours	—
FQ	Square wave frequency	Hertz	Hz
I?	Load current	Amperes	Amps
I1	First current value	Amperes	Amps
I2	Second current value	Amperes	Amps
P?	Load power	Watts	Watts
P1	First power value	Watts	Watts
P2	Second power value	Watts	Watts
R1	First resistance value (ohms mode)	Ohms	Ohms
R2	Second resistance value (ohms mode)	Ohms	Ohms
S1	First slew	Microseconds	µs
S2	Second slew	Microseconds	µs
SR	Slew rate (1st and 2nd)	Microseconds	µs
T1	First duration	Microseconds	µs
T2	Second duration	Microseconds	µs
V?	Load voltage	Volts	Volts
V1	First voltage value	Volts	Volts
V2	Second voltage value	Volts	Volts
XM PLUS (XM +)	External modulation constant current offset	Amperes	Amps

Power-on Defaults

The following table indicates the factory default conditions are in effect every time the load is switched on. This can be re-configured by the user in memory location zero (0).

Table N. Power-on Defaults

Parameter	Setting
CI — Constant current setpoint	0
CP — Constant power setpoint	0
CR — Constant resistance setpoint	∞
CV — Constant voltage setpoint	Vmax
DU — Square wave duty cycle	50%
FQ — Square wave frequency	1000 Hz
I1 — First current value	0
I2 — Second current value	0
IL — Current limit	105% of full scale
LOAD — Relay	Open
MODE — Mode	Constant current
P1 — First power value	0
P2 — Second power value	0
PL — Power limit	105% of full scale
R1 — First resistance value	∞
R2 — Second resistance value	∞
RNG — Range	High Volts, High Amps
S1 — First slew rate	100 microseconds (0-FS)
S2 — Second slew rate	100 microseconds (FS-0)
SHORT — Short	OFF
STATXT — Status text	ON (factory default)
T1 — First duration	500 microseconds
T2 — Second duration	500 microseconds
TEXT — Text	ON
V1 — First voltage value	Vmax
V2 — Second voltage value	Vmax
VL — Voltage limit	105% of full scale
XM — External modulation	OFF

Commands

The basis of the RBL488 syntax are the instrument control commands. Each command sends an instruction to the Dynaload. A query command requests information from the Dynaload.

Each element of the load syntax commands consists of two or more letters or a combination of letters and numbers. The simpler elements are mnemonic in nature while the longer elements explain a complete action.

EXAMPLE:
CI 10 This places the load in it's Constant Current Mode set at 10 amps
LOAD ON This closes the load's input relay.

Queries

Commands followed by a question mark "?" are queries. When received by the Dynaload, the appropriate information is stored for reading by the IEEE-488 bus controller. It is important to note that the results of a query must be read back before sending another command to the Dynaload. If this is not the case, the information requested is lost.

There are two categories of queries. One is a request for real time load values: voltage, current, and power. The second is request for the present value of programmed parameters or status.

Many of the commands may be turned into queries by the addition of a question mark (?). The Dynaload will respond with the requested information when the load is addressed to talk over the IEEE-488 bus.

EXAMPLE:
CI? This requests the present value of the Constant Current program.
LOAD? This requests the state of the load's input relay.

Multipart Commands

As specified in the IEEE 488.2 specifications the load supports use of multipart commands. This is a single command line that has multiple commands and/or queries separated by semicolons as follows:

<command1>;<command2>[;<command3>] . . . [;<command x>]

Each of these commands or queries within the multipart command is known as an element. Each element is executed sequentially as if they had been issued separately with the following exceptions:

(1) If multiple query elements are within the command line, the responses to these elements will be returned as a multipart response on a single line. Semicolons will separate the individual response elements as follows:

<response1>;< response2>[;< response3>] . . . [;<response x>]

Furthermore the multipart response is not available to be read back over the IEEE 488 bus until all commands have been processed. This means that if a Wait (*WAI) delays processing of the remaining commands or an Operation Complete query (*OPC?) holds up completion of the response message, attempting to read the response will result in a IEEE 488 bus hold-off until all has been completed.

(2) A device clear, selective device clear or reception of a new command line will flush any commands that have not been executed. This means they will be removed from the queue and won't be executed. This can only happen when a Wait (*WAI) or an Operation Complete Query (*OPC?) was used since it is only these that will suspend execution of some commands till other events have occurred. If neither is in the command line, all commands will execute since a device clear, selected device clear or a new command line could not be received.

Command and Queries Listed Alphabetically

***CLS**	Clear Status
***ESE <NR1>**	Set Event Status Enable Register
***ESE?**	Read Event Status Enable register
***ESR?**	Read Event Status Register
***IDN?**	Read 488.2 Identification string
***OPC**	Operation Complete
***OPC?**	Operation Complete query
***RST**	Reset
***SRE <NR1>**	Set Service Request Enable register
***SRE?**	Read Service Request Enable register
***STB?**	Read Status Byte
***TST?**	Self Test
***WAI**	Wait
AV1 <NR2>	Set Amps/Volt pulse base level
AV1?	Read Amps/Volt pulse base setting
AV2 <NR2>	Set Amps/Volt pulse peak level
AV2?	Read Amps/Volt pulse peak setting
AV?	Read Amps/Volt setting
AVH <NR2>	Set Amps/Volt High mode
AVL <NR2>	Set Amps/Volt Low mode
CI <NR2>	Set Constant Current Mode
CI?	Read Constant Current setting
CON?	Read Condition register
CP <NR2>	Set Constant Power mode
CP?	Read Constant Power setting
CR?	Read Constant Resistance setting
CRH <NR2>	Set Constant Resistance High mode
CRL <NR2>	Set Constant Resistance Low mode
CV <NR2>	Set Constant Voltage mode
CV?	Read Constant Voltage setting
DU <NR2>	Set Duty Cycle
DU?	Read Duty Cycle setting

ERR?	Read Error Register
ET RST	Reset Elapsed Timer
ET?	Read Elapsed Time
FQ <NR2>	Set Frequency
FQ?	Read Frequency Setting
I?	Read Current
I1 <NR2>	Set Constant Current pulse base level
I1?	Read Constant Current pulse base setting
I2 <NR2>	Set Constant Current pulse peak level
I2?	Read Constant Current pulse peak setting
ID?	Read Identification string
IL <NR2>	Set Current Limit
IL?	Read Current Limit Setting
IST?	Internal Self-Test
LAT <NR1>	Set the fault Latch register
LAT?	Read the Latch register setting
LOAD OFF	Open load connect relay
LOAD ON	Close load connect relay
LOAD?	Read load connect relay setting
LOCK OFF	Unlock front panel
LOCK ON	Lock front panel
LOCK?	Read front panel lock setting
MODE?	Read mode
MR <NR1>	Memory Recall
MS <NR1>	Memory Save
P?	Read Power
P1 <NR2>	Set Constant Power pulse base level
P1?	Read Constant Power pulse base setting
P2 <NR2>	Set Constant Power pulse peak level
P2?	Read Constant Power pulse peak setting
PL <NR2>	Set Power Limit
PL?	Read Power Limit setting
R1 <NR2>	Set Constant Resistance pulse base level
R1?	Read Constant Resistance pulse base setting
R2 <NR2>	Set Constant Resistance pulse peak level

R2?	Read Constant Resistance pulse peak setting
RNG <NR1>	Set Voltage/Current Range
RNG?	Read Voltage/Current Range status
RNGS?	Read Voltage/Current Range setting
RST	Reset
S1 <NR2>	Set rising edge slew rate
S1?	Read rising edge slew setting
S2 <NR2>	Set falling edge slew rate
S2?	Read falling edge slew setting
SBE <NR1>	Set Summary Bit Enable register
SBE?	Read Summary Bit Enable register
SDN <NR1>	Set Shutdown register
SDN?	Read Shutdown register
SF	Set for Fast Slew rates
SHORT OFF	Remove Short circuit from input
SHORT ON	Apply Short circuit to input
SHORT?	Read Short circuit setting
SLAVE	Set Slave move
SR <NR2>	Set Slew Rate
SR?	Read Slew Rate settings
SRQ <NR1>	Set Service Request register
SRQ?	Read Service Request register
SS	Set for Slow Slew rates
STA?	Read Status register
STATXT OFF	Set numeric status query responses
STATXT ON	Set descriptive status query responses
STATXT?	Read Status Text on/off setting
SW [<NR1>]	Set Square Wave pulsing on
SW OFF	Set Square Wave pulsing off
SW?	Read Square Wave pulse setting
T1 <NR2>	Set pulse base duration
T1?	Read pulse base duration
T2 <NR2>	Set pulse peak duration
T2?	Read pulse peak duration

TEXT OFF	Set numeric query responses
TEXT ON	Set descriptive query responses
TEXT?	Read Text on/off setting
UV <NR2>	Set programmable Under Voltage
UV?	Read programmable Under Voltage setting
V?	Read Voltage
V1 <NR2>	Set Constant Voltage pulse base level
V1?	Read Constant Voltage pulse base level
V2 <NR2>	Set Constant Voltage pulse peak level
V2?	Read Constant Voltage pulse peak level
VER?	Read software version string
VL <NR2>	Set Voltage Limit
VL?	Read Voltage Limit setting
WF [<NR1>]	Set Square Wave pulsing on
WF OFF	Set Square Wave pulsing off
WF?	Read Square Wave pulse setting
XM ON	Set External Modulation on
XM OFF	Set External Modulation off
XM PLUS <NR2>	Set External Modulation with programmed offset
XM + <NR2>	Alternate Syntax for XM PLUS <NR2>
XM?	Read External Modulation setting

Commands and Queries Listed by Category

Configuration

LAT <NR1>	Set the fault Latch register
LAT?	Read the Latch register setting
LOCK OFF	Unload front panel
LOCK ON	Lock front panel
LOCK?	Read front panel lock setting
MR <NR1>	Memory Recall
MS <NR1>	Memory Save
SDN <NR1>	Set Shutdown register
SDN?	Read Shutdown register
STATXT OFF	Set numeric status query responses
STATXT ON	Set descriptive status query responses
STATXT?	Read Status Text on/off setting
TEXT OFF	Set numeric query responses
TEXT ON	Set descriptive query responses
TEXT?	Read Text on/off setting

Identification

***IDN?**	Read 488.2 Identification string
ID?	Read Identification string
VER?	Read software version string

IEEE-488.2 Commands

***CLS**	Clear Status
***IDN?**	Read 488.2 Identification string
***ESE <NR1>**	Set Event Status Enable register
***ESE?**	Read Event Status Enable register
***ESR?**	Read Event Status Register
***OPC**	Operation Complete
***OPC?**	Operation Complete query
***RST**	Reset
***SRE <NR1>**	Set Service Request Enable register

***SRE?**	Read Service Request Enable register
***STB?**	Read Status Byte
***TST?**	Self Test
***WAI**	Wait

Limit Control

IL <NR2>	Set Current Limit
IL?	Read Current Limit Setting
PL <NR2>	Set Power Limit
PL?	Read Power Limit setting
UV <NR2>	Set programmable Under Voltage
UV?	Read programmable Under Voltage setting
VL <NR2>	Set Voltage Limit
VL?	Read Voltage Limit setting

Load Control

LOAD OFF	Open load connect relay
LOAD ON	Open load connect relay
LOAD?	Read load connect relay setting
SHORT OFF	Remove Short circuit from input
SHORT ON	Apply Short circuit to input
SHORT?	Read Short circuit setting
RNG <NR1>	Set Voltage/Current Range
RNG?	Read Voltage/Current Range status
RNGS?	Read Voltage/Current Range setting

Operation Modes

AV?	Read Amps/Volt setting
AVH <NR2>	Set Amps/Volt High mode
AVL <NR2>	Set Amps/Volt Low mode
CI <NR2>	Set Constant Current Mode
CI?	Read Constant Current setting
CP <NR2>	Set Constant Power mode
CP?	Read Constant Power setting
CR?	Read Constant Resistance setting
CRH <NR2>	Set Constant Resistance High mode

CRL <NR2>	Set Constant Resistance Low mode
CV <NR2>	Set Constant Voltage mode
CV?	Read Constant Voltage setting
MODE?	Read mode
SLAVE	Set Slave move
XM ON	Set External Modulation on
XM OFF	Set External Modulation off
XM PLUS <NR2>	Set External Modulation with programmed offset
XM + <NR2>	Alternate Syntax for XM PLUS <NR2>
XM?	Read External Modulation setting

Pulsing

DU <NR2>	Set Duty Cycle
DU?	Read Duty Cycle setting
FQ <NR2>	Set Frequency
FQ?	Read Frequency Setting
SW [<NR1>]	Set Square Wave pulsing on
SW OFF	Set Square Wave pulsing off
SW?	Read Square Wave pulse setting
T1 <NR2>	Set pulse base duration
T1?	Read pulse base duration
T2 <NR2>	Set pulse peak duration
T2?	Read pulse peak duration
WF [<NR1>]	Set Square Wave pulsing on
WF OFF	Set Square Wave pulsing off
WF?	Read Square Wave pulse setting

Pulsing Level Parameters

AV1 <NR2>	Set Amps/Volt pulse base level
AV1?	Read Amps/Volt pulse base setting
AV2 <NR2>	Set Amps/Volt pulse peak level
AV2?	Read Amps/Volt pulse peak setting
I1 <NR2>	Set Constant Current pulse base level
I1?	Read Constant Current pulse base setting
I2 <NR2>	Set Constant Current pulse peak level

I2?	Read Constant Current pulse peak setting
P1 <NR2>	Set Constant Power pulse base level
P1?	Read Constant Power pulse base setting
P2 <NR2>	Set Constant Power pulse peak level
P2?	Read Constant Power pulse peak setting
R1 <NR2>	Set Constant Resistance pulse base level
R1?	Read Constant Resistance pulse base setting
R2 <NR2>	Set Constant Resistance pulse peak level
R2?	Read Constant Resistance pulse peak setting
V1 <NR2>	Set Constant Voltage pulse base level
V1?	Read Constant Voltage pulse base level
V2 <NR2>	Set Constant Voltage pulse peak level
V2?	Read Constant Voltage pulse peak level

Readbacks

I?	Read Current
P?	Read Power
V?	Read Voltage
ET RST	Reset Elapsed Timer
ET?	Read Elapsed Time

Slew Rate Commands

S1 <NR2>	Set rising edge slew rate
S1?	Read rising edge slew setting
S2 <NR2>	Set falling edge slew rate
S2?	Read falling edge slew setting
SF	Set for Fast Slew rates
SR <NR2>	Set Slew Rate
SR?	Read Slew Rate settings
SS	Set for Slow Slew rates

Status Related Commands

***CLS**	Clear Status
***ESE <NR1>**	Set Event Status Enable register
***ESE?**	Read Event Status Enable register
***ESR?**	Read Event Status Register

***SRE <NR1>**	Set Service Request Enable register
***SRE?**	Read Service Request Enable register
***STB?**	Read Status Byte
CON?	Read Condition register
ERR?	Read Error Register
LAT <NR2>	Set the fault Latch register
LAT?	Read the Latch register setting
SBE <NR1>	Set Summary Bit Enable register
SBE?	Read Summary Bit Enable register
SDN <NR1>	Set Shutdown register
SDN?	Read Shutdown register
SRQ <NR1>	Set Service Request register
SRQ?	Read Service Request register
STA?	Read Status register

Miscellaneous

IST?	Internal Self-Test
RST	Reset

Detail Language Elements

This is an alphanumerical listing that gives the syntax and required parameters for all elements in the programmable load's syntax. The syntax is generic for all load ratings.

The following section provides the following information below for each command:

- **DESCRIPTION:** Describes the function of the command and gives information about its use.
- **COMMAND SYNTAX:** Shows the proper form(s) of the command. Spaces are optional as the command processor ignores these.
- **EXAMPLE:** Gives an example of command usage.
- **QUERY SYNTAX:** Provides the proper query form.
- **RETURNED PARAMETERS:** Indicates the response format(s) to the query form of the command. Where the TEXT ON and TEXT OFF modes responses differ, both will be indicated.

❑ Required Parameters List

*CLS *Clear Status*

Description	This command clears the IEE 488.2 related status registers and any pending Operation Complete (*OPC) signaling.
Command Syntax	*CLS
Example	*CLS This will clear the *STB, *ESR and CON registers and terminate any pending *OPC or *OPC? signaling.
Query Syntax	NONE
Returned Parameters	N/A

*ESE *Event Status Enable register*

Description	This command provides access to the Event Status Enable register. The bits in this register define which bits of the Event Summary Register (ESR) will set the ESB bit in the Status Byte (STB). Setting one bit by writing its bit weight into the ESE register enables its equivalent bit in the ESR. The individual bits are defined below. More than one bit can be enabled by writing a value that is a sum of the individual bit weights. A query form is provided so the setting can be read back.

Bit	Weight	Description	Default Value
7	128	Power-on	0
6	64	User Request	0
5	32	Command Error	0
4	16	Execution Error	0
3	8	Device Dependant Error	0
2	4	Query Error	0
1	2	Request Control	0
0	1	Operation Complete	0

Command Syntax	*ESE <NR1>
Example	*ESE 36 This will write the value of 36 into the ESE register. This enables bit 2 (Query Error) and bit 5 (Command Error) in the ESR so that if either is set, the ESB bit in the Status Byte will also be set.
Query Syntax	*ESE?
Returned Parameters	<NR1>

*ESR? *Event Status Register*

<table>
<tr><td rowspan="10">Description</td><td colspan="3">This query returns the contents of the Event Status Register and clears its contents. Each bit in this register represents an event that has occurred since the last time it was cleared. The returned value will be between 0 and 255 and is the sum of the individual bit weights. A *CLS command will also clear this register. The individual bits are defined below.</td></tr>
<tr><td>Bit</td><td>Weight</td><td>Description</td></tr>
<tr><td>7</td><td>128</td><td>Power-on</td></tr>
<tr><td>6</td><td>64</td><td>User Request</td></tr>
<tr><td>5</td><td>32</td><td>Command Error</td></tr>
<tr><td>4</td><td>16</td><td>Execution Error</td></tr>
<tr><td>3</td><td>8</td><td>Device Dependant Error</td></tr>
<tr><td>2</td><td>4</td><td>Query Error</td></tr>
<tr><td>1</td><td>2</td><td>Request Control</td></tr>
<tr><td>0</td><td>1</td><td>Operation Complete</td></tr>
<tr><td>Command Syntax</td><td colspan="3">NONE</td></tr>
<tr><td>Example</td><td colspan="3">N/A</td></tr>
<tr><td>Query Syntax</td><td colspan="3">*ESR?</td></tr>
<tr><td>Returned Parameters</td><td colspan="3"><NR1></td></tr>
</table>

*IDN? *Identification*

Description	This query returns the loads IEEE-488.2 defined identification string. This string has four comma delimited fields and takes the form: <manufacturer>,<model number>,<serial number >,<software version> Each field is a variable length alphanumeric string. Since the unit serial number is not encoded into the unit, the <serial number> field will contain a zero as specified in the IEEE 488.2 specification.
Command Syntax	NONE
Example	N/A
Query Syntax	*IDN?
Returned Parameters	DYNALOAD,RBL <voltage>-<current>-<power>,0,<version>

*OPC *Operation Complete*

Description	This command enables the Operation Complete bit in the Event Status Register (ESR) to be set when all commands in a multipart command string have finished executing. The query form of this command causes a “1” to be placed in the Output Queue instead of setting the Operation Complete bit. In IEEE-488 interfaced units an attempt to perform a read before the “1” is placed in the Output Queue will result in a bus hold-off state until the operation completes. The *OPC command or *OPC? query must appear as the last command unit in a multipart command string and only applies to the proceeding commands in the string. Should the load receive any new commands or queries before an *OPC? query sequence has finished, the Operation Complete signaling will be cancelled. This does not affect an *OPC command so the Operation Complete bit will still be set upon completion even though subsequent commands or queries have been issued. Both the query and command will be cancelled upon receipt of a *CLS or *RST . On IEEE-488 units a device clear or selective device clear will cancel any pending Operation Complete signaling as well. Most of the commands in the Dynaload are immediate commands and execution completes before it moves onto the subsequent commands. Currently the only exception is the SW <NR1> (and WF <NR1> alternate syntax). The SW <NR1> command executes for a specified number of pulses and then stops. Using the *OPC provides a means for identifying when it has completed.
Command Syntax	<command1>[;<command2>] . . . [;<command x>];*OPC
Example	FQ 10;SW 2000;*OPC This multipart command sets the pulse frequency for 10Hz and then turns on pulsing for 2000 pulses. The *OPC command at the end will cause the Operation Complete bit in the ESR to be set when it is finished with all 2000 pulses.
Query Syntax	<command1>[;<command2>] . . . [;<command x>];*OPC?
Returned Parameters	1 (not placed in the message queue until the operation completes)

RST** ***Reset

Description	This command resets the load to its factory default settings as specified in the IEEE-488.2 specifications. This does not affect the loads IEEE-488 bus address, any of the status registers or the output queue.
Command Syntax	*RST
Example	*RST This will reset the load to its factory default settings.
Query Syntax	NONE
Returned Parameters	N/A

*SRE *Service Request Enable register*

Description	This command provides access to the Service Request Enable register. The bits in this register define which bits of the Status Byte (STB) will set the Master Summary Status (MSS) bit in the STB. On IEEE-488 units it also defines which STB bits will generate a service request (RQS). Setting one bit by writing its bit weight into the SRE register enables its equivalent bit in the STB. Bit 6 is ignored. The individual bits are defined below. More than one bit can be enabled by writing a value that is a sum of the individual bit weights. A query form is provided so the setting can be read back.

Bit	Weight	Description	Default Value
7	128	Reserved	0
6	—	—	—
5	32	Error Summary Bit (ESB)	0
4	16	Message Available (MAV)	0
3	8	Minor Fault Summary Bit	0
2	4	Major Fault Summary Bit	0
1	2	Reserved	0
0	1	Reserved	0

Command Syntax	*SRE <NR1>
Example	*SRE 44 This will write the value of 44 into the SRE register. This enables bit 2 (Major Fault Summary Bit), bit 3 (Minor Fault Summary Bit) and bit 5 (Error Summary Bit) in the STB so that if any of them are set, the MSS bit in the STB will be set and a RQS will be generated.
Query Syntax	*SRE?
Returned Parameters	<NR1>

*STB? *Status Byte*

Description

This query returns the contents of the Status Byte. This byte contains summary information from the Error Status Register (ESR), Condition Register (CON) and the Output Queue thus providing a simple means of examining the load's status. See the *Status and Event Register* section of this chapter and Figure 12 for further information.

The returned value will be between 0 and 255 and is the sum of the individual bit weights. The individual bits are defined below.

Bit	Weight	Description
7	128	Reserved
6	64	Master Summary Status (MSS)/Request Service (RQS)
5	32	Error Summary Bit (ESB)
4	16	Message Available (MAV)
3	8	Minor Fault Summary Bit
2	4	Major Fault Summary Bit
1	2	Reserved
0	1	Reserved

Reading this register does not clear its contents. A *CLS command is required to clear it.

On IEEE-488 units the information in this byte along with the Service Request Enable register (SRE) can be used to generate a service request. With the exception of the Master Summary Status (MSS) bit, this is the same byte that is returned when a serial poll is performed.

Command Syntax	NONE
Example	N/A
Query Syntax	*STB?
Returned Parameters	<NR1>

*TST? *Test*

Description	This IEEE-488.2 defined query instructs the load to perform an internal self test and return the result. It is provided to comply with the IEEE-488.2 specification however there are no internal tests that can be performed. Therefore this query will always return a zero indicating the test has passed.
Command Syntax	NONE
Example	N/A
Query Syntax	*TST?
Returned Parameters	0

*WAI *Wait*

Description	This command causes the load to wait for all proceeding commands in a multipart command to complete before continuing with the remaining commands in the string. Should the load receive any new commands or queries before a *WAI delayed command string finishes executing, the remaining commands will be ignored and the new command commands will be processed. The use of *WAI can be combined with a *OPC command or *OPC? query to provide positive feedback that the command line has finished executing. Most of the commands in the Dynaload are immediate commands and execution completes before it moves onto the subsequent commands. Currently the only exception is the SW <NR1> (and WF <NR1> alternate syntax). Therefore the *WAI command will have no effect except with all but these commands.
Command Syntax	<cmd1>[;<cmd2>] . . . [;<cmd x>];*WAI;<cmd y>[;<cmd z>]….
Example	FQ 10;SW 100;*WAI; FQ 20;SW 400 This will set a pulse frequency of 10Hz and turn on square wave pulsing for 100 pulses. The load will then wait until the 100 pulses have finished and then set the frequency to 20Hz and pulse for 400 pulses.
Query Syntax	NONE
Returned Parameters	N/A

AV1 *Amps/Volt Pulsing Base Level*

Description	This command is used to set the base level when pulse loading in the Amps/Volt mode. **NOTE:** AVL or AVH must have been previously set.
Command Syntax	AV1 <NR2>
Example	AV1 25.0 This will set the base Amps/Volt level to 25 amps/volt
Query Syntax	AV1?
Returned Parameters	TEXT ON: <NR2> amps/v TEXT OFF: <NR2>

AV2 *Amps/Volt Pulsing Peak Level*

Description	This command is used to set the peak level relative to the base level when pulse loading in the Amps/Volt mode. **NOTE:** AVL or AVH must have been previously set.
Command Syntax	AV2 <NR2>
Example	AV2 50.0 This will set the peak level to 50 Amps per Volt above the base level. Therefore if the base level setting is 25A, the peaks will be 75 Amps per Volt.
Query Syntax	AV2?
Returned Parameters	TEXT ON: <NR2> amps/v TEXT OFF: <NR2>

AV?

See query form of AVH and AVL that immediately follow.

AVH *Amps/Volt High*

Description	This command places the load into Amps/Volt High mode at the specified level.
Command Syntax	AVH <NR2>
Example	AVH 25.0 This will place the load in Amps/Volt High mode at 25 Amps per Volt.
Query Syntax	AV?
Returned Parameters	TEXT ON: <NR2> amps/v TEXT OFF: <NR2>

AVL *Amps/Volt Low*

Description	This command places the load into Amps/Volt Low mode at the specified level.
Command Syntax	AVL <NR2>
Example	AVL 2.5 This will place the load in Amps/Volt Low mode at 2.5 Amps per Volt.
Query Syntax	AV?
Returned Parameters	TEXT ON: <NR2> amps/v TEXT OFF: <NR2>

CI *Constant Current*

Set Constant Current mode and current value

Description	This command places the load into Constant Current mode at the specified level.
Command Syntax	CI <NR2>
Example	CI 10.5 This will place the load in Constant Current at 10.5 Amps.
Query Syntax	CI?
Returned Parameters	TEXT ON: <NR2> amps TEXT OFF: <NR2>

CLS

See **CLS* on page 55.

CON? *Condition register*

Description

This query returns the contents of the Condition register and clears its contents. The response is either numeric or a text description depending on the TEXT ON/OFF and STATXT ON/OFF settings.

Each bit in this register provides information about the load's condition. A bit being set indicates that the condition is present or has occurred. Normally the bit will clear when the condition clears unless its respective bit in the Latch (LAT) register is set. Furthermore if its respective bit in the Shutdown (SDN) register is set the load will shutdown.

The returned value will be between 0 and 255 and is the sum of the individual bit weights. A *CLS command will clear this register as well. The individual bits are defined below.

Bit	Weight	Description	Text On Response Message
7	128	Under Voltage	UNDER VOLTAGE
6	64	Over Voltage	VOLTAGE LIMIT
5	32	Over Temperature	TEMPERATURE LIMIT
4	16	—	—
3	8	Over Current	CURRENT LIMIT
2	4	Over Power	POWER LIMIT
1	2	Saturation	LOAD SATURATED
0	1	Module Fault	MODULE FAULT

The text response will return a string containing the Text On Response Message as listed above for each bit that is set. These will be separated by commas. If no bits are set, "CLEAR" will be returned.

Command Syntax	NONE
Example	N/A
Query Syntax	CON?
Returned Parameters	TEXT ON and STATXT ON: <text response string> TEXT OFF or STATXT OFF: <NR1>

CP *Constant Power*

Description	This command places the load into Constant Power mode at the specified level.
Command Syntax	CP <NR2>
Example	CP 20.0 This will place the load in Constant Power at 20 Amps.
Query Syntax	CP?
Returned Parameters	TEXT ON: <NR2> watts TEXT OFF: <NR2>

CR?

See query form of CRH and CRL that immediately follow.

CRH *Constant Resistance High*

Description	This command places the load into Constant Resistance High mode at the specified level.
Command Syntax	CRH <NR2>
Example	CRH 100.0 This will place the load in Constant Resistance High mode at 100 Ohms.
Query Syntax	CR?
Returned Parameters	TEXT ON: <NR2> ohms TEXT OFF: <NR2>

CRL *Constant Resistance Low*

Description	This command places the load into Constant Resistance Low mode at the specified level.
Command Syntax	CRL <NR2>
Example	CRL 1.5 This will place the load in Constant Resistance Low mode at 1.5 Ohms.
Query Syntax	CR?
Returned Parameters	TEXT ON: <NR2> ohms TEXT OFF: <NR2>

CV *Constant Voltage*

Description	This command places the load into Constant Voltage mode at the specified level.
Command Syntax	CV <NR2>
Example	CV 100.0 This will place the load in Constant Voltage at 100 Volts.
Query Syntax	CV?
Returned Parameters	TEXT ON: <NR2> volts TEXT OFF: <NR2>

DU *Duty Cycle*

Description	This command is used to set the Duty Cycle for square wave pulsing. This defines the percentage of peak pulse time and will set the Pulsing Base Time (T1) and Pulsing Peak Time (T2) accordingly based upon the defined frequency.
Command Syntax	DU <NR2>
Example	DU 40.0 This will set the duty cycle to 40%. If the frequency was 100Hz meaning a pulse period of 10,000µs, T2 will be set to 4000µs and T1 will be set to 6000µs.
Query Syntax	DU?
Returned Parameters	TEXT ON: <NR2> % TEXT OFF: <NR2>

ERR? *Error Register*

Description

This query returns the contents of the Error register and then clears its contents. The response is either numeric or a text description depending on the TEXT ON/OFF and STATXT ON/OFF settings.

This register contains information about command errors and serves a function that is similar to the Error Status Register (*ESR?) in the IEEE-488.2 status structure. This query is provided for backward compatibility with systems designed to use the pre-IEEE 488.2 status structure.

The value in this register is a number between 0 and 255 and is the sum of the individual bit weights as defined below.

Bit	Weight	Description	Text On Response Message
7	128	—	—
6	64	—	—
5	32	Command not allowed	NOT ALLOWED
4	16	Command too long	TOO LONG
3	8	Numeric Error	NUMERIC
2	4	—	—
1	2	Out of Range	RANGE
0	1	Unrecognized Command	UNRECOGNIZED

The text response will return a string containing the Text On Response Message as listed above for each bit that is set. These will be separated by commas. If no bits are set, "NO COMMAND ERROR" will be returned.

Command Syntax	NONE
Example	N/A
Query Syntax	ERR?
Returned Parameters	TEXT ON and STATXT ON: <text response string> TEXT OFF or STATXT OFF: <NR1>

ESE

See **ESE* on page 56.

ESR

See **ESR?* on page 57.

ET RST *Elapsed Time Reset*

Description	This command resets the Elapsed Timer.
Command Syntax	ET RST
Example	ET RST This will reset the load connect Elapsed Timer.
Query Syntax	NONE
Returned Parameters	N/A

ET? *Elapsed Time*

Description	This query returns the amount of elapsed time the load connect relay has been closed since the load was powered on or the timer was reset. The Text On response returns a abbreviated string with hours, minutes and seconds. The Text Off response returns decimal hours.
Command Syntax	NONE
Example	N/A
Query Syntax	ET?
Returned Parameters	TEXT ON: Elapsd hh:mm:ss TEXT OFF: <NR2>

FQ *Frequency*

Description	This command is used to set the Frequency in Hertz for square wave pulsing. The Pulsing Base Time (T1) and Pulsing Peak Time (T2) will be adjusted accordingly based upon the defined duty cycle.
Command Syntax	FQ <NR2>
Example	FQ 1000.0 This will set the frequency to 1000Hz. If the duty cycle was 30%, T2 will be set to 300µs and T1 will be set to 700µs.
Query Syntax	FQ?
Returned Parameters	TEXT ON: <NR2> Hz TEXT OFF: <NR2>

I? *Read Current*

Description	This query returns the actual current reading in Amps passing through the load.
Command Syntax	NONE
Example	N/A
Query Syntax	I?
Returned Parameters	TEXT ON: <NR2> amps TEXT OFF: <NR2>

I1 *Constant Current Pulsing Base Level*

Description	This command is used to set the base level when pulse loading in the Constant Current mode.
Command Syntax	I1 <NR2>
Example	I1 10.5 This will set the base Constant Current level to 10.5 Amps.
Query Syntax	I1?
Returned Parameters	TEXT ON: <NR2> amps TEXT OFF: <NR2>

I2 *Constant Current Pulsing Peak Level*

Description	This command is used to set the peak level relative to the base level when pulse loading in the Constant Current mode.
Command Syntax	I2 <NR2>
Example	I2 25.0 This will set the peak level to 25 Amps above the base level. Therefore if the base level setting is 10.5A, the peaks will be 35.5 Amps.
Query Syntax	I2?
Returned Parameters	TEXT ON: <NR2> amps TEXT OFF: <NR2>

ID? *Identification*

Description	This query returns the load's model identification string that includes its rated Voltage, power and current in the format: RBL <rated Voltage>-<rated power>-<rated current>
Command Syntax	NONE
Example	N/A
Query Syntax	ID?
Returned Parameters	RBL <Voltage>-<current>-<power>

IDN

See **IDN?* on page 58.

IL *Current Limit*

Description	This command is used to set the Current Limit set point. The Current Limit circuit will not allow the load current to exceed this level.
Command Syntax	IL <NR2>
Example	IL 50.0 This will set the Current Limit to 50 Volts.
Query Syntax	IL?
Returned Parameters	TEXT ON: <NR2> amps TEXT OFF: <NR2>

IST? *Internal Self Test*

Description	This command is provided for backwards compatibility with the earlier DCL models. No internal tests are performed so it always returns a response indicating the test has passed.
Command Syntax	NONE
Example	N/A
Query Syntax	IST?
Returned Parameters	TEXT ON: IST : 0 TEXT OFF: 0

LAT *Latch register*

Description	This command provides access to the Latch register. The bits in this register define which bits of the Condition (CON) register will latch on if set until the CON register is read. Setting one bit by writing its bit weight into the LAT register enables its equivalent bit in the CON register. The individual bits are defined below. More than one bit can be enabled by writing a value that is a sum of the individual bit weights. The Over Voltage and Over Temperature bits in this register will remain set regardless of what value is written to this register. The value in this register is a number between 0 and 255 and is the sum of the individual bit weights as defined below.

Bit	Weight	Description	Text On Response Message	Default Value
7	128	Under Voltage	UV	0
6	64	Over Voltage	OV	0
5	32	Over Temperature	OT	0
4	16	—	—	0
3	8	Over Current	OC	0
2	4	Over Power	OP	0
1	2	Saturation	SAT	0
0	1	Module Fault	MOD FLT	0

	The query form of this command will either return a numeric or a text response depending on the TEXT ON/OFF and STATXT ON/OFF settings. The text response will return a string containing the Text On Response Message as listed above for each bit that is set. These will be separated by commas. If no bits are set “CLEAR” will be returned.
Command Syntax	LAT <NR1>
Example	LAT 12 This will write the value of 12 into the LAT register. This enables bit 2 (Over Power) and bit 3 (Over Current) in the CON register so that if either is set they will remain set until the CON register is read or a *CLS command is received. Since the Over Voltage and Over Temperature bits remain unaffected these will remain enabled. Therefore the value in the LAT after this command will be 108.
Query Syntax	LAT?
Returned Parameters	TEXT ON and STATXT ON: <text response string> TEXT OFF or STATXT OFF: <NR1>

LOAD *Load On/Off Control*

Description	This command is used to instruct to load to close its load connect relay and apply loading, or to open its connect relay removing the load from the device under test.
Command Syntax	LOAD ON LOAD OFF
Example	LOAD ON This will close the load connect relay and start loading the device under test at the programmed settings. LOAD OFF This will open the load connect relay and stop loading.
Query Syntax	LOAD?
Returned Parameters	TEXT ON: LOAD ON LOAD OFF TEXT OFF: 1 (meaning On) 0 (meaning Off)

LOCK *Front Panel Lock*

Description	This command is used to lock or unlock the load's front panel. When locked, manual operation through the load's front panel is inhibited.
Command Syntax	LOCK ON LOCK OFF
Example	LOCK ON This will lock the front panel. LOCK OFF This will unlock the front panel.
Query Syntax	LOCK?
Returned Parameters	Text On: LOCK ON LOCK OFF Text Off: 1 (meaning On) 0 (meaning Off)

MODE? *Operating Mode*

Description

This query returns the load's operating mode. The response is either numeric or a text description depending on the TEXT ON/OFF and STATXT ON/OFF settings. The returned value will be the sum of the individual bit weights of the mode plus any mode modifiers. The individual bits are defined below.

Mode Modifiers

Bit	Weight	Description	Text On Response Message
8	256	Pulsing	PULSING
7	128	External Modulation	EXTERNAL MODULATION

Operating Modes

Bit	Weight	Description	Text On Response Message
6	64	Slave Mode	SLAVE
5	32	Constant Amps/Volt High	CONSTANT AMPS/VOLT HIGH
4	16	Constant Amps/Volt Low	CONSTANT AMPS/VOLT LOW
3	8	Constant Resistance High	CONSTANT RESISTANCE HIGH
2	4	Constant Resistance Low	CONSTANT RESISTANCE LOW
1	2	Constant Power	CONSTANT POWER
0	1	Constant Voltage	CONSTANT VOLTAGE
Default		Constant Current	CONSTANT CURRENT

The text response will return a string containing the Text On Response Message as listed above for each bit that is set. These will be separated by commas. If none of the mode bits are set, "CONSTANT CURRENT" will be returned as the mode.

Command Syntax	NONE
Example	N/A
Query Syntax	MODE?
Returned Parameters	TEXT ON and STATXT ON: <text response string> TEXT OFF or STATXT OFF: <NR1>

MR *Memory Recall*

Description	This command recalls the load's setup stored in the specified memory location. The memory location number must be a value from 1 through 9.
Command Syntax	MR <NR1>
Example	MR 3 This will recall the setup stored in memory location 3.
Query Syntax	NONE
Returned Parameters	N/A

MS *Memory Save*

Description	This command saves the load's setup into the specified memory location. The memory location number must be a value from 1 through 9.
Command Syntax	MS <NR1>
Example	MS 3 This will store the load's current setup in memory location 3.
Query Syntax	NONE
Returned Parameters	N/A

OPC

See **OPC* on page 59.

P? *Read Power*

Description	This query returns the computed load power in Watts. This value is computed from the load's current (I?) and Voltage (V?) readings.
Command Syntax	NONE
Example	N/A
Query Syntax	P?
Returned Parameters	TEXT ON: <NR2> watts TEXT OFF: <NR2>

P1 *Constant Power Pulsing Base Level*

Description	This command is used to set the base level when pulse loading in the Constant Power mode.
Command Syntax	P1 <NR2>
Example	P1 25.3 This will set the base Constant Power level to 25.3 Watts.
Query Syntax	P1?
Returned Parameters	TEXT ON: <NR2> watts TEXT OFF: <NR2>

P2 *Constant Power Pulsing Peak Level*

Description	This command is used to set the peak level relative to the base level when pulse loading in the Constant Power mode.
Command Syntax	P2 <NR2>
Example	P2 20.0 This will set the peak level to 20 Watts above the base level. Therefore if the base level setting is 25.3, the peaks will be 45.3 Watts.
Query Syntax	P2?
Returned Parameters	TEXT ON: <NR2> watts TEXT OFF: <NR2>

PL *Power Limit*

Description	This command is used to set the Power Limit set point. The Power Limit circuit will not allow the load power to exceed this level.
Command Syntax	PL <NR2>
Example	PL 250.0 This will set the Power Limit to 250 Watts.
Query Syntax	PL?
Returned Parameters	TEXT ON: <NR2> watts TEXT OFF: <NR2>

R1 *Constant Resistance Pulsing Base Level*

Description	This command is used to set the base level when pulse loading in the Constant Resistance mode. **NOTE:** CRH or CRL must have been previously set.
Command Syntax	R1 <NR2>
Example	R1 10.0 This will set the base resistance to 10 Ohms.
Query Syntax	R1?
Returned Parameters	TEXT ON: <NR2> ohms TEXT OFF: <NR2>

R2 *Constant Resistance Pulsing Peak Level*

Description	This command is used to set the peak level relative to the base level when pulse loading in the Constant Resistance mode. This resistance will be applied in parallel to the base resistance. **NOTE:** CRH or CRL must have been previously set.
Command Syntax	R2 <NR2>
Example	R2 1.1 This will set the peak level to 1.1 Ohms that will be applied in parallel with the base level. Therefore if the base level setting is 10 Ohms, the peaks will be 0.99 Ohm.
Query Syntax	R2?
Returned Parameters	TEXT ON: <NR2> ohms TEXT OFF: <NR2>

RNG _Range_

Description

This command is used to set the load's Voltage and current range settings. This is done by writing a value from 1 through 9 as indicated below.

Range Number	Voltage	Current
1	High	High
2	Medium	High
3	Low	High
4	High	Medium
5	Medium	Medium
6	Low	Medium
7	High	Low
8	Medium	Low
9	Low	Low

The Query form of this command returns actual operating range. This can be different than the range setting when the load is connected in the master/slave arrangement. The range setting can be read back by the RNGS? query.

The text response to a query will be a string specifying the Voltage and current ranges. The numeric response will be the range number.

Command Syntax	RNG <NR1>
Example	RNG 2 This will set the load to the medium Voltage and high current range.
Query Syntax	RNG?
Returned Parameters	TEXT ON: <V range> VOLT, <I range> AMP TEXT OFF: <NR1>

RNGS? *Range Setting*

Description	This query returns the range setting. This can differ from the actual operating range when the load is connected in a master/slave arrangement. In a master/slave arrangement, all units will operate in the lowest current range selected on any of the loads regardless of it being the master or one of the slaves

Range Number	Voltage	Current
1	High	High
2	Medium	High
3	Low	High
4	High	Medium
5	Medium	Medium
6	Low	Medium
7	High	Low
8	Medium	Low

The text response to a query will be a string specifying the Voltage and current ranges. The numeric response will be the range number.

Command Syntax	NONE
Example	N/A
Related Query	RNGS?
Returned Parameters	TEXT ON: <V range> VOLT, <I range> AMP TEXT OFF: <NR1>

RST *Reset*

Also see **RST Reset* on page 60 for the IEEE-488.2 version of this command.

Description	This command resets the load to its factory default power-on settings.
Command Syntax	RST
Example	RST This will reset the load to its factory default power-on settings.
Related Query	NONE
Returned Parameters	N/A

S1 *Rising Slew Rate*

Description	This command is used to set the rise time in microseconds for a full-scale transition within the selected range. **NOTE:** Unless different rising and falling slew limits are required, it is recommended that the SR command be used to set both limits simultaneously. If the rising limit is not the same as the falling limit, the load set point will have small offset errors.
Command Syntax	S1 <NR2>
Example	S1 500.0 Sets the rise time to 500 microseconds for a zero to full-scale transition within the selected range.
Query Syntax	S1?
Returned Parameters	TEXT ON: <NR2> us zero to full TEXT OFF: <NR2>

S2 *Falling Slew Rate*

Description	This command is used to set the fall time in microseconds for a full-scale transition within the selected range. **NOTE:** Unless different rising and falling slew limits are required, it is recommended that the SR command be used to set both limits simultaneously. If the rising limit is not the same as the falling limit, the load set point will have small offset errors.
Command Syntax	S2 <NR2>
Example	S2 500.0 Sets the rise time to 500 microseconds for a full-scale to zero transition within the selected range.
Query Syntax	S2?
Returned Parameters	TEXT ON: <NR2> us full to zero TEXT OFF: <NR2>

SBE *Summary Bit Enable register*

Description

This command provides access to the Summary Bit Enable register. The bits in this register define which bits of the Condition (CON) register will set the Major Fault and Minor Fault summary bits in the Status Byte (STB) and the Status Register (STA). Setting one bit by writing its bit weight into the SBE register enables its equivalent bit in the CON register. The individual bits are defined below. More than one bit can be enabled by writing a value that is a sum of the individual bit weights.

Bit	Weight	Description	Text On Response Message	Default Value
7	128	Under Voltage	UV	1
6	64	Over Voltage	OV	1
5	32	Over Temperature	OT	1
4	16	—	—	0
3	8	Over Current	OC	1
2	4	Over Power	OP	1
1	2	Saturation	SAT	1
0	1	Module Fault	MOD FLT	1

The query form of this command will either return a numeric or a text response depending on the TEXT ON/OFF and STATXT ON/OFF settings. The text response will return a string containing the Text On Response Message as listed above for each bit that is set. These will be separated by commas. If no bits are set “CLEAR” will be returned.

Command Syntax

SBE <NR1>

Example

SBE 12
This will write the value of 12 into the SBE register. This enables bit 2 (Over Power) and bit 3 (Over Current) in the CON register so that if either is set the relevant summary bit(s) in the STB and STA register will be set.

Related Query

SBE?

Returned Parameters

TEXT ON and STATXT ON: <text response string>

TEXT OFF or STATXT OFF: <NR1>

SDN *Shutdown register*

Description	This command provides access to the Shutdown register. The bits in this register define which bits of the Condition (CON) register will cause the load to shutdown. Setting one bit by writing its bit weight into the SDN register enables its equivalent bit in the CON register. The individual bits are defined below. More than one bit can be enabled by writing a value that is a sum of the individual bit weights. The Over Voltage and Over Temperature bits in this register will remain set regardless of what value is written to this register.

Bit	Weight	Description	Text On Response Message	Default Value
7	128	Under Voltage	UV	0
6	64	Over Voltage	OV	1
5	32	Over Temperature	OT	1
4	16	—	—	0
3	8	Over Current	OC	0
2	4	Over Power	OP	0
1	2	Saturation	SAT	0
0	1	Module Fault	MOD FLT	0

The query form of this command will either return a numeric or a text response depending on the TEXT ON/OFF and STATXT ON/OFF settings. The text response will return a string containing the Text On Response Message as listed in the table above for each bit that is set. These will be separated by commas. If no bits are set "CLEAR" will be returned.

Command Syntax	SDN <NR1>
Example	SDN 12 This will write the value of 12 into the SBE register. This enables bit 2 (Over Power) and bit 3 (Over Current) in the CON register so that if either becomes set the load will shutdown. Since the Over Voltage and Over Temperature bits remain unaffected these will remain enabled. Therefore the value in the SDN register after this command will be 108.
Related Query	SDN?
Returned Parameters	TEXT ON and STATXT ON: <text response string> TEXT OFF or STATXT OFF: <NR1>

SF *Slew Fast*

Set for fast slew range

Description	This command is used to set the slew rate limiter to the fast range. In the fast range, full-scale rise and fall times can be programmed between 10µs and 4000µs using the SR, S1 or S2 commands. **NOTE:** Maximum slew rate is highly dependent on factors including power source, source to load wiring, and operating mode.
Command Syntax	SF
Example	SF Sets the slew rate limiter to the fast range.
Query Syntax	NONE
Returned Parameters	NONE

SHORT *Short Circuit*

Description	This command is used to apply or remove a simulated short circuit from the device being tested while the load connect relay is closed. **CAUTION:** ***This function is intended for use only when testing current limited power sources. Use of the Short Circuit feature with power sources which do not limit their current to values within the load's ratings could result in damage to the load or device under test, FIRE or EXPLOSION.***
Command Syntax	SHORT ON SHORT OFF
Example	SHORT ON This will apply a simulated short circuit at the load's input terminals. SHORT OFF This will remove the simulated short circuit from the load's input terminals.
Query Syntax	SHORT?
Returned Parameters	Text On: SHORT ON SHORT OFF Text Off: 0 (meaning Off) 1 (meaning On)

SLAVE *Slave Mode*

Description	This command is used to put the load in slave mode. In slave mode the load will mimic the operation of the master. The unit will exit slave mode should any other operating mode be selected.
Command Syntax	SLAVE
Example	SLAVE This will place the unit in slave mode.
Query Syntax	NONE
Returned Parameters	N/A

SR *Slew Rate*

Description	This command is used to set both the rise and fall time in microseconds for a full-scale transition within the selected range. The query form of this command returns the Rising Slew Rate (S1). The rising and falling slew rates should be identical as long as the S1 and S2 commands are not used.
Command Syntax	SR <NR2>
Example	SR 200 Sets the rise or fall time for a full-scale transition to 200 microseconds.
Query Syntax	SR?
Returned Parameters	TEXT ON: <NR2> us TEXT OFF: <NR2>

SRE

See **SRE Service Request Enable register* on page 61.

SRQ *Service Request Register*

Description

This command provides access to the Service Request register. In IEEE-488 equipped units the bits in this register define which bits of the Status Register (STA) will generate a service request. A query form is provided so the setting can be read back.

The function of this register is similar to that of the Service Request Enable (*SRE) register in the IEEE-488.2 status structure. This query is provided for backward compatibility with systems designed to use the pre-IEEE-488.2 status structure.

The value in this register is a number between 0 and 255 and is the sum of the individual bit weights as defined below.

Bit	Weight	Description	Text On Response Message
7	128	Reserved	RESERVED
6	64	Change In Status	STA CHANGE
5	32	Single Shot Complete	SINGLE SHOT COMPLETE
4	16	Command Error	COMMAND ERROR
3	8	Minor Fault	MINOR FAULT
2	4	Major Fault	MAJOR FAULT
1	2	System Minor Fault	SYSTEM MINOR
0	1	System Major Fault	SYSTEM MAJOR

The query form of this command will either return a numeric or a text response depending on the TEXT ON/OFF and STATXT ON/OFF settings. The text response will return a string containing the Text On Response Message as listed above for each bit that is set. These will be separated by commas. If no bits are set “CLEAR” will be returned.

Command Syntax

SRQ <NR1>

Example

SRQ 12
This will write the value of 12 into the SRQ register. This enables bit 2 (Major Fault) and bit 3 (Minor Fault) in the STA register so that if either is set a service request will be generated.

Query Syntax

SRQ?

Returned Parameters

TEXT ON and STATXT ON: <text response string>

TEXT OFF or STATXT OFF: <NR1>

SS *Slew Slow*

Description	This command is used to set the slew rate limiter to the slow range. In the slow range, full-scale rise and fall times can be programmed between 1,000µs and 400,000µs using the SR, S1 or S2 commands. **NOTE:** Maximum slew rate is highly dependent on factors including power source, source to load wiring and operating mode.
Command Syntax	SS
Example	SS Sets the slew rate limiter to the slow range.
Query Syntax	NONE
Returned Parameters	NONE

STA? *Status Register*

<table>
<tr><td>Description</td><td>
This query returns the contents of the Status register and then clears its contents. The response is either numeric or a text description depending on the TEXT ON/OFF and STATXT ON/OFF settings.
This register contains summary status information and serves a function that is similar to the Status Byte (*STB?) in the IEEE 488.2 status structure. This query is provided for backward compatibility with systems designed to use the pre-IEEE 488.2 status structure.
The value in this register is a number between 0 and 255 and is the sum of the individual bit weights as defined below.
<table>
<tr><th>Bit</th><th>Weight</th><th>Description</th><th>Text On Response Message</th></tr>
<tr><td>7</td><td>128</td><td>Reserved</td><td>RESERVED</td></tr>
<tr><td>6</td><td>64</td><td>Change In Status</td><td>STA CHANGE</td></tr>
<tr><td>5</td><td>32</td><td>Single Shot Complete</td><td>SINGLE SHOT COMPLETE</td></tr>
<tr><td>4</td><td>16</td><td>Command Error</td><td>COMMAND ERROR</td></tr>
<tr><td>3</td><td>8</td><td>Minor Fault</td><td>MINOR FAULT</td></tr>
<tr><td>2</td><td>4</td><td>Major Fault</td><td>MAJOR FAULT</td></tr>
<tr><td>1</td><td>2</td><td>System Minor Fault</td><td>SYSTEM MINOR</td></tr>
<tr><td>0</td><td>1</td><td>System Major Fault</td><td>SYSTEM MAJOR</td></tr>
</table>
The text response will return a string containing the Text On Response Message as listed above for each bit that is set. These will be separated by commas. If no bits are set, “CLEAR” will be returned.
</td></tr>
<tr><td>Command Syntax</td><td>NONE</td></tr>
<tr><td>Example</td><td>N/A</td></tr>
<tr><td>Query Syntax</td><td>STA?</td></tr>
<tr><td>Returned Parameters</td><td>TEXT ON and STATXT ON: <text response string>

TEXT OFF or STATXT OFF: <NR1></td></tr>
</table>

STB

See **STB? Status Byte* on page 62.

STATXT *Status Text*

Description	This command is used to turn off descriptive responses for the CON?, ERR?, LAT?, SBE?, SDN?, SRQ? and STA? queries without affecting other Text Mode responses. This allows the status related registers to be read in an easily decoded numeric form while all other queries retain their descriptive responses. This differs from the TEXT ON/OFF command in that it only applies to the status related queries while TEXT ON/OFF applies to all queries. Both the STATXT and TEXT must be on for descriptive responses to the above queries. Unlike most other commands, the load will retain its STATXT setting even after powering it down.
Command Syntax	STATXT ON STATXT OFF
Example	STATXT ON This will enable descriptive responses to the CON?, ERR?, LAT?, SBE?, SDN?, SRQ? and STA? queries provided Text Mode is also on. STATXT OFF This will force a numerical responses to the CON?, ERR?, LAT?, SBE?, SDN?, SRQ? and STA? queries regardless of the Text Mode setting.
Query Syntax	STATXT?
Returned Parameters	Text On: STATXT ON STATXT OFF Text Off: 1 (meaning On) 0 (meaning Off)

SW *Square Wave Pulsing*

Description	This command is used to turn on and off Square Wave pulsing. It functions exactly the same as the WF command with all the same forms. This is done to provide compatibility with other model types. Supplying the optional parameter sets the number of pulses that will be generated. The load will automatically return to the base drive level when the set number of pulses has completed.
Command Syntax	SW [<NR1>] SW OFF
Example	SW This will turn on Square Wave pulsing until explicitly turned off. SW 50 This will turn on Square Wave pulsing for 50 pulses and then return to the base drive level. SW OFF This will turn off Square Wave pulsing.
Query Syntax	NONE
Returned Parameters	Text On: SW ON SW OFF Text Off 1 (meaning On) 0 (meaning Off)

T1 *Pulsing Base Time*

Description	This command is used to directly set the base time in microseconds for square wave pulsing. This will also set the Duty Cycle (DU) and Frequency (FQ) accordingly based upon the Pulsing Peak Time (T2).
Command Syntax	T1 <NR1>
Example	T1 2000 This will set the pulse base time to 2000µs. If T2 were 3000µs, the duty cycle (DU) would be 60% and frequency would be 200Hz.
Query Syntax	T1?
Returned Parameters	TEXT ON: <NR1> us TEXT OFF: <NR1>

T2 *Pulsing Peak Time*

Description	This command is used to directly set the peak time in microseconds for square wave pulsing. This will also set the Duty Cycle (DU) and Frequency (FQ) accordingly based upon the Pulsing Base Time (T1).
Command Syntax	T2 <NR1>
Example	T2 4000 This will set the pulse base time to 4000µs. If T1 were 6000µs, the duty cycle (DU) would be 40% and frequency would be 100Hz.
Query Syntax	T2?
Returned Parameters	TEXT ON: <NR1> us TEXT OFF: <NR1>

TEXT *Text Mode*

Description	This command is used to turn on or off the descriptive responses that are available on many queries.
Command Syntax	TEXT ON TEXT OFF
Example	TEXT ON This will turn on the descriptive responses. TEXT OFF This will turn off the descriptive responses.
Query Syntax	TEXT?
Returned Parameters	Text On: TEXT ON Text Off: 0 (meaning Off)

TST

See **TST? Test* on page 63.

UV *Under Voltage*

Description	This command is used to set the Programmable Under Voltage threshold. When the input voltage drops below this threshold the load will disconnect from the device under test and indicate an Under Voltage fault. Unlike the hardware Under Voltage, the load will not automatically reconnect when the Voltage rises above the threshold. Setting the Programmable Under Voltage to zero will disable it. The programmable Under Voltage operation is not affected by the UV bit in the Shutdown (SDN) register.
Command Syntax	UV <NR2>
Example	UV 9.6 This will set the Programmable Under Voltage to 9.6 Volts. The load will shutdown if the Voltage on its input terminals drops below this threshold. UV 0 This will disable the Programmable Under Voltage feature.
Query Syntax	UV?
Returned Parameters	Text On: <NR2> volts Text Off: <NR2>

V? *Read Voltage*

Description	This query returns the actual Voltage in Volts measured at the load's Voltage sense terminals. **NOTE:** If remote Voltage sensing is not used, this voltage may differ from the output voltage of the device. This is due to the Voltage drops in the conductors between the load and the device under test. Therefore remote voltage sensing is recommended when high currents are involved.
Command Syntax	NONE
Example	N/A
Query Syntax	V?
Returned Parameters	TEXT ON: <NR2> volts TEXT OFF: <NR2>

V1 *Constant Voltage Pulsing Base Level*

Description	This command is used to set the base level when pulse loading in the Constant Voltage mode. **NOTE:** When pulsing in constant voltage mode, higher voltage corresponds to less drive. Therefore, V1 is a higher value than V2.
Command Syntax	V1 <NR2>
Example	V1 75.0 This will set the base Constant Voltage level to 75.0 Volts.
Query Syntax	V1?
Returned Parameters	TEXT ON: <NR2> volts TEXT OFF: <NR2>

V2 *Constant Voltage Pulsing Peak Level*

Description	This command is used to set the peak level relative to the base level when pulse loading in the Constant Voltage mode. In Constant Voltage, peak refers to peak drive hence lower Voltage. Therefore the peak level this command specifies is the Voltage to be subtracted from the base level (V1).
Command Syntax	V2 <NR2>
Example	V2 24.3 This will set the peak level to 24.3 Volts below the base level. Therefore if the base level setting is 75.0, the peaks will be 50.7 Volts.
Query Syntax	V2?
Returned Parameters	TEXT ON: <NR2> volts TEXT OFF: <NR2>

VER? *Version*

Description	This query returns the load's firmware version as a variable length alphanumeric string.
Command Syntax	NONE
Example	N/A
Query Syntax	VER?
Returned Parameters	<version string>

VL *Voltage Limit*

Description	This command is used to set the Voltage Limit trip level. The load will disconnect from the device under test if the Voltage exceeds this level.
Command Syntax	VL <NR2>
Example	VL 16.5 This will set the Voltage Limit to 16.5 Volts.
Query Syntax	VL?
Returned Parameters	TEXT ON: <NR2> volts TEXT OFF: <NR2>

WAI

See **WAI Wait* on page 63.

WF *Waveform*

Description	This command is used to turn on and off Square Wave pulsing. It functions exactly the same as the SW command with all the same forms. This is done to provide compatibility with other model types. Supplying the optional parameter sets the number of pulses that will be generated. The load will automatically return to the base drive level when the set number of pulses has completed.
Command Syntax	WF [<NR1>] WF OFF
Example	WF This will turn on Square Wave pulsing until explicitly turned off. WF 50 This will turn on Square Wave pulsing for 50 pulses and then return to the base drive level. WF OFF This will turn off Square Wave pulsing.
Query Syntax	NONE
Returned Parameters	Text On: WF ON WF OFF Text Off: 1 (meaning On) 0 (meaning Off)

XM *External Modulation*

Description	This command places the load in Remote Programming mode. In this mode a 0 to 10V signal at the load's Remote Programming Input terminal on the back of the unit will program the load from zero to full scale of the selected range. This is inverted when in Constant Voltage mode so that zero programs full scale while 10V programs zero. When in Constant Current mode a digitally programmed offset current can be specified. This is done using the "XM PLUS <NR2>" syntax. "XM + <NR2>" is an alternate syntax that can be used as well. In any mode other than Constant Current the offset specification will be ignored. The query form of this command returns only the XM ON/OFF status. The digitally programmed current offset issued with a XM PLUS (or XM +) command can be read back using either a CI? or I1? query.
Command Syntax	XM ON XM OFF XM PLUS <NR2> or XM + <NR2>
Example	XM ON This will place the load in Remote Programming mode. XM PLUS 45.0 (or XM + 45.0) When in Constant Current mode this will place the load into Remote Programming and apply a digitally programmed offset of 45 Amps. In any mode other than Constant Current it will act the same as the XM ON command. XM OFF This turns off Remote Programming and resumes internal digitally programmed operation.
Query Syntax	XM?
Returned Parameters	Text On: EXTERNAL MODULATION ON EXTERNAL MODULATION OFF Text Off: 1 (meaning On) 0 (meaning Off)

Status and Event Registers

The load status structure illustration (refer to Figure 12) shows the logical relationship between the various status registers. Most of these registers are defined in the IEEE-488.2 specifications however the CON (Condition) register and its SBE (Summary Bit Enable) enable register are device dependent. Bit 2 in the IEEE-488.2 Status Byte (*STB) has been defined to provide a summary indication of a Major Fault indicated in the CON register. Accordingly Bit 3 has been defined to provide a summary indication of a Minor Fault.

The power-on value for the SBE (Summary Bit Enable) register is 239. This enables all Major and all Minor faults represented in the CON (Condition) register to set their respective bit in the Status Byte (*STB).

The power-on value for the Event Status Enable (*ESE) register is zero. This means no bits of the Event Status Register (*ESR) will set the Event Summary Bit (ESB, bit 5) in the Status Byte (*STB). To enable any of the Event Status Register bits so they will set the summary bit, the appropriate value needs to be written into the event status enable register.

The power-on value for the Service Request Enable (*SRE) register is zero. This means no bits of the Status Byte (*STB) will generate a service request. To enable any of the Status Byte bits so they will generate a service request, the appropriate value needs to be written into the Service Request Enable Register.

In addition to the registers shown in the status structure diagram there are two other registers that affect the behavior of the load when a fault condition occurs. These are the LAT (Latch) and the SDN (Shutdown) registers.

The Latch (LAT) register defines which bits of the CON (Condition) register will latch on until the CON register is read. Otherwise the CON register bit will clear automatically when the fault condition clears. The default value of the LAT register is zero. This means any bit indicating a fault in the CON register will clear when the fault condition goes away.

The Shutdown (SDN) register defines which bits of the CON (Condition) register will cause the load to open its load connect relay and latch in the off condition (shutdown). The default value for the SDN register is 96. This means that an Over Voltage or Over Temperature indicating in the CON register will cause a shutdown.

For further information see SBE, CON, *ESE, *ESR, *SRE, *STB, LAT and SDN in the Detail Language Elements section.

> **NOTE:**
> See *Appendix C — Legacy Status Structure* for information about the pre IEEE-488.2 Status and Event Registers.

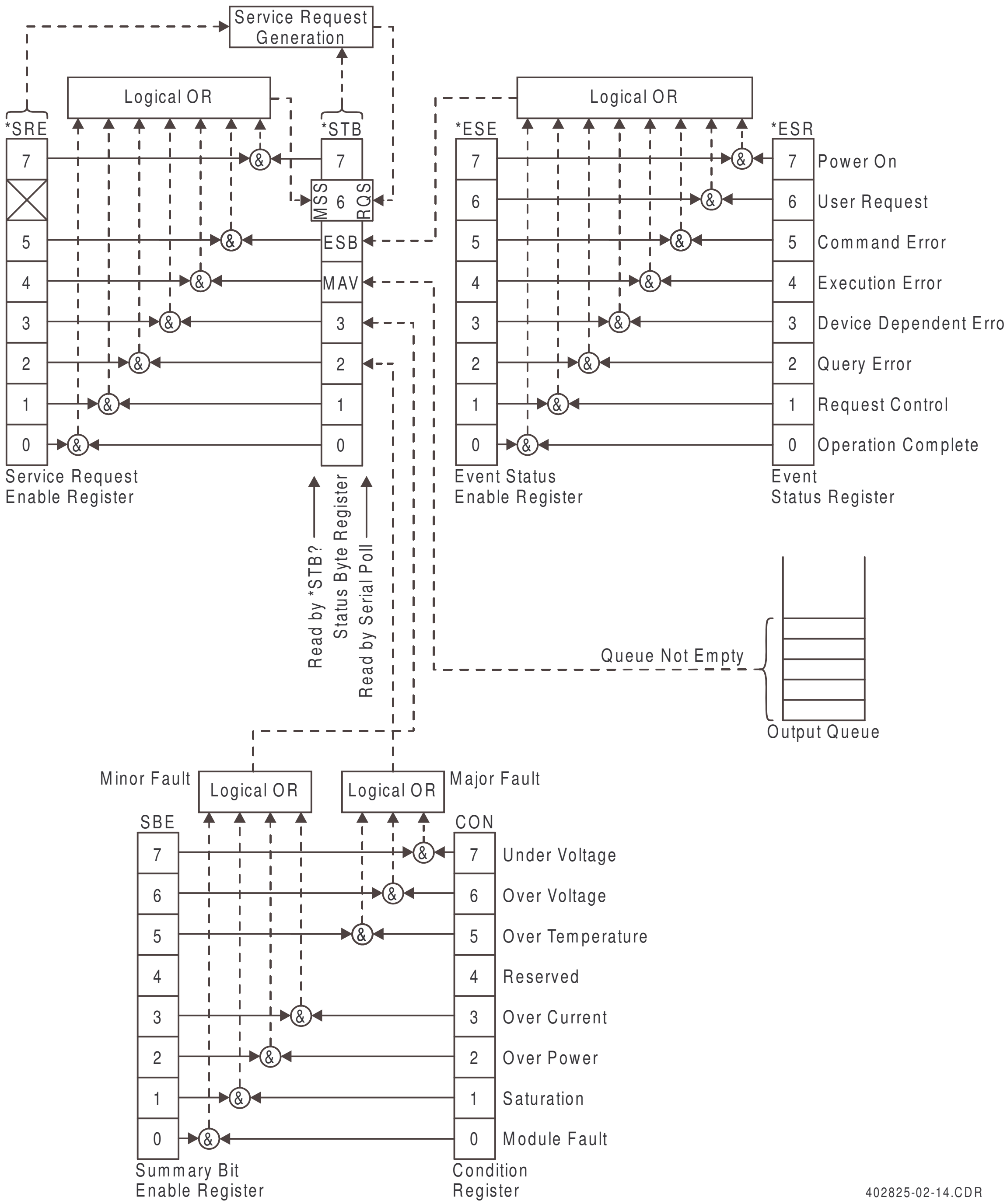


Figure 12. Load Status Structure

Glossary

This glossary includes explanations and definitions of terms that may be found in this manual or encountered while working with the Dynaload. Many of these words are commonly used in electrical, electronic and computer related technologies.

A

AC	*Alternating Current.*
AC Power Supply	Power supply that delivers an AC voltage.
A/D Conversion	*Analog-To-Digital Conversion.* The process of changing an analog signal into a digital value.
Alternating Current	Electric current that rises to a maximum in one direction, falls back to zero, and then rises to a maximum in the opposite direction and then repeats.
Ammeter	Instrument for measuring the current in amps, milliamps or microamps.
Ampere	Also referred to as an Amp. The unit of electrical current (represented by the symbol “A”).
Amplitude	The highest value reached by voltage, current or power during a complete cycle.
Analog	System in which data is represented as a continuously varying voltage. Also spelled *Analogue*.
ANSI	*American National Standards Institute.*
ASCII	*American Standard Code for Information Interchange*. Standardized method of encoding alphanumeric characters into 7 or 8 binary bits.

Apparent Power Power attained in an AC circuit as a product of effective voltage and current (which reach their peak at different times).

Astable Circuit that does not have a stable state and as a result oscillates at a frequency dependent upon component values.

AWG *American Wire Gauge.* A system that assigns a number value to the diameter of a wire.

B

Base One terminal of a transistor that is usually the input lead. It separates the collector and emitter regions of a transistor.

Battery DC voltage source containing two or more cells that convert chemical energy to electrical energy.

Baud Unit of signaling speed equal to the number of signal events per second.

Binary System based on the number 2. (The binary digits are 0 and 1.)

Binary-Coded Decimal Code for representing decimal digits in a binary format. Also referred to as *BCD*.

Bit *Binary Digit*. Smallest unit of binary data.

Bleeder Current Current drawn continuously from a source and is used to stabilize the output voltage of a source.

Bus In Electricity. A bus bar.
In Computer Science. A parallel circuit that connects the major components of a computer, allowing the transfer of electric impulses from one connected component to any other.

Byte A sequence of adjacent bits operated on as a unit by a computer.

C

Capacitance Ability of a capacitor to store an electrical charge. The basic unit of capacitance is the Farad.

Capacitor Electronic component that stores an electrical charge.

Cascade Method of connecting circuits in series so that the output of one is the input of the next.

Charge Quantity of electrical energy.

Chassis Metal box or frame into which components are mounted.

Chassis Ground Connection to a chassis.

Choke Inductor designed to present a high impedance to alternating current.

Circuit Interconnection of components to provide an electrical path between two or more components

Circuit Breaker Protective device used to open a circuit when current is greater than a maximum value. A circuit breaker acts as a reusable fuse.

Circuit Diagram Structural or procedural diagram of an electrical system. Also see Schematic.

Closed Circuit Circuit having a complete path for current flow.

Coil Conductor wound in a series of turns.

Collector One of three terminals of a transistor.

Continuity The state that occurs when a complete path for current is present.

Current Passage of electrons measured in amps (milliamps and microamps).

D

D/A Conversion *Digital-To-Analog Conversion.* Translating discrete data into continuously varying signals.

DC *Direct Current.* Current that flows in one direction.

DC Power Supply Any source of DC power for electrical equipment.

Digital Electronics Branch of electronics dealing with information in binary form.

Distortion Amount by which a circuit or component fails to accurately reproduce the characteristics of the input.

Duplex Transmission Ability to both send and receive data at the same time over the same communications line.

E

Earth *Ground.* Connection to the earth itself or the negative lead to a chassis or to any point to zero voltage.

Electron Flow Direction in which electrons flow (from negative to positive since electrons are negatively charged).

EMF *Electromotive Force.* Force that causes the motion of electrons due to potential difference between two points (voltage).

Emitter One of three terminals of a transistor.

F

Farad	Basic measuring unit of capacitance.
Feedback	Portion of the output signal of an amplifier that is connected back to the input of the same amplifier.
Firmware	Computer software usually permanently stored in a computer.
Fuse	Protective device in the current path that melts or breaks when current is over a predetermined maximum value.

G

Gain	Ratio of the output level of a circuit to the input.
GFCI	*Ground Fault Circuit Interrupt*. Used for AC convenience outlets to provide maximum personal protection from electrical shock. A GFCI is not suitable for use with certain portable test equipment.
Ground	A large conducting body, such as the earth or an electric circuit connected to the earth, used as an arbitrary zero of potential. A ground is often used as the common wiring point or reference in a circuit.
Ground Plane	Earth or negative rail of a circuit and a considerable mass that presents the effect of earth (ground) to a signal.

H

Handshaking Exchange of signals (usually part of a communications protocol) between two devices to establish a connection.

Henry Basic unit of inductance.

Hertz Number of cycles per second for any periodic waveform (measured in cycles per second). One hertz is equal to one cycle per second.

I

Impedance Impedance is similar to resistance but applies to alternating current circuits and is measured in ohms (represented by the symbol “Z”).

Input The part of a circuit that accepts a signal for processing.

Insulator Material that resists the flow of current.

Interface Usually the hardware that provides communication between various items of equipment using common physical interconnection characteristics, signal characteristics, and meanings of interchanged signals.

Inverter A device used to convert direct current into alternating current.

I/O *Input/Output.*

K

Kilowatt - hour kWh	Unit of energy when one kilowatt of power is expended for one hour.

L

Leakage	Passage of small electric current through an insulator or dielectric that is unintended and undesirable.
LED	*Light-emitting diode,* a semi-conductor that emits light, used in displays such as meters, clocks and calculators.
Limiter	Circuit or device that prevents some portion of its input from reaching the output.
Line Regulation	Ability of a voltage regulator to maintain a constant voltage when the regulator input voltage varies.
Load	Component or piece of equipment connected to a source and draws current from a source is a load on that source.
Load Current	Current drawn from a source by a load.
Load Impedance	Sum of reactance and resistance in a load.
Load Regulation	Ability of a voltage regulator to maintain a constant output voltage under varying load currents.
Load Resistance	The resistance of a load.
Logic	The principle and applications of gates, relays and switches.

M

Matched Impedance	Condition that exists when the output impedance of a source is equal to the input impedance of a load.
Megohm	One million ohms (represented by the symbol “M”).
Mnemonic	Relating to, assisting, or intended to assist the memory. A device, such as a formula used as an aid in remembering.
MOSFET	*Metal Oxide Field Effect Transistor*. Field effect transistor with a metal oxide insulating layer between the gate electrode and the channel. Also referred to as an *insulated gate field effect transistor*.
Multimeter	Electronic test equipment that can perform multiple tasks (such as measuring AC and DC voltage, current and resistance. A digital multimeter is often referred to as a DVM.
Multiplexer	Device that sends messages or signals simultaneously using a multiplex system.
Mutual Inductance	The ability of one inductor's lines of force to link with another inductor.
MUX	*Multiplexer*.

N

Noise	Unwanted electromagnetic radiation within an electrical system.
Normally Closed	When the contacts of a switch or relay are closed or connected when at rest. When activated, the contacts open or separate.
Normally Open	When the contacts of a switch or relay are normally open or not connected. When activated the contacts close or are connected.

NPN Transistor using n-type p-type n-type semiconductor material.

O

Ohm Unit of resistance (represented by the Greek capital letter omega "Ω" and the symbol "R").

Ohm's Law I=V/R where I is the current flowing, V is the voltage and R is the resistance.

Open Circuit Circuit having an incomplete path for current flow.

Oscilloscope Electronic instrument that produces an instantaneous trace on the screen of a cathode ray tube corresponding to oscillations of voltage and current.

Output Part of a circuit where the processed signal is available.

Output Impedance Impedance measured at the output terminals of a device, without a load connected.

Output Power Amount of power that a component, circuit or system can deliver to a load.

Overload Condition that occurs when the load is greater than a system can handle.

Overload Protection Protective device such as a circuit breaker that automatically disconnects a load when current exceeds a predetermined value.

P

Parallel Circuit	Circuit having two or more paths for current flow.
Passive Component	Component that does not amplify a signal (such as resistors and capacitors).
PCB	*Printed Circuit Board.* See also PWB.
Phase	The angular relationship between two waves.
Polarity	Terminology used to describe positive and negative charges.
Polarized	Component that must be connected in correct polarity to function and/or prevent destruction.
Power	The amount of energy converted by a circuit or component in a specific unit of time, normally seconds. Measured in watts.
Power Factor	The ratio of actual power to apparent power.
Power Loss	The ratio of power absorbed to power delivered.
Power Supply	Electrical equipment used to deliver either voltage (either AC or DC).
PNP	Transistor using p-type, n-type, n-type semiconductor material.
PWB	*Printed Wiring Board.* See also PCB.

R

Real Time	Data that is immediately acted upon rather than being accumulated and processed at a later time.
Rectifier	AC-to-DC converter with output typically connected in parallel with battery backup.
Regulated Power Supply	A power supply that maintains a constant output voltage under changing load conditions.
Relay	An electromechanical device that opens or closes contacts when current is passed through a coil.
Resistance	Opposition of a body or substance to current passing through it (resulting in a change of electrical energy into heat or another form of energy).
Resistor	Passive component with a known resistance.
Rheostat	Variable resistor used to control current.

S

Schematic	Structural or procedural diagram of an electrical or electronic circuit with the components represented by symbols. Also see Circuit Diagram.
Semiconductor	Any of various solid crystalline substances, such as silicon, having electrical conductivity greater than insulators but less than good conductors. S semiconductors properties can be altered by a control voltage.
Series Circuit	Circuit in which the components are connected end to end so that current has only one path to follow.
Series Parallel	Circuit that contains components connected in both series and parallel.

Circuit

Short-Circuit Unintended path that conducts electricity that typically causes excessive current.

Signal Impulse or a fluctuating electric quantity, such as voltage, current, or electric field strength, whose variations represent coded information.

Signal Generator Circuit that produces a variable and controllable signal.

Simplex Transmission Data transmission in only one direction at a time.

Sink Load or other device that consumes power or conducts away heat from a circuit.

Source A device that provides signal power or energy to a load.

Spike A brief and sudden change (usually an increase) in the voltage on a power line. A surge is similar to a spike, but is of longer duration.

Step-Down Transformer A transformer in which the output AC voltage is less than the input AC voltage.

Step-Up Transformer A transformer in which the output AC voltage is greater than the input AC voltage.

Supply Voltage The voltage that is provided by a power source.

Surge A sudden change (usually an increase) in the voltage on a power line. A surge is similar to a spike, but is of longer duration.

Surge Current The high charging current that flows into a power supply filter capacitor when power is first turned on.

Switch Device for connecting and disconnecting power to a circuit.

T

Telemetry Usually refers to transmission of alarm, status, and other information by an embedded data channel multiplexed into a digital bit stream.

Terminal A point at which electrical connections are made.

Test A methodical sequence of operations or steps intended to verify the correct operation or malfunctioning of a piece of a system or piece of equipment.

Thermistor Resistor that varies according to temperature.

Three Phase Supply AC power supply that has three AC voltages, 120° out of phase with each other.

Threshold Minimum point at which an effect is produced or detected.

Transducer Device that receives energy in one form and supplies an output in another form.

Transformer An inductor with two or more windings.

Transformer Coupling The coupling of two circuits using mutual inductance provided by a transformer.

Transistor Three leaded device (Collector, Base, Emitter) used for amplifying or switching.

Trigger A pulse used to start a circuit action.

Trimmer Small value variable resistor, capacitor, or inductor used to finely adjust a larger value.

Troubleshooting A methodical or systematic series of steps for locating the cause of a fault or problem in an electronic circuit or system.

Tuned Circuit Circuit in resonance at a particular frequency.

U

Uncontrolled Environment In thermal and humidity terms this mean to be without heating or air-conditioning and therefore subject to the normal range of outdoor conditions. Electronics must generally be "hardened" for use in such an environment. In safety terms (for example, UL), a building or space in a building that is accessible by untrained personnel.

UPS *Uninterruptible Power Supply.*

V

VA *Volt Ampere.*

VFC *Voltage-To-Frequency Converter.* Device that converts an analog input voltage into a sequence of digital pulses.

Volt Unit of voltage.

Volt-ampere A unit of electric power equal to the product of one volt and one ampere, equivalent to one watt.

Voltage Electromotive force or potential difference, usually expressed in volts.

Voltage Drop Due to current flow, the voltage or difference in potential developed across a component.

Voltage Feedback Voltage feedback where a portion of the output voltage is fed back to the input of an amplifier.

Voltage Rating The maximum voltage a component can withstand without breaking down.

Voltage Regulator A circuit or device that maintains a constant output voltage even when there is changing line voltage and/or load current.

Voltage Source Circuit or device that supplies voltage to a load.

W

Watt Unit of power. One watt is the product of one volt and one amp (represented by the symbol "W").

Wattage An amount of power, especially electric power, expressed in watts or kilowatts. Also, the electric power required by an appliance or a device.

Wattage Rating The maximum amount of power a device can continuously safely handle.

X -Z

X-ON/X-OFF *Transmitter On/Transmitter Off.* Used for flow control, instructing a terminal to start transmission and end transmission.

Zener Diode Silicon semiconductor device used as a voltage regulator because of its ability to maintain an almost constant voltage with a wide range of currents.

Appendix A — List of Commands

*CLS	LOAD OFF	SRQ <NR1>
*ESE <NR1>	LOAD ON	STATXT OFF

*OPC
*RST
*SRE <NR1>
*WAI
AV1 <NR2>
AV2 <NR2>
AVH <NR2>
AVL <NR2>
CI <NR2>
CP <NR2>
CRH <NR2>
CRL <NR2>
CV <NR2>
DU <NR2>
ET RST
FQ <NR2>
I1 <NR2>
I2 <NR2>
IL <NR2>
LAT <NR2>

LOCK OFF
LOCK ON
MR <NR1>
MS <NR1>
P1 <NR2>
P2 <NR2>
PL <NR2>
R1 <NR2>
R2 <NR2>
RNG <NR1>
RST
S1 <NR2>
S2 <NR2>
SBE <NR1>
SDN <NR1>
SF
SHORT OFF
SHORT ON
SLAVE
SR <NR2>

STATXT ON
SS
SW [<NR1>]
SW OFF
T1 <NR2>
T2 <NR2>
TEXT OFF
TEXT ON
UV <NR2>
V1 <NR2>
V2 <NR2>
VL <NR2>
WF [<NR1>]
WF OFF
XM OFF
XM
XM PLUS <NR2>
XM + <NR2>

Appendix B — List of Queries

*ESE?
*ESR?
*IDN?
*OPC?
*SRE?
*STB?
*TST?
AV1?
AV2?
AV?
CI?
CON?
CP?
CR?
CV?
DU?
ERR?
ET?
FQ?
I1?
I2?
I?
ID?
IL?
IST?
LAT?
LOAD?
LOCK?
MODE?
P1?
P2?
P?
PL?
R1?
R2?
RNG?
RNGS?
S1?
S2?
SBE?
SDN?
SHORT?
SR?
SRQ?
STA?
STATXT?
SW?
T1?
T2?
TEXT?
UV?
V1?
V2?
V?
VER?
VL?
WF?
XM?

Appendix C — Legacy Status Structure

To maintain backwards compatibility with systems designed before the implementation of the IEEE-488.2 compliant status structure, the load retains it complete original (legacy) status structure. For the most part the legacy status structure operates in parallel with the IEEE-488.2 defined status structure however there are some shared registers. Where these are shared, the functions are identical. Therefore the load will operate with systems designed to use either status structure transparently. This appendix documents the legacy status structure to provide a reference when working with older systems.

The Legacy Status Logic illustration in this appendix shows the logical relationship between the status registers. Three of the registers, the condition (CON) register, the error (ERR) register, and the status (STA) register reflect the condition of the load.

Two of the registers, the fault shutdown mask (SDN) and the fault latch mask (LAT) control which of the condition register bits cause a load shutdown (shutdown mask) and/or are latched until read (latch mask).

The summary bit enable (SBE) register controls, which condition bits, are passed through to the system status register (STA). The system status register is available either in response to an STA? query or in response to an IEEE-488 bus serial poll.

The service request (SRQ) enable mask controls which bits in the status register can assert the SRQ line. Additional information about the registers appears in tables that follow.

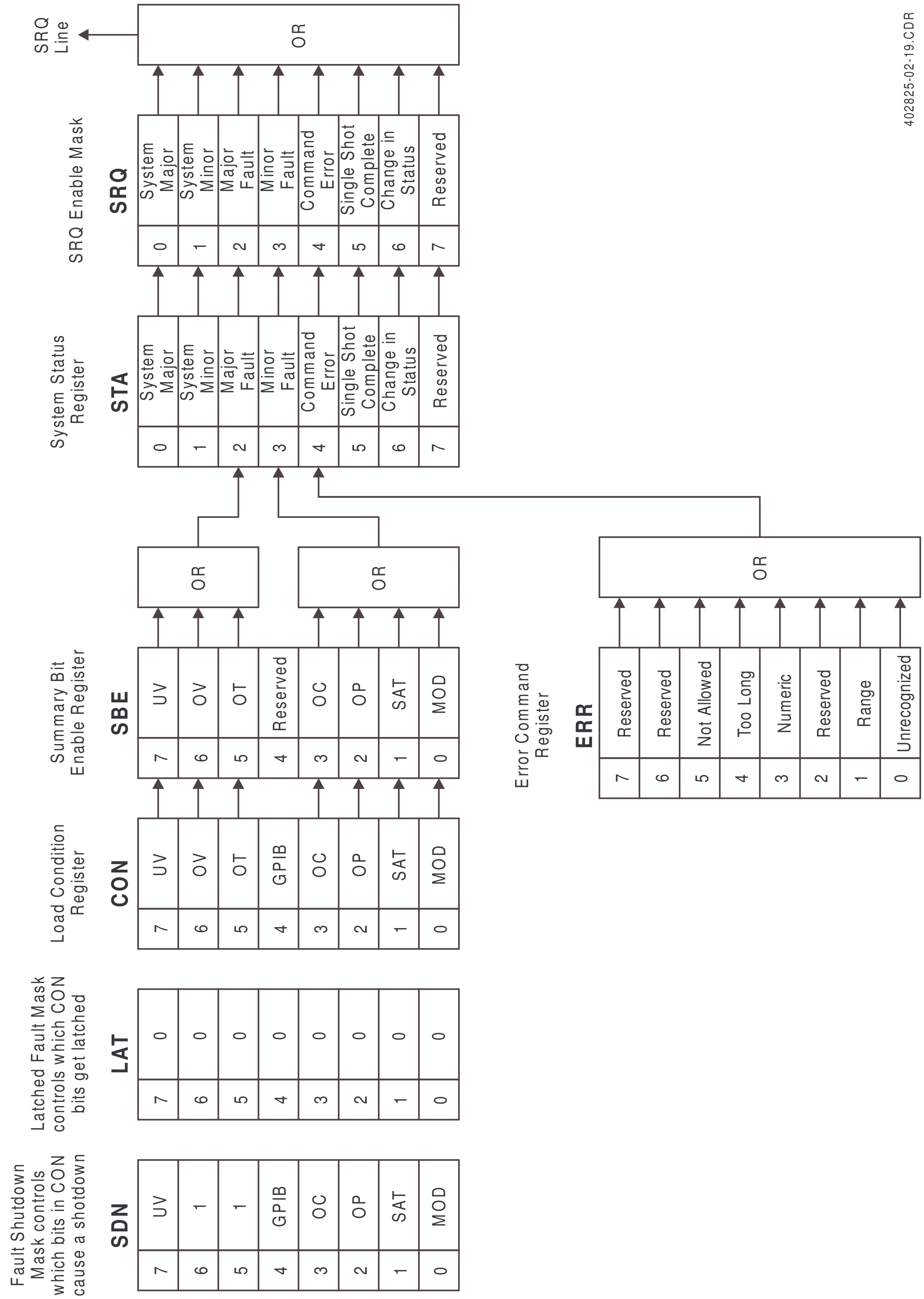
Refer to the CON?, ERR?, LAT, SBE, SDN, SRQ and STA? in the *Detail Language Elements* section of Chapter 3 for additional information about the specific registers.

Condition, Latch, Shutdown and Summary Bit Enable Registers

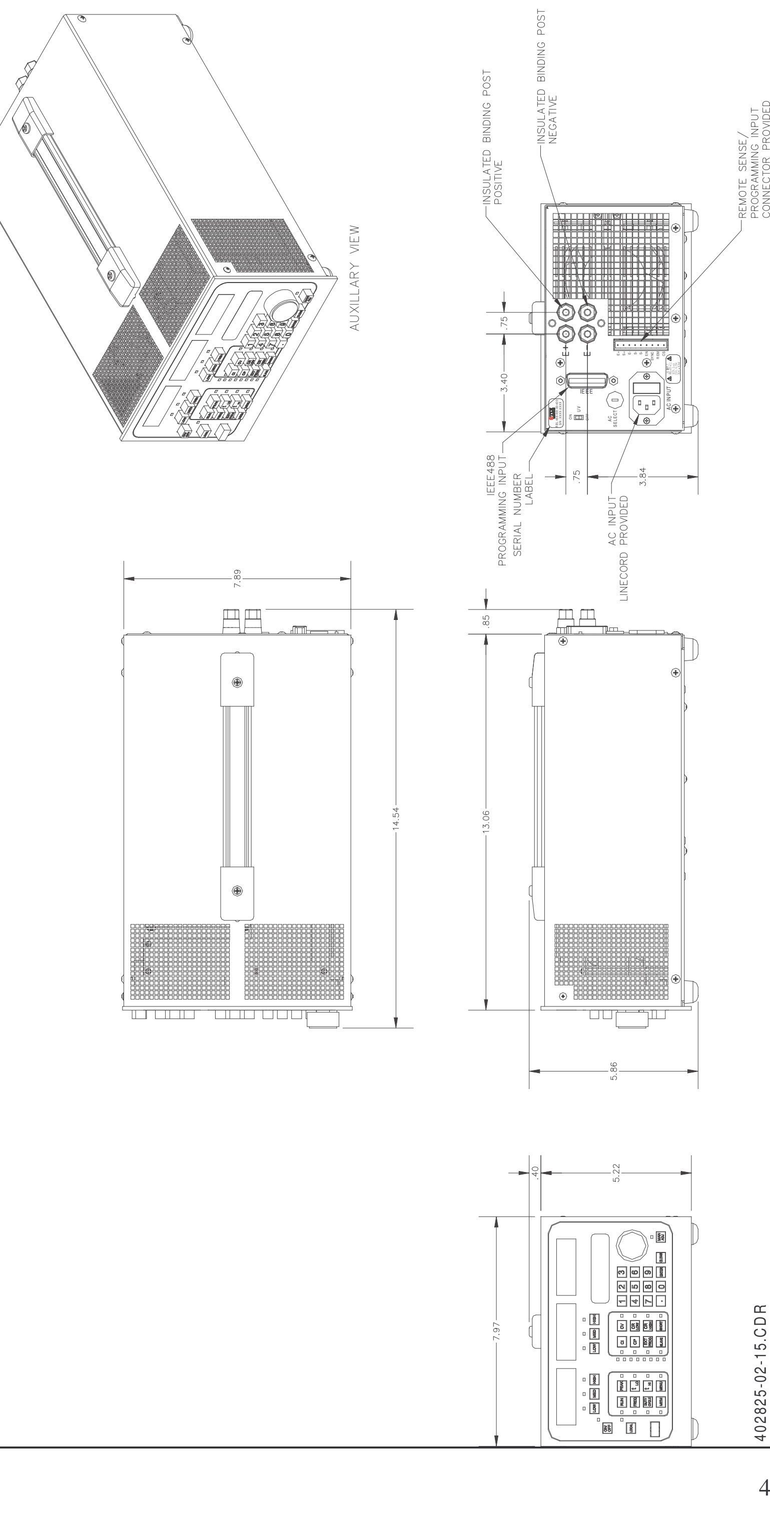
Bit	Mnemonic	Interpretation
7	UV	Indicates an under voltage condition
6	OV	Indicates an over voltage condition
5	OT	Indicates an over temperature condition
4	GPIB ERROR	Indicates a GPIB bus error
3	OC	Indicates current limit condition
2	OP	Indicates a power limit condition
1	SAT	Indicates a load or module saturation condition
0	MOD	Indicates a module level fault

Error Register		
Bit	**Mnemonic**	**Interpretation**
7	Reserved	Reserved for future use.
6	Reserved	Reserved for future use.
5	Not allowed	The received command is not permitted in the loads present state. For example, a LOAD ON in the face of a HARDWARE FAIL.
4	Too long	The program line length exceeds the loads input buffer.
3	Numeric	A number has been received that can not be interpreted for example, 3.14A2 instead of 3.14.
2	Reserved	Reserved for future use.
1	Range	A numerical value either too low or too high has been received.
0	Unrecognized	A command has been received that is not in the loads syntax.

Legacy Status Logic

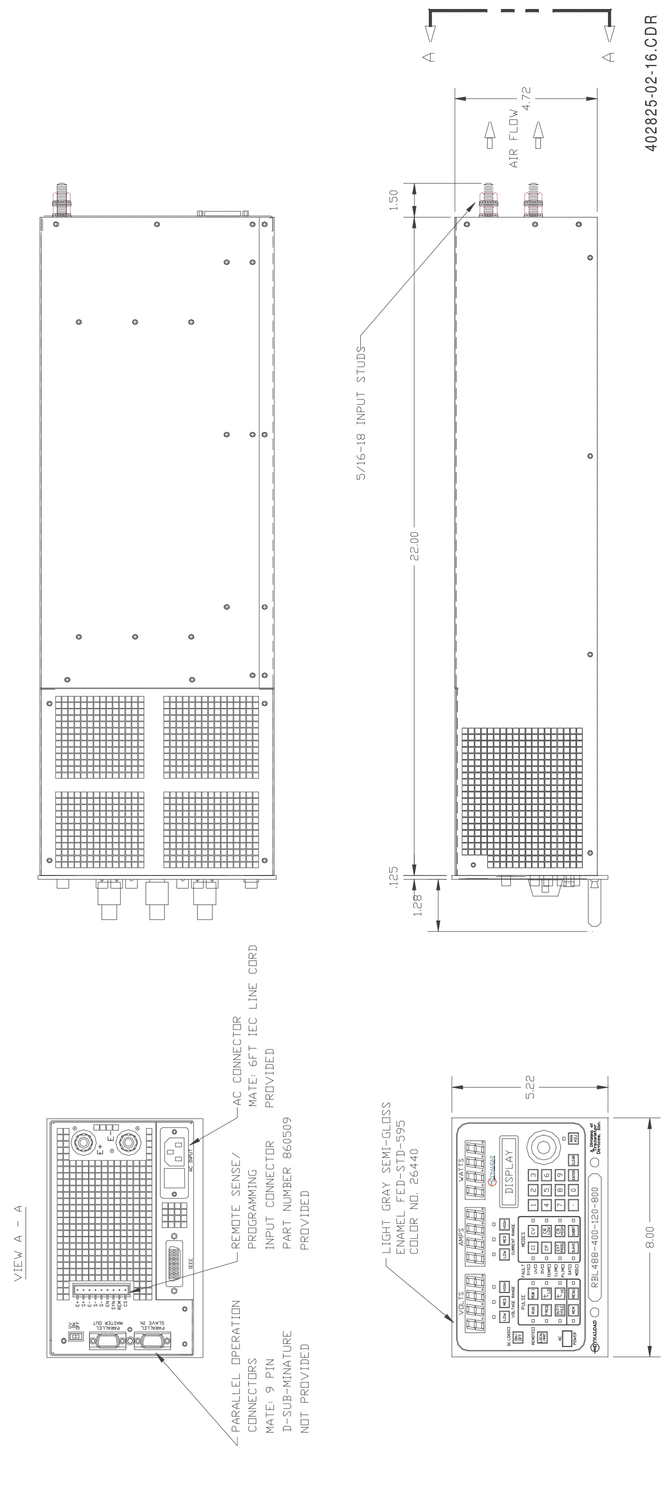


Appendix D — Outline Drawings by Model

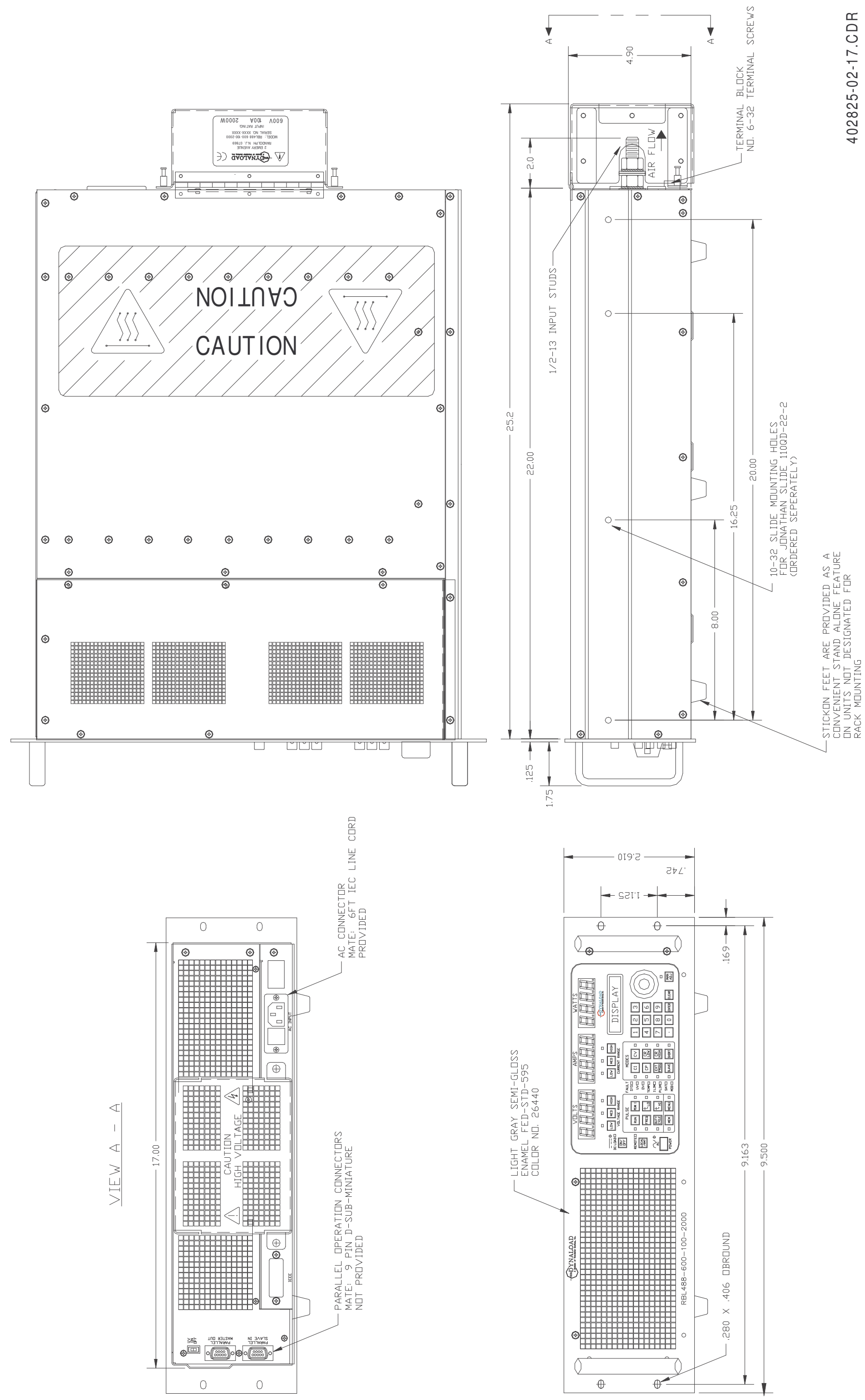


Outline Drawing of RBL 400 Watt

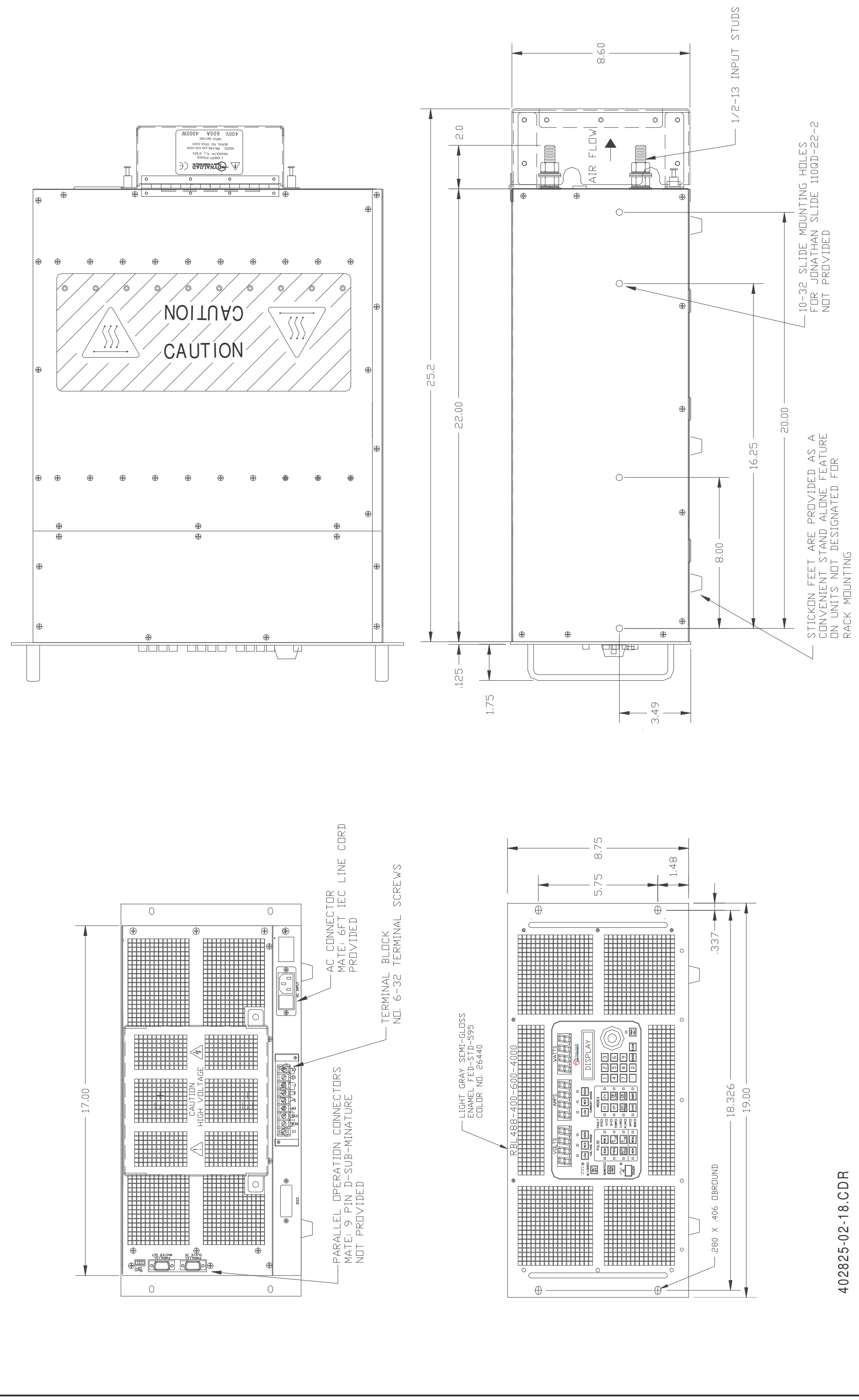
Outline Drawing of RBL 800 Watt



Outline Drawing of RBL 2000 Watt



Outline Drawing of RBL 4000 Watt



Appendix E — Specifications by Model

RBL488 4000

RBL 400

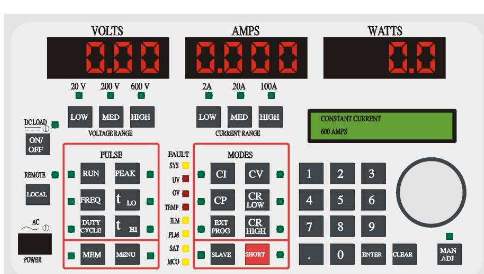
RBL488 800

RBL488 2000

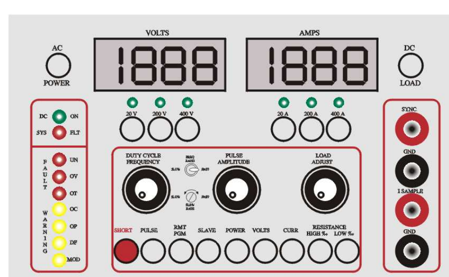
The RBL and RBL488 series single channel loads are ideal for testing of large batteries, power supplies, fuel cells and other related DC power equipment. The high range current capability and constant power feature facilitate battery testing and analysis. The ultra-fast slew rate provides unmatched power supply transient testing capabilities. The ultra-low voltage, high current capability makes the RBL and RBL488 series an ideal solution for any fuel cell requirement.

Standard Features

- Ratings from 0-1000 Volts*, 0-1000 Amps, up to 4000 watts in a single unit
- Units available:
  400 Watt
  800 Watt (8"W x 5.25"H x 22"D)
  2000 Watt (19"W x 5.25"H x 22"D)
  4000 Watt (19"W x 8.75"H x 22"D)
- Variable speed fans minimize fan noise
- Operation below .5 volts at 1000 Amps
- 5 Modes of operation: Constant Current, Constant Resistance, Constant Power, Constant Voltage, Pulse Mode
- Full Scale Range Switching: for increased resolution and accuracy.
- Synchronized paralleling to create larger systems that are controlled simultaneously
- Internal pulse generator with variable slew adjust for transient testing.
- GUI and Lab View drivers are available for IEEE-488 or RS232 computer control



RBL488 Front Panel (Digital)



RBL Front Panel (Analog)

Features

- Front Panel, Analog, IEEE-488, or RS-232 Control
- Current and Voltage Range Selection
- Constant Current, Resistance, Voltage, Power
- Operation at a Fraction of 1 Volt
- High Speed Adjustable Slew Rate
- Software Drivers Available
- Master/Slave Paralleling
- Pulse Load Shaping
- Short Circuit Capability

Series Specifications

OPERATION

Constant Current: 0 to selected full scale current
*Prog. Accuracy (Range): (high/med) ranges: ±0.25%
(low) range: ±0.5%
Regulation: ±0.1% of selected full scale
Resolution(IEEE): 1/4000 of selected full scale
Constant Resistance: Constant Resistance mode operates in Amps/Volt, IEEE units entered in ohms or A/V
*Prog. Accuracy: ±3% of selected full scale
Regulation: ±3% of selected full scale
Resolution(IEEE): 1/4000 of selected full scale
Constant Voltage: 0 to selected selected full scale
*Prog. Accuracy (Range):
(high/med) ranges: ±0.25%
(low): ± 0.5%
Regulation: ±0.15% of selected full scale
Resolution(IEEE): 1/4000 of selected full scale
Constant Power: 0 to full scale power
*Prog. Accuracy: ±3% of full scale
Regulation: ±3% of full scale
Resolution(IEEE): 0.25% of full scale power

ANALOG MODE

Ext. Prog: 0 to 10 Volts input yields 0 to selected full scale loading in alloperating modes.
Input Impedance: 330k Ohms
Prog. Response: Limited by internal adjustableslew rate limiter

PULSE MODE

** Frequency: 0.06Hz to 20kHz
Accuracy: 0.1%
Duty Cycle: 0 - 100%(IEEE),10 - 90%(Analog)
Accuracy: 0.1%
Adjustable Slew Rate:
** Max: 0 to full scale in 10µS
Min: 0 to full scale in 10mS

OUTPUT SIGNALS

Current Sample Output:
Scaling: 10 Volts = selected full scale
Accuracy: ±0.5% of selected full scale
Sync Output:
Timing: Synchronous with pulsegenerator.
Output: Sink with 10k pull up to +15V

PROTECTION

Current Limit:
Analog Models: Approximately 105% of selected full scale current
Range(IEEE): 0 - 105% of selected full scale
Resolution(IEEE): 0.5% of selected full scale
Voltage Limit:
Analog Models: Load disconnect at 105% of selected full scale voltage
Range(IEEE): 0 - 105% of selected full scale
Resolution(IEEE): 0.5% of selected full scale
Power Limit:
Analog Models: Approximately 4250 Watts
Range(IEEE): 0 - 4200 Watts
Resolution(IEEE): 20 Watts
Thermal: Load disconnect at internal temperature of 105°C
Undervoltage: Load inhibited at less than1 Volt, when enabled

IEEE-488 READBACKS

Current:
Resolution: 1/4000 of Selected Full Scale
Accuracy(Range): (High/Med): ±0.25% ±1 Digit
(Low): ±0.5% ±1 Digit
Voltage:
Resolution: 1/4000 of Selected Full Scale
Accuracy(Range): (High/Med): ±0.25% ±1 Digit
(Low): ±0.5% ±1Digit
Power:
Resolution: 1 Watt
Accuracy: 0.50%

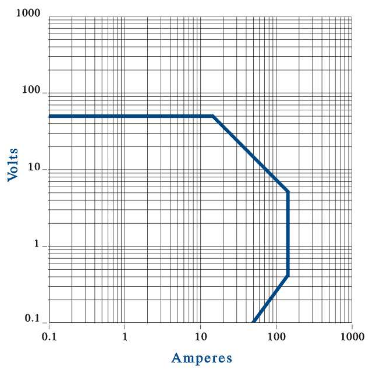
MISCELLANEOUS

AC Input: User Selectable 100VAC, 120VAC, 200VAC, 240VAC, ±10%, 48 - 62 Hz @ 350W
Ambient Temp: 0°C to 40°C

* Where applicable, stated accuracies are with respect to an externally programmed reference. Meters may be used together with calibration data for increased accuracy.

** Practical upper limits of pulse frequency and maximum slew rate are highly dependent on operating mode, source characteristics, and source to Dynaload wiring.

RBL488 50-150-800



OPERATING RANGES (FULL SCALES)
Voltage: 10 Volts, 20 Volts, 50 Volts
Current: 2 Amps, 20 Amps, 150 Amps
Power: 800 Watts
Short Circuit: 0.0026 Ohms max.

CONSTANT RESISTANCE RANGES

High Ohms Mode

Range	2A	20A	150A
10V	0 - .1 A/V	0 - 1 A/V	0 - 7.5 A/V
20V	0 - .05 A/V	0 - .5 A/V	0 - 3.75 A/V
50V	0 - .02 A/V	0 - .2 A/V	0 - 1.5 A/V

Low Ohms Mode

Range	2A	20A	150A
10V	0 - 1 A/V	0 - 10 A/V	0 - 75 A/V
20V	0 - .5 A/V	0 - 5 A/V	0 - 37.5 A/V
50V	0 - .2 A/V	0 - 2 A/V	0 - 15 A/V

IEEE METER RESOLUTION

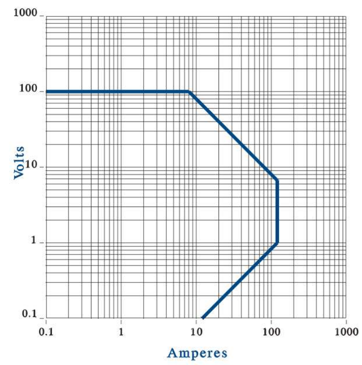
	2A	20A	150A
Ammeter:	1mA	10mA	100mA
	10V	20V	50V
Voltmeter:	10mV	10mV	10mV

Powermeter: 0.1 Watts

MECHANICAL
Size: 8"W x 5.25"H x 22"D
203mm W x 133mm H x 589mm D
19" sub-rack housing available
Weight: 56 lbs. / 25.40kg

INPUT CHARACTERISTICS: See Chart

RBL488 100-120-800
& RBL 100-120-800



OPERATING RANGES (FULL SCALES)
Voltage: 10 Volts, 50 Volts, 100 Volts
Current: 2 Amps, 20 Amps, 120 Amps
Power: 800 Watts
Short Circuit: 0.007 Ohms max.

CONSTANT RESISTANCE RANGES

High Ohms Mode

Range	2A	20A	120A
10V	0 - .1 A/V	0 - 1 A/V	0 - 6 A/V
50V	0 - .02 A/V	0 - .2 A/V	0 - 1.2 A/V
100V	0 - .01 A/V	0 - .1 A/V	0 - .6 A/V

Low Ohms Mode

Range	2A	20A	120A
10V	0 - 1 A/V	0 - 10A/V	0 - 60 A/V
50V	0 - .2 A/V	0 - 2 A/V	0 - 12 A/V
100V	0 - .1 A/V	0 - 1 A/V	0 - 6 A/V

IEEE METER RESOLUTION

	2A	20A	120A
Ammeter:	1mA	10mA	100mA
	10V	50V	100V
Voltmeter:	10mV	100mV	100mV

Powermeter:0.1 Watts

METERS (ANALOG UNIT)

Ammeter Accuracy(±1 Digit):

2A	20A	120A
±0.5%	±0.25%	±0.25%

Ammeter Resolution:

		120A
1mA	10mA	100mA

Voltmeter Accuracy(±1 Digit):

10V	50V	100V
±0.5%	±0.25%	±0.25%

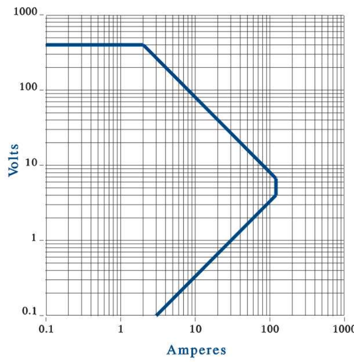
Voltmeter Resolution:

10V	50V	100V
10mV	100mV	100mV

MECHANICAL
Size: 8"W x 5.25"H x 22"D
203mm W x 133mm H x 589mm D
19" sub-rack housing available
Weight: 56 lbs. / 25.40kg

INPUT CHARACTERISTICS: See Chart

RBL488 400-120-800
& RBL 400-120-800



OPERATING RANGES (FULL SCALES)
Voltage: 20 Volts, 200 Volts, 400 Volts
Current: 2 Amps, 20 Amps, 120 Amps
Power: 800 Watts
Short Circuit: 0.03 Ohms max.

CONSTANT RESISTANCE RANGES

High Ohms Mode

Range	2A	20A	120A
20V	0 - .05 A/V	0 - .5 A/V	0 - 3 A/V
200V	0 - .005 A/V	0 - .05 A/V	0 - .3 A/V
400V	0-.0025 A/V	0 - .025 A/V	0 - .15 A/V

Low Ohms Mode

Range	2A	20A	120A
20V	0 - .5 A/V	0 - 5 A/V	0 - 30 A/V
200V	0 - .05 A/V	0 - .5 A/V	0 - 3 A/V
400V	0 - .025 A/V	0 - .25 A/V	0 - 1.5 A/V

IEEE METER RESOLUTION

	2A	20A	40A
Ammeter:	1mA	10mA	10mA
	20V	200V	400V
Voltmeter:	10mV	100mV	100mV

Powermeter: 0.1 Watts

METERS (ANALOG UNIT)

Ammeter Accuracy(±1 Digit):

2A	20A	120A
±0.5%	±0.25%	±0.25%

Ammeter Resolution:

2A	20A	120A
1mA	10mA	100mA

Voltmeter Accuracy(±1 Digit):

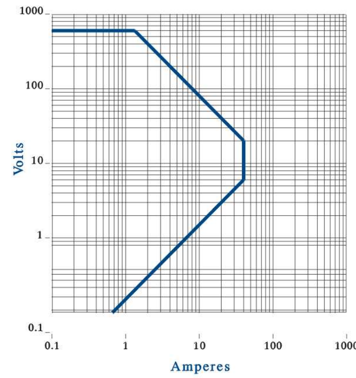
20V	200V	400V
±0.5%	±0.25%	±0.25%

Voltmeter Resolution:

20V	200V	400V
10mV	100mV	1V

MECHANICAL
Size: 8"W x 5.25"H x 22"D
203mm W x 133mm H x 589mm D
19" sub-rack housing available
Weight: 56 lbs. / 25.40kg
INPUT CHARACTERISTICS: See Chart

RBL488 600-40-800
& RBL 600-40-800



OPERATING RANGES (FULL SCALES)
Voltage: 20 Volts, 200 Volts, 600 Volts
Current: 2 Amps, 20 Amps, 40 Amps
Power: 800 Watts
Short Circuit: 0.035 Ohms max.

CONSTANT RESISTANCE RANGES

High Ohms Mode

Range	2A	20A	40A
20V	0-.05 A/V	0-.5 A/V	0-1 A/V
200V	0-.005 A/V	0-.05 A/V	0-.1 A/V
400V	0-.00033 A/V	0-.0033 A/V	0-.0066 A/V

Low Ohms Mode

Range	2A	20A	40A
20V	0-.5 A/V	0-5 A/V	0-10 A/V
200V	0-.05 A/V	0-.5 A/V	0-1 A/V
400V	0-.0033 A/V	0-.033 A/V	0-.066 A/V

IEEE METER RESOLUTION

Ammeter:

2A	20A	40A
1mA	10mA	10mA

Voltmeter:

20V	200V	600V
10mV	100mV	100mV

Powermeter: 0.1 Watts

METERS (ANALOG UNIT)

Ammeter Accuracy(±1 Digit):

2A	20A	40A
±0.5%	±0.25%	±0.25%

Ammeter Resolution:

2A	20A	40A
1mA	10mA	100mA

Voltmeter Accuracy(±1 Digit):

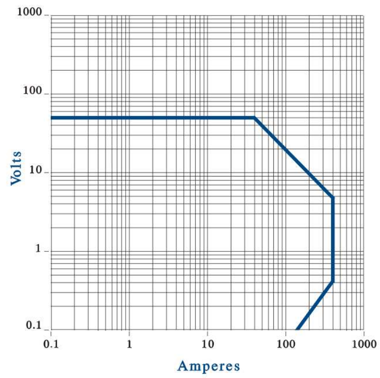
20V	200V	600V
±0.5%	±0.25%	±0.25%

Voltmeter Resolution:

20V	200V	600V
10mV	100mV	1V

MECHANICAL
Size: 8"W x 5.25"H x 22"D
203mm W x 133mm H x 589mm D
19" sub-rack housing available
Weight: 56 lbs. / 25.40kg
INPUT CHARACTERISTICS: See Chart

RBL488 50-400-2000



OPERATING RANGES (FULL SCALES)
Voltage: 10 Volts, 20 Volts, 50 Volts
Current: 20 Amps, 200 Amps, 400 Amps
Power: 2000 Watts
Short Circuit: 0.001 Ohms max.

CONSTANT RESISTANCE RANGES
High Ohms Mode

Range	20A	200A	400A
10V	0 - 1A/V	0 - 10A/V	0 - 20A/V
20V	0 - .5A/V	0 - 5A/V	0 - 10A/V
50V	0 - .2A/V	0 - 2A/V	0 - 4A/V

Low Ohms Mode

Range:	20A	200A	400A
10V	0 - 10A/V	0 - 100A/V	0 - 200A/V
20V	0 - 5A/V	0 - 50A/V	0 - 100A/V
50V	0 - 2A/V	0 - 20A/V	0 - 40A/V

IEEE METER RESOLUTION
Ammeter:

100A	???A	500A
10mA	100mA	100mA

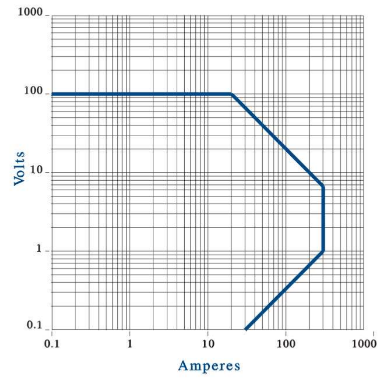
Voltmeter:

10V	20V	50V
10mV	10mV	10mV

Powermeter: 0.5 Watts

MECHANICAL
Size: 19"W x 5.25"H x 22"D
483mm W x 133mm H x 589mm D
Rack Mountable
Weight: 56 lbs. / 25.40kg
INPUT CHARACTERISTICS: See Chart

RBL488 100-300-2000 &
RBL 100-300-2000



OPERATING RANGES (FULL SCALES)
Voltage: 10 Volts, 50 Volts, 100 Volts
Current: 20 Amps, 200 Amps, 300 Amps
Power: 2000 Watts
Short Circuit: 0.005 Ohms max.

CONSTANT RESISTANCE RANGES
High Ohms Mode

Range	20A	200A	300A
10V	0-1 A/V	0-10 A/V	0-15 A/V
50V	0-.2 A/V	0-2 A/V	0-3 A/V
100V	0-.1 A/V	0-1 A/V	0-1.5 A/V

Low Ohms Mode

Range	20A	200A	300A
10V	0-10 A/V	0-100 A/V	0-150 A/V
50V	0-2 A/V	0-20 A/V	0-30 A/V
100V	0-A/V	0-10 A/V	0-15 A/V

IEEE METER RESOLUTION
Ammeter:

20A	200A	300A
10mA	100mA	100mA

Voltmeter:

10V	50V	100V
10mV	100mV	100mV

Powermeter: 0.5 Watts

METERS (ANALOG UNIT)
Ammeter Accuracy(±1 Digit):

20A	200A	300A
±0.5%	±0.25%	±0.25%

Ammeter Resolution:

20A	200A	300A
10mA	100mA	1A

Voltmeter Accuracy(±1 Digit):

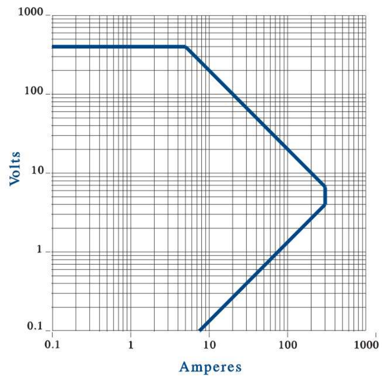
10V	50V	100V
±0.5%	±0.25%	±0.25%

Voltmeter Resolution:

10V	50V	100V
10mV	100mV	100mV

MECHANICAL
Size: 19"W x 5.25"H x 22"D
483mm W x 133mm H x 589mm D
Rack Mountable
Weight: 56 lbs. / 25.40kg
INPUT CHARACTERISTICS: See Chart

RBL488 400-300-2000 & RBL 400-300-2000



OPERATING RANGES (FULL SCALES)
Voltage: 20 Volts, 200 Volts, 400 Volts
Current: 20 Amps, 200 Amps, 300 Amps
Power: 2000 Watts
Short Circuit: 0.010 Ohms max.

CONSTANT RESISTANCE RANGES
High Ohms Mode

Range	20A	200A	300A
20V	0-.5 A/V	0-5 A/V	0-7.5 A/V
200V	0-.05 A/V	0-5 A/V	0-.75 A/V
400V	0-.025 A/V	0-.25 A/V	0-.375 A/V

Low Ohms Mode

Range	20A	200A	300A
20V	0-5 A/V	0-50 A/V	0-75 A/V
200V	0-.5 A/V	0-2.5 A/V	0-7.5 A/V
400V	0-.25A/V	0-2.5 A/V	0-3.75 A/V

IEEE METER RESOLUTION
Ammeter:

20A	200A	300A
10mA	10mA	100mA

Voltmeter:

20V	200V	400V
10mV	100mV	100mV

Powermeter: 0.5 Watts

METERS (ANALOG UNIT)
Ammeter Accuracy(±1 Digit):

20A	200A	300A
±0.5%	±0.25%	±0.25%

Ammeter Resolution:

20A	200A	300A
10mA	100mA	1A

Voltmeter Accuracy(±1 Digit):

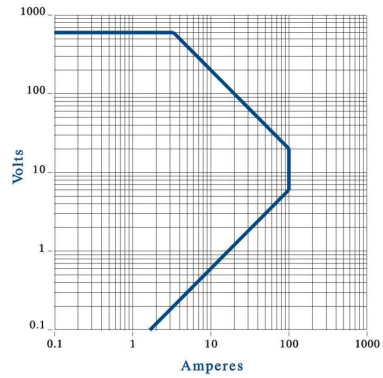
20V	200V	400V
±0.5%	±0.25%	±0.25%

Voltmeter Resolution:

20V	200V	400V
10mV	100mV	1V

MECHANICAL
Size: 19"W x 5.25"H x 22"D
483mm W x 133mm H x 589mm D
Rack Mountable
Weight: 56 lbs. / 25.40kg
INPUT CHARACTERISTICS: See Chart

RBL488 600-100-2000 & RBL 600-100-2000



OPERATING RANGES (FULL SCALES)
Voltage: 20 Volts, 200 Volts, 600 Volts
Current: 2 Amps, 20 Amps, 100 Amps
Power: 2000 Watts
Short Circuit: 0.035 Ohms max.

CONSTANT RESISTANCE RANGES
High Ohms Mode

Range	2A	20A	100A
20V	0-.05 A/V	0-.5 A/V	0-2.5 A/V
200V	0-.005 A/V	0-.05 A/V	0-.25 A/V
600V	0-.0016 A/V	0-.016 A/V	0-.083 A/V

Low Ohms Mode

Range	2A	20A	100A
20V	0-.5 A/V	0-5 A/V	0-25 A/V
200V	0-.05 A/V	0-.5 A/V	0-2.5 A/V
600V	0-.016 A/V	0-.166 A/V	0-.833A/V

IEEE METER RESOLUTION
Ammeter:

2A	20A	100A
1mA	10mA	100mA

Voltmeter:

20V	200V	600V
10mV	100mV	100mV

Powermeter: 0.5 Watts

METERS (ANALOG UNIT)
Ammeter Accuracy(±1 Digit):

2A	20A	100A
±0.5%	±0.25%	±0.25%

Ammeter Resolution:

2A	20A	100A
1mA	10mA	100mA

Voltmeter Accuracy(±1 Digit):

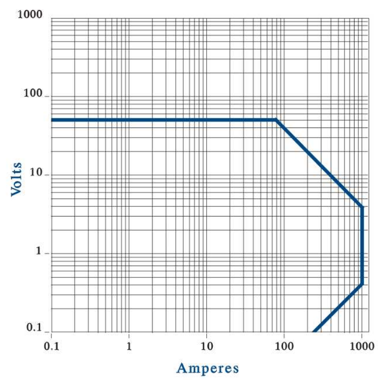
20V	200V	600V
±0.5%	±0.25%	±0.25%

Voltmeter Resolution:

20V	200V	600V
10mV	100mV	1V

MECHANICAL
Size: 19"W x 5.25"H x 22"D
483mm W x 133mm H x 589mm D
Rack Mountable
Weight: 56 lbs. / 25.40kg
INPUT CHARACTERISTICS: See Chart

RBL488 50-1000-4000



OPERATING RANGES (FULL SCALES)
Voltage: 10 Volts, 20 Volts, 50 Volts
Current: 100 Amps, 500 Amps, 1000 Amps
Power: 4000 Watts
Short Circuit: 0.0004 Ohms max.

CONSTANT RESISTANCE RANGES

High Ohms Mode

Range	100A	500A	1000A
10V	0 - 5 A/V	0 - 25 A/V	0 - 50 A/V
20V	0 - 2.5 A/V	0 - 12.5 A/V	0 - 25 A/V
50V	0 - 1 A/V	0 - 5 A/V	0 - 10 A/V

Low Ohms Mode

Range	100A	500A	1000A
10V	0 - 50 A/V	0 - 250 A/V	0 - 500 A/V
20V	0 - 25 A/V	0 - 125 A/V	0 - 250 A/V
50V	0 - 10 A/V	0 - 50 A/V	0 - 100 A/V

IEEE METER RESOLUTION

Ammeter:

100A	500A	1000A
10mA	100mA	100mA

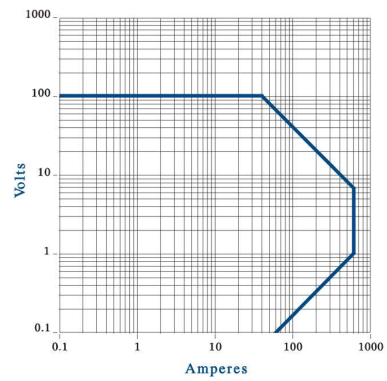
Voltmeter:

10V	20V	50V
10mV	10mV	10mV

Powermeter: 1 Watt

MECHANICAL
Size: 19"W x 8.75"H x 22"D
483mm W x 222mm H x 589mm D
Rack Mountable
Weight: 85 lbs. / 39kg
INPUT CHARACTERISTICS: See Chart

RBL488 100-600-4000 & RBL 100-600-4000



OPERATING RANGES (FULL SCALES)
Voltage: 10 Volts, 50 Volts, 100 Volts
Current: 20 Amps, 200 Amps, 600 Amps
Power: 4000 Watts
Short Circuit: 0.003 Ohms max.

CONSTANT RESISTANCE RANGES

High Ohms Mode

Range	20A	200A	600A
10V	0 - 1 A/V	0 - 10 A/V	0 - 30 A/V
50V	0 - .2 A/V	0 - 2 A/V	0 - 6 A/V
100V	0 - .1 A/V	0 - 1 A/V	0 - 3 A/V

Low Ohms Mode

Range	20A	200A	600A
10V	0 - 10 A/V	0 - 100 A/V	0 - 300 A/V
50V	0 - 2 A/V	0 - 20 A/V	0 - 60 A/V
100V	0 - 1 A/V	0 - 10 A/V	0 - 30 A/V

IEEE METER RESOLUTION

Ammeter:

20A	200A	600A
10mA	100mA	100mA
10V	50V	100V

Voltmeter:

10V	50V	100V
10mV	100mV	100mV

Powermeter: 1 Watt

METERS (ANALOG UNIT)

20A	200A	600A
±0.5%	±0.25%	±0.25%

Ammeter Resolution:

20A	200A	600A
10mA	100mA	1A

Voltmeter Accuracy(±1 Digit):

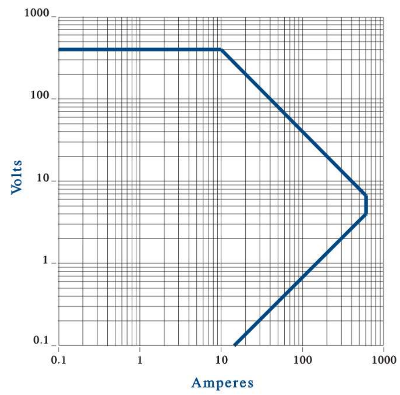
10V	50V	100V
±0.5%	±0.25%	±0.25%

Voltmeter Resolution:

10V	50V	100V
10mV	100mV	100mV

MECHANICAL
Size: 19"W x 8.75"H x 22"D
483mm W x 222mm H x 589mm D
Rack Mountable
Weight: 85 lbs. / 39kg
INPUT CHARACTERISTICS: See Chart

RBL488 400-600-4000 & RBL 400-600-4000



OPERATING RANGES (FULL SCALES)

Voltage:	20 Volts, 200 Volts, 400 Volts
Current:	20 Amps, 200 Amps, 600 Amps
Power:	4000 Watts
Short Circuit:	0.008 Ohms max.

CONSTANT RESISTANCE RANGES

High Ohms Mode

Range	20A	200A	600A
20V	0 - .5 A/V	0 - 5 A/V	0 - 15 A/V
200V	0 - .05 A/V	0 - .5 A/V	0 - 1.5 A/V
400V	0 - .025 A/V	0 - .25 A/V	0 - .75 A/V

Low Ohms Mode

Range	20A	200A	600A
20V	0 - 5 A/V	0 - 50 A/V	0 - 150 A/V
200V	0 - .5 A/V	0 - 5 A/V	0 - 15 A/V
400V	0 - .25 A/V	0 - 2.5 A/V	0 - 7.5 A/V

IEEE METER RESOLUTION

	20A	200A	600A
Ammeter:	10mA	100mA	100mA
	20V	**200V**	**400V**
Voltmeter:	10mV	100mV	100mV
Powermeter:	1 Watt		

METERS (ANALOG UNIT)

	20A	200A	600A
Ammeter Accuracy(±1 Digit):	±0.5%	±0.25%	±0.25%
Ammeter Resolution:	10mA	100mA	1A
	20V	**200V**	**400V**
Voltmeter Accuracy(±1 Digit):	±0.5%	±0.25%	±0.25%
Voltmeter Resolution:	10mV	100mV	1mV

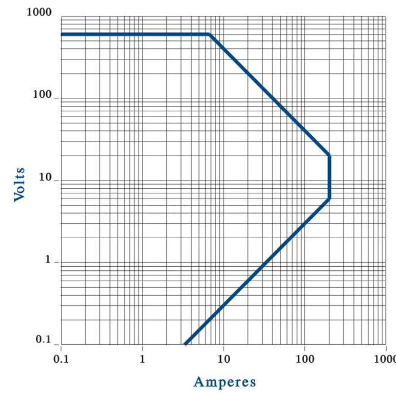
MECHANICAL

Size: 19"W x 8.75"H x 22"D
483mm W x 222mm H x 589mm D
Rack Mountable

Weight: 85 lbs. / 39kg

INPUT CHARACTERISTICS: See Chart

RBL488 600-200-4000 & RBL 600-200-4000



OPERATING RANGES (FULL SCALES)

Voltage:	20 Volts, 200 Volts, 600 Volts
Current:	2 Amps, 20 Amps, 200 Amps
Power:	4000 Watts
Short Circuit:	0.02 Ohms max.

CONSTANT RESISTANCE RANGES

High Ohms Mode

Range	2A	20A	200A
20V	0 - .05 A/V	0 - .5 A/V	0 - 5 A/V
200V	0 - .005 A/V	0 - .05 A/V	0 - .5 A/V
600V	0 - .00166 A/V	0 - .0166 A/V	0-.166 A/V

Low Ohms Mode

Range	2A	20A	200A
20V	0 - .5 A/V	0 - 5 A/V	0 - 50 A/V
200V	0 - .05 A/V	0 - .5 A/V	0 - 5 A/V
600V	0 - .0166 A/V	0 - .1666 A/V	0-.1666A/V

IEEE METER RESOLUTION

	2A	20A	200A
Ammeter:	1mA	10mA	100mA
	20V	**200V**	**600V**
Voltmeter:	10mV	100mV	100mV
Powermeter:	1 Watt		

METERS (ANALOG UNIT)

	2A	20A	200A
Ammeter Accuracy(±1 Digit):	±0.5%	±0.25%	±0.25%
Ammeter Resolution:	10mA	100mA	100mA
	20V	**200V**	**600V**
Voltmeter Accuracy(±1 Digit):	±0.5%	±0.25%	±0.25%
Voltmeter Resolution:	10mV	100mV	1V

MECHANICAL

Size: 19"W x 8.75"H x 22"D
483mm W x 222mm H x 589mm D
Rack Mountable

Weight: 85 lbs. / 39kg

INPUT CHARACTERISTICS: See Chart