California Instruments

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CS Series
AC Power Source
User Manual

AMETEK®
PROGRAMMABLE POWER

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Refers to:

CS Series AC Power Sources

Models:

Single chassis:	3000CS, 4500CS
Multiple chassis:	9000CS/2, 13500CS/3, 18000CS

Manual revision: G.

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Date and Revision

March 2009 Revision AK

Part Number

7003-960

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Important Safety Instructions

Before applying power to the system, verify that your product is configured properly for your particular application.

 WARNING	**Hazardous voltages may be present when covers are removed. Qualified personnel must use extreme caution when servicing this equipment. Circuit boards, test points, and output voltages also may be floating above (below) chassis ground.**
 WARNING	**The equipment used contains ESD sensitive parts. When installing equipment, follow ESD Safety Procedures. Electrostatic discharges might cause damage to the equipment.**

Only *qualified personnel* who deal with attendant hazards in power supplies, are allowed to perform installation and servicing.

Ensure that the AC power line ground is connected properly to the Power Rack input connector or chassis. Similarly, other power ground lines including those to application and maintenance equipment *must* be grounded properly for both personnel and equipment safety.

Always ensure that facility AC input power is de-energized prior to connecting or disconnecting any cable.

In normal operation, the operator does not have access to hazardous voltages within the chassis. However, depending on the user's application configuration, **HIGH VOLTAGES HAZARDOUS TO HUMAN SAFETY** may be normally generated on the output terminals. The customer/user must ensure that the output power lines are labeled properly as to the safety hazards and that any inadvertent contact with hazardous voltages is eliminated.

Guard against risks of electrical shock during open cover checks by not touching any portion of the electrical circuits. Even when power is off, capacitors may retain an electrical charge. Use safety glasses during open cover checks to avoid personal injury by any sudden component failure.

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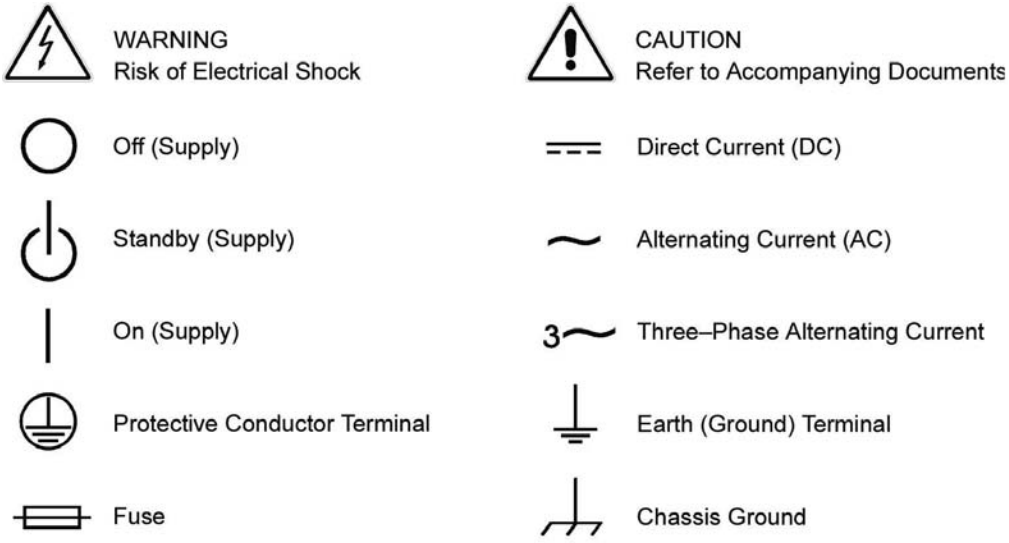
SAFETY SYMBOLS



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AMETEK Programmable Power, Inc. (“AMETEK”), provides this written warranty covering the Product stated above, and if the Buyer discovers and notifies AMETEK in writing of any defect in material or workmanship within the applicable warranty period stated above, then AMETEK may, at its option: repair or replace the Product; or issue a credit note for the defective Product; or provide the Buyer with replacement parts for the Product.

The Buyer will, at its expense, return the defective Product or parts thereof to AMETEK in accordance with the return procedure specified below. AMETEK will, at its expense, deliver the repaired or replaced Product or parts to the Buyer. Any warranty of AMETEK will not apply if the Buyer is in default under the Purchase Order Agreement or where the Product or any part thereof:

- is damaged by misuse, accident, negligence or failure to maintain the same as specified or required by AMETEK;
- is damaged by modifications, alterations or attachments thereto which are not authorized by AMETEK;
- is installed or operated contrary to the instructions of AMETEK;
- is opened, modified or disassembled in any way without AMETEK’s consent; or
- is used in combination with items, articles or materials not authorized by AMETEK.

The Buyer may not assert any claim that the Products are not in conformity with any warranty until the Buyer has made all payments to AMETEK provided for in the Purchase Order Agreement.

PRODUCT RETURN PROCEDURE

Request a Return Material Authorization (RMA) number from the repair facility (**must be done in the country in which it was purchased**):

- **In the USA**, contact the AMETEK Repair Department prior to the return of the product to AMETEK for repair:

  Telephone: 800-733-5427, ext. 2295 or ext. 2463 (toll free North America)
  858-450-0085, ext. 2295 or ext. 2463 (direct)

- **Outside the United States**, contact the nearest Authorized Service Center (ASC). A full listing can be found either through your local distributor or our website, www.programmablepower.com, by clicking Support and going to the Service Centers tab.

When requesting an RMA, have the following information ready:

- Model number
- Serial number
- Description of the problem

NOTE: Unauthorized returns will not be accepted and will be returned at the shipper’s expense.

NOTE: A returned product found upon inspection by AMETEK, to be in specification is subject to an evaluation fee and applicable freight charges.

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1. Introduction

This CS Series User manual (P/N 7004-987) contains information on the installation, operation, calibration and maintenance of the CS Series AC current sources. The terms AC power source and AC current source may be used in this manual to refer to a CS Series unit.

1.1 General Description

The CS Series of AC Current Sources is a family of high efficiency, rack mountable, AC Power Source/Analyzer combinations that provide a precise current output with low distortion and advanced measurements. Output current range is up to 14.8 Arms per phase at full power for the three-phase mode and 44.4 Arms for the single-phase mode. The CS Series can be operated in either single or three-phase mode.

For higher power levels, two to four CS series chassis can be combined using the system interface in a parallel mode of operation. These multi chassis systems consist of one master unit with controller and one to three auxiliary units without controllers. Only the master unit has a front panel keyboard and display.

The CS Series comes standard with USB, RS232C and GPIB interfaces.

Read the installation instructions carefully before attempting to install and operate the CS AC current source.

Note: All interfaces use the SCPI command syntax as described in the programming manual.

1.2 Manual organization and format

All user documentation for California Instruments power sources is provided on CDROM in electronic format. (Adobe Portable Document Format) The required Adobe PDF viewer is supplied on the same CDROM. This manual may be printed for personal use if a hardcopy is desired. To request a hardcopy from California Instruments, contact customer service at support@programmablepower.com. There will be an additional charge for printed manuals.

This manual contains sections on installation, normal use, maintenance and calibration. The CS Series is equipped with GPIB, USB and RS232C interfaces. An optional LAN interface can be specified at the time of order. Refer to the CS Series Programming manual for information on using the remote control interface and command syntax. The programming manual (P/N 7004-988) is provided on the same CDROM as this user manual.

California Instruments may make updated versions of this manual available from time to time in electronic format through it's website. To obtain an updated manual revision if available, check the California Instruments Manual download page at www.programmablepower.com. You need to register as a customer to obtain free access to manual and software downloads.

2. Specifications

Specifications shown are valid over an ambient temperature range of 25 ± 5° C and apply after a 30 minute warm-up time. Unless otherwise noted, all specifications are per phase for sine wave output into a resistive load. For three phase configurations or mode of operation, all specifications are for Line to Neutral (L-N) and phase angle specifications are valid under balanced load conditions only.

2.1 Electrical

2.1.1 Input

Parameter	Specification		
Line Voltage: (3 phase, 3 wire + ground (PE))	3000CS, 4500CS, 9000CS/2, 13500CS/3, 18000CS/4: Std: 208 - 230 VLL ± 10% -400: 400 V_{LL} ±10%		Note: Each CS chassis requires its own AC service. Note: 3000CS may be operated from 208-230 V L-N single phase AC input between B and C on TB3 for 3000CS.
Line VA: (total)	3000CS	5900 VA / 4100 W	
	4500CS	8900 VA / 5900 W (x2 for 9000CS/2, x3 for 13500CS/3, x4 for 18000CS/4)	
Line Current: (per phase)	3000CS	Std: 19 Arms @ 187 VLL, 3 phase AC input. [32 Arms @ 187 VLN single phase AC input. Connect between TB3-B and TB3-C] -400: 10 Arms @ 360 VLL, 3 phase AC input.	
	4500CS	Std: 31 Arms @ 187 VLL -400: 16 Arms @ 360 VLL	
	Currents shown are for single chassis models. For multi-chassis configurations, currents are per chassis.		
Line Frequency:	47-440 Hz		
Efficiency:	75 % (typical) depending on line and load		
Power Factor:	0.65 (typical)		
Inrush Current:	50 Apk @ 253VLL per chassis 83 A_{pk} @ 400 V_{LL} per chassis		Note: Each CS chassis requires its own AC service.
Hold-Up Time:	> 10 ms		
Isolation Voltage:	2200 VAC input to chassis and input to output.		

2.1.2 Output

Output Parameter	Specification
Modes	AC
Current (as a function of selected compliance voltage range):	
Ranges (L-N):	**3000CS/ 4500CS Series**
135V CVR[1]	0 – 14.81 Arms, three phase mode 0 – 44.44 Arms, single phase mode 3000CS Max. current is power limited above 67.5V. 4500CS Max. current is power limited above 101V
270V CVR	0 – 7.4 Arms, three phase mode 0 – 22.22 Arms, single phase mode 3000CS Max. current is power limited above 135V. 4500CS Max. current is power limited above 202V
Resolution:	0.01 A
Ranges (L-N):	**9000CS/2**
135V CVR	0 – 29.62 Arms, three phase mode 0 – 88.88 Arms, single phase mode Max. current is power limited above 101V
270V CVR	0 – 14.81 Arms, three phase mode 0 – 44.4 Arms, single phase mode Max. current is power limited above 202V
Resolution:	0.01 A
Ranges (L-N):	**13500CS/3**
135V CVR	0 – 44.44 Arms, three phase mode 0 – 133.3 Arms, single phase mode Max. current is power limited above 101V
270V CVR	0 – 22.22 Arms, three phase mode 0 – 66.66 Arms, single phase mode Max. current is power limited above 202V
Resolution:	0.01 A
Ranges (L-N):	**18000CS/4**
135V CVR	0 – 59.24 Arms, three phase mode 0 – 177.76 Arms, single phase mode Max. current is power limited above 101V
270V CVR	0 – 29.62 Arms, three phase mode 0 – 88.86 Arms, single phase mode Max. current is power limited above 202V
Resolution:	0.01 A
Programming Accuracy:	3 Phase mode: ± (0.1% + 0.05 A) from .5A to FS 1 Phase mode: ± (0.1% + 0.15 A) from .5A to FS
Distortion THD[2]:	Standard: < 1.2 % [60 - 500 Hz]

[1] CVR = Compliance Voltage Range.
[2] *The distortion specification for the CS Series applies at full-scale current, full resistive load conditions, using 30Khz LP Filter on distortion analyzer.*

Output Parameter	Specification
	< 2% [500 - 1000 Hz] < 2.5% [1000 - 2000 Hz] With –LKM option: < 2.2 % [60 - 500 Hz] < 3% [500 - 1000 Hz] < 3.5% [1000 - 2000 Hz]
Load Regulation: ALC mode ON	0.1 % FS
Line Regulation:	0.02% for 10% input line change
Output Noise: (20 kHz to 1 MHz, full current output)	3 Phase mode: < 13 mA_{RMS} 1 Phase mode: < 40 mA_{RMS}
Temp. Coefficient	± 0.01% of range / °C
Stability:	± 0.01 A over 24 Hours
DC Offset Current:	0.0 A
Output Coupling	Transformer coupled
Output Impedance (Z)	>100k

Maximum Peak Current[1] – CS Series, data shown for 135 compliance voltage range.

Model	3000CS / 4500CS
Single Phase Mode: Max. Peak	133 A
Three Phase Mode: Max. Peak, per phase	44.4 A

Note: For 9000CS/2, currents are 2 x 4500CS.
For 13500CS/3, currents are 3 x 4500CS.
For 18000CS/4, currents are 4 x 4500CS.

Compliance Voltage:

Ranges	135Vrms or 270Vrms	
Minimum compliance voltage as a function of current, voltage range and phase mode:	3000CS: Vcomp * Iprog <= 1 KVA (3 phase mode) Vcomp * Iprog <= 3 KVA (1 phase mode) 4500CS: Vcomp * Iprog <= 1.5 KVA (3 phase mode) Vcomp * Iprog <= 4.5 KVA (1 phase mode) Vcomp >= Iprog x (Vrange) ^2 / 1500 (3 phase mode). Vcomp >= Iprog x (Vrange) ^2 / 4500 (1 phase mode). Vrange = Voltage Range selected. For multi chassis systems, multiple donominator by no of chassis to determine minimum available compliance voltage.	

Voltage Limit Programming:

Model / Range	135 Range, 3 Phs	270 Range, 3 Phs
3000CS Max. setting:	135 Vrms @ 7.41A 67.5 Vrms @ 14.81 A	270Vrms @ 3.7A 135Vrms @ 7.4A

[1] Note: Maximum peak current can only be supported with loads for which compliance voltage peak is less than 190V peak in 135 Range or 380V peak in 270 Range.

Output Parameter	Specification	
4500CS Max. setting:	135 Vrms @ 11.11A 101Vrms @ 14.81A	270Vrms @ 5.5A 202Vrms @ 7.4A
Programming resolution:	0.1 Vrms	
Voltage Limit mode	Programmable, CC or CV mode	
Power – CS Series (total power for all phases, either range, at full scale voltage)		
Model	**3000CS**	**4500CS**
Single Phase Mode	3.0 KVA	4.5 KVA
Three Phase Mode (per phase)	1.0 KVA	1.35 KVA
Model	**9000CS/2**	**13500CS/3**
Single Phase Mode	9 KVA	13.5 KVA
Three Phase Mode (per phase)	3 KVA	4.5 KVA
Model	**18000CS/4**	
Single Phase Mode	18 KVA	
Three Phase Mode (per phase)	6 KVA	
Frequency		
Range:	45 Hz - 2000 Hz	
Resolution[1]:	0.01 Hz [< 81.91 Hz] 0.1 Hz [> 82.0 to 819.1 Hz] 1 Hz [> 819 Hz]	
Accuracy:	± 0.025 %	
Temp Coefficient::	+/- 5 ppm of value / °C	
Stability:	+/- 15 ppm of value / year	
Phase (3 phase mode)		
Range:	Phase B/C relative to phase A 0.0 to 360.0°	
Resolution:	0.1° < 819.1 Hz 0.5° > 819.1 Hz	
Accuracy:	< 2° [45 Hz - 1000 Hz] < 1° + 1°/kHz [> 1000 Hz]	

Note: All output specifications apply below the Current / Voltage rating line shown in the V/I rating charts of section 2.1.3 for 3000CS and 4500CS.

Note: For maximum impedance of EUT as a function of programmed current, refer to R/I rating charts in section for 3000CS and 4500CS. Data is shown for 135 Range. For 270 Range mode, divide current by 2 and multiply voltage by 2.

2.1.3 Voltage versus Current Rating Charts - CS Series, 135 Range

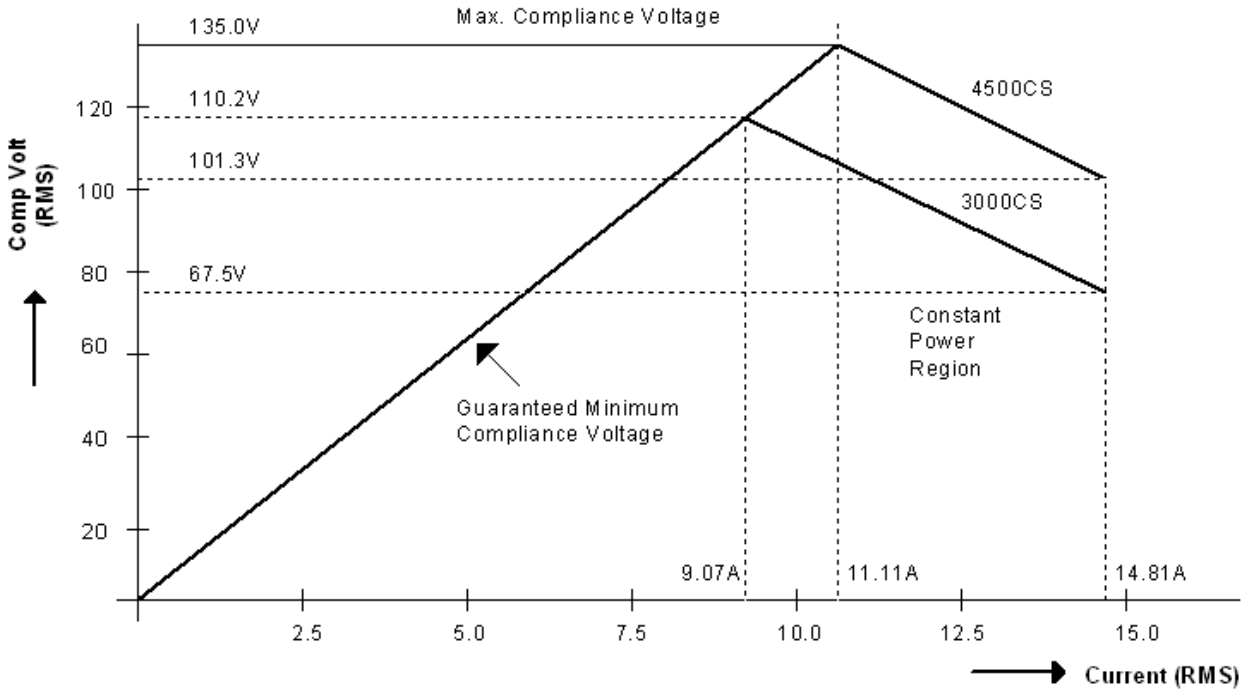


Figure 2-1: Voltage / Current Rating Chart in 3 phase mode, 135 Range.

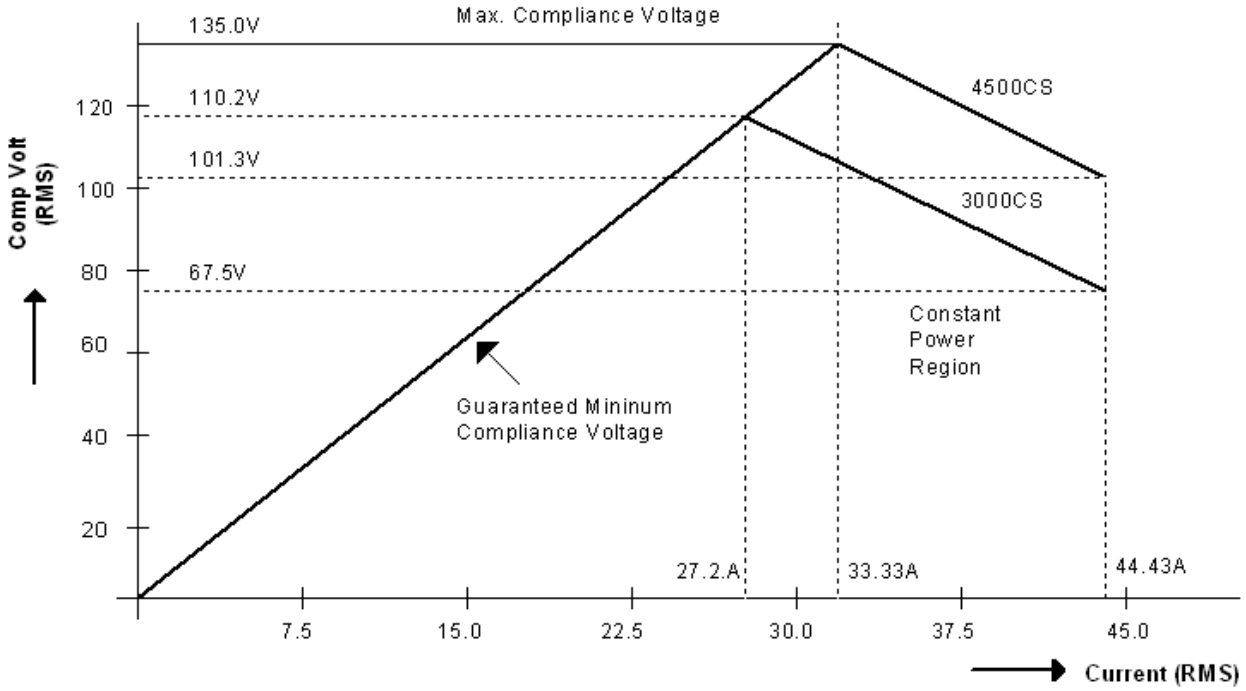


Figure 2-2: Voltage / Current Rating Chart in 1 phase mode, 135 Range.

[1] Programming resolution reduced if –LKM/-LKS option is installed. See paragraph 2.6.2.

2.1.4 Voltage versus Current Rating Charts - CS Series, 270 Range

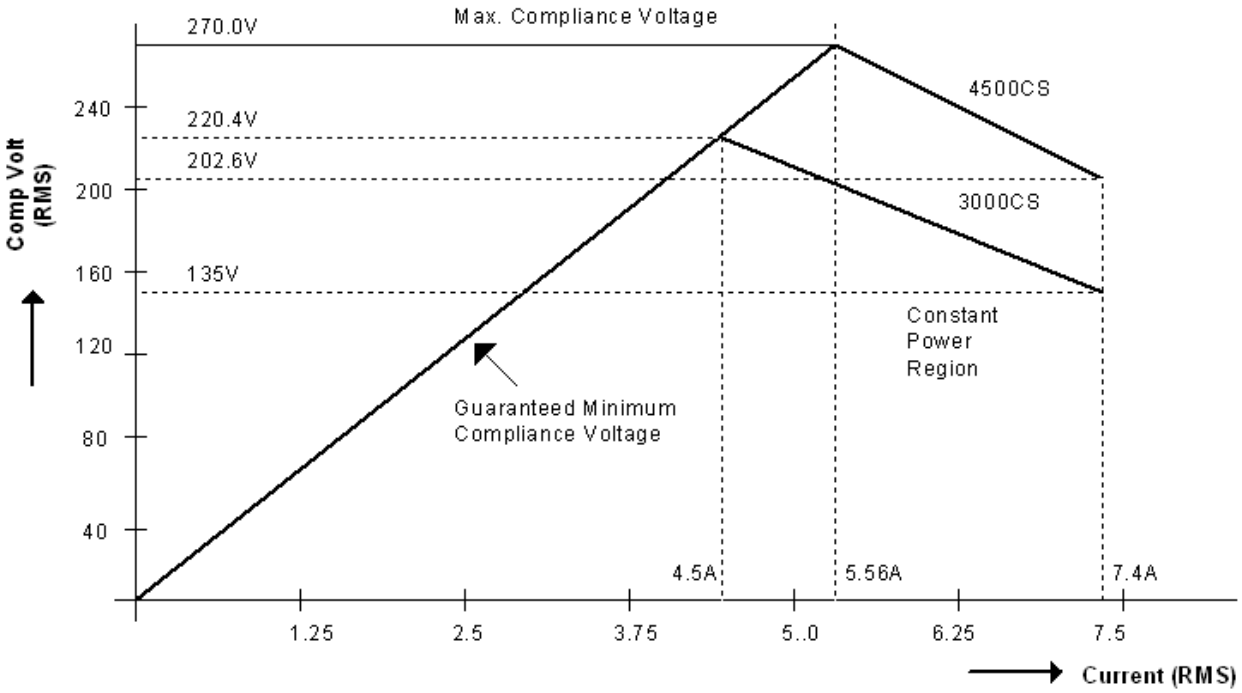


Figure 2-3: Voltage / Current Rating Chart in 3 phase mode, 270 Range.

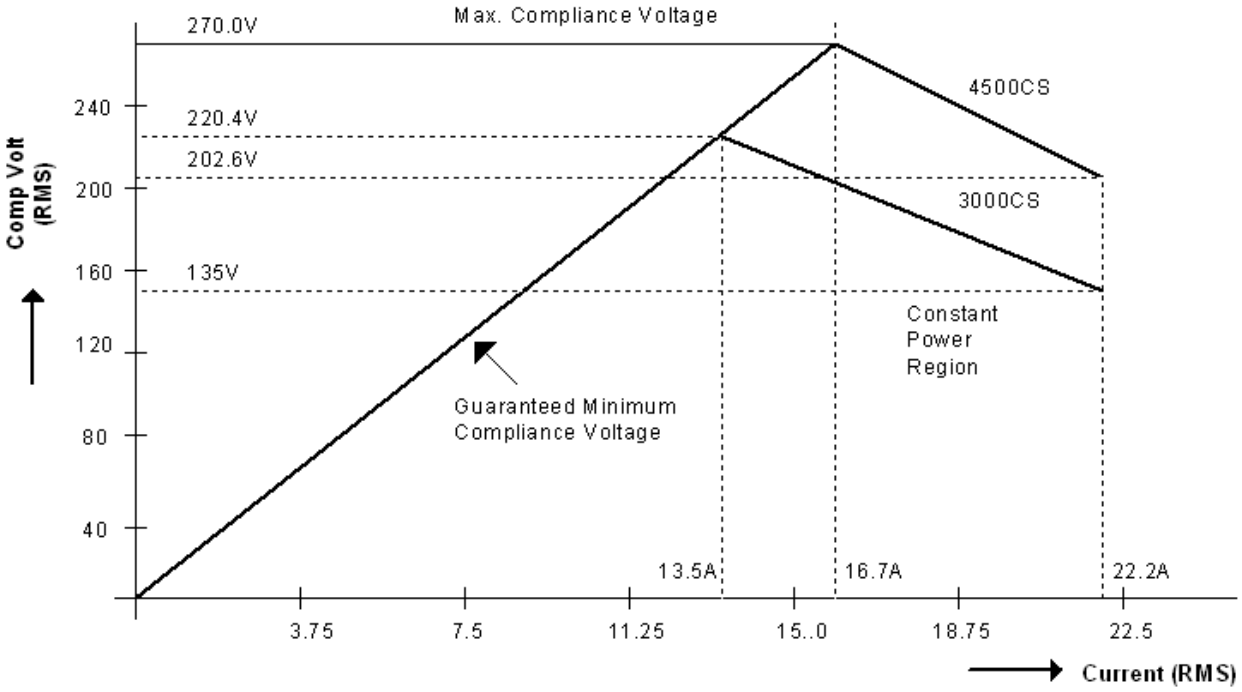


Figure 2-4: Voltage / Current Rating Chart in 1 phase mode, 270 Range.

2.1.5 Load Impedance versus Current Rating Charts - CS Series, 135 Range

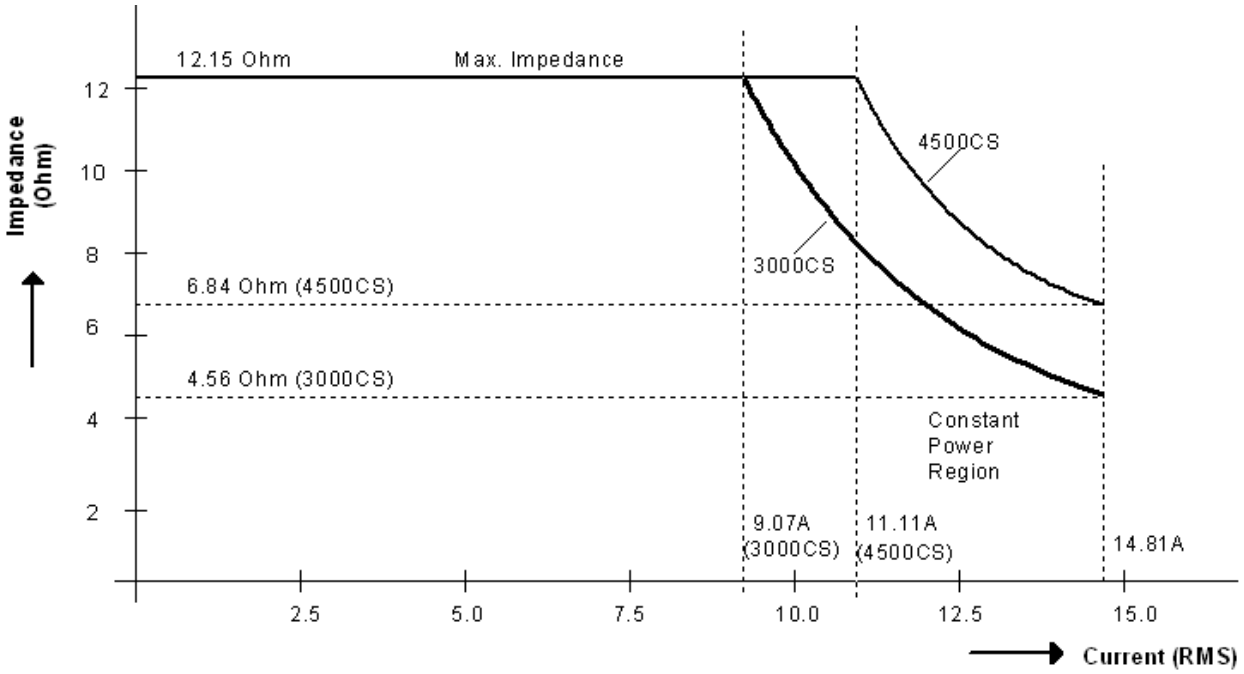


Figure 2-5: Load Impedance / Current Rating Chart in 3 phase mode, 135 Range.

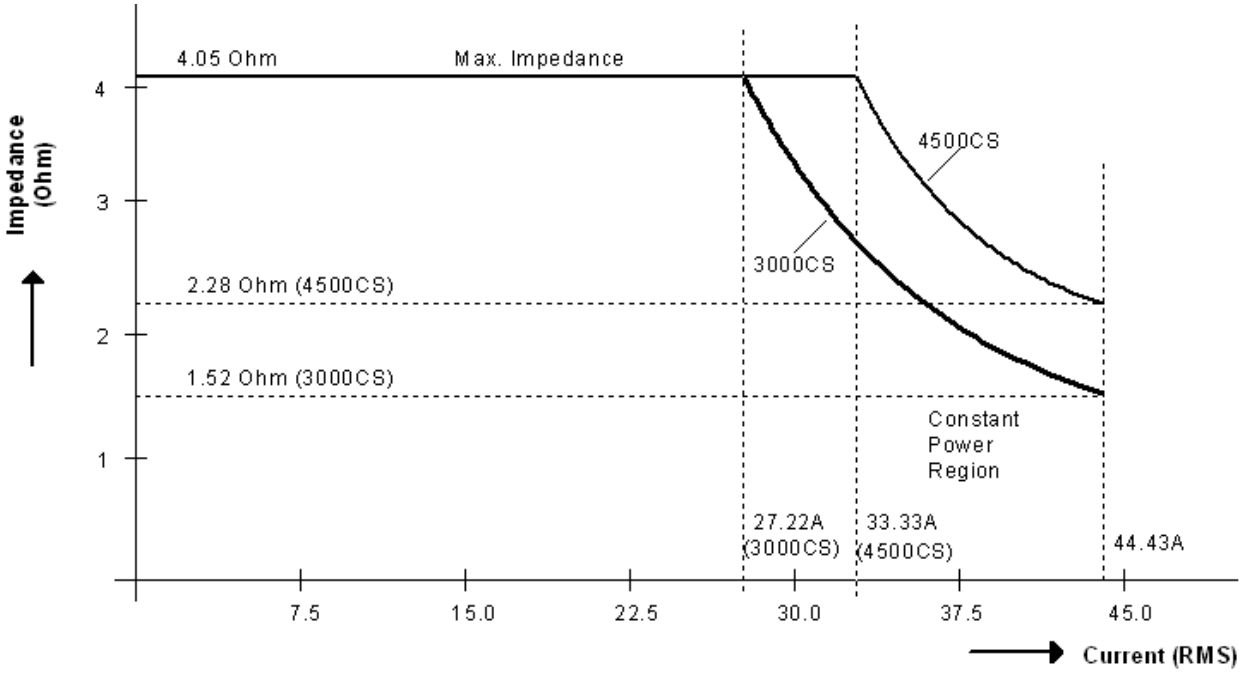


Figure 2-6: Load Impedance / Current Rating Chart in 1 phase mode, 135 Range.

2.1.6 Load Impedance versus Current Rating Charts - CS Series, 135 Range

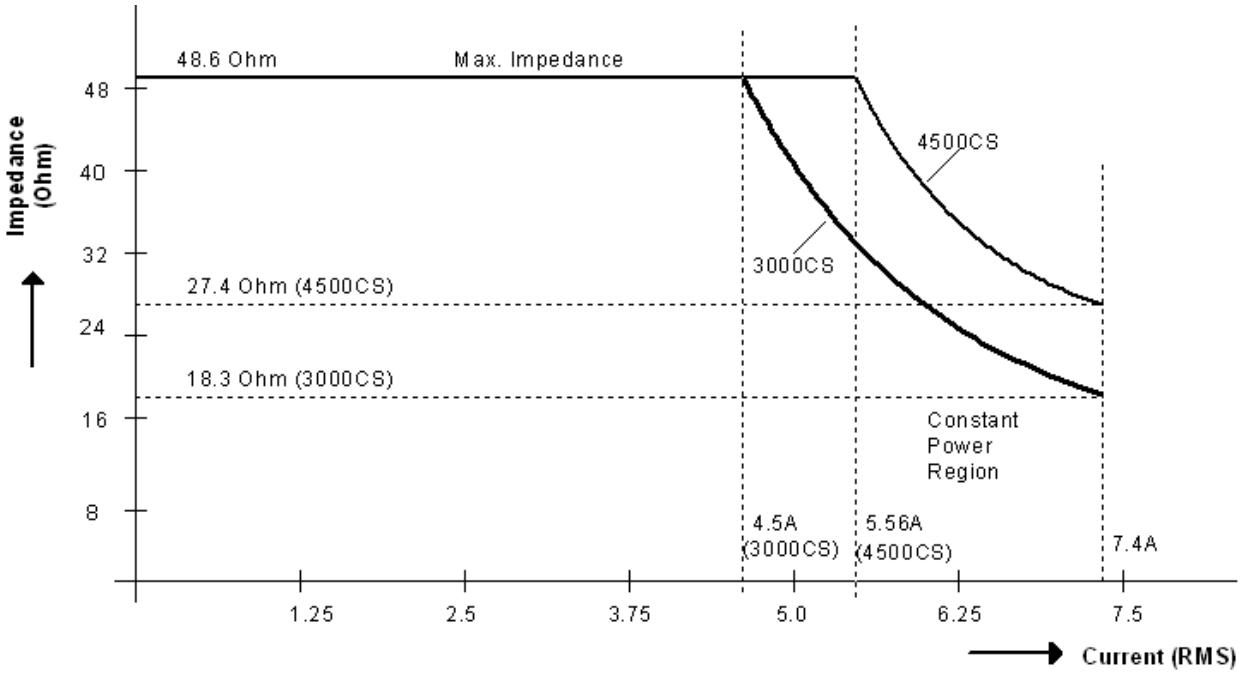


Figure 2-7: Load Impedance / Current Rating Chart in 3 phase mode, 270 Range.

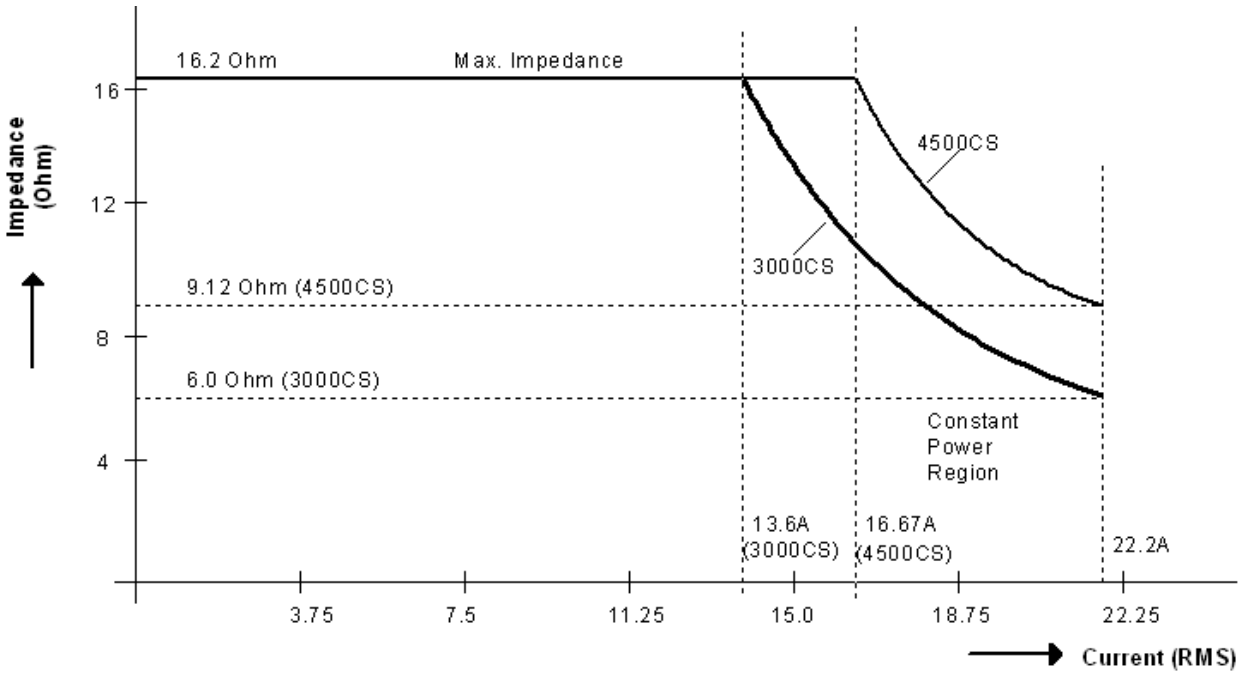


Figure 2-8: Load Impedance / Current Rating Chart in 1 phase mode, 270 Range.

2.1.7 AC Measurements

Measurement specifications apply to single chassis CS Series AC source in single or three-phase mode. See notes for other models and configurations.

Parameter	Range	Accuracy (±)		Resolution
		1 Phase Mode	3 Phase Mode	
Frequency[1]	45.00-2000 Hz	0.1% ± 1 digit		0.01 Hz to 81.91 Hz 0.1 Hz to 819.1 Hz 1 Hz > 819.1 Hz
Phase	0.0 – 360.0 °	0.5° < 500 Hz 2° > 500 Hz		0. 1°
RMS Voltage	0 - 400 Volts	0.05% + 0.25V		0.01 Volt
RMS Current	0 - 50 Amps	0.1% + 0.15A	0.1% + 0.05A	0.001 Amp
Peak Current	0 - 150 Amps	0.2% + 0. 5A	0.1% + 0.15A	0.001 Amp
Crest Factor	1.00 – 10.00	1.5 %	1.5 %	0.01
VA Power	0 - 6 KVA	0.15% + 9 VA	0.15% + 3 VA	1 VA
Real Power	0 - 6 KW	0.15% + 9 W	0.15% + 3 W	1 W
Power Factor	0.00 - 1.00	0.03	0.01	0.01
Note: Accuracy specifications are valid above 100 counts. For multi-chassis configurations, Current and Power range and accuracy specifications are times the number of chassis. *Note: Frequency measurement specification valid for output > 1 Arms.* *Note: Crest Factor accuracy applies for Irms > 50% of max.* *Note: Power Factor accuracy applies for PF > 0.5 and VA > 50% of max.*				

2.1.8 Harmonic Measurements

Harmonic measurement specifications apply to CS Series AC sources in three-phase mode. See notes for single-phase mode.

Parameter	Range	Accuracy (±)	Resolution
Frequency fundamental	45.00 - 81.91 Hz 82.0 - 819.1 Hz > 819.1 Hz	0.1% ± 1 digit	0.01 Hz 0.1 Hz 1 Hz
Frequency harmonics	45.00 Hz – 16 kHz	0.1% + 2 digits	0.1 Hz
Voltage			
Fundamental	0 - 400 Volts	0.05% + 0.25V	0.01V
Harmonic 2 - 50		0.1% + 0.1%/kHz + 0.25	0.01V
Current			
Fundamental	0 - 20 Amps	0.1% + 0.05A	0.01A
Harmonic 2 - 50		0.1% + 0.1%/kHz + 0.05A	0.01A
Note: Current range and accuracy specifications are times three in single-phase mode. For multi-			

[1] Frequency measurement specifications valid with output current of 1 Arms or higher. If output relay is open, frequency measurement will return 0.0 Hz.

chassis configurations, current accuracy specifications are times the number of chassis.

2.1.9 System Specification

Parameter	Specification
Trigger Input:	External trigger source input. Requires TTL level input signal. Triggers on negative edge. Response time 80 - 100 μs.
Non volatile memory storage:	16 complete instrument setups and transient lists, 100 events per list. 50 User defined waveforms.
Waveforms	Sine, square, clipped, user defined
Transients	*Parameters:* Current: Level, Slew rate Function: Sine, Clip, Square, User Frequency: Level, Slew rate Voltage: Trip level Time: Dwell time, Trigger out *Modes:* Fixed, Pulse, Step, List
Limit Modes:	Two selectable modes of operation: 1. Constant voltage mode (current folds back with automatic recovery) 2. Constant current mode with trip-off (Relays open).
Interfaces	
IEEE-488	AH1, DC1, DT1, L3, RL2, SH1, SR1, T6 IEEE 488.2 and SCPI Response time is 10 ms (typical)
LAN / Ethernet (-LAN Option)	RJ45 Connector, 10BaseT, 100BaseT or 1000BaseT, Data transfer rate: 460,800 bps Protocol: TCP/IP. Note: If –LAN is installed, RS232C interface is disabled.
RS232C	Baud rates, 9600, 19200, 38400, 57600 and 115200 Data bits: 8, Start bits: 1, Stop bits: 1, Parity: None Syntax: SCPI Response time is 10 ms (typical @ 115200 baud)
USB	Standard USB 2.0 peripheral. Data transfer rate: 460,800 bps Syntax: SCPI Note: Use of the USB port to control more than one power source from a single PC is not recommended, as communication may not be reliable. Use GPIB interface for multiple power source control.

2.1.10 Unit Protection

Parameter	Specification
Input Over current:	Input Circuit breaker. This breaker protects the equipment only and is not a branch protection device. AC input connection should be make using a suitable branch protection device per local electrical code.
Input Over voltage Transients:	Surge protection to withstand EN50082-1 (IEC 801-4, 5) levels.

Parameter	Specification
Output Over Voltage:	Adjustable level constant voltage mode with programmable set point.
Open Circuit:	Automatic shutdown.
Over temperature:	Automatic shutdown.

2.2 Mechanical

Parameter	Specification
Dimensions:	Height: 10.5 inches (26.7 cm) 3000CS / 4500CS 21 inches (53.4 cm) 9000CS/2 31.5 inches (80.1 cm) 13500CS/3 42 inches (106.8 cm) 18000CS/4 Depth: 23 inches (58.4 cm) Width: 19 inches (48.3 cm) *All dimensions are per chassis. For /2, /3 or /4 model configurations, multiply height by 2, 3 or 4 for total height. Width includes integrated front panel rack mount ears.*
Equipment Rack depth requirement	25 inches (63.5 cm)
Unit Weight: Per chassis	Net: 193 lbs / 87.7 Kg *approximately* Shipping: 280 lbs / 127.3 Kg *approximately* *All weights are per chassis. For /2 or /3 model configurations, each chassis is packaged individually.*
Material:	Steel chassis with aluminum top cover
Finish:	Anodized external surfaces. Front panel color medium gray.
Cooling:	Fan cooled with air intake on the sides and exhaust to the rear. Variable speed fan control.
Acoustic Noise (Supplemental specification)	Measured at 1 m distance: Fan speed: Low power mode Full power mode Front of unit: 47 dBA 50 dBA Rear of unit: 62 dBA 67 dBA
Internal Construction:	Modular sub assemblies.
Rear Panel Connections:	(See section 3 for description of connections) • AC input wiring • AC output wiring • External sense terminal block (Remote voltage sense) • System interface (2x) • GPIB (std CS), USB, LAN (option) and RS232C • Trigger In and Out SMA's (Master CS chassis only)

2.3 Environmental

Parameter	Specification
Operating Temp:	0° to +35° C, full power, 0° to +50° C, reduced power +32° to +95° F, full power, +32° to +122° F, reduced power.
Storage Temp:	-40° to +85 °C. -40° to +185° F.

Parameter	Specification
Altitude:	< 2000 meters < 6000 feet
Relative Humidity:	0-95 % RAH, non-condensing maximum for temperatures up to 31°C decreasing linearly to 50% at 40°C.
	Indoor Use Only
Vibration:	Designed to meet NSTA project 1A transportation levels.
Shock:	Designed to meet NSTA project 1A transportation levels.

2.4 Front Panel Controls

Controls:	
Shuttle knob:	The shuttle knob may be used to adjust current and frequency for selected phase or all three phases while in the SET menu. In all other menus, the shuttle may be used to change parameter values and settings.
Up/down arrow keys:	A set of up and down arrow keys is used to move the cursor position in all menus. This allows quick selection of the desired function or parameter.
Function keys:	**Set** key will show output voltage and frequency setting. **Meas** key displays the measurement screens. Measure key will display measurement values for selected phase or phase A if all three phases are selected. **Menu** key selects main menu. **Enter** key is used to confirm selections. **Back** key is used to back up to previous screen. **Output on/off** key for output relay control. **Phase** key toggles between phase A, B, C or all phases selection. **Keypad** is used to enter numeric values without using the shuttle knob.
Displays:	
LCD graphics display:	Large high contrast backlit LCD display. An adjustable viewing angle makes it easy to read from all practical locations.
Status indicators:	Large and bright status indicators inform the user of important power source conditions. The Remote lamp informs the user that the unit is under remote control. The Overvoltage lamp indicates that excessive compliance voltage is present at the output. The Over temperature lamp illuminates when internal heat sink temperatures are too high. The Hi Range indicator is lit any time the unit is switched to the high current range. The Output On/Off indicator is on when the power source output relays are closed. The Phase A, B and C indicators are lit when the relevant phase is selected with the Phase key.

2.5 Special Features

Controller Features	
Mode:	Switches between 1 and 3 phase outputs.
Parallel Operation:	9000CS/2, 13500CS/3, 18000CS/3 systems use two to four 4500CS chassis in parallel operation. The individual chassis must be connected using the system interface cable supplied with the system.
Controller:	Programmable controller front panel assembly.
Output Relay:	Standard output relay feature to isolate power source from the load.
Output On/Off:	The output relay can be used to quickly disconnect the load. A yellow status indicator displays the status of the output relay.
External Trigger Output or Function Strobe	An external TTL output is available which may be used to trigger other equipment. The TTL output can be controlled by the transient programming system. This requires the trigger mode to be set to EXT (factory default). This can only be done over the bus using the OUTP:TTLT:MODE TRIG command. It can also be configured to generate an output pulse any time the current, frequency, voltage limit or phase programming is updated. This requires the trigger mode to be set to FSTR. This can only be done over the bus using the OUTP:TTLT:MODE FSTR command. The Trigger Output (Trig Out1) / function strobe is an active low[1] TTL signal with a duration of no less than 400 usec.
Clock and Lock Mode	Enables two or more independent CS power systems to be phase synchronized to each other. One system (-LKM) acts as the master, the other(s) (-LKS) as auxiliaries. The –LKS units are synced to the –LKM unit. Refer to section 3.9 for details on Clock and Lock mode.
Trigger Input	A TTL input signal may be used as an external trigger source for output changes programmed on the AC power source transient system. This requires the trigger source to be set to EXT. This can only be done over the bus.

2.6 Available Options – CS Series

Output Options	
-AX	Auxiliary outputs, 5 VAC and 26 VAC, 400 Hz. (Output D and E)
-LF	Low frequency option. Limits maximum output frequency to 500 Hz.
Misc. Options	
-L22	Locking Knob. Shaft lock screw replaces shuttle knob to prevent turning of shuttle.
-LAN	Ethernet LAN interface connection. RJ45 connector. Note: When installed, RS232C interface is disabled.
-LKM	Clock and Lock Master. Enables synchronizing outputs of two CS AC sources, one acts as master. This mode supports a frequency range of 45 to 819 Hz on standard CS models. See section 3.9.
-LKS	Clock and Lock Auxiliary. See -LKM for details. (see Notes) See section

1 Note: Early production models may have an active high Trig Out1 polarity.

	3.9.
-LNS	Line Sync (see Notes)
-EXS	External Sync (see Notes)
-RMS	Set of 2 Rack mount slides. (Left and Right) Recommended to mount CS Chassis in 19 inch instrument cabinet.
Notes:	External Trigger input is standard. Line sync and External sync are mutually exclusive. External Trigger input and External sync are mutually exclusive. Units with -LKS (auxiliary) cannot have Line Sync or External Sync.
-RPV	Remote programming voltage. DC voltage input 0 to 10 VDC for 0 to full-scale output voltage programming.

2.6.1 -AX Option CS Series - Supplemental Specifications

Specifications for -AX auxiliary output voltage option on the CS units are listed below. This output is available on the Phase D and E terminal strip. There is no external sense connection for the –AX outputs. Sense is internal only. Specifications apply for programmed frequency range of 360 Hz to 440 Hz.

Parameter	**Supplemental Specification**
Phase D Output	
Voltage	26.0 Vrms ± 0.52 V
Load Regulation	< 1.5 %
Voltage Distortion	< 1.0 % THD
Max. Current	3.0 Arms
Frequency range:	360 – 440 Hz, locked to programmed frequency. If programmed exceeds 819 Hz, -AX outputs will turn off.
Phase error to phase 1	< 3.0°
Phase E Output	
Voltage	5.0 Vrms ± 0.25 V
Load Regulation	< 10 %
Max. Current	1.0 Arms
Frequency range:	360 – 440 Hz, locked to programmed frequency. If programmed exceeds 819 Hz, -AX outputs will turn off.
Phase error to phase 1	< 3.0°

2.6.2 -LKM and -LKS Options CS Series - Supplemental Specifications

The Clock and Lock option enables two or more independent CS power systems to be phase synchronized to each other. One system (-LKM) acts as the master, the other(s) (-LKS) as auxiliaries. The –LKS units are synced to the –LKM unit. Refer to section 3.9 for details on Clock and Lock mode.

The following supplemental specifications apply when the CS is configured with the Clock and Lock option. (-LKM or –LKS).

Parameter	Supplemental Specification
Current	
Current Distortion	Standard: add 1% to standard specifications.
Frequency	
Range	45 – 819 Hz
Resolution	0.1 Hz
Accuracy	± 0.025%
Phase	
Phase Resolution	standard specifications apply.
Phase Accuracy	standard specifications apply.

2.6.3 –EXS Option CS Series - Supplemental Specifications

The –EXS (External Sync) option allows the output frequency of the AC source to be synchronized to an external TTL level clock signal.

The following supplemental specifications apply when the CS is configured with the external sync option. (-EXS).

Parameter	Supplemental Specification
Input	
Voltage Input	TTL Level square wave.
Impedance	10 KOhm.
Frequency	
Range	Same as internal clock mode. See configuration limits.
Max Sync Input Slew Rate	< 80 Hz / sec. Changes in sync input frequency occurring faster than this rate will result in Error 804: External Sync Error. Output relay is opened on Error.
Max Sync Step	< 20 Hz. Sudden changes in sync input frequency greater than 20 Hz will result in Error 804: External Sync Error. Output relay is opened on Error.
Mode Selection	When switching between INT and EXT sync mode, the output of the AC source will be dropped momentarily.
Restrictions	Frequency cannot be programmed in external sync mode. Frequency transient list system is not available in sync mode. Transient list dwell times are not correlated to external sync but based on internal timebase.

2.6.4 –LNS Option CS Series - Supplemental Specifications

The –LNS(AC Line Sync) option allows the output frequency of the AC source to be synchronized to the AC line frequency used to feed the power source.

The following supplemental specifications apply when the CS is configured with the AC line sync option. (-LNS).

Parameter	Supplemental Specification
Input	
AC Line	Synced to Phase B-C (line to line) AC input.
Frequency	
Range	Same as allowable AC input frequency range.
Max Sync Input Slew Rate	< 80 Hz / sec. Changes in sync input frequency occurring faster than this rate will result in Error 804: External Sync Error. Output relay is opened on Error.
Max Sync Step	< 20 Hz. Sudden changes in sync input frequency greater than 20 Hz will result in Error 804: External Sync Error. Output relay is opened on Error.
Mode Selection	When switching between INT and LINE sync mode, the output of the AC source will be dropped momentarily.
Restrictions	Frequency cannot be programmed in line sync mode. Frequency transient list system is not available in line sync mode. Transient list dwell times are not correlated to line sync but based on internal timebase.

3. Unpacking and Installation

3.1 Unpacking

Inspect the unit for any possible shipping damage immediately upon receipt. If damage is evident, notify the carrier. ***DO NOT*** return an instrument to the factory without prior approval. Do not destroy the packing container until the unit has been inspected for damage in shipment. If possible, retain the container in the event the system ever has to be returned to the factory for either repair of upgrades

WARNING: This power source weighs approximately* 175 lbs / 79.2 Kg per chassis (2 chassis total) *Obtain adequate help when moving or installing the unit. Make sure the cabinet and rack slides used to install the CS Series unit(s) can support the weight of the unit(s).

3.2 Power Requirements

The CS Series power Source has been designed to operate from a three-phase, three wire (Wye or Delta) AC input line. A protective earth connection is required as well. (PE).

Available three-phase input setting is 208 to 230 V_{LL} nominal for standard CS models or 400 V_{LL} nominal for CS Series with option –400. All three phase input is three wire plus ground.

CAUTION: Do not connect 400V into a unit designed for 208 use. The result could be a severely damaged unit. Always check the input rating on the model number tag before connecting AC input power. AC voltage input settings CANNOT be changed in the field.

3.3 Mechanical Installation

The CS Series AC power sources can be used free standing on a solid surface or mounted in a 19” instrument cabinet. The units are fan cooled, drawing air in from the side and exhausting at the rear. The back of each unit must be kept clear of obstruction and a 3” clearance must be maintained to the rear. Special consideration of overall airflow characteristics and the resultant internal heat rise must be considered at all times to avoid self heating and over temperature problems.

Multi chassis configurations such as the 9000CS/2 consist of two self-contained 4500CS power sources. They must be connected through the system interface using the supplied DB25 to DB25 cable. Output wiring from each chassis to the EUT must be of **equal wire gage and length** to ensure proper current sharing between units.

Note that for multi-chassis systems, it is recommended to turn the Master unit ON first and then the Auxiliary unit(s). To turn the system off, turn OFF the Auxiliary unit(s) first and then the Master unit.

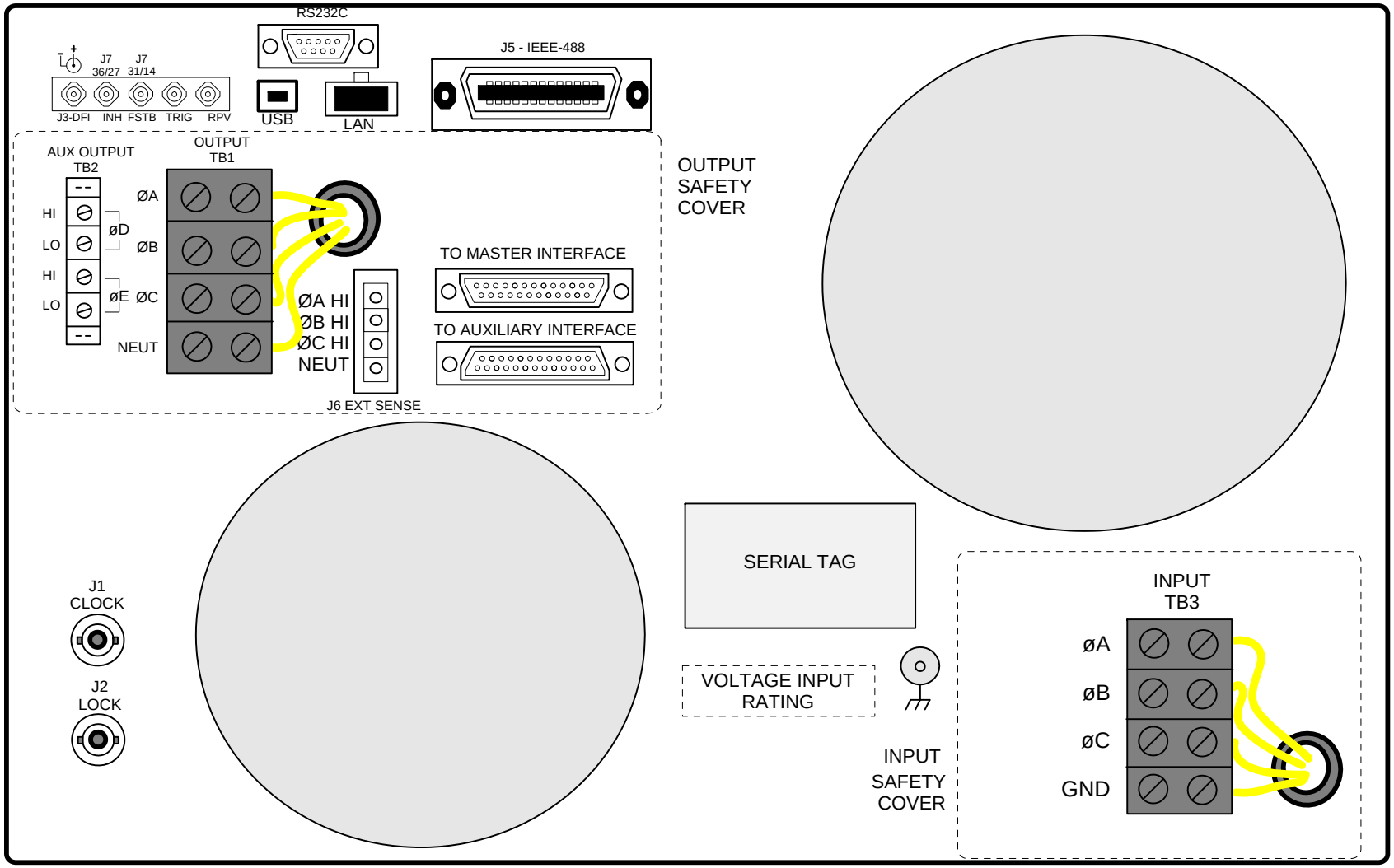


Figure 3-1: Rear Panel Connector Locations – CS Series

3.4 AC Input Wiring - INPUT

AC input connections are to be made directly to the input fuse block of all units that make up a CS system. The input block is located on the lower right hand corner of the back of the 4500CS and 4500CS-NO chassis. It is labeled "INPUT (TB3)."

Ground (earth) wire must be connected to the chassis of the AC power system using the ground connection of the AC input fuse block. The mains source must have a current rating equal to or greater than the input fuses and the input wiring must be sized to satisfy the applicable electrical codes.

The input power cables must be large enough to handle the input current of the power source and must conform to local electrical codes. Consult a qualified electrician prior to installation. Note that all wires must be sized to accommodate the worst-case maximum current that may occur under low line conditions. Local electrical codes may also require different wire types and sizes.

Cable lengths must not exceed twenty-five (25) feet. For lengths greater than 25 feet, calculate the voltage drop from the following formula:

2 X DISTANCE X CABLE RESISTANCE PER FT. X CURRENT = VOLT DROP

Note: If possible, keep input cable lengths for Master and Auxiliary chassis equal.

CAUTION: Capacitors in the power source may hold a hazardous electrical charge even if the power source has been disconnected from the mains supply. Allow capacitors to discharge to a safe voltage before touching exposed pins of mains supply connectors.
Power modules need at least 10 Minutes to discharge to safe levels before they can be removed.

3.5 Output Connections

3.5.1 Output Wiring

The output terminal blocks for each unit are located at the rear of the unit. Three phase output connections are made to the terminal block labeled OUTPUT. For a 9000CS/2 two-box system, the output terminals from both the master 4500CS and Auxiliary 4500CS must be connected together. See Figure 3-2.

On CS Series, the phase outputs are labeled øA, øB, øC and NEUT. The common (neutral) connection (if needed) can be made on the same terminal block labeled NEUT. If the power source is operated in single-phase mode, all power is available from the øA output connection. The neutral connection (NEUT) is always required for single-phase output mode on a CS system and may be used if needed for the EUT for all three-phase output modes.

The external sense inputs allow the power system output voltages to be monitored directly at the load and must be connected at external sense connector. The external sense wires should be run as a twisted pair for short lengths. Sense leads over three (3) feet long should be run as a twisted shielded pair.

Note: The output of the power source is isolated from the input line and floating with respect to chassis ground. If needed, either side (HI or LO) may be grounded.

The output power cables must be large enough to prevent a total voltage drop exceeding the programmed voltage limit or 135 Vrms across the terminals of the current source. Note that wires must be sized to accommodate the maximum current that is available. Always use the current rating size the wires.

Cable lengths must not exceed twenty-five (25) feet. For lengths greater than 25 feet, calculate the voltage drop from the following formula:

2 X DISTANCE X CABLE RESISTANCE PER FT. X CURRENT = VOLT DROP

Note: Ensure that output cable lengths from Master and Auxiliary chassis to EUT are of identical length.

3.5.2 Output Terminal Block – OUTPUT (TB1)

Each CS chassis has a single AC output terminal block. For tabletop operation of a single chassis system, the output terminal block must be covered using the supplied AC Output safety cover. The terminal blocks are large enough to accommodate required wire gauge sizes. The terminal block is located in the upper left corner on the rear panel of the unit. (Looking from the back).

Multi-chassis configurations have two or more output terminal blocks, one on the master CS chassis and one on the auxiliary CS chassis.

For operation as a multi-chassis system, the outputs of all CS chassis' must be connected together using the additional terminal blocks provided in the CS ship kit. **Keep the wire lengths between each chassis and this common terminal block the same.**

See Figure 3-2 for output wiring diagram.

Connector	Terminal	Mode	CS Output OUTPUT (TB1)
	1	3 Phase & 1 Phase	ØA
	2	3 Phase	ØB
	3	3 Phase	ØC
	4	Common / Neutral	NEUTRAL

Table 3-1: Output Terminal connections.

3.5.3 Multi-chassis Output Wiring Diagram

Figure 3-2 shows the required output connections for a 9000CS/2 two chassis system (rear-view perspective). **Always turn off AC mains power to the 9000CS/2 by turning off the circuit breakers on both the Master and Auxiliary 4500CS power source before making or changing output connections.** The terminal block shown to connect the outputs of both chassis together is provided in the 9000CS/2 ship kit. The System Interface cable is a DB25 to DB25 M/F cable approximately 2 meters in length. (CI P/N 250778). This cable connects between the male DB25 connector on the Master unit rear panel labeled TO AUXILIARY INTERFACE and the female DB25 connector on the Auxiliary unit rear panel labeled TO MASTER INTERFACE as shown in Figure 3-2. The OUTPUT SAFETY COVER must be removed to use the System Interface and the AC Source must be installed in a cabinet with a protective rear screen or door.

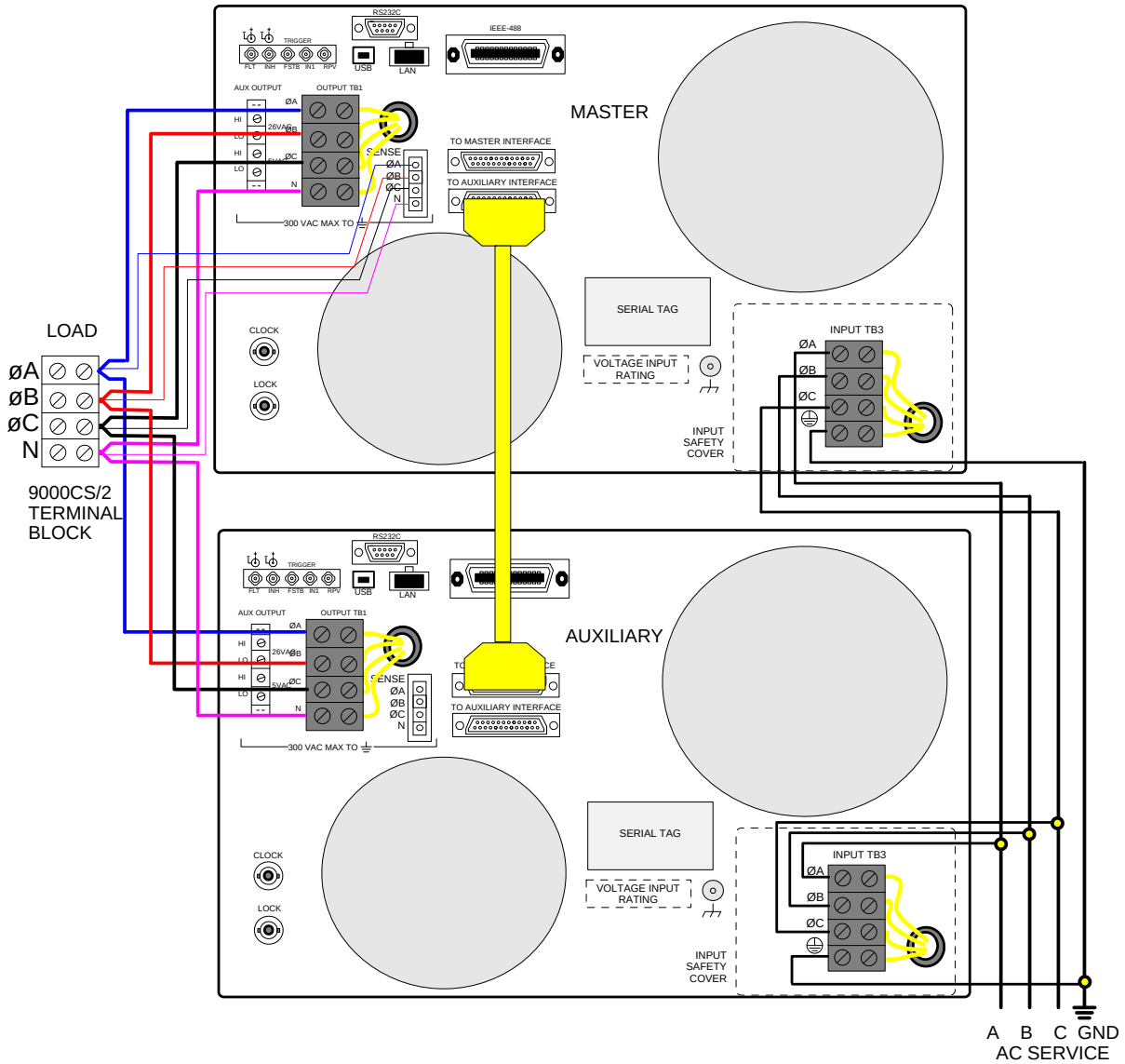


Figure 3-2: 9000CS/2 Output Wiring

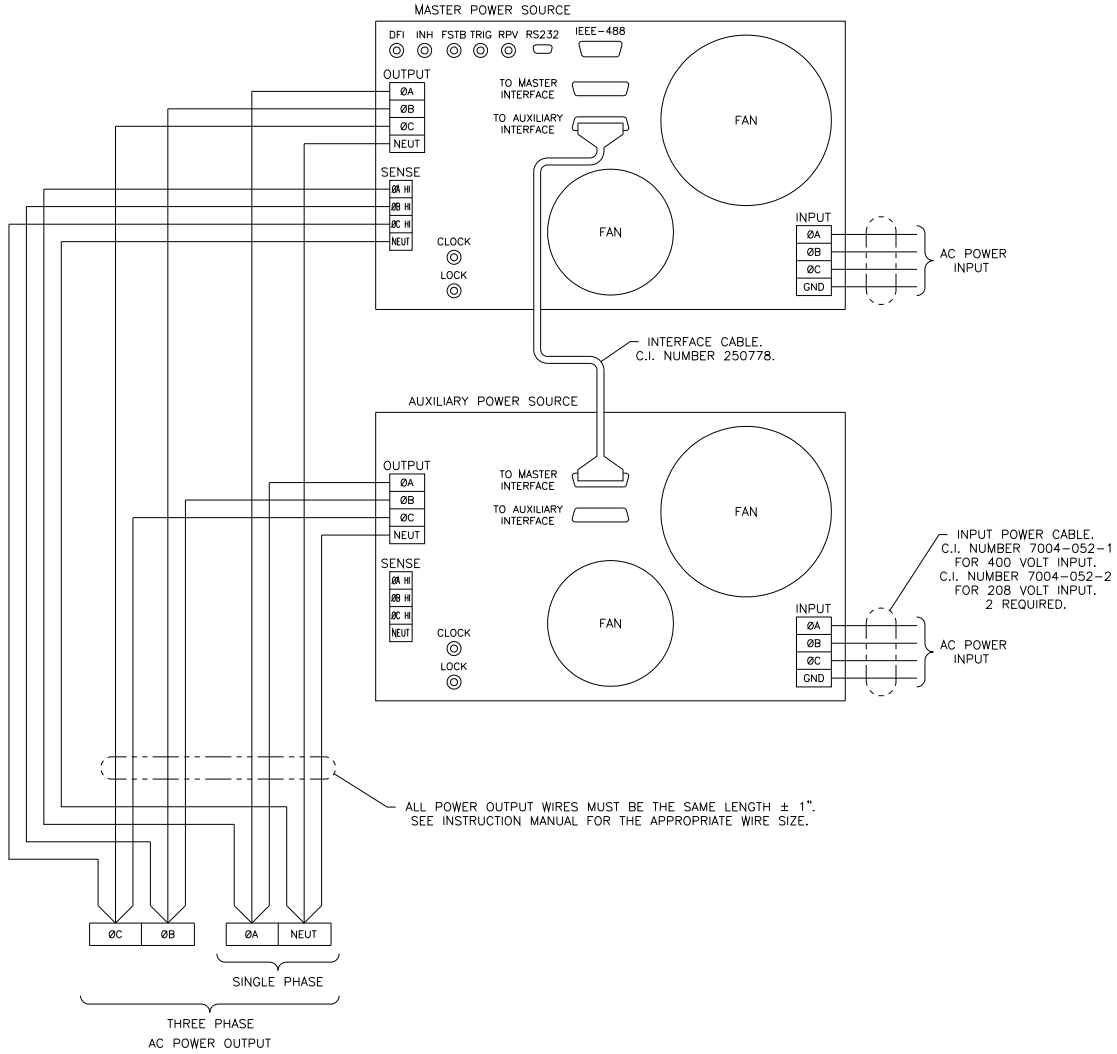


Figure 3-3: 9000CS/2 Wiring diagram - 3 Phase mode

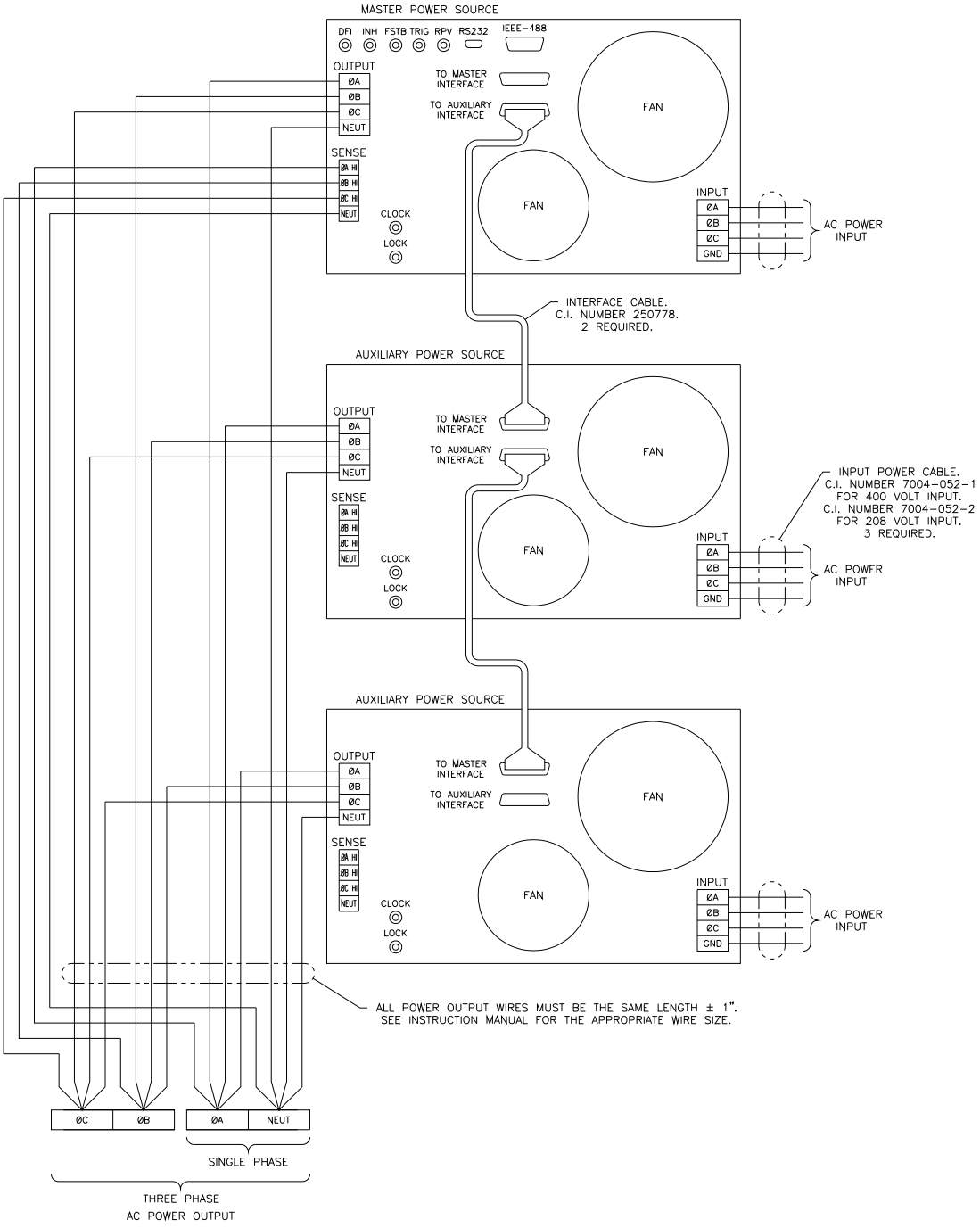


Figure 3-4: 13500CS/3 Wiring diagram - 3 Phase mode

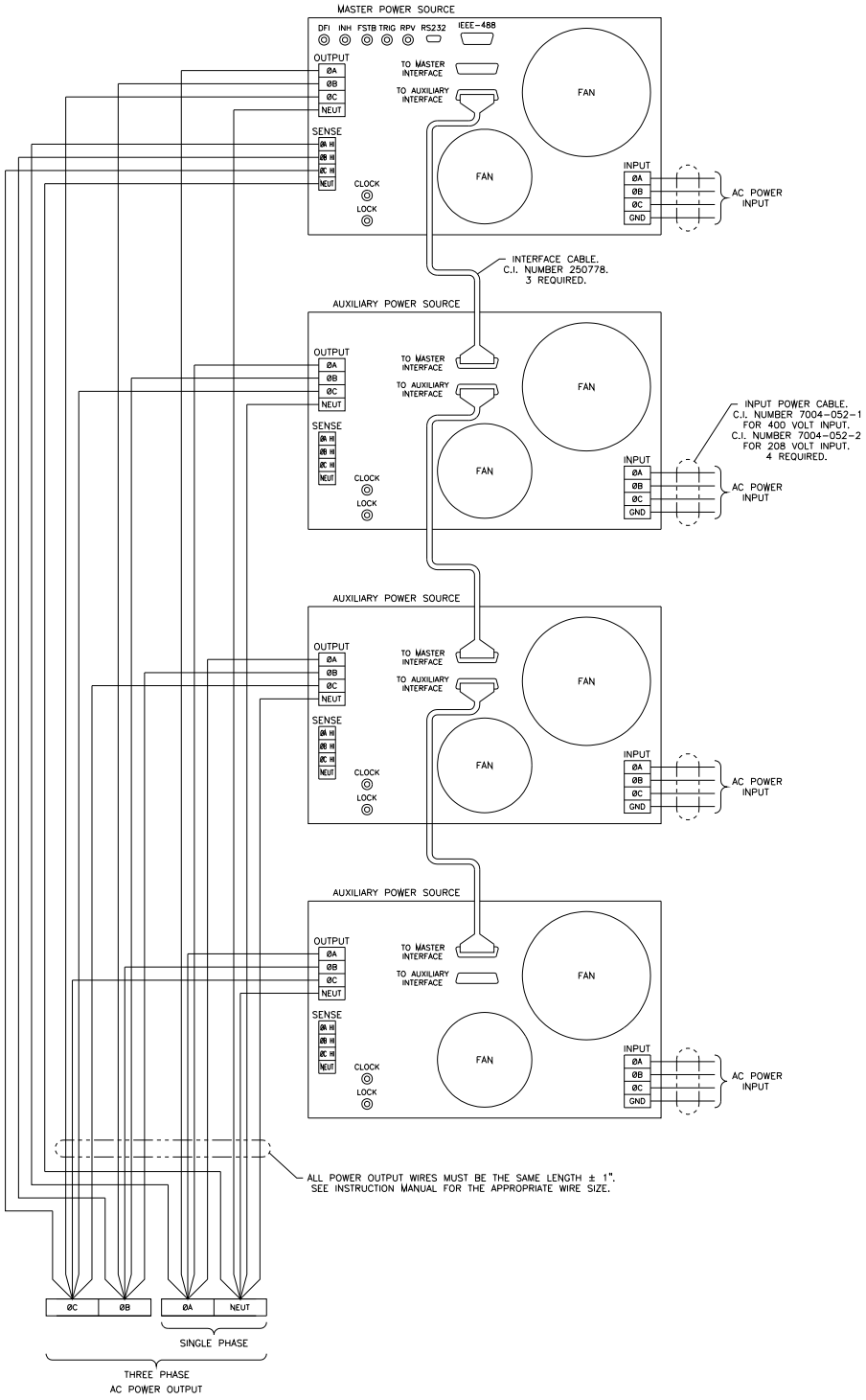


Figure 3-5: 18000CS/4 Wiring diagram - 3 Phase mode

3.6 Connectors - Rear Panel

A number of connectors are located along the top rear covers. These connectors are in a recessed area to protect them from shipment damage. A summary of available connectors is provided in the table below.

Connector		
CS Series		
AC Input (INPUT – TB3)	**Function**	**Connects To**
ØA – AC in ØB – AC in ØC – AC in CHASSIS - GND	Primary AC Power Input	208 - 230 VAC nominal (Std) 400 VAC nominal (-400 option)
AC Output (OUTPUT – TB1)	**Function**	**Connects To**
ØA ØB ØC NEUT	AC output	User Load
External Sense	**Function**	**Table**
Sense ØA HI, ØB HI, ØC NI, NEUT	External Sense	Table 3-6
Remote Control	**Function**	**Table**
RS232	Serial Control Interface	Table 3-7
IEEE-488	GPIB Control Interface	See IEEE-488 standard for pin out.
LAN	Ethernet Interface	Optional, -LAN option
USB	USB Control Interface	
System Interface	**Function**	**Table**
Master	Connects to Master	DB25, MALE
Auxiliary	Connects to Auxiliary	DB25, FEMALE
Other	**Function**	**Table**
SMA Connectors	Discrete Fault Indicator	Table 3-4
	Remote Inhibit	Table 3-4
	Function Strobe	Table 3-4
	Trigger	Table 3-4
	RPV	Table 3-4
BNC Connectors	Clock	Table 3-5 -LKM / -LKS option
	Lock	Table 3-5
	RPV (N/A)	Table 3-4

Table 3-2: Rear Panel Connectors

3.6.1 AC Input Connector – INPUT (TB3)

See section 3.4 for details on connecting AC input power. Labeled INPUT on CS models.

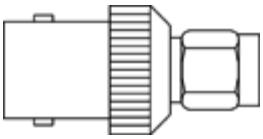
INPUT.	Designator CS Series	Direction	Connection Description
1	ØA	Input	AC Line
2	ØB	Input	AC Line
3	ØC	Input	AC Line
4	GND		Chassis Ground

Table 3-3: AC Input Terminal Block Connection Description

3.6.2 SMA Connectors

SMA connectors. Functions are called out on rear panel decal. Table 3-4 shows connections from left to right when standing at the rear of the CS cabinet. SMA connectors are small high frequency capable coax connectors that can be screwed down securely to prevent signal loss. Adaptor for SMA to BNC conversion are readily available.

To connect these signals using more conventional BNC cables, SMA Male to BNC Female adapters may be used. These are available from www.pasternack.com , P/N PE9074.


PE9074 Adaptor.

SMA	Description
FLT	Discrete Fault Indicator output. Isolated Open Collector. Can be used to signal external devices when a fault condition is detected.
INH	Remote Inhibit. (TTL input)
FSTB	Function Strobe / Trigger Output (TTL output)
TRIG	Trigger Input (TTL input)
RPV(N/A)	Remote programming voltage. DC voltage input 0 to +10 VDC for 0 to full-scale output voltage programming.(RPV option)

Table 3-4: SMA Connectors – CS Series

3.6.3 BNC Connectors (-LKM / -LKS options)

BNC connectors. Functions are called out on rear panel decal. Table 3-5 shows connections for the optional -LKM and -LKS clock and lock mode. Refer to section 3.9 for more details.

BNC	CS Series Ref.	Description
CLOCK	J1	Clock Option (TTL output on Master / TTL input on Auxiliary) N/A
LOCK	J2	Lock Option (TTL output on Master / TTL input on Auxiliary) N/A

Table 3-5: BNC Connectors

3.6.4 External Sense Connector – SENSE

The external sense connections for Phase A, B and C in three-phase mode and Phase A in single phase mode MUST be connected for correct operation unless internal sense mode is selected. Sense connections must be made at the MASTER 4500CS unit for a multi-box CS system.

Pin	Description - CS Series
1	Phase A sense Hi
2	Phase B sense Hi
3	Phase C sense Hi
4	Neutral sense
5	-AX Option Phase D Hi – N/A
6	-AX Option Phase D Lo – N/A

Table 3-6: External Sense Connector

3.6.5 RS232C Serial Interface – RS232C

A standard RS232C DB9 connector is located on the rear panel for serial control. A straight thru DB9 male to DB9 female interface cable to 9-pin PC serial port connector may be used

Pin	Designator	Dir.	Description
1	Not used		N/C
2	TxD	Output	Transmit data
3	RxD	Input	Receive data
4	Not used		N/C
5	Common		Common
6	Not used		N/C
7	CTS	Input	Clear to send
8	RTS	Output	Request to send
9	Not used		N/C

Table 3-7: RS232C Connector

3.6.6 System Interface Connectors – MASTER and AUXILIARY

WARNING: The system interface connectors are for use with California Instruments supplied cables, and only between California Instruments equipment.

A set of two System Interface connectors is located on the rear panel of each 4500CS chassis. The system interface is used to connect the multiple 4500CS current sources in a Master/Auxiliary configuration to create a 9000CS/2, 13500CS/3 or 18000CS/4 AC current source configuration. In this configuration, only the Master power source has a built-in controller and front panel. The System Interface cable provided in the CS Series ship kit (CI P/N 250778) MUST be used to connect both chassis as shown in Figure 3-2.

Note that no user accessible signals are provided on the System Interface connections and they should only be used for their intended purpose. To use the System Interface capability, the output safety cover has to be removed. As such, multi-chassis configurations cannot be used outside of a cabinet with proper rear screens.

Note that for multi-chassis systems, it is recommended to turn the Master unit ON first and then the Auxiliary unit(s). To turn the system off, turn OFF the Auxiliary unit(s) first and then the Master unit.

3.6.7 USB Interface

A standard USB Series B device connector is located on the rear panel for remote control. A standard USB cable between the AC Source and a PC or USB Hub may be used.

Note: Use of the USB port to control more than one power source from a single PC is not recommended, as communication may not be reliable. Use GPIB interface for multiple power source control.

Figure 3-6: USB Connector pin orientation.

Pin	Name	Description
1	VBUS	+5 VDC
2	D-	Data -
3	D+	Data +
4	GND	Ground

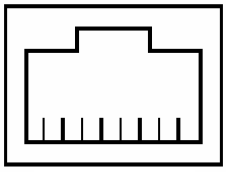
Table 3-8: USB Connector pin out.

3.6.8 LAN Interface – RJ45

An optonal RJ45 Ethernet 10BaseT connector is located on the rear panel for remote control. A standard RJ45 UTP patch cord between the AC Source and a network Hub may be used to connect the AC source to a LAN. For direct connection to a PC LAN card, a crossover RJ45 cable is required. Consult your network administrator for directions on connecting the AC source to any corporate LAN.

If the –LAN Ethernet interface option is present, the MAC Address (Media Access Control) of the Ethernet port is printed on the serial tag of the power source. The serial tag is located on the rear panel of the unit.

For information on how to set up a network connection or a direct PC connection using the LAN interface, refer to the CS Series Programming Manual P/N 7004-988 distributed in Adobe PDF format on CD ROM CIC496.



LAN

Pin #	Ethernet TPE 10BaseT/100BastT/1000BaseT	EIA/TIA 568A	EIA/TIA 568B Crossover
1	Transmit/Receive Data 0 +	White with green stripe	White with orange stripe
2	Transmit/Receive Data 0 -	Green with white stripe or solid green	Orange with white stripe or solid orange
3	Transmit/Receive Data 1 +	White with orange stripe	White with green stripe
4	Transmit/Receive Data 2 +	Blue with white stripe or solid blue	Blue with white stripe or solid blue
5	Transmit/Receive Data 2 -	White with blue stripe	White with blue stripe
6	Transmit/Receive Data 1 -	Orange with white stripe or solid orange	Green with white stripe or solid
7	Transmit/Receive Data 3 +	White with brown strip or solid brown	White with brown strip or solid brown
8	Transmit/Receive Data 3 -	Brown with white stripe or solid brown.	Brown with white stripe or solid brown

Table 3-9: RJ45 LAN Connector pin out.

3.7 Basic Initial Functional Test

CAUTION: Work carefully when performing these tests; hazardous voltages are present on the input and output during this test.

Note: Never program a current source with the output terminals open-circuit. A no load is a short circuit.

Refer to Figure 3-7 for the required functional test set up. Proceed as follows to perform a basic function check of the power system:

1. Verify the correct AC line input rating on the nameplate of the CS unit(s) and make sure the correct three-phase line voltage is wired to the input of the CS before applying input power.

2. Connect a suitable resistive or other type load to the output of the CS. Suggested load values for the 135 range rounded up to the nearest 0.1 Ohm are shown in Table 3-10. Make sure the power resistor has sufficient power dissipation capability for full load test and that the load used does not exceed the maximum power rating of the AC source. For three phase configurations, this test can be performed on one phase at a time if needed.

3. Connect an oscilloscope and DMM / voltmeter to the AC source output. Set both for AC mode.
   Note: The voltage across the output will only be representative of the actual output current if a purely resistive load is used.

4. If the correct AC input voltage is present, turn on the CS unit(s) by closing the On/Off circuit breaker on the front panel of both chassis.

5. Program the low voltage range, the output current to 0 amps and close the output relay with the OUTPUT ON/OFF button. There should be little or no output although the DMM may show a noise level, especially if the DMM is in auto ranging mode.

6. Select the **Set** screen and use the shuttle to program a small current (0.5 A). Observe the DMM reading. The reading should track the programmed current.

7. Also monitor the scope. The output should be a sinusoidal voltage waveform.

8. If the output tracks, increase the current until you reach 100 % of the current range. Check the output voltage reading and waveform.

9. Select the measurement screen by pressing the **Meas** button. The output current, voltage, and power will be displayed. For three phase configurations, use the PHASE button to select individual phase data. If all phases are loaded equally, the same current and power should be visible for all three unless the currents are not programmed to the same level. If only one phase is loaded, current and power will only be shown for the loaded phase.

In the unlikely event the power source does not pass the functional test, refer to the calibration procedure in Section 6 or call California Instrument's customer satisfaction department for further assistance. The voltage across the load will not represent the actual current unless the load resistance is better than 0.1% at the programmed current level.

Model	3 Phase Mode	1 Phase Mode
3000CS	4.5 Ohms, 1.5 KW rating	1.5 Ohms, 4 KW rating
4500CS	6.8 Ohms, 2 KW rating	2.2 Ohms, 6 KW rating
9000CS/2	3.4 Ohms, 4 KW rating	1.1 Ohms, 12 KW
13500CS/3	2.28 Ohms, 6 KW rating	0.76 Ohms, 18 KW rating
18000CS/4	1.71 Ohms, 8 KW rating	0.43 Ohms, 24 KW rating

Table 3-10: Full Load Resistance – CS Series

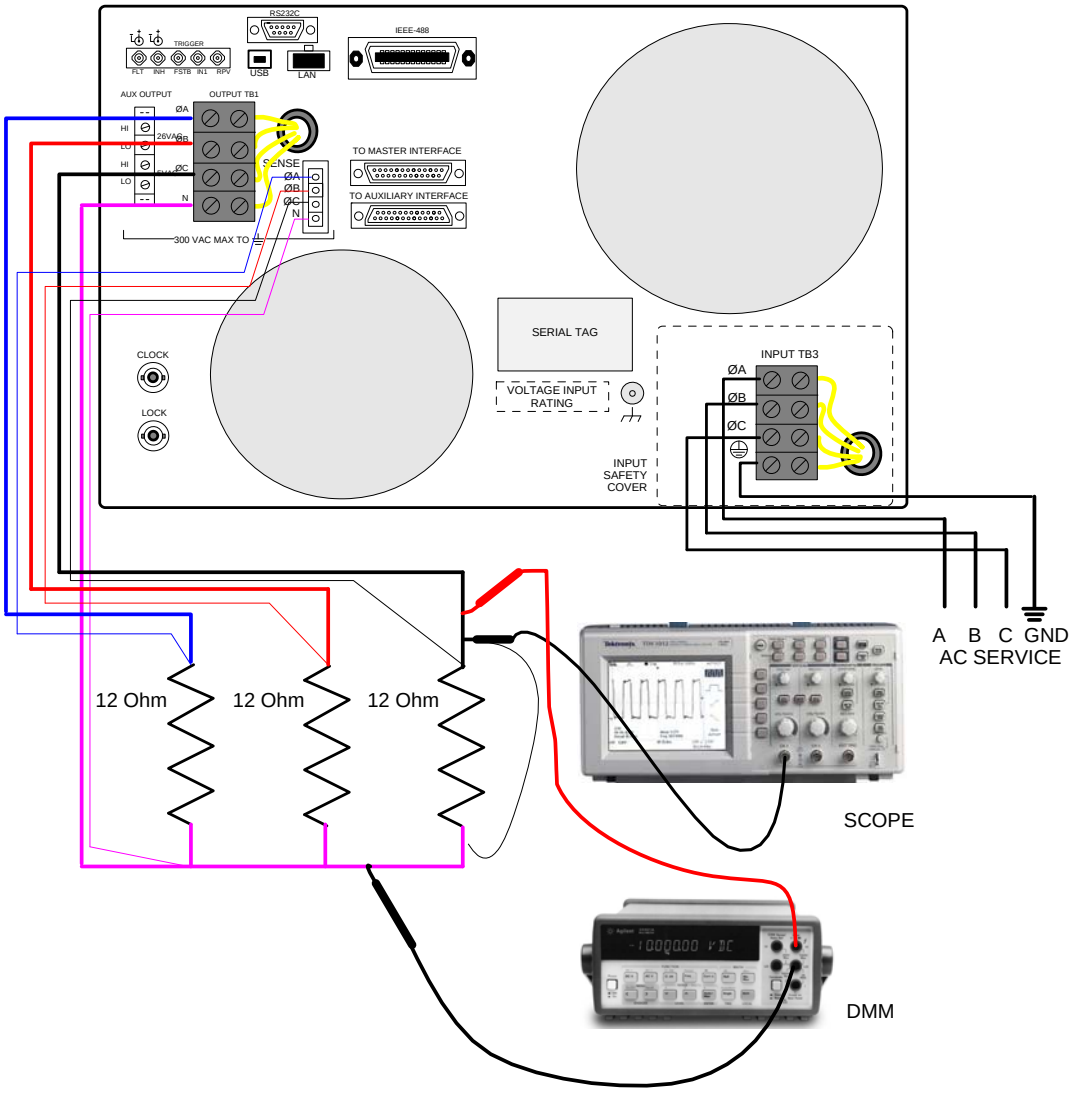


Figure 3-7: Functional Test Setup

3.8 Multi-box Configurations (-MB Option)

Multi-box configurations are identical to a two or three box system except each chassis (box) has its own controller. When connected as a multi-chassis system through the system interface, the controller in the auxiliary chassis is disabled and the entire system is controlled from the master unit. Operation is identical to a normal multi-box model. E.g. a 9000CS/2-MB is connected and operated the same way as a 9000CS/2. While a 9000CS/2 will have one chassis with a blank front panel, a 9000CS/2-MB will have a controller on both front panels of which only one is used when configured as a 9000CS/2. The other controller will display a message indicating it is operating as an auxiliary unit[1].

The benefit of the –MB option is that both units can be separated and operated independently. To so do, proceed as follows:

1. Turn off both units.
2. Disconnect the output terminals (A,B,C, COM) from each other.
3. Disconnect the system interface cable between the two (or three) units.

When powered up, each unit will power up as a stand-alone unit. Connection diagrams for a –MB system are identical to those for a 9000CS/2 13500CS/3 or 18000CS/4. See section 3.5.3, Figure 3-3 through Figure 3-5 for wiring diagrams.

3.8.1 Power Up and Power Down sequence.

A multi-box CS system can be turned on in either order. Generally, it is recommended to turn on the master unit before turning on the auxiliary unit and turn off in the opposite order but no damage will occur if the order is reversed.

Note: It is not recommended to turn off either unit without turning off the other unit and then turning it back on. This may result in miscellaneous error messages occurring on the unit that was not powered down. If one unit has been turned off, turn off all units first before turning the system back on.

If a master unit is to be used by itself, it is not sufficient to just leave the auxiliary unit off while the system interface cable remains connected. Disconnect the system interface from the back of the master unit and then turn the unit on for stand-alone use.

[1] This message will disappear when the controls on the auxiliary unit are operated. However, changing settings on the auxiliary unit controller will not affect the output. Use the master unit controller and or remote control interface to operate the system.

3.9 Clock and Lock Mode (-LKM/-LKS Option)

Clock and lock mode operation of two or more CS AC power sources or a Lx/Ls Series AC voltage source with a CS Series Current source is available only if the –LKM and –LKS options have been installed at the factory. With these options installed, it is possible to lock an auxiliary unit (-LKS) to a master unit (-LKM). The master unit controls the frequency. This configuration can be used to create multiphase power systems such as split-phase or six phases or Power simulation systems. The auxiliary unit must be set to external clock mode from the Control screen. See section 4.2.5.

Two BNC connectors are provided on the rear panel of the CS for clock and lock mode. Both need to be connected between the master and auxiliary unit. On the master unit (-LKM), both are outputs. On the slave unit (-LKS), both are inputs. Do not connect these BNC's between two master units (-LKM's) or damage to the unit could result.

Refer to Figure 3-8 for the required connections between the –LKM and –LKS units. The example is shown for two units, one master, one auxiliary. More than one auxiliary can be used to create additional phase outputs. In this case, the BNC cables can be daisy chained using BNC T connectors.

WARNING: DO NOT CONNECT THE AC OUTPUTS OF THE –LKM AND –LKS UNITS TOGETHER. CLOCK AND LOCK OUTPUTS CANNOT BE PARALLELED TO OBTAIN HIGHER OUTPUT CURRENTS.

Do not use clock and lock mode to obtain higher power capability on the same phase(s). For higher power configurations, use the multi-chassis configuration through the system interface connection instead. Refer to section 3.5.3 for multi-chassis configuration and connection information.

The frequency of the auxiliary unit will track that of the master. The output phase angle of phase A will be locked to the auxiliary unit as well to within 3°. This allows split phase or six phase configurations to be created.

3.9.1 Configuration settings

Units configured with the –LKM option will show the Clock as INT (internal) and the mode as CLK/LOC on the CONTROL screen. Units configured with the –LKS option can be set to INT (internal) or EXT (external) clock from the CONTROL screen. The MODE setting on the CONTROL screen of the –LKS unit determines the power on state for the clock setting. When set to STAN (Stand-alone operation), the unit powers up with INT clock. When set to CLK/LOC mode, it powers up in EXT clock mode suitable to clock and lock system operation. See section 4.2.5 for details.

3.9.2 Frequency measurements on –LKS units

CS models configured with the –LKS option used in a clock and lock configuration will not accurately measure frequency if the programmed frequency of the master unit (-LKM) exceeds 2000 Hz unless the frequency setting of the –LKS is set to the a value close to the programmed frequency of the –LKM master unit. Setting the –LKS programmed frequency when it is operating as a clock and lock auxiliary does not affect its actual output frequency as it is controlled by the
–LKM master unit. This provides the controller with the required information to accurately measure the frequency.

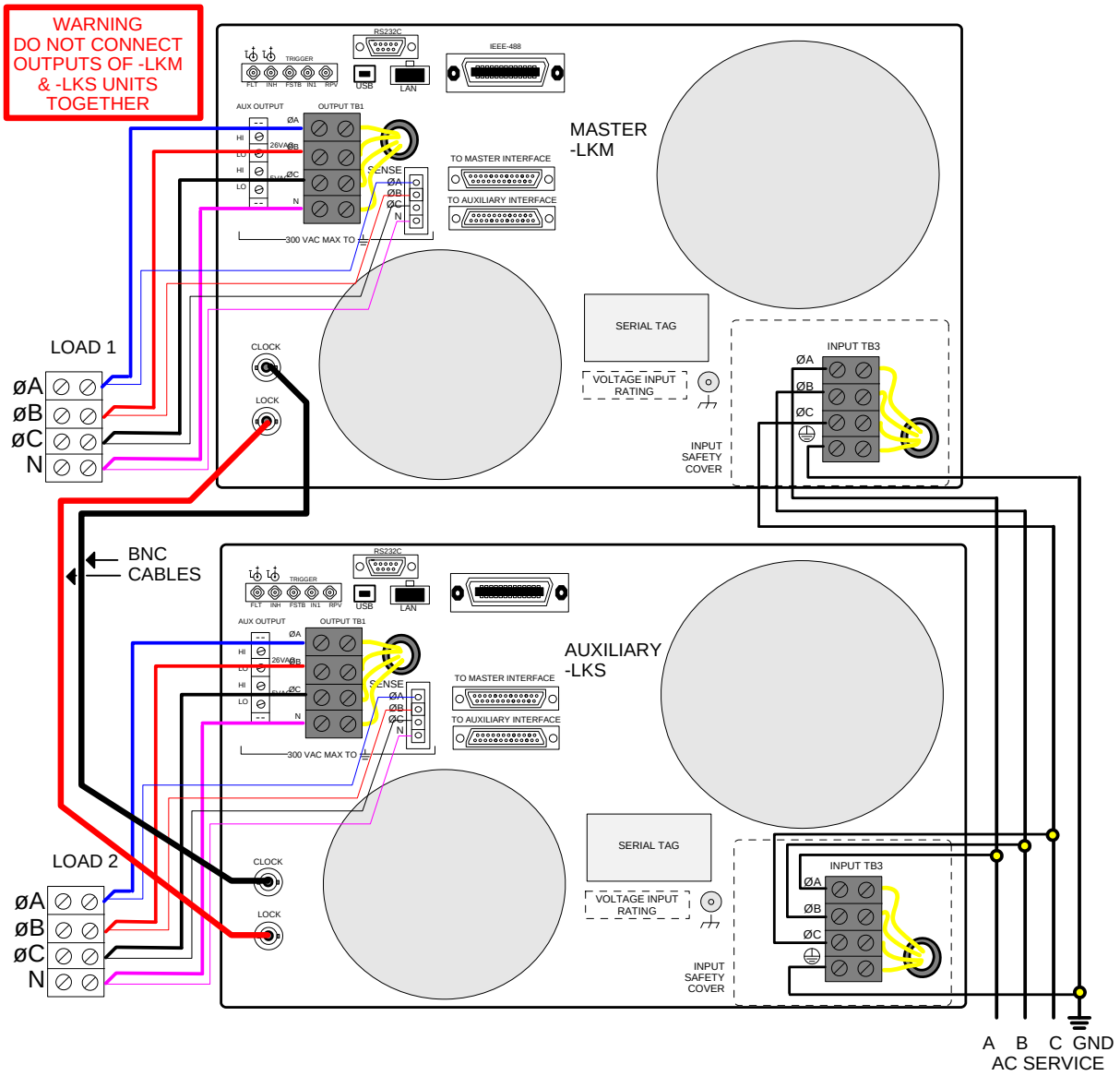


Figure 3-8: Clock and Lock Connections

3.10 Remote Control Interfaces and CSGui Program

Setup and connection information on setting up remote control using either GPIB, RS232, USB or LAN interfaces is provided in the CS Series Programming Manual P/N 7004-988. This manual is distributed on the same CD ROM (P/N CIC496) as this user manual. It can also be downloaded from the California Instruments website (www.programmablepower.com).

Connector pin out information is provided in sections 3.6.5, 3.6.7 and 3.6.8 of this manual.

A Windows XP/2000 graphical user interface program (CSGui, P/N CIC913) is provided on CD ROM CIC496. The CSGui may be used to control the CS Series units from a PC[1].

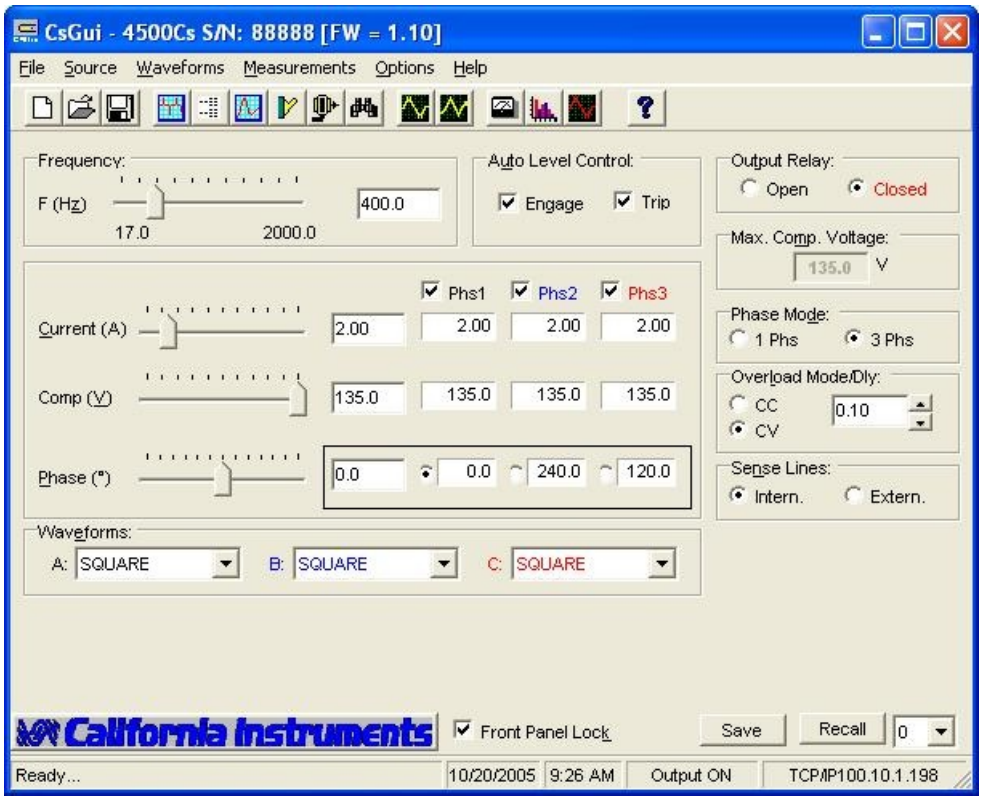


Figure 3-9: CSGui Windows application software

Note: Use of the USB port to control more than one power source from a single PC is not recommended, as communication may not be reliable. Use GPIB interface for multiple power source control.

3.11 RPV Input (RPV option)

The –RPV option is factory installed only. If installed, this option disables the internal controller voltage programming reference. Instead, a user provided DC signal is used to drive all

[1] Note: The CSGui is a Microsoft .NET based application program and requires the .NET Framework Version 2.0. The .NET framework may be downloaded from Microsoft's website. (http://www.microsoft.com/downloads/)

amplifiers. Note that only one RPV input is available so in three phase modes, all three outputs will track the same RPV DC input signal.

A 0 to +10 VDC signal will provide a 0 to full-scale voltage output on the selected voltage range.

To enable the RPV mode, press the MENU key until the CONTROL screen and scroll to the ALC setting entry. If the ALC is set to REG or ON, turn if OFF first. Then scroll to the VOLT REF entry. Select EXT to use the RPV (remote programming voltage).

The presence of the RPV option is indicated by the –RPV field in the model number on the serial tag. Note that the –EXT and –RPV options are mutually exclusive so only one or the other can be present.

4. Front Panel Operation

4.1 Tour of the Front Panel

Before operating the AC source using the front panel, it helps to understand the operation of the front panel controls. Specifically, the operation of the knob, keyboard and the menu layout are covered in the next few paragraphs.

4.1.1 Front Panel Controls and Indicators

The front panel can be divided in a small number of functional areas:

- Mains circuit breaker
- Keyboad/ Display panel:
  - Status Indicator lights
  - Shuttle knobs (Voltage / Frequency)
  - LCD display
  - MENU and CURSOR keys

4.1.2 System On/Off Circuit Breaker

The circuit breaker located on the top left side of the front panel of the unit and disconnects the three phase Line input. As such, the circuit breaker acts as a power on/off switch for the CS Series unit.

When the input current rating of the CS Series AC power source is exceeded or an input over voltage condition occurs, the circuit breaker will trip.

Note that for multi-chassis systems, it is recommended to turn the Master unit ON first and then the Auxiliary unit(s). To turn the system off, turn OFF the Auxiliary unit(s) first and then the Master unit.

4.1.3 Status Indicator Lights

Eight yellow LED status indicators are located on the left hand side of the keyboard/display panel. These LED's correspond to the following conditions:

Hi Range — The **Hi Range** LED is on when the high voltage output range has been selected.

Overtemp — The **Overtemp** LED indicates an overheating problem inside the unit. This is an abnormal condition, which will cause the unit to shut off. Check the air openings to make sure they are not blocked.

Overvoltage — The **Overvoltage** LED indicates an output overvoltage condition. This condition can be controlled by setting the compliance voltage value in the PROGRAM menu. The output will fault in the CC mode or reduce the current to limit the voltage in the CV mode.

Remote — The **Remote** LED indicates that the unit is in remote control mode. If the IEEE-488 interface is used, this indicator will be lit whenever the ATN line (Attention) line is asserted by the IEEE controller. If the RS232C, USB or LAN interface is used, the REMOTE state can be enabled by the controller using the SYST:REM command. Any time the **Remote** LED is lit, the front panel of the power source is disabled. Note: The BACK button doubles as a GOTO LOCAL button (LOCAL) while the unit is in remote state. This allows the user to regain control of the front panel. The LOCAL button can be disabled by sending a Local Lockout bus command. This prevents unauthorized changes of settings in ATE applications.

Output on/off — The **Output on/off** LED indicates the output relay status. If the LED is off, the output relays for all output phases are open and the external sense lines are wrapped around internally. If the LED is on, the output relays are closed and the external sense lines are connected to the SENSE terminal block.

ØA, ØB, ØC — The **ØA, ØB, ØC** LED indicates the output phase selection for either settings or measurements. Phase selection can be changed using the **Phase** button to the right of the MEMU keys. Pressing the **Phase** button repeatedly will cycle through phase A, B, C and ALL PHASES. The **ØA, ØB, ØC** indicators correspond to outputs ØA, ØB and ØC on the CS Series rear panel. If all three phase selection LED's are lit, all three phases are selected and changes made to voltage and current limit settings will apply to all three phases.
Note that in single-phase mode, the ØA LED is always lit and the Phase button is inactive.

4.1.4 The Shuttle Knob

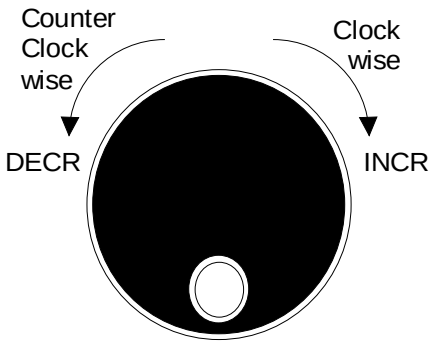


Figure 4-1: Shuttle Knob

The shuttle knob is located to the right of the LCD screen and is used to change setup parameters. Note that it cannot be used to move the cursor position between menu fields. Use the UP and DOWN arrow keys for this.

The shuttle knob can operate in one of two distinct modes of operation:

MODE	DESCRIPTION
IMMEDIATE mode	Any time the ENTER key is pressed, the CS Series returns to its normal mode of operation. In this mode, changes made with the shuttle knob will take immediate effect. The IMMEDIATE mode is useful for slewing output values such as current and frequency and observing the effect on the load.
SET mode	When the **Set** key is pressed again while the PROGRAM screen is already displayed, changes made with the shuttle to any output parameter will not take effect until the ENTER key is pressed. In this mode, any changes made to a setup menu will have a blinking cursor to indicate the pending change condition. This mode allows changes to be made to all output parameters and executing them all at once by pressing the ENTER key.

4.1.5 Menu Keys

The CS Series is operated through a series of menus. These menus can be reached by using a number of menu keys located along the bottom of the LCD display and the UP/DOWN cursors keys. Several menus have more than two entries. Since the LCD display only has two display lines, additional entries may not be visible and can be reached only by scrolling up or down using the UP/DOWN cursor keys. The following menu keys are available:

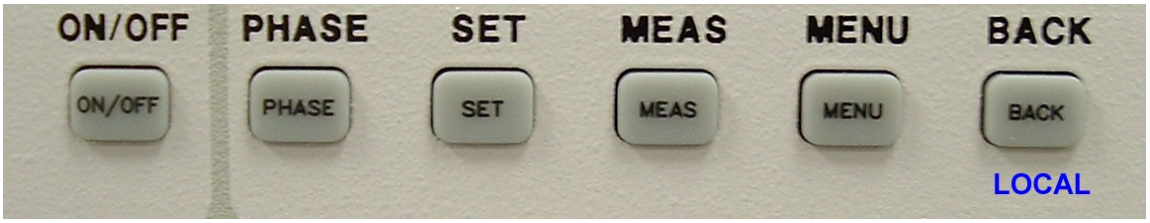


Figure 4-2: Menu Keys

KEY	DESCRIPTION
Set	The **Set** key selects the output setting screen. While this screen is displayed, the voltage and frequency shuttle knobs can be used to change voltage and frequency for the selected phase(s). Additional output settings such as current limit can be reached by using the down ▼ cursor key.
Meas	The **Meas** key selects the measurement screen for the selected phase. If all three phases are selected, the measurement data for phase A will be displayed. There are no user changeable fields in the measurement screen. The voltage and frequency shuttles are active while the measurement screen is displayed. Additional measurement data can be displayed by using the up ▲ and down ▼ cursor keys.
Menu	The top-level menu is accessed by pressing the **Menu** key. Refer to section 4.2 for details on available menus.
Enter	The **Enter** key is used to confirm selections made in menus or to activate settings made in SET mode.
Decimal Keypad	A conventional decimal keypad facilitates quick entry of numerical values such as voltage, current limit, etc. The large blue enter key will make the value you enter effective. Using the SET key allows the user to preset all parameter values and update them all at once by pressing the Enter key.
Back	The Back key may be used to back up to the previous menu level or previously selected screen. It can also be used as a backspace key to delete the last digit entered. If the unit is in remote mode, (**Remote** LED is lit), the front panel of the power source is disabled. The BACK button doubles as a GOTO LOCAL button (LOCAL) while the unit is in remote state. This allows the user to regain control of the front panel. This LOCAL button can be disabled by sending a Local Lockout bus command. This prevents unauthorized changes of settings in ATE applications.

4.1.6 Cursor Keys

The cursor keys can be used to scroll through a list of menu entries.:

CURSOR UP (▲)	The UP key moves the cursor position upwards one position to the previous available cursor position. If the present cursor position is at the top of the right hand column, the cursor is moved to the bottom position of the left hand column. If the present cursor is at the top of the left hand column, the cursor is moved to the bottom of the right hand column.
CURSOR DOWN (▼)	The DOWN key moves the cursor position downwards one position to the next available cursor position. If the present cursor position is at the bottom of the left hand column, the cursor is moved to the top position of the right hand column. If the present cursor is at the bottom of the right hand column, the cursor is moved to the top of the left hand column.

4.1.7 Output on/off Key

The **Output on/off** key located to the left of the Menu keys may be used to control the state of the output relays. The active state is indicated by the LED directly above the on/off key. If the output relays are open (LED is off), the output is floating. The ON/OFF button provides a convenient way to disconnect the load without having to remove any wires.

4.1.8 Phase Key

The **Phase** key may be used to select the desired output phase. (ØA, ØB, ØC). Pressing the **Phase** button repeatedly will cycle through phase A, B, C and ALL PHASES. The **ØA, ØB, ØC** indicators correspond to outputs ØA, ØB and ØC respectively.

If all three phase selection LED's are lit, all three phases are selected and changes made to voltage and current limit settings will apply to all three phases.

Note that in single-phase mode, the ØA LED is always lit and the Phase button is inactive.

4.1.9 LCD Display

The LCD display of the CS Series power source provides information on instrument settings and also guides the user through the various menus. A sample of the measurement display screen is shown in Figure 4-3. Due to the two line (x 20 characters) display limitation of the LCD display, most menus are accessed by scrolling through two or more entries. Alternatively, the Menu key may be pressed repeatedly to access additional available menu entries.

The active cursor position is indicated by a LEFT POINTING ARROW (←) and can be moved by using the UP (▲)and DOWN (▼) keys located to the right of the LCD display.

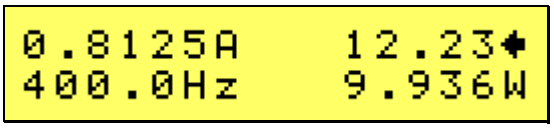


Figure 4-3: Measurement Screen

4.2 Menu Structure

The next few pages show a map of the available menus in the CS Series. All menus can be reached by repeatedly pressing the **Menu** key. Frequently used menus have a short cut key that provides direct access. Examples of such menus are Program and Measurements. In any case, there are never more than two levels of menus although some menus may be spread across more than one screen.

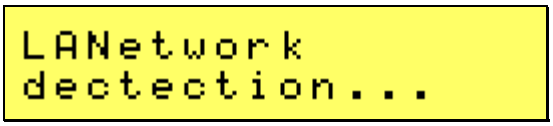
4.2.1 Power on screens

At initial power up, the CS Series power supply will display important configuration information in a series of power on screens. These displays are only visible for a short period of time and will not re-appear until the next time the unit is turned on.

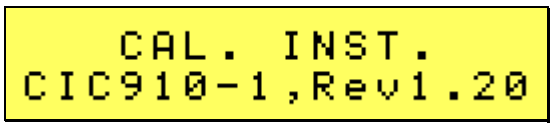
There are three screens that will appear in the same order:

1. LANetwork detection... At power up, the unit will try to detect a LAN interface. If not found, a "LAN not available" message will appear. The LAN will not be detected if:
   1. No –LAN option is installed.
   2. The USB port is connected to a computer.
   3. The RS232 port is enabled (jumper is not installed).

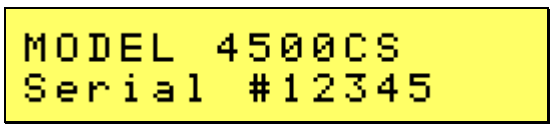
   This process may take several seconds.



2. Company and firmware information. Displays the manufacturer (Cal Inst., which is short for California Instruments) and the firmware part number and revision. The firmware part number starts with CIC followed by a three-digit code and dash number. The firmware revision has a major revision before the decimal point and a minor revision after the decimal point.

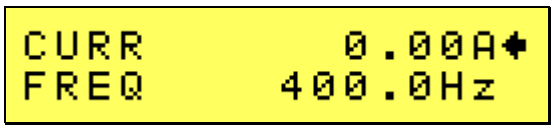


3. Model and Serial number information. The model will be a function of the configuration and will include the series designation (CS). The serial number is a 5 digit number. This number should match the model type sticker located on the back of the unit.



4. Self test result. If all internal functions pass the power-on self-test, the message "Self test passed" will appear. If any part of the internal self-test fails, an error message will be displayed instead. This information may be useful when calling in for service support.

Once the power on sequence is completed, the power source will always revert to the PROGRAM screen shown here.



The power source is now ready to be used.

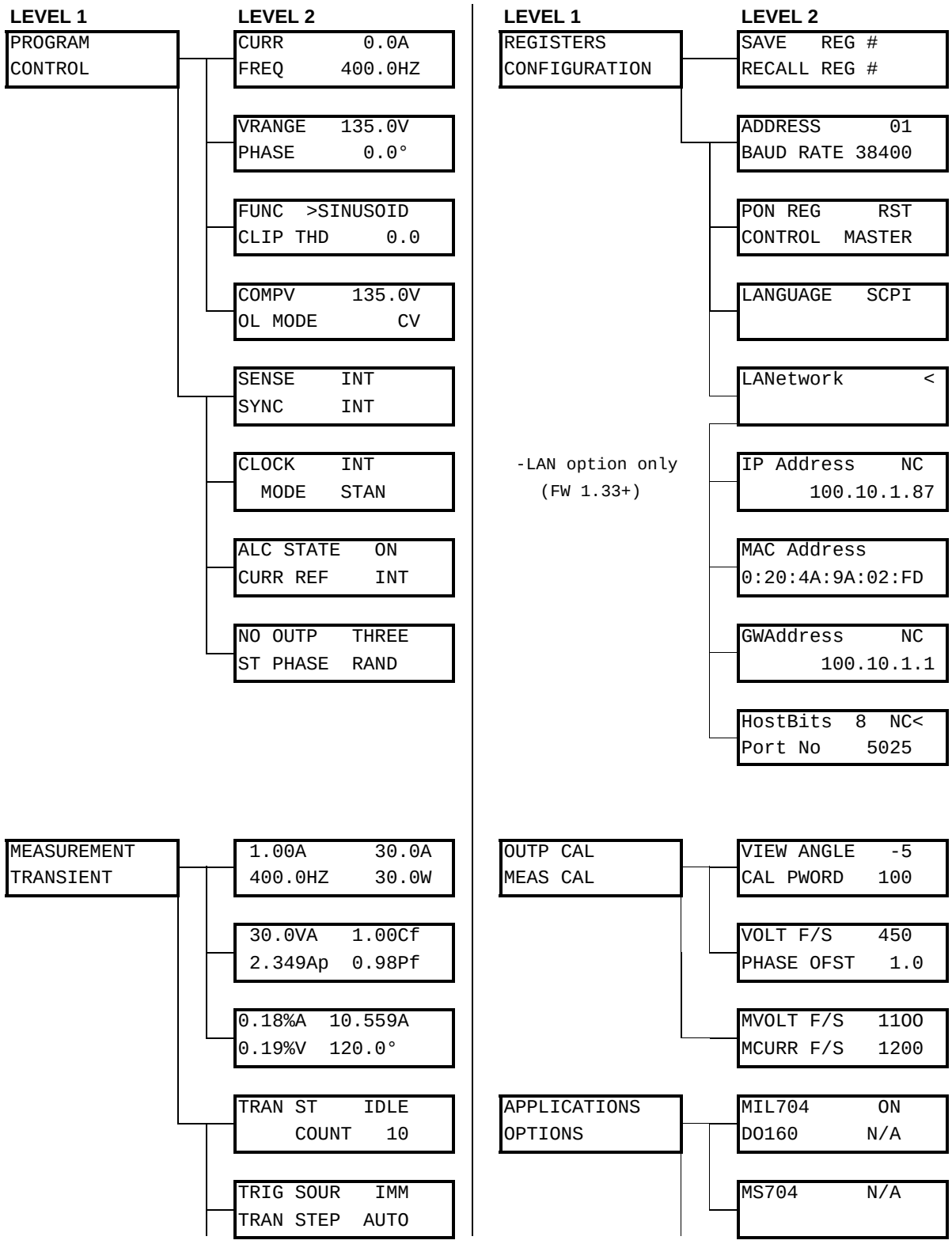
4.2.2 Top Level Menus

The following top-level menu choices can be accessed using the **Menu** key:

ENTRY	DESCRIPTION
PROGRAM	The PROGRAM menu allows primary output parameters such as current, frequency, compliance voltage, and waveform shape to be changed.
CONTROL	The CONTROL menu allows secondary setting parameters such as sense mode, phase mode and ALC mode to be changed.
MEASUREMENTS	The MEASUREMENT screen is not a menu in that no user entries are required. It displays read-back data.
TRANSIENTS	The TRANSIENTS menu allows output transients to be programmed.
REGISTERS	The SETUP REGISTERS menu allows complete instrument settings and transient list programs to be saved to nonvolatile memory.
CONFIGURATION	The CONFIGURATION menu allows changes to be made to configuration settings such as the IEEE-488 address, RS232C or USB/LAN internal baudrate, power on state and Master/Auxiliary control mode.
OUTPUT CAL	The OUTPUT CAL menu provides access to the LCD viewing angle and Calibration password entry. If the correct calibration password is entered, additional Calibration screens can be accessed.
MEAS CAL	The MEAS CAL menu allows for calibration of the AC source measurement system.
APPLICATIONS	The APPLICATIONS menu provides access to the optional firmware application programs that may be installed in the CS Series AC source.
OPTIONS	The OPTIONS menu provides access optional functions that may be present on the CS unit.
ETIME/TEMP	The ETIME/TEMP screen displays the Elapsed time (Time the unit has been in operation) in hours, minutes and seconds. It also displays the internal temperature of the unit in degrees Celsius.
LIMITS	The LIMITS screen display the hardware configuration limits of the AC power source. It is for display purposes only and the user can change none of these fields.

4.2.3 Menu Tree

Lx/Ls Series Menu Structure



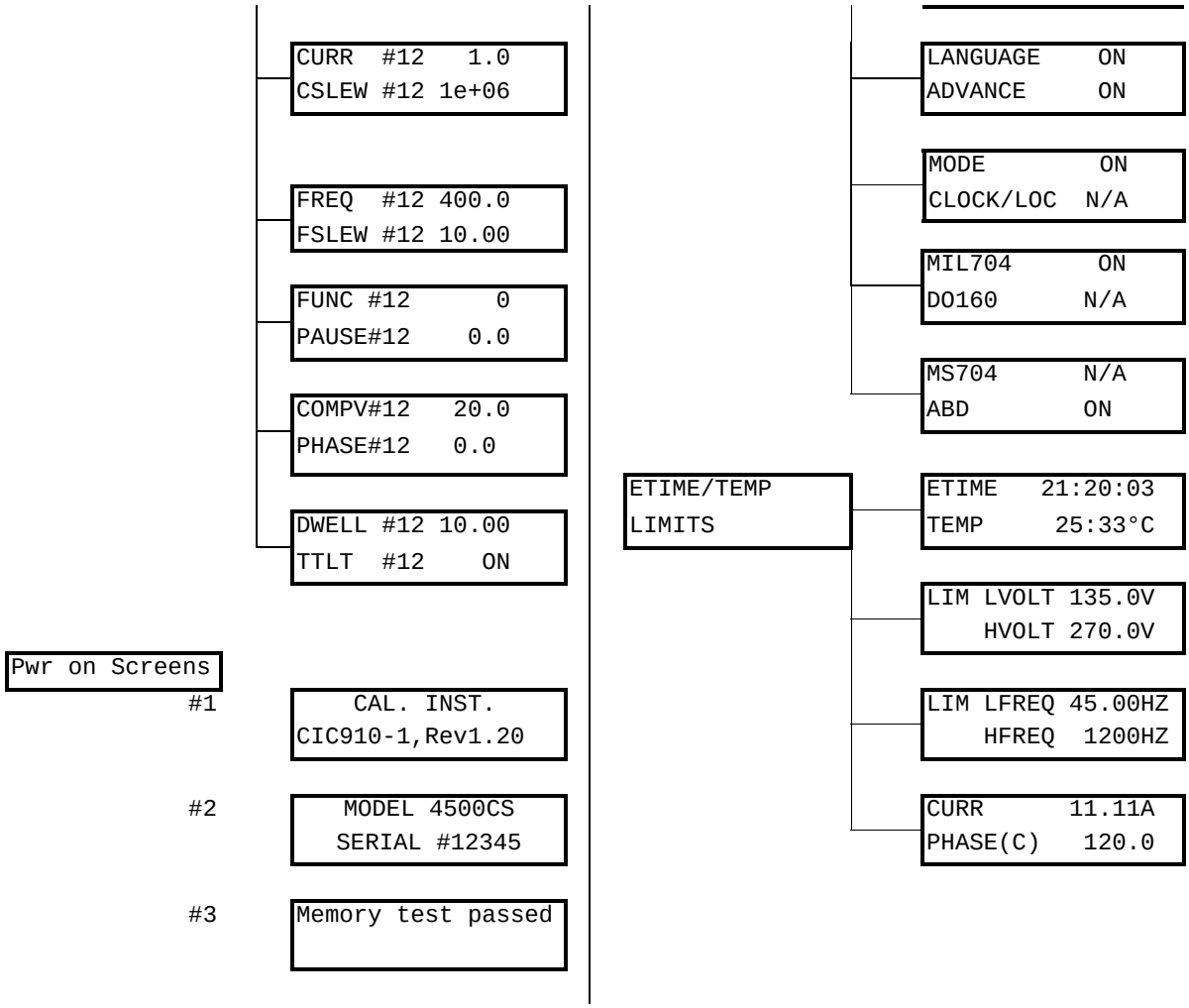


Table 4-1: Menu Tree

4.2.4 PROGRAM Menu

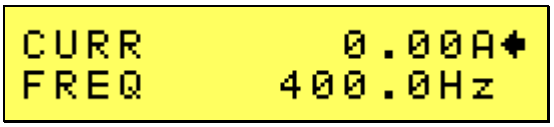


Figure 4-4: PROGRAM Menu

The PROGRAM menu is shown in Figure 4-4. It can be reached in one of two ways:

1. by selecting the **Menu** key, selecting the PROGRAM entry and pressing the **Enter** key.
2. by pressing the **Set** key.

The PROGRAM menu is used to change primary output parameters. Less frequently used parameters are located in the CONTROL menu.

The following choices are available in the PROGRAM menus:

ENTRY	DESCRIPTION
CURR	Programs the output current in Arms. The current can be changed from 0 to its max range value as determined by the configuration settings.
FREQ	Programs the output frequency The frequency can be changed from its min to its max value as determined by the configuration settings using the shuttle knob or the keypad.
VRANGE	Shows the maximum supported compliance voltage.
PHASE	Selects the phase angle between the external clock and the output of the AC source. If the clock source is internal, this parameter has no effect.
FUNC	Selects the waveform for the selected phase. Available choices are SINE, SQUARE and CLIPPED or any user defined waveform that was downloaded to the AC source waveform memory using the IEEE-488, LAN, RS232C or USB interface.
CLIP LEVEL	Sets the clip level for the CLIPPED sine wave in percent of % total harmonic current distortion (ITHD). The range is 0 to 20 %.
COMPV	Sets the compliance voltage limit value for the voltage detection system. When the compliance voltage exceeds the set limit, a fault condition is generated. The actual response of the AC Source to a compliance voltage limit fault is determined by the protection mode selected in the OL MODE field. (CC = Constant Current, CV = Constant Voltage).
OL MODE	Sets the voltage limit over load mode. The actual response of the AC Source to a voltage limit fault is determined by this setting. Available settings are CC for Constant Current mode or CV for Constant Voltage mode. In CC mode, the AC source output will trip off and stay off until re-engaged. In CV mode, the current will be reduced to maintain the set voltage level.

4.2.5 CONTROL Menus

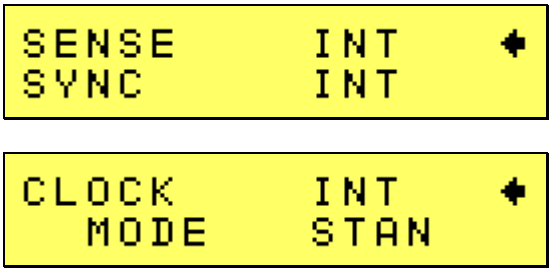


Figure 4-5: CONTROL Menus

The CONTROL menu is shown in Figure 4-5 and can be reached by selecting the **Menu** key, selecting the CONTROL entry using the DOWN cursor key and then pressing the **Enter** key.

The CONTROL menu is used to change secondary output parameters. The following choices are available in the CONTROL menus:

ENTRY	DESCRIPTION	
SENSE	Selects internal or external remote sense mode. If INT is selected, the voltage is sensed at the output terminal block. If EXT is selected, the voltage is sensed at the external sense connector. If external sense is selected, care must be taken to connect the external sense lines at the load. For sense leads longer than 1 meter, twisted pairs should be used.	
SYNC	Selects the external or line sync mode if available. Default is internal sync, which means a free running time base. The timebase can be synchronized to either the AC line frequency (-LNS option required) or an external sync signal (-EXS option required) depending on the installed option. The sync parameter field will display INT, EXT or LINE depending on the selected sync mode.	
	INT	Default, internal sync.
	EXT	External sync. Requires –EXS option/
	LINE	AC line sync. Requires –LNS option.
CLOCK	Selects internal or external clock source. The CS Series controller uses an open-air crystal time base with an accuracy of 50 ppm. The external clock mode is used to support the –LKS option. For use as an auxiliary unit in a clock and lock system, this field must be set to EXT. A unit with –LKS option can be used stand-alone if needed by setting the INT clock mode.	
	INT	Default, internal clock.
	EXT	Auxiliary unit (-LKS) driven by master (-LKM) clock input. **Note:** When selecting EXT mode, make sure the Clock and Lock BNC cables are connected to the Master (-LKM) unit. If not, there will be no output on the –LKS unit. See section 3.9 for connection

ENTRY	DESCRIPTION	
		information.
MODE	Power on clock mode. The following two modes can be selected.	
	STAND	Power up in INT (internal) clock mode for stand-alone operation. This is the only mode for CS unit without the –LKS option. For units with the –LKM option installed, this field is fixed to CLK/LOCK. For units with the –LKS option installed, this field can be changed to CLK/LOCK for use as an auxiliary unit in a clock and lock system or to STAND for use as a stand alone unit.
	CLK/LOCK	Fixed on master (-LKM) unit configuration in a clock and lock system. Power up with EXT (external) clock mode on unit with –LKS option. (See OPTION menu section.). **Note** that this field cannot be changed if the –LKM option is installed. The frequency resolution below 81.9 Hz in MAST clock and lock mode is reduced to 0.1 Hz from the normal 0.01 Hz.
ALC STATE	Sets the Auto Level Control (ALC) mode. This mode uses the internal measurement system to zero regulate the output. There are three modes of operation: OFF No measurement based output regulation. REG Output regulation is enabled. AC source will continuously regulate output but will not trip off output. ON Output regulation is enabled and output will fault (trip off) with Error 802 “Output current fault” if regulation cannot be maintained and the programmed output current is 100 mA or higher. No error is generated for settings below 100 mA. In most situations, the ALC mode should be set to REG or ON for optimal performance. **Note:** The ALC mode only functions for programmed output currents above 100 mA.	
CURR REF	Selects internal or external current programming. Select INT for programming of current from the front panel or over the bus. Select EXT to use the RPV (remote programming current). The RPV input expects a 0 to +10 Vdc signal for 0 to full-scale current.	
NO OUTP	Selects SINGLE or THREE phase mode of operation. In SINGLE-phase mode, all current is delivered to the øA and COM terminals of the OUTPUT terminal block.	

ENTRY	DESCRIPTION
	Note that even in SINGLE-phase mode, a voltage is present at øB and øC terminals. Connect only a single-phase load when operating in single-phase mode.
ST PHASE	Selects the start phase angle for output changes made to either current or frequency. This allows changing the output at a specific phase angle. The **Output on/off** key also uses this phase angle setting to program the output current up to the set level after the output relay is closed. The default value for this field is RAND. To set the start phase angle, set the cursor to the ST PHASE field and use either shuttle knob to adjust between ± 360°. To set to RAND, use the **BACK** key.

4.2.6 MEASUREMENTS Screens

The CS Series uses a DSP based data acquisition system to provide extensive information regarding the output of the Source. This data acquisition system digitizes the voltage and current waveforms and calculates several parameters from this digitized data. The results of these calculations are displayed in a series of measurement data screens. A total of three measurement screens are used to display all this information.

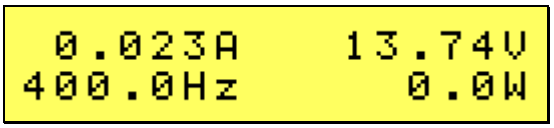


Figure 4-6: MEASUREMENT Screen

The three Measurement screens available on the CS Series are not menus in that no changes can be made anywhere. Instead, these three screens provide load parameter readouts. The measurement screens can be reached by successively pressing the **Meas** key, which will toggle to all available screens

In three-phase mode, measurements are available for each phase individually. To select the desired phase, use the PHASE key to toggle through phase A, B, C, or ABC. The ABC mode displays the data for phase A only.

The following parameters are available in the measurement screens:

ENTRY	DESCRIPTION
	MEASUREMENTS 1
CURRENT (A)	This value is the true rms output current drawn by the load.
VOLTAGE (V)	This value is the true rms output voltage measured at the voltage sense lines.
FREQ (Hz)	The output frequency is measured at the sense lines. For CS units with –LKS option, see note below.
POWER (W)	This value is the real power.
	MEASUREMENTS 2
VA POWER (VA)	This value is the apparent power.
VAR POWER (VAR)	This value is the reactive power.
POWER FACTOR (PF)	This readout shows the power factor of the load.
CREST FACTOR (CF)	This readout displays the ratio between peak voltage and rms voltage.
	MEASUREMENTS 3
VOLT THD (%V)	This readout displays the total voltage distortion for the selected phase. The distortion calculation is based on the H2 through H50

ENTRY	DESCRIPTION
	with the RMS voltage in the denominator. Note that some definitions of THD use the fundamental component (H1) of the voltage as the denominator. CS units can be programmed to use the fundamental component as the denominator. This mode can only be programmed over the bus by sending the “MEAS:THD:MODE FUND” command. At power up or after a reset command, the mode will revert back to RMS.
CURR THD (%A)	This readout displays the total current distortion for the selected phase. The distortion calculation is based on the H2 through H50 with the RMS current in the denominator. Note that some definitions of THD use the fundamental component (H1) of the current as the denominator. CS units can be programmed to use the fundamental component as the denominator. This mode can only be programmed over the bus by sending the “MEAS:THD:MODE FUND” command. At power up or after a reset command, the mode will revert back to RMS.
PEAK VOLT	This readout reflects the peak current value detected at the output. To measure inrush current for a unit under test, open the output relay and reset the peak current value using the PEAK VOLT RESET entry. Then program the output voltage and frequency and turn on the output relay. The peak current measurement will continuously track the maximum current value detected until reset.
PHASE	Relative voltage phase angle measurement with respect to phase A.

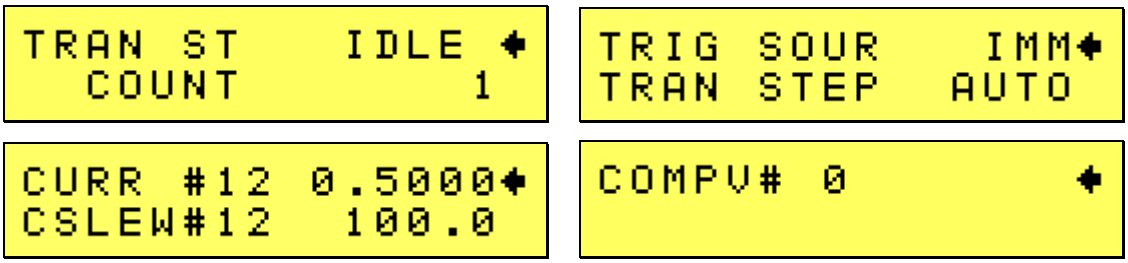
Update Program Functions from Measurement Screen

The shuttle (rotary knob) can be used to update voltage or frequency settings from the measurement screen. While the measurement screen is visible, the shuttle continues to operate. The parameter affected is determined by the last selection made on the program screen.

Frequency measurements on –LKS units

CS models configured with the –LKS option used in a clock and lock configuration will not accurately measure frequency if the programmed frequency of the master unit (-LKM) exceeds 2000 Hz unless the frequency setting of the –LKS is set to the a value close to the programmed frequency of the –LKM master unit. Setting the –LKS programmed frequency when it is operating as a clock and lock auxiliary does not affect its actual output frequency as it is controlled by the
–LKM master unit. It does provide the controller with the required information to accurately measure the frequency.

4.2.7 TRANSIENT Menu



The transient menu is used to program and execute user-defined output sequences. These output sequences are defined as a sequential list of voltage and/or current settings that can be executed in a time controlled manner.

Each step in these lists is assigned a sequence number ranging from #0 through #99. The numbering determines the order in which each step is executed.

Each step can control the voltage setting, voltage slew rate, frequency setting, frequency slew rate and dwell time. The dwell time determines how long the output dwells at the current step before progressing to the next step. Dwell times can range from 1 msec up to 900000 secs.

Transient lists can be set up from the front panel or over the bus. The transient list can be saved with the rest of the front panel settings in one of the setup registers. (See Register Menu).

ENTRY	DESCRIPTION	
TRAN ST	Indicates the status of the transient system. Available modes of operation are:	
	IDLE	Transient system is in IDLE or inactive state. To start a transient list, press the ENTER key while on the TRAN STATE field. Note that the output must be ON to run a transient program or an error message will be displayed.
	WTRIG	Transient system is armed and waiting for a trigger event.
	BUSY	Transient system is active. A transient list execution is in progress.
COUNT	Sets the execution count for the transient system. A count of 1 indicates the transient will run 1 times. The count value can be set with either voltage or current knob while the cursor is on this field. The count range is from 1 through 2E+08. Values below 200,000 are displayed in fixed point notation. Value higher than 200,000 are displayed as a floating point number (2E+05). The display has insufficient characters to display the entire mantissa so entering values above 2E+05 from the keyboard is not recommended.	
TRIG SOURCE	Indicates the trigger source for transient system. Available trigger sources are:	

ENTRY	DESCRIPTION	
	IMM	Immediate mode. The transient is started from the front panel using the ENTER key.
	BUS	Bus mode. The transient system is started by a bus command or a group execute trigger (GET).
	EXT	External mode. The transient system is started by a user-provided external TTL trigger signal on TRIGGER IN1.
TRAN STEP	Indicates the transient system execution mode. Available modes are:	
	AUTO	When triggered, the transient system will automatically execute each list point sequentially without waiting for a trigger between list points. This execution is paced by the dwell time set for each data point.
	ONCE	When triggered, the transient system will execute the first list point and wait for a new trigger once the dwell time expires. This allows triggered execution of each step in the transient list.
List parameters:		
CURR	Step #	Current set point
CSLEW	Step #	Current slew rate in A/sec
FREQ	Step #	Frequency set point
FSLEW	Step #	Frequency slew rate in Hz/sec
FUNC	Step #	Waveform selection. Available choices are Sine, Square, Clipped or any of the user provided waveforms in waveform memory.
PAUSE	Step #	Delay
COMPV	Step #	Compliance voltage limit set point
DWELL	Step #	Dwell time in seconds. Range is 0.001 to 900000
TTLT	Step #	ON: Generates an output trigger pulse at this list step. OFF: No output trigger. The output trigger is available on the Function Strobe SMC connector on the rear panel.

Transient List Points data entry method.

Transient list points are numbered sequentially from 0 through 99 and executed in this order. Each list point or list entry has 6 parameters as shown in the table above. To enter list point data, the **Keypad** is used to increment or decrement the parameter value. The shuttle knob is used to increment or decrement the list point sequence number (#). The sequence number can only be increased to the next available empty (new) list point.

To move to the next or previous parameter, use the UP (▲) or DOWN (▼) cursor keys

The voltage and frequency slew parameters can be set to their maximum slew rates by entering a value of 0 with the keypad and pressing the Enter key. Once the Enter key is pressed, the value “MAX” will be displayed.

It is not necessary to use all list points, only as many needed to accomplish the desired output sequence.

Setting Data Values

Data values can be set for each point in a list. If all data values in a specific list are going to be the same value (e.g. the current limit parameter is set to the same value for the entire transient program), only the first data value for that parameter has to be set. Setting only the first data point will automatically repeat that value for all subsequent points in the transient list.

Setting Slew Rates

Very often, output changes must be done as fast as the power source can make them. This means the transient list slew rate is set to its maximum value. If this is the case for all the data points in the list, it is sufficient to set just the first data point's slew rate for either voltage and/or current. Setting only the first point of any parameter in the list will automatically cause all points for that parameter to be set to the same value. This saves a lot of data entry time.

If however, one or more data points require a specific slew rate such as needed to do a ramp, all other points have to be specifically set to their required slew rates, including the maximum slew rate.

Saving Transient Lists

Once completed, a transient sequence can be saved along with the steady state setup of the instrument by using the REGISTER, SAVE menu. Registers that may be used for this purpose are 1 through 15. It is advisable to do so, especially for longer transient lists.

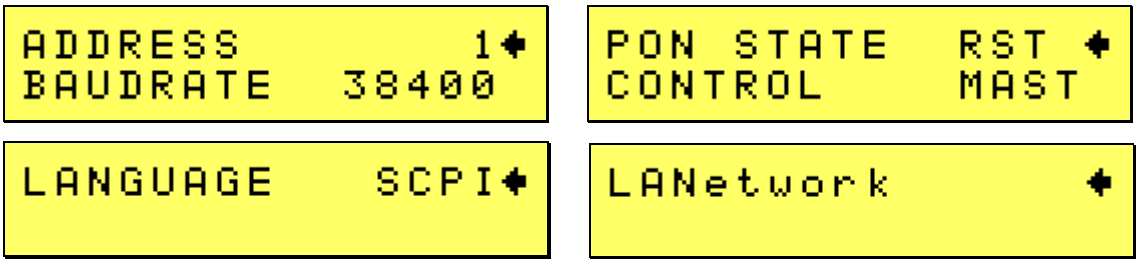
4.2.8 REGISTERS Menu

The registers menu provides access to the non-voltage setup storage of the power source. A total of 8 front panel setups can be stored in registers numbered from 0 through 7. Each register except register 0 can hold the complete front panel setup, including the programmed transient list. This allows for quick recall of different setups and transient programs.

Register 0 is reserved to be used as the power-on setting as assigned by the user. To have the power source start in a specific setting, save the desired setting to Register 0 and assign register zero as the power-on default in the CONFIGURATION menu. Alternatively, the CS can be set to power up with the RST factory default settings. See 4.9 for factory default settings.

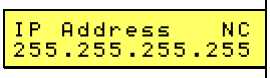
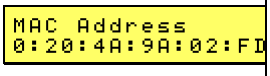
ENTRY	DESCRIPTION	
SAVE	REG 0 – 7	Saves the selected setup and transient list from memory. (Setup only for Reg 0) The shuttle knob may be used to scroll through the available list of setup register numbers. Use the ENTER key to perform the save operation. Register 0 can be assigned as the power-on state setup from the CONFIGURATION menu. A valid setup must be saved in REG0 to do so. **Note** that REG0 only saves the setup, not the transient list. All other registers also save the transient list.
RECALL	REG 0 – 7	Recalls the selected setup and transient list to memory. (Setup only for Reg 0) The shuttle knob may be used to scroll through the available list of setup register numbers. Use the ENTER key to perform the recall operation. Register 0 can be assigned as the power-on state setup from the CONFIGURATION menu. A valid setup must be saved in REG0 to do so. **Note** that REG0 only saves the setup, not the transient list. All other registers also save the transient list.

4.2.9 CONIGURATION Menu

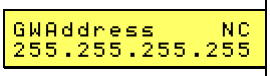
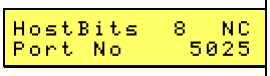
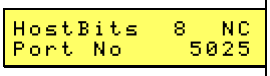


The configuration menu may be used to configure various aspects of the instrument such as the serial port, IEEE-488/GPIB address and the power-on settings of the supply.

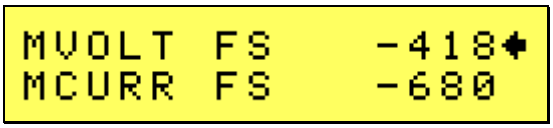
ENTRY	DESCRIPTION	
ADDRESS	0 - 31	Sets the selected IEEE / GPIB bus address for the optional IEEE/GPIB interface. Factory default is address 1. The shuttle knob can be used to scroll through the 0 through 31 address range. Do not use address 0 as this address is typically reserved for the GPIB controller.
BAUD RATE	9600 19200 38400 57600 115200 230400 460800	Sets the baud rate for the RS232C serial communications port. The same setting applies to the internal baud rate used to interface with the USB and LAN interface of the power source. Factory default is 38400 baud. Available settings are 9600 through 460800 baud for RS232C. **Note:** For USB use, you must set the baud rate to 460800. For LAN use, any baud rate can be used but 460800 is recommended. The shuttle knob can be used to scroll through these selections.
POWER ON	REG0 RST	Selects either non-volatile REG0 to be recalled automatically at power-on or factory default (RST). Factory default is RST, which recalls the factory settings. Note that to use REG0 for power-on default, the contents of the register must be programmed first. See section 4.2.8. If an empty register is selected, the power source will revert back to RST (factory setting).
CONTROL	MASTER AUX	This is an information-only field that displays the controller operation mode. For a single stand-alone CS unit, the mode is always MASTER.

ENTRY	DESCRIPTION	
		Alternatively, the auxiliary mode may be detected if the system interface cable at the rear panel is plugged in and connected to another CS unit. In AUX mode, the AC source is controlled by another unit (Master unit). The controller will be disabled and has no control over the amplifiers, the measurements or any other function. A message will be displayed at power indicating it is in Auxiliary mode. You can press any key to get in the menus but no control is possible.
LANGUAGE	SCPI Reserved	The standard bus syntax used by the CS Series is the Standard Commands for Programmable Instruments (SCPI).
LANetwork1	LAN	If the –LAN option is installed; pressing Enter while the cursor is on the LANetwork entry provides access to the LAN interface setting screens listed below.
	IP Address	Displays the IP address setting. This value can be changed by pressing the SET key and entering a new value from the keypad or using the Voltage and Frequency shuttles. Use the numeric data pad or the voltage shuttle to enter each field. To move between the four fields, use the decimal point key on the keypad or the Frequency shuttle. To set a fixed IP address, press SET and enter the desired IP address. To set the unit to Dynamic Host Configuration Protocol (DHCP) mode, press SET and enter all zeros (0.0.0.0) as the IP address and cycle power two times. The obtained IP address will be displayed after the second power on. For the DHCP setting to work however, the unit MUST be connected to a network with a DHCP server. Any change to this value will NOT take effect until after power on the unit has been cycled. When changing mode from static IP to DHCP, it is necessary to cycle power on the unit twice, once to change mode and again to obtain and display a new IP address from the network.
	MAC Address	Displays the network Media Acces Control address. This value is fixed and cannot be changed. The same MAC is normally printed on the model serial tag. The MAC address is

[1] This feature requires firmware revision 1.40 or higher. If you upgraded from a lower firmware revision, the LAN configuration has to be enabled to display this menu. Contact customer service for information on enabled this screen.

ENTRY	DESCRIPTION	
		shown as six hexadecimal numbers separated by a colon, e.g. 00:20:4A:9A:02:FD. Note that the leading '0' is never visible due to the maximum number of LCD characters per line. Note: If the MAC Address displayed is corrupted or does not match the serial tag, there may have been a problem retrieving the LAN port settings. This can happen if a static IP was set that conflicts with another device on the network. To recover, turn on power to the unit while holding down the SET key. This will allow the unit to boot without attempting to collect the IP settings. You can then set the required IP values. [See IP Address above].
	GWAddress	Gateway address setting. A default gateway is a node (a router) on a computer network that serves as an access point to another network. This value can be changed by pressing the SET key and entering a new value from the keypad or using the Voltage and Frequency shuttles. Use the numeric data pad or the Voltage shuttle to enter each field. To move between the four fields, use the decimal point key on the keypad or the Frequency shuttle. Any change to this value will NOT take effect until after power on the unit has been cycled.
	HostBits	Number of host bits as opposed to network bits in network mask. A CIDR class C network uses 24 network bits and 8 host bits. (Class A = 24, Class B = 16). This value can be changed by pressing the SET key and entering a new value from the keypad. Any change to this value will NOT take effect until after power on the unit has been cycled.
	Port No	TCP remote port number. This value must be set to 5025 (SCPI) to support the built in web page. This value can be changed by pressing the SET key and entering a new value from the keypad. Any change to this value will NOT take effect until after power on the unit has been cycled.
	LAN Default	LAN default setting can be achieve by selecting the Mac address screen and press the set key followed by the Enter key. Press the Enter key again to confirm. The IP address is set to DHCP or AUTO IP.

4.2.10 CALIBRATION Menus



The measurement calibration menu can be used to perform routine calibration of the internal measurement system. The recommended calibration interval is 12 months. To enter the calibration screens, the calibration password must be entered first.

Note: Refer to chapter 6 for details on routine calibration procedures and equipment requirements. Do not attempt calibration without consulting the user manual.

This menu also contains the LCD viewing angle adjustment.

ENTRY	DESCRIPTION	
VIEW ANGLE	-10 to +10	LCD viewing angle adjustment.
CAL PWORD	V range	Calibration password required to access all calibration screens. The calibration password is the highest voltage range value. [270] The password can be entered using the keypad followed by the **ENTER** key.
		Measurement Calibration Screens
MVOLT F/S	± 9999	Calibration coefficient for full-scale voltage measurement.
MCURR F/S	± 9999	Calibration coefficient for full-scale current measurement.
		Output Calibration Screens
VOLT F/S	± 9999	Calibration coefficient for full-scale voltage output. (Calibrated by measurement)
CURR F/S	± 9999	Calibration coefficient for full-scale current ouptut. (Calibrated by measurement)

4.2.11 APPLICATIONS Menu

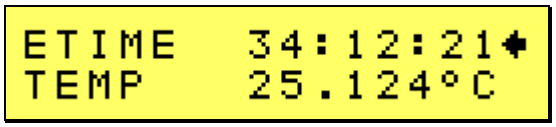
The Applications menu provides access to application specific firmware functions if available. Note that there may be no applications installed in which case this screen will still be shown but has no function.

4.2.12 OPTIONS Menu

The Options menu provides access to available optional features. Note that there may be no options installed in which case this screen will still be shown but has no function. The option settings are protected and cannot be changed by the user. These screens are provided for information purposes only.

ENTRY	DESCRIPTION	
LANGUAGE	N/A	Standard SCPI command language.
ADVANCE	ON	Standard on all CS Series models.
MODE	ON	Standard on all CS Series models. Allows the output to be switched between single and three phase modes of operation.
CLOCK/LOC	N/A	Clock and lock is an option. If no –LKM option is installed, this field will show N/A.
	MAST	-LKM Option installed. The unit can be used as a Clock and Lock system master or stand alone.
	AUX	-LKS option installed. The unit can be used as a Clock and Lock system auxiliary or stand alone.

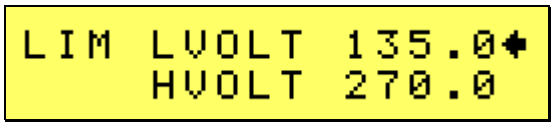
4.2.13 Elapsed Time and Temperature Screen



The Etime/Temp screen displays the elapsed time since the power source has first been turned on. This is an accumulated total time in hours, minutes and seconds.
The same screen also displays the internal temperature of the power supply.

ENTRY	DESCRIPTION	
ETIME	01:23:45	The ETIME field displays the total accumulated elapsed time for the instrument since it's initial manufacture. This value cannot be changed or reset.
TEMP	37.342°	The TEMP field is not a user selectable parameter but rather a read-out of the internal temperature in degrees Celsius. It is provided for informational purposes only.

4.2.14 LIMIT Menu



The Limit menu displays the maximum available value for current, frequency and compliance voltage of the power supply. This screen is used for information only and contains no user changeable fields. The limit values shown cannot be changed.

ENTRY	DESCRIPTION	
LIM LVOLT	Low Voltage Range	Displays low compliance voltage range value.
HVOLT	High Voltage Range	Displays low compliance voltage range value. On CS Series with only one compliance voltage range, both Low and High Limit are set to same value.
LIM LFREQ	Low Frequency Limit	Displays minimum available output frequency.
HFREQ	High Frequency Limit	Displays maximum available output frequency.
CURR	C range	Displays maximum available current per phase for three-phase mode per chassis at maximum compliance voltage (Thus, not including constant power mode.)

ENTRY	DESCRIPTION	
		In three-phase mode, available current is three times limit shown. For multi-chassis configuration, limit field still shows current per chassis and phase.
PHASE (C)	Phase Setting	Displays phase angle for phase C. Valid values are 120 for three-phase or mode configuration, 0 for single-phase only configuration. Any other value indicates split (2) phase configuration.

4.3 Output Programming

4.3.1 Set the Output

Output parameters are all set from the PROGRAM screen.

1. Use the MENU key and select the PROGRAM entry.
2. Press the ENTER key to bring up the PROGRAM menu.

   or

2. Use the PROG key to directly bring up the PROGRAM menu.

There are two methods for programming output parameters:

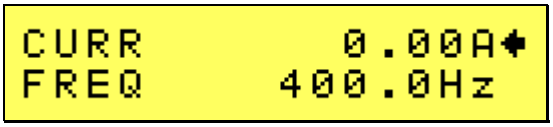
IMMEDIATE mode

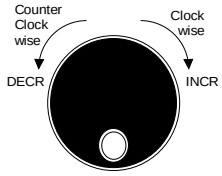
SET mode

4.3.2 Slewing Output Values with the Knob in IMMEDIATE Mode

The default mode of operation is an immediate mode in which changes to output parameters made with the knob or the entry keypad are immediately reflected at the output.

To change the output current:

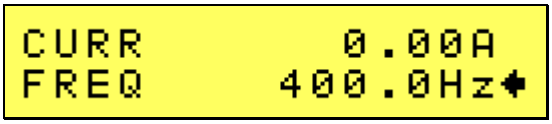


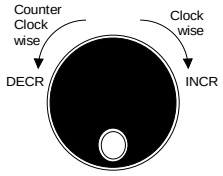


1. Place the cursor on the CURR entry
2. Rotate the shuttle knob clockwise to increase the value, counterclockwise to decrease the value or use the Keypad to enter a value and press the Enter key.

These changes take effect immediately.

To change the output frequency:





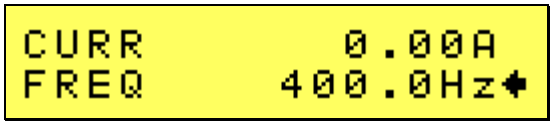
1. Place the cursor on the FREQ entry
2. Rotate the shuttle knob clockwise to increase the value, counterclockwise to decrease the value or use the keypad to enter a value and press the Enter key.

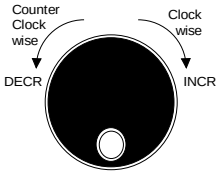
These changes take effect immediately.

4.3.3 Change Output Values with the Knob in SET Mode

The SET mode of operation is a mode in which changes to output parameters made with the knob or the entry keypad do not affect the output until the **Enter** key is pressed. The AC source is put in this SET mode by pressing the **Set** key twice.

To change the output current:





1. Press the **Set** key twice
2. Place the cursor on the CURR entry
3. Rotate the knob clockwise to increase the value, counterclockwise to decrease the value or use the keypad to enter the value.
4. A blinking underline cursor will appear in the data for the CURR field to indicate a change in settings but the output remains unchanged.
5. Place the cursor on the FREQ entry
6. Rotate the knob clockwise to increase the value, counterclockwise to decrease the value or use the keypad to enter the value.
7. A blinking underline cursor will appear in the data for the FREQ field to indicate a change in settings but the output remains unchanged.
8. Press the **Enter** key.

Both new voltage and frequency output values are now present at the output. The unit has returned to immediate mode of operation until the **Set** key is pressed again.

Note that output settings such as current and frequency can be changed from the measurement screen as well. If all three phases are selected, slewing the knob will change the output current on all three phases. If only one phase is selected, only the output of the selected phase will be affected. This is only possible if the measurement screen is accessed by pressing the **MEAS** key while in the program menu (an arrow will prompt which value will be changed).

4.3.4 Change Compliance Voltage Range

The change between the 135 or 270 Volt compliance range, use the SET key to select the setuo screen and scroll to the VRANGE field. If the CS you are using has dual ranges, you can toggle the compliance voltage range by using the shuttle to toggle back and forth or enter the relevant value (135 or 270) using the keypad followed by the ENTER key. Not the the 270 range provides only half the current of the 135 range but will support twice the compliance voltage.

4.4 Waveform Management

The CS Series employs independent arbitrary waveform generators for each phase. This allows the user to create custom waveforms. In addition, three standard waveforms are always available. This chapter covers issues that relate to defining, downloading and managing custom waveforms.

4.4.1 Standard Waveforms

For most AC applications, a sine wave shape is used. The sine wave is one of the standard waveforms provided on all CS Series models. This standard sine wave is always available and is the default waveform at power-on. Two more standard waveforms are available, square and clipped.

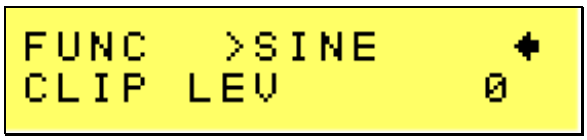


Figure 4-7: Selecting a Waveform

The square wave provides a high frequency content waveform with relatively fast rise and fall times. Due to AC amplifier bandwidth limitations, the frequency content of the standard square wave has been kept within the amplifier's capabilities. As the fundamental frequency is increased, the relative contribution of higher harmonics is reduced.

The clipped sine wave may be used to simulate voltage distortion levels to the unit under test. The total harmonic distortion level may be programmed in percent using the CLIP LEV field directly below the FUNC entry.

Note that changing the distortion level of the clipped waveform forces the AC source to regenerate the clipped sine wave's data points and reload the waveform register with the newly requested data. This process requires the output to be dropped briefly. To avoid interrupting the voltage output to the unit under test, set the clip level needed before closing the output relay and do not change it while the EUT is under power. You can then toggle between the clipped sine wave and any other waveform in memory without interrupting the output.

4.4.2 Phase Selection

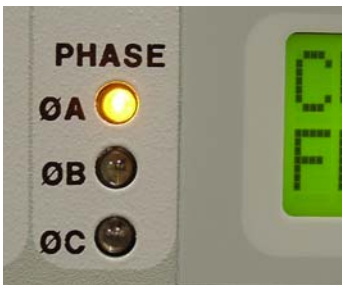


Figure 4-8: Selecting Waveforms for Single Phase or All Phases

Different waveforms may be selected for each phase. The number of custom waveforms from which to select remains 50 but each phase can be assigned a different custom or standard waveform. The specific output phase for which the wave shape is programmed is selected with the **Phase** key on the front panel. To select the same wave shape for all three phases in a three-phase configuration, press the **Phase** key until all phase enunciators (øA, øB and øC) are lit. Waveform selections made in this mode will apply to all three phases.

4.4.3 Creating Custom Waveforms

The CS controller supports up to 50 user defined waveforms in addition to the 3 standard waveforms. Custom waveforms cannot be created from the front panel of the CS Series. Rather, they have to be downloaded through the IEEE-488, RS232C, LAN or USB interface.

Each waveform is defined by 1024 data points. Each data point can range between –1 and +1 (floating point number). See CS Series programming Manual (P/N 7004-988) for details on downloading waveforms.

Once downloaded, waveforms remain in non-volatile memory and will be visible in the WAVEFORMS menu for selection. The user can assign a 12-character name to each custom waveform. Avoid using any of the standard waveform names (SINE, SQUARE or CLIPPED) as these names will not be accepted. Also, names cannot begin with a number.

Waveforms may be deleted using the IEEE-488, RS232C, LAN or USB interface as well. Custom waveforms cannot be deleted from the front panel however to avoid accidental erasure.

4.4.4 RMS Amplitude Restrictions

The output of a sine wave may be programmed to the full rms value of the current range . If the The maximum programmable rms current is 14.8 Amps. If a custom waveform is used however, the maximum programmable rms current may be less than the maximum range value. The current limit is based on the use of a sine wave with a 1.414 crest factor. A 14.8 Arms sine wave has a 20.93 Volt peak voltage. If the user selects a custom waveform with a crest factor that is higher than 1.414, the peak current would exceed this maximum if the rms current were to be programmed at 14.8 Arms.

The CS Series power source automatically limits the maximum allowable programmed rms current of any custom waveform by calculating the crest factor of the selected waveform and controlling the rms limit accordingly. Thus, each custom waveform may have a different maximum rms value. The controller will prevent the user from programming the rms current above this limit. If a value is entered in the PROGRAM menu above this value, a “Current peak error” message is generated.

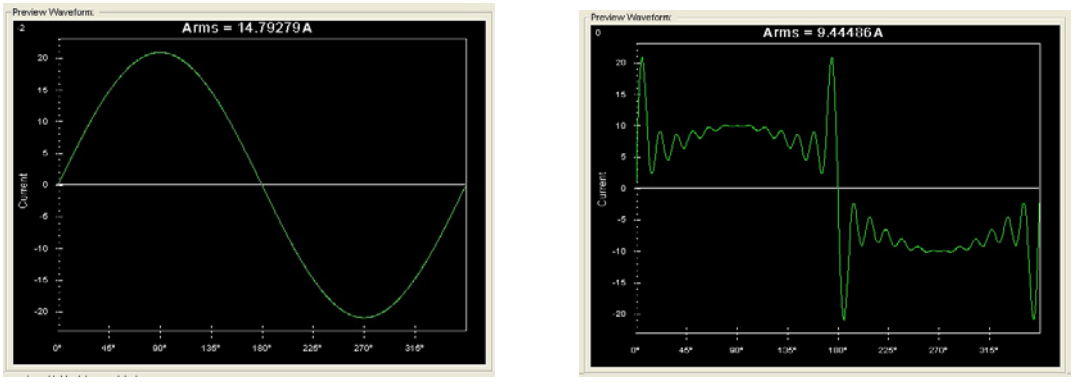


Figure 4-9: Waveform Crest Factor Affects Max. RMS Current.

The figure shown here illustrates the relationship between the crest factor of the wave shape (or its “peakiness”) and the maximum peak current allowed. Since the peak current cannot exceed the AC source’s capabilities, the programmable rms current has to be restricted, in this case to only 9.45 amps for the waveform on the right. The sine wave on the left can be programmed to the full 14.8 Arms as this still falls within the same peak voltage limitation of the AC source.

If the CS Series is used over the bus, the “:CURR? MAX” query command can be used to determine the maximum allowable RMS voltage for the selected waveform. Using the returned value as part of a program will prevent range errors.

4.4.5 Frequency Response Restrictions

The user may create a waveform that contains any number of harmonic frequencies of the fundamental. The AC Source itself however has a finite signal bandwidth and will attenuate higher frequency components of the signal. To limit the maximum frequency component of the output signal, the controller automatically applies a band-pass filter to all custom waveforms as they are downloaded. The controller implements the following process for user-defined waveforms:

Each down loaded waveform will have a computed frequency limit that is less than or equal to the maximum frequency limit of the AC source. The frequency limit is a function of the harmonics content of the waveform and will follow the equation below.

$$Fmax_h = Fmax/(level * h_n)$$

If $Fmax_h$ is below the minimum frequency limit, the waveform will be rejected at down load time and the label will be deleted from the waveform catalogue.

If the CS Series is used over the bus, the “:FREQ? MAX” query command can be used to determine the maximum allowable fundamental frequency for the selected waveform. Using the returned value as part of a program will prevent range errors.

Limits assume a program of full-scale voltage. No adjustments for voltage setting are made below the full-scale value.

Waveform selection and frequency programming will be subject to the above limit. An error message will be generated to reflect this type of error:

"22,Waveform harmonics limit"

Transient editing will also generate the above error during keyboard entry. Remote transient entry will not check for the error until transient execution.

4.4.6 Switching Waveforms

Waveforms can be switched as part of the transient system. Each transient type setup menu has a FUNC field. This field allows selection of any of the standard or custom waveforms available in waveform memory. Refer to the section on transients for more details on using transient list to switch output waveforms.

4.5 Measurements

Standard measurements are always available through the **Meas** key on the front panel. These measurements are spread across multiple screens to enhance readability. Switching between these screens can be done by successively pressing the **Meas** button on the front panel. This will cause the screen to cycle through all available measurement screens.

4.5.1 Basic Measurements

The following three measurement screens are available:

Parameter	
MEASUREMENTS 1	
VOLTAGE	AC rms voltage
CURRENT	AC rms current
FREQUENCY	Frequency
POWER	Real power
MEASUREMENTS 2	
VA POWER	Apparent power
VAR POWER	Reactive power
POWER FACT	Power factor
CREST FACT	Crest factor
MEASUREMENTS 3	
VOLT THD	Voltage distortion
CURR THD	Current distortion
PEAK CURR	Highest AC current found
PHASE	Phase angle (relative to phase A (ø1))

Note: The V and I distortion calculations are based on H2 through H50 with the fundamental component (H1) in the denominator.

Measurements are always running in the background. When the user selects a measurement screen for display, the AC source first updates all the measurement parameters before displaying the requested screen. Consequently, pressing the MEAS key may not always bring up the selected screen immediately. There will be a perceptible delay. This will prevent the screen from appearing with invalid or blank readouts.

Note that all measurements are AC coupled only so any DC offset will not be reported.

4.5.2 Accuracy Considerations

Any measurement system has a finite accuracy specification. Measurement specifications are listed in Section 2. When using the AC source for measurement purposes, always consider these specifications when interpreting results. Measurement inaccuracies become more pronounced as the signal being measured is at the low end of the measurement range. This is particularly relevant for low current measurements. The CS Series is a high power AC source optimized for providing and measuring high load currents. When powering low power loads, measurement inaccuracies on rms and peak current measurements will greatly affect derived measurements such as power, power factor and crest factor.

The measurement system on the CS Series uses a digital data acquisition system with a 96 Ks/sec sampling rate and 16 KHz bandwidth. This means that higher frequency components of the measured signal are filtered out. Any contribution to the rms value of voltage and current

above this cutoff frequency will not be reflected in the CS Series measurements. When using an external measurement reference, this may account for discrepancies in readings.

4.6 Harmonic Analysis

The CS Series controller offers advanced power analyzer measurement capabilities. These functions may be accessed from the **Meas** screen. The phase for which the analysis or waveform acquisition is done may be selected using the **Phase** key when in three-phase mode.

The controller's power analyzer performs fast Fourier transformation (FFT) on both voltage and current on each available phase. The resulting frequency spectrum can be obtained over the bus only.

4.7 Transient Programming

4.7.1 Introduction

Transient programming provides a precise timing control over output current and frequency changes. This mode of operation can be used to test a product for susceptibility to common AC line conditions such as surges, sags, brownouts and spikes. By combining transient programming with custom waveforms, virtually any AC condition can be simulated on the output of the AC source.

The default current mode is FIXED which means the output current is constant and remains at the level set by the user. Changes made to the output current made from the PROGRAM menu take effect immediately. In front panel operation mode, the current and frequency slew rates (rate of change) are always at their maximum of 2E5 V/s and 2E5 Hz/s. Slew rate programming is only possible over the IEEE-488, RS232C, LAN or USB bus. On power up, the AC source always reverts to the maximum slew rate for both current and frequency.

4.7.2 Using Transient Modes

The current can be programmed in the following transient operating modes:

STEP	Causes the output to permanently change to its triggered value.
PULSE	Causes the output to change to its triggered value for a specific time, as determined by the Pulse menu parameters.
LIST	Causes the output to sequence through a number of values, as determined by points entered in the List menu.
FIXED	Disables transient operation for the selected function.

4.7.3 Step Transients

Step transients let you specify an alternate or triggered current level that the AC source will apply to the output when it receives a trigger. Because the default transient current level is zero volts, you must first enter a triggered current before you can trigger the AC source to change the output amplitude. Step transients can only be programmed through the bus, not the front panel. Refer to the SCPI Programming Manual for more information about programming Step transients and triggers.

4.7.4 Pulse Transients

Pulse transients let you program the output to a specified value for a predetermined amount of time. At the end of the Pulse transient, the output current returns to its previous value. Parameters required to set up a Pulse transient include the pulse count, pulse period, and pulse duty cycle.

Note that Pulse transients can only be programmed over the bus, not the front panel. Refer to the SCPI Programming Manual for more information about programming Pulse transients and triggers.

4.7.5 List Transients

List transients provide the most versatile means of controlling the output in a specific manner as they allow a series of parameters to be programmed in a timed sequence. Transient list programming is supported from the front panel and may be accessed by selecting the TRANSIENTS screen. Transient lists can also be programmed over the bus. Refer to the SCPI Programming Manual for more information about programming List transients and triggers over the bus.

4.7.6 Programming list transients from the front panel

The output transient system allows sequences of programmed current and or frequency changes to be executed in a time controlled manner. Changes can be either step changes (maximum slew rate) or ramps (specified slew rates).

This section provides some examples of programming output changes (transients). Transients are defined as a series of numbered steps in a list. The list is executed sequentially. Each step has a number of fields that can be set by the user:

> Current, Current slew rate, Frequency, Frequency slew rate, Compliance voltage, Function, Dwell time, Trigger out, Phase.

The current, compliance voltage and frequency settings are the same as one would do form the setup screen using the knobs. At each step, the output will be set to the specified current, voltage, and/or frequency. The rate of change for current and frequency is determined by the slew rate set. Voltage slew is fixed at MAX and cannot be programmed.

If the current is changed from 1 A to 2 A and the Current slew is set to 10 A/sec, the current will ramp from 1 to 2 A in 100 msec. ([2 - 1] / 10 = 0.1 sec). The dwell time is the time the output will remain at this setting. In this example, it should be set long enough to reach the final programmed value of 2 A, e.g. it should be at least 0.1 sec. If not, the current will never reach the final value of 2 A before the next step in the transient list is executed. The dwell time may be set longer than 0.1 sec in this example. If for example the dwell time is set to 1.0 sec, the voltage will ramp from 1 A to 2 A over a 0.1 sec period and then remain at 2 A for 0.9 sec.

Once the dwell time set for a step in the list expires, the next step is entered (if available, if not, execution stops and the output remains at the final values set in the last step of the list.)

Note that while there are parameters for both current and frequency level and slew rates, there is only one dwell time, which applies to each step in the transient list.

Front panel entry only supports the LIST mode of operation. For Pulse and Triggered modes, the remote control interface must be used.

When entering transient lists, each list must be entered sequentially starting with step #0. If a list point is not yet set, the step number cannot be increased past it.

4.7.7 Waveforms Function List

The FUNCTION field available in each transient list event setup menu may be used to dynamically switch waveforms during transient execution. This allows different waveforms to be used during transient execution. Waveforms may be switched without the output of the source being turned off. For three phase configurations, each phase has its own waveform list so different waveforms may be programmed on different phases during transient execution.

Figure 4-10 illustrates the concept of using different waveforms at different steps in a transient list. In this case, the change was programmed to occur at the zero crossing. Any phase angle can be used to start the transient execution however. To keep the phase angle synchronization, the dwell times have to be set to an integer number of periods. Over long periods of time, phase synchronization may get lost due to timing skew between the waveform generator and the transient state machine.

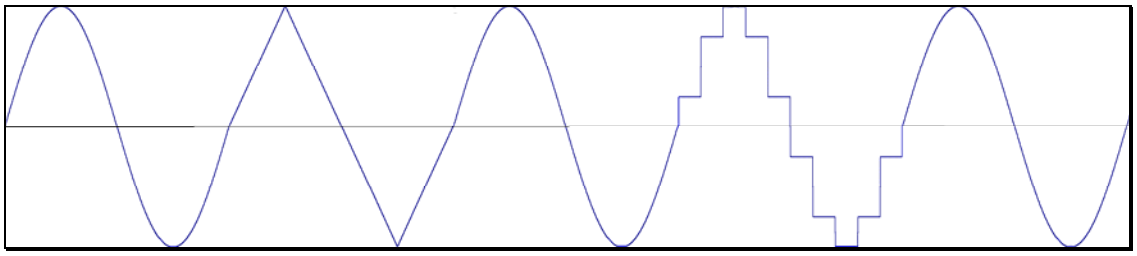


Figure 4-10: Switching Waveforms in a Transient List

4.7.8 Transient Execution

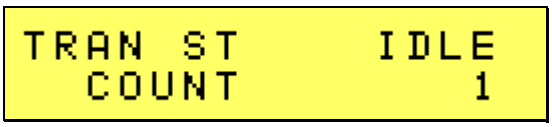


Figure 4-11: TRANSIENT Menu

A transient list can be executed from the TRANSIENT menu. To start a transient list, position the cursor on the TRAN ST field as shown in Figure 4-11 and press the ENTER key. Transients may be aborted by pressing the ENTER key again while on the same field as the field changes to ABORT while a transient execution is in progress. For short duration transients, this will likely not be visible, as the transient will complete before the screen is updated. Longer duration transients however may be aborted in this fashion.

4.7.9 Saving Transient List Programs

When the AC source is turned off, the transient list that was programmed is not automatically retained. Thus, if you turn the unit off, you will lose your programmed transient list. However, transient programs may be saved in nonvolatile memory for later recall. This allows multiple transient list programs to be recalled quickly without the need to enter all parameters each time. Transient lists are stored as part of the overall instrument front panel setup in any of the available setup registers.

To save the transient list you created in the previous example, proceed as follows:

1. Press the **Menu** key repeatedly until the REGISTERS / CONFIGURATION menu is displayed.
2. Move the cursor to the REGISTERS entry and press the ENTER key.
3. The cursor will default to the SAVE REGISTER # position. Enter a number from 1 through 15 and press the ENTER key. **DO NOT USE REGISTER 0 (REG0)** as it is reserved for power-on setting recall and does not include a transient list.
4. A message will appear indicating that the front panel settings and the transient list data have been saved in the setup register you selected.

4.8 Setting the Power-on Initialization Values

The power source is shipped with default factory settings when the unit is powered up. The factory settings are:

Parameter	Factory default setting
Current	0.00 A
Frequency	60 Hz
Compliance Voltage	135 V
Output state	OFF
Local / Remote State	Local

Table 4-2: Factory Default Power on Settings

It is possible to change the power on initialization values in one of two ways:

1. Using the IEEE-488, RS232C, LAN or USB bus interface.
2. Using the front panel.

To change the power on initialization values from the front panel, proceed as follows:

1. Set the AC power source output parameters from the front panel as you want to power up the unit.
2. Save this setting to setup register 0 from the REGISTERS menu.
3. Select the CONFIGURATION menu and move to the POWER ON field.
4. Change the POWER ON field to REG0.
5. This will recall the settings contained in register 0 at power up.

4.9 Remote Inhibit Function

The remote inhibit input on the rear panel can be used to disable the output of the AC source. This SMC input takes either a low level TTL signal or a contact closure. The mode of operation can be programmed over the remote control interface using the OUTP:RI:MODE command. See 7004-988 programming manual for details.

The following modes are supported.

MODE	OPERATION
LATCHING	A TTL low at the RI input latches the output in the protection shutdown state, which can only be cleared by an OUTPut:PROTection:CLEar command or by manually resetting the output.
LIVE	The output state follows the state of the RI input. A TTL low at the RI input turns the output off; a TTL high turns the output on. This mode is equivalent to using the Output On/Off button on the front panel. Default mode. This mode is active at power up.
OFF	The instrument ignores the RI input.

Table 4-3: Factory Default Power on Settings

The RI output state is saved as part of an instrument setup using the REGISTERS menu. It can be made part of the power on setting if needed. The default state is LIVE.

5. Principle of Operation

5.1 Overall Description

Three-phase input power is routed from the back of the cabinet to a fuse holder terminal block located in the bottom front of the unit. AC power is converted to a 300 VDC bus using a switching buck converter. The DC bus is used to power all three DC/AC transconductance current amplifiers, one for each phase. The AC input converter also generates the required DC bias supply voltages to power the auxiliary circuits of the power source such as the programmable controller and keyboard display.

The output of each amplifier is fed through an output transformer which steps the current down to the required 14.80 Arms output range. The output transformers provide the required isolation between input and output and also block any DC at the output of the power source.

The CPU controller / oscillator assembly generates the reference waveforms and provides frequency, amplitude, and current limit control. A current and voltage sense board is located at the top right of the unit above the transformers and is used to sense all output current and voltage for both control and measurement purposes. The current sensor board, in conjunction with the CPU controller, also supports the programmable RMS current limit function.

To obtain higher power levels, two to foure 4500CS (4500 VA) current sources are paralleled together to form a 9000VA to 18000VA three-phase AC current source. This is accomplished through the system interface, which routes the required analog and digital signals from the 4500CS master (unit with controller front panel) to the 4500CS auxiliaries.

5.2 Controller Assembly

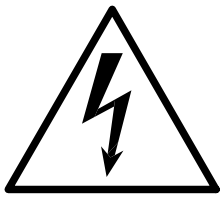
The Controller Assembly is located on the front panel the CS master unit. The controller assembly consists of a single printed circuit board that plugs into the backplane motherboard. The controller contains the main oscillator, which generates the sine wave signal setting the frequency, amplitude and current limit level. It also senses the output voltage to provide closed loop control of the output. The controller also handles all user interface and remote control related tasks. The function of each of the two boards that make up the controller module is described in the following paragraphs.

5.2.1 Programmable Controller

This board assembly, A7, consists of the components for the CPU (DSP), generating all three Phase waveform signals to the power amplifier and the entire program, waveform and data memory. In addition, this board contains the circuits for all measurements. The clock and lock circuit required to support the clock and lock mode of operation of multiple CS units is also on this board assembly.

5.2.2 Keyboard / Display Board

The keyboard/display assembly is assembly A9 and is mounted to the front panel. If the CS system is used over one of the remote control interfaces, the keyboard functions can be locked out by asserting the REMOTE state. See the CS Series Programming Manual (P/N 7004-988) for details.



CAUTION

VOLTAGES UP TO 480 VAC AND 500 VDC ARE PRESENT IN CERTAIN SECTIONS OF THIS POWER SOURCE. THIS EQUIPMENT GENERATES POTENTIALLY LETHAL VOLTAGES.

DEATH

ON CONTACT MAY RESULT IF PERSONNEL FAIL TO OBSERVE SAFETY PRECAUTIONS. DO NOT TOUCH ELECTRONIC CIRCUITS WHEN POWER IS APPLIED.

6. Calibration

The Routine Calibration should be performed every 12 months. Non-routine Calibration is only required if a related assembly is replaced or if the periodic calibration is unsuccessful. Calibration of the CS Series can be performed from the front panel or over the bus. This section covers calibration from the front panel.

Note: The output calibration is based on the current measurement function. In order to calibrate the output current, the current measurements must be calibrated.

6.1 Recommended Calibration Equipment

Equipment	Description
External Signal coupling transformer	Signal Transformer DPC-56-20
AC Calibrator	Fluke 5200A or equivalent
Oscilloscope:	General Purpose
Computer (minimum requirement):	Pentium, 1GHz, 256MB Ram, CD ROM
Digital Multimeter:	Agilent 34401A or equivalent / better (2x)
Current Shunt	Isotek RUG-2-R100-0.1 (100 milliohm) calibrated to 0.25% (single chassis CS) Isotek RUG-2-R10-0.1 (10 milliohm) calibrated to 0.25% (multi-chassis CS)
Phase Meter	Krohn-Hite Model 6620 or equivalent phase meter (0.01° resolution, 0.02° accuracy).
Distortion Meter	Agilent 339A or equivalent
Resistive Load	Three 18 ohm, 1.5-kilowatt power resistors.
Current Transformer, 0.1 volt/ amp	Pearson model 110
Frequency Counter	Philips PM6670, PM6671, PM6672

6.2 Calibration Password

The calibration screens for output or measurement calibration can be selected from the **MENU** screen. (Press MENU button several times to toggle to select the CALIBRATION screen.)

To select the CALIBRATION screen press the ↑ or ↓ key several times to select PASSWORD. Then press the **ENTER** key. This will bring up the PASSWORD screen. To prevent unauthorized access to calibration data, a password must be entered to access any calibration screen. The calibration password is a numeric value equal to 135 for the CS Series. Check the LIMIT screen when in doubt.

The password can be entered using the Keypad to input the number. Once the correct value is reached, press the **ENTER** key. Once set, the calibration screens remain accessible until the CS unit is powered down. If you leave the calibration screen and return, toggle the value up or down and back, followed by the **ENTER** key to re-engage the calibration mode.

Use the PHASE key on the front panel to select the phase to be calibrated.

To select the MEAS CAL screen, follow the same steps as outlined above but select the MEAS CAL entry. If another CALIBRATION screen has been accessed since power-up, no password is needed. Otherwise, enter the same password as indicated above.

6.3 Voltage Measurement Calibration

The CS Series controller measures voltage and current by digitizing both voltage and current waveforms on each available output phase. This data is subsequently processed and used to calculate all measurement parameters such as VRMS, IRMS, Power, VA, Frequency etc. To calibrate all measurements, only the voltage and current measurement need to be calibrated specifically. All other measurements are derived from these.

Note: The Agilent HP 34401A Digital Multi meter (or higher AC accuracy DMM) must be used for the following calibration. The DMM must be set to the AC HI ACCUR mode for all AC measurements.

To calibrate all voltage measurement functions, the desired value for the measurement value of voltage must be entered for each calibration coefficient. Make the indicated adjustments by entering in the external DMM measurement value. This should be the value indicated by the external DVM.

1. For 3000CS/4500CS: Connect an 18-ohm 1.5 kilowatt resistive load across each output phase. Use a 100 mOhm current shunt of sufficient power rating in series with the load to measure the AC load current. For multi-box systems, a 10 mOhm current shunt will be required.
2. Connect the external AC DVM between the External Sense Neutral and Phase A terminals. Select the Ext Sense mode, program the output relay on, ALC mode off, 400 Hz and 7.4 amps.
3. Go to the Measurement Calibration screen by repeatedly pressing the MENU key until MEAS CAL is displayed. Move the arrow cursor to point to this screen and press the ENTER key. If the password has been previously entered it will still be displayed. The encoder may have to be moved up and back on value to allow the password to be reused. If the password (135) is not displayed it will have to be reentered. Press the PHASE key so only the ∅A is indicated.
4. Move the arrow to point to MVOLT and dial in the exact voltage indicated by the external AC DVM for the Phase A output. Press the ENTER key and wait until the new calibration coefficient is displayed. ***Save this value by pressing the ENTER key.***
5. Repeat steps 2 through 4 for B and C phases.

Note: For multi-box power systems, eg. 9000CS/2, the voltage measurement calibration should be done with only the Master power source. Remove all auxiliary power sources and disconnect the system interface cable to the Master power source.

6.3.1 Single and Three Phase Modes

As indicated earlier, for 3-Phase power system, repeat the preceding steps for the Phase B and C outputs. The order in which the outputs for each phase are calibrated is not important.

Press the PHASE key to select each output to be calibrated. Monitor the output of the respective phase by moving the HI input of the Digital Multimeter and the current shunt as needed. The LO input should remain connected to the common LO of the sense connector.

The current measurement calibration for Phase A should be done in both single and three phase modes as separate calibration coefficients apply to each phase mode. Voltage measurement calibration for phase A can be done in either phase mode.

6.4 Current Measurement Calibration

Note: The Agilent HP 34401A Digital Multi meter (or higher AC accuracy DMM) must be used for the following calibration. The DMM must be set to the AC HI ACCUR mode for all AC measurements.

To calibrate all current measurement functions, the desired value for the measurement value of current must be entered for each calibration coefficient. Make the indicated adjustments by entering load current indicated by the external shunt and DVM. This should be the value indicated by the external DVM connected to the shunt. If a 100 mOhm current shunt is used for current, 100 mV represents 1 Amp.

Note that multi-chassis CS series will require the use of a 10 mOhm shunt, especially in single-phase mode. Check the max power rating of the current shunt used to avoid damage to the shunt used.

1. Connect the 100 milliohm current shunt from the Phase A Output terminal to the Neut terminal of the power source. Connect the AC DVM to the shunt monitor terminals. All other unused outputs must also be shorted to the Neut terminal.
2. Close the output relay. Program 11 amps, or the maximum output current of the power system if different, and 60 Hz.
3. Go to the MEAS CAL screen. If necessary, refer to section 6.2 to get to this screen. Press the PHASE key so only the ∅A is indicated.
4. Move the arrow to point to MCURR FS and dial in the exact current indicated by the external shunt and AC DVM for the Phase A output. Press the ENTER key and wait until the new calibration coefficient is displayed. ***Save this value by pressing the ENTER key.***

Repeat steps 1) through 4) for the other outputs and change the indications from A to the respective phase to be calibrated.

6.4.1 Single and Three Phase Modes

As indicated earlier, for 3-Phase power system, repeat the preceding steps for the Phase B and C outputs. The order in which the outputs for each phase are calibrated is not important.

Press the PHASE key to select each output to be calibrated. Monitor the output of the respective phase by moving the HI input of the Digital Multimeter and the current shunt as needed. The LO input should remain connected to the common LO of the sense connector.

The current measurement calibration for Phase A should be done in both single and three phase modes as separate calibration coefficients apply to each phase mode. Voltage measurement calibration for phase can be done in either phase mode.

6.5 Output Calibration

The output calibration is performed automatically when the measurement calibration takes place. As such, there is no need to perform this calibration again. The output calibration coefficients may be viewed by selecting the OUTPUT CAL screen.

Output gain is set at the factory and the output calibration coefficients are pre-set. They is no need to change the factory default settings unless any of the following conditions occurs:

1. Replacement of one or more amplifiers as a result of a service action.
2. Replacement of the current limit board. (CI P/N 7004-703-3)
3. Replacement of the controller board. (CI P/N 7004-715-4)

If the output gains are found to be out of tolerance, they need to be adjusted. This requires removal of the top cover and should only be done by qualified service personnel. In that case, refer to the non-routine gain calibration section.

The factory output calibration coefficients are shown in the table below.

Output Phase	Current Limit Board Adjustment Pots	OUTP CAL value
A	R1	450
B	R2	450
C	R3	450

Table 6-1: Output Calibration Coefficients - Factory Defaults.

6.6 Phase Offset Calibration

The phase offsets for phase B and C can be calibrated using the OUTPUT CALIBRATION screen. The same calibration can be done over the IEEE-488, RS232C or USB bus if needed. Refer to the CS Series programming manual (P/N 7004-988) for command syntax on bus calibration.

Phase offset calibration requires a phase meter for reference. See section 6.1 for recommended equipment list.

For front panel calibration, proceed as follows.

1. To sense the phase of the output current the Pearson CT, use a 0.01 V/amp CT for multi-box power systems, must be used for both inputs of the Phase Meter. A no-load condition must be used, shorted output.
2. Connect the reference input of the Phase Meter to the Phase A output. Connect the other input of the Phase Meter to the Phase B output.
3. Program the output to 11 amps, 60 Hz. Check the output phase angle accuracy. See the note below if it is more than 0.5 degrees in error.

Repeat step 1) through 3) for the Phase C output.

NOTE: If the output phase accuracy is out of spec at low frequencies, 400 Hz, it must be calibrated. Always check the calibration at 400 Hz before making the checks at the higher frequencies.

To calibrate the output phase angle at 60 Hz, proceed as follows:

1. Press the MENU key several times to display OUTP CAL.
2. Press the enter key. Again you must enter the password, which will be the value for the highest voltage range and press ENTER.
3. Press the ↓ key to point to the PHASE OFST value. This will be the phase calibration value for the phase selected.

4. Adjust the calibration value so the output phase angle is calibrated. Press the ENTER key to save the calibration.

Repeat step 1) through 4) for the Phase C output.

6.7 Non-Routine Output Gain Calibration

If the Current Limit board assembly (P/N 7004-703-3) is replaced in the field or one of the amplifiers has been replaced, it is necessary to check the gain of each phase and adjust as needed.

WARNING: ***This requires the top cover to be removed and should be done by qualified service personnel only. Dangerous Voltages are present inside the AC power source.***

6.7.1 Output Signal Gain Adjustment

Note: ***For multi-box power systems, eg. 9000CS/2, the output signal gain adjustment should be done with only the Master power source. Remove all auxiliary power sources and disconnect the system interface cable to the Master power source.***

To adjust internal output gains, proceed as follows:

1. Loosen the top cover and slide back until the Current Limit board assembly (P/N 7004-703-3) is uncovered. This is the vertical board directly behind the CPU/Controller board. Refer to Figure 6-1.

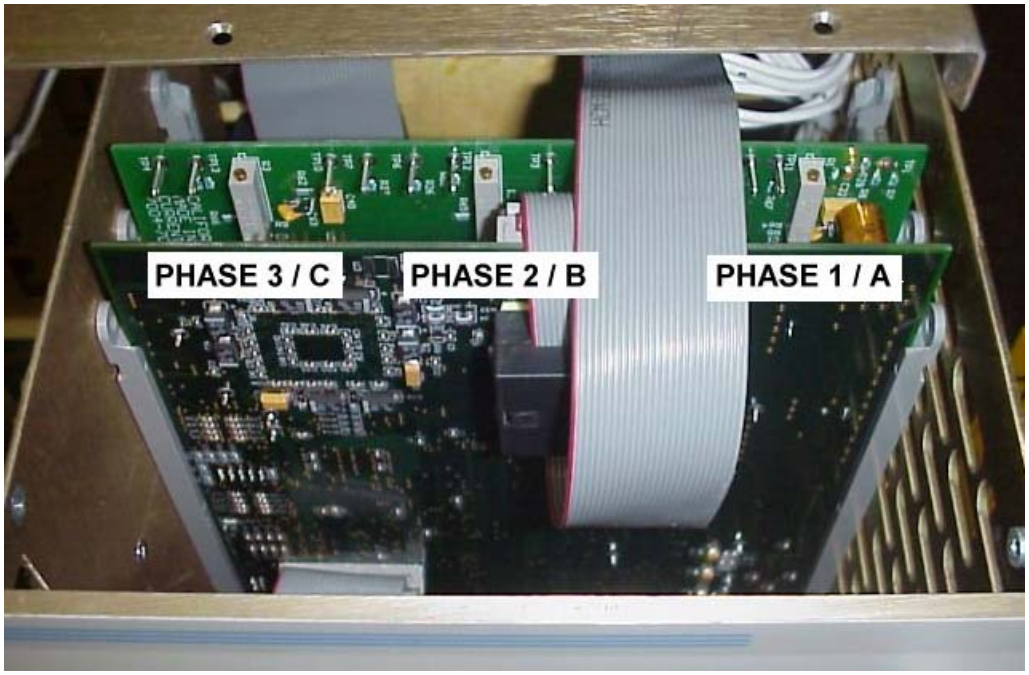


Figure 6-1: Location of Gain pot adjustments

2. Go to the Output Calibration screen by repeatedly pressing the MENU key until OUTP CAL is displayed.

3. Select this function by pressing the cursor until the arrow on the right side of the display point to OUTP CAL. Press the ENTER key.
4. A Calibration Password (CAL PWORD) will be required. The password will be the value of the high voltage range. For this power source the value is 135 or 270 (check configuration limit for HIGH VOLT range limit value used). Enter this value with the Front Panel encoder and press the ENTER key.
5. Select Phase A and enter a value of 450 (see table below) and press the ENTER key.
6. Select Phase B and enter the same value.
7. Repeat the entry for Phase C. Make sure the ENTER key is pressed each time to store this value.
8. Connect the external current shunt and AC DVM to the Phase A output.
9. Close the output relay.
10. Set the ALC off and set the program value for the output current for Phase A to 10 amps and 400 Hz with respect to Neut or Com. and use the adjustment indicated below to set the output current to 10.00 ± 0.10 amps.
11. Open the output relays and repeat steps 8 through 10 for phase B and C.

Output Phase	Current Limit Board Adjustment Pots	OUTP CAL value
A	R1	450
B	R2	450
C	R3	450

Table 6-2: Output Calibration Coefficients - Factory Defaults.

6.8 Non-Routine Distortion Adjustment

If an amplifier assembly (CI P/N 3009-411-1) has been replaced as a result of a service action, it may be necessary to adjust the distortion setting.

The Distortion is checked with the resistive load mentioned below. The output current distortion is an indication of the amplifier offset miss-adjustment. The Distortion Analyzer must be connected to the current transformer for the correct indication of the distortion. A 0.01 V/amp current transformer must be used for multi-box systems.

Note: Make this adjustment at the nominal AC line input voltage

1. Connect the Current Transformer in series with the Phase A output.
2. Program the Phase A output to the current specified below, 60Hz.
3. Adjust R105 on the Phase A amplifier to the lowest distortion level. This level should be less than 1.0% THD.
4. Record the lowest distortion value.
5. Program the output to 2000 Hz and record the distortion value.
6. Repeat steps 1 through 3 for the Phase B and C outputs.

Load values for distortion adjustment:

MODEL	LOAD	PROGRAM HI	PROGRAM LO		MODEL	LOAD	PROGRAM HI	PROGRAM LO
3000Cs	20 Ω	6 A	1.0 A					
4500Cs	12 Ω	10 A	1.0 A		9000Cs/2	6.0 Ω	20 A	1.0 A
13500Cs/3	4.0 Ω	30	1.0 A		18000Cs/4	3.0 Ω	40 A	1.0 A

7. Service

7.1 Cleaning

The exterior of the power source may be cleaned with a cloth dampened with a mild detergent and wrung out. Disconnect mains power to the source before cleaning. Do not spray water or other cleaning agents directly on the power source.

7.2 General

This section describes the suggested maintenance and troubleshooting procedures. The troubleshooting procedure is divided into two sections. The first section deals with basic operation and connection of the equipment. The second section requires opening the unit and using LED indicators and a simple multimeter to troubleshoot the unit down to the module level. Only a qualified electronic technician should attempt this level troubleshooting.

7.3 Basic operation

Table 7-1: Basic Symptoms

PARAGRAPH	PROBLEM
7.3.1	Excessive Output Current
7.3.2	Poor Output Voltage Regulation
7.3.3	Overload Light On
7.3.4	Distorted Output
7.3.5	Unit Shuts Down After 1-2 Seconds
7.3.6	No Output and no lights on front panel
7.3.7	No output, but front panel controller is active.

7.3.1 Excessive Output Voltage

CAUSE	SOLUTION
External sense not connected(If used)	If external sense mode is selected, make sure the external sense wires on the rear panel are connected to the AC power outputs either at TB1 on the AC source or at the load.
Output Open	If no load is present and a current is programmed, the compiance voltage will exceed the maximum. Short the output or apply a load < 12 Ohm.

7.3.2 Poor Output Current Regulation

CAUSE	SOLUTION
Unit is overloaded	Remove overload
Input line has fallen below spec. limit.	Check input supply voltage.

7.3.3 Overload Light is On

CAUSE	SOLUTION
Unit is overloaded	Remove overload or check CL setting

7.3.4 Distorted Output

CAUSE	SOLUTION
Power source is grossly overloaded.	Reduce load
The crest factor of the load exceeds 3:1.	Reduce load current peaks by reducing load.

7.3.5 Unit Shuts Down after 1-2 Seconds

CAUSE	SOLUTION
Output open	Apply < 12 Ohm load or short for no load
Output grossly overloaded.	Remove overload.
-400 Input module failure	Have power module serviced
Operating load with too high inrush or start up currents.	Consult factory for application advice.

7.3.6 No Output and No Lights on Front Panel

CAUSE	SOLUTION
Input circuit breaker switched off.	Switch the breaker on.
No input power.	Ensure 3 phase power is present at AC input terminal block
-400 Input Power Supply failure	Have -400 input supply serviced.

7.3.7 No Output But Front Panel controller is active

CAUSE	SOLUTION
"OUTPUT ON" button is turned off.	Press OUTPUT ON so that "ON" LED is lit.
Compliance voltage programmed down or set to zero.	Program compliance voltage higher.
Current programmed down or to zero.	Turn current set point up.

7.4 Isolating amplifier failures in multi-box systems

A self-test can be performed over the bus by sending the *TST? query command. The self-test will run until the first error is encountered and terminate. The response to the query will either be the first error encountered or 0 is no error was found. (Selftest passed).

On multi-box model configurations such as 9000CS/2, 13500CS/3 or 18000CS/4, it is possible to isolate certain failures to a particular chassis. This can be done using the *TST? Self-test error codes.

Note: The self-test should always be run in 3-phase mode on all CS models. If the self-test is run in single-phase mode, not all aspects of the Phase B and C hardware will be tested as a result.

To execute a self-test, the IEEE-488, RS232C, LAN or USB interface must be used. The supplied CSGui[1] Windows program command line can be used to send the *TST? Command. The following rules apply:

1. If a current error is reported on phase øA, øB or øC, it indicates the corresponding amplifier in the Master chassis has most likely failed.
2. If a voltage error is reported on phase øA, øB or øC, it indicates one of the auxiliary chassis amplifiers on the phase indicated has failed. On a 2-box configuration, there is only one auxiliary chassis. On a three or four-box configuration, it is not possible to tell which of the two or three auxiliary amps have failed. They could also both or all have failed in this case.

To further isolate the failed amplifier in a three or four-box configuration, the outputs of all chassis must be disconnected from each other. Then program each phase and close the output relay. Check the output of each chassis for the expected output current or compliance voltage. The chassis with not output(s) will have the failed amplifier.

[1] CSGui software (CI P/N 913) for Windows XP/2000 supplied on CD ROM CIC496

7.5 Advanced Troubleshooting.

WARNING: Do not connect 400-480V into the 208-240V unit, the result could be a severely damaged unit.

CAUTION: VOLTAGES UP TO 400 VAC AND 450 VDC ARE PRESENT IN CERTAIN SECTIONS OF THIS POWER SOURCE.

WARNING: THIS EQUIPMENT GENERATES POTENTIALLY LETHAL VOLTAGES. DEATH ON CONTACT MAY RESULT IF PERSONNEL FAIL TO OBSERVE SAFETY PRECAUTIONS. DO NOT TOUCH ELECTRONIC CIRCUITS WHEN POWER IS APPLIED

Switch Off Units

Switch off each unit at the circuit breaker on the front panel as well as removing the input power from the unit.

WARNING: Wait 10 minutes for all internal capacitors to discharge.

Removing Cover

Remove the screws securing the top cover and remove it.

Initial Inspection

Make a visual inspection of the unit and ensure all the connectors are properly mated and there are no loose wires.

7.6 Factory Assistance

If the problem with the cabinet or one of the power modules cannot be isolated, contact the factory for assistance.

7.7 Fuses

See Table 7-2 for replaceable fuses and ratings for each of the sub assemblies in the CS Power source.

7.8 Replaceable Parts

In order to ensure prompt, accurate service, please provide the following information, when applicable for each replacement part ordered.

a. Model number and serial number of the instrument.

b. Argantix part number for the sub-assembly where the component is located. (California Instruments PART #)

c. Component reference designator if applicable (REF #)

d. Component description.

e. Component manufacturers (VENDOR)

All replaceable part orders should be addressed to:

AMETEK Programmable Power.
Attention: Customer Service
9250 Brown Dear Road
San Diego, California 92121
United States of America

Orders may also be placed using the following fax number: 1 858 458-0267 or via email: support@programmablepower.com

REF #	Sub	PART #	DESCRIPTION	MNF, P/N	QTY
Common Assemblies					
A1-2,3		3009-411-1	Heatsink assembly (Amplifier)	CI	3
	A1	5001-725-3[1]	Amplifier Power board	CI	1
	A2	3009-703-6[1]	Amplifier Control board	CI	1
A5		7004-700-1	Power Mother board	CI	1
	F1,2,3	270176	Fuse, 20A / 250V	Bussmann, ABC20	3
A6		7004-705-1	Control Mother board	CI	1
A8		4009-737-1	EMI board, 208V & 400V	CI	1
A9		7004-703-3	Current Limit board	CI	1
A12		7004-716-2	Range Relay board	CI	1
A13		7004-704-1	System Interface board	CI	1
A18		7004-401-1	Controller Assembly, Single Phase	CI	1
A18		7004-401-3	Controller Assembly, Three Phase	CI	1
A19		4009-737-3	EMI board, 400V	CI	1
	A1	7004-715-4	Controller Board	CI	1
	A2	7004-709-1	Keyboard / Display board	CI	1
B1		241182	Fan, 4" 24 VDC	Rotron, MD24B2 Nidec, B31257-10 EBM, 4292H	1

[1] This assembly is part of 3009-411-1 Heatsink assembly. It is best to replace the entire heatsink assembly at once.

REF #	Sub	PART #	DESCRIPTION	MNF, P/N	QTY
B2		241183	Fan, 6" 24 VDC	Rotron, JQ24B4 NMB, 5920PL-05W-B50-D00 EBM, 6424	1
208 V Input Models (-208)					
A7		7004-706-1	DC Power Supply	CI	1
	F1	270193	Fuse, 7A / 250V SB	LittleFuse, 313007	1
	F2	270174	Fuse, 1A / 250V	Bussmann, PCC1	1
	F4	270230	Polyfuse, 9A / 30V	Raychem, RUE600	1
	CB1	270220	Circuit breaker, 40A, 240V	Airpax, IELK1111-31311-2-V	1
DS1		250412	Lamp, neon, amber, 125V	IDI, 1050QN3	1
C1		611295	Electrolytic Cap, 3900uF, 400V	CDE, 500R392T400DE2B 500X442T450DF2A	1
400 V Input Models (-400)					
A7		7004-712-1	Input Power Supply	CI	1
	F1	270193	Fuse, 7A / 250V Slow Blow	LittleFuse, 313007	1
	CB1	270221	Circuit breaker, 15A, 415V	Airpax, IELK1111-31311-1-V	1
	C27	611305	Electrolytic Cap, 3900uF / 350V	CDC, 550392T350DC2B	1
	C17,18	611306	Electrolytic Cap, 1600uF / 350V	CDC, 550162T350BC2B	2
A16		7004-710-1	Bias Startup Supply board	CI	1
A17		7004-711-1	LV Supply board	CI	1
	F1	270174	Fuse, 1A / 250V	Bussmann, PCC1	1
	F4	270230	Polyfuse, 9A / 30V	Raychem, RUE600	1
DS1		250786	Lamp, neon, amber, 12V	IDI, 1050N3	1

Table 7-2: Replaceable Parts and Assemblies

8. Error Messages

Any errors that occur during operation from either the front panel or the remote control interface will result in error messages. Error messages are displayed on the LCD display. They are also stored in the error message queue from which they can be queried using the SYST:ERR? Query. The error queue has a finite depth. If more error messages are generated than can be held in the queue, a queue overflow message will be put in the last queue location. To empty the queue, use the error query until the No Error result is received.

Errors appearing on the LCD will generally remain visible until the user moves to another screen. If multiple error messages are generated in succession, only the last message will be visible as there is only space for one error message on the LCD display.

The same area of the display is also used to display status messages. While error messages always have a negative error number, status messages have a positive number.

The table below displays a list of possible error and status messages along with their possible cause and remedy.

Number	Message String	Cause	Remedy
0	"No error"	No errors in queue	
-100	"Command error"	Unable to complete requested operation	Unit may be in a mode inconsistent with request.
-102	"Syntax error"	Command syntax incorrect.	Misspelled or unsupported command
-103	"Invalid separator"	SCPI separator not recognized	See SCPI section of programming manual.
-104	"Data type error"	Data type invaled.	Check command for supported data types
-108	"Parameter not allowed"	One or more additional parameters were received.	Check programming manual for correct number of parameters
-109	"Missing parameter"	Too few parameters received for requested operation	Check programming manual for correct number of parameters
-110	"Command header error"	Command header incorrect	Check syntax of command.
-111	"Header separator error"	Invalid command separator used.	Use semi-colon to separate command headers
-112	"Program mnemonic too long"	Syntax error	Check programming manual for correct command syntax
-113	"Undefined header"	Command not recognized error	Check programming manual for correct command syntax
-120	"Numeric data error"	Data received is not a number	Check programming manual for correct command syntax
-121	"Invalid character in number"	Number received contains non-numeric character(s)	Check programming manual for correct command syntax
-123	"Exponent too large"	Exponent in number exceeds limits	Check programming manual for correct parameter range
-128	"Numeric data not allowed"	Number received when number is not allowed.	Check programming manual for correct command syntax

Number	Message String	Cause	Remedy
-168	"Block data not allowed"	Block data was sent.	Check programming manual for correct command syntax
-200	"Execution error"	Command could not be executed	Command may be inconsistent with mode of operation.
-201	"Invalid while in local"	Command issued but unit is not in remote state	Put instrument in remote state before issuing GPIB commands.
-203	"Command protected"	Command is locked out	Some commands are supported by the unit but are locked out for protection of settings and are not user accessible.
-210	"Trigger error"	Problem with trigger system.	Unit could not generate trigger for transient execution or measurement.
-211	"Trigger ignored"	Trigger request has been ignored.	Trigger setup incorrect or unit was not armed when trigger was received. Check transient system or measurement trigger system settings.
-213	"Init ignored"	Initialization request has been ignored	Unit was told to go to armed state but was unable to do so. Could be caused by incorrect transient system or measurement acquisition setup.
-220	"Parameter error"	Parameter not allowed.	Incorrect parameter or parameter value. Check programming manual for allowable parameters
-221	"Setting conflict"	Transient programmed with more than 1 mode.	Check other settings. E.g. Redefine transient mode. As result of *TST? execution, indicates ALC mode is off or waveform not set to Sine.
-222	"Data out of range"	Parameter data outside of allowable range.	Check programming manual for allowable parameter values
-223	"Too much data"	More data received than expected	Check programming manual for number of parameters or data block size
-224	"Illegal parameter value"	Parameter value is not suppored	Check programming manual for correct parameters
-226	"Lists not same length"	One or more transient lists programmed has different length.	All lists must be of same length or transient cannot be compiled and executed.
-241	"Hardware missing"	N/A	N/A
-254	"Media full"	No storage space left to save settings or data.	Delete other settings or data to make room.
-255	“Directory full”	Too many waveform directory entries	Delete one or more waveforms from waveform memory to make room.
-256	“File name not found”	Waveform requested not in directory	Check waveform directory for waveform names present.
-257	“File name error”	Incorrect filename	Too many or non ASCII characters used in waveform file definition.
-283	“Illegal variable name”	Variable name illegal.	Use ASCII characters only

Number	Message String	Cause	Remedy
-300	"Device specific error"	Hardware related error	Check hardware for proper operation.
-311	"Memory error"	Waveform memory checksum error.	May be the result of incomplete user-defined waveform download. Check interface and try downloading waveform again. Successful download may clear this error condition. Alternatively, use TRAC:DEL:ALL command to clear waveform memory.
-314	"Save/recall memory lost"	User setup register contents lost	Store setup in same register again.
-315	"Configuration memory lost"	Hardware configuration settings lost.	Contact CI service department at support@programmablepower.com to obtain instructions on restoring configuration data.
-330	"Self-test failed"	Internal error	Contact CI service department at support@programmablepower.com
-350	"Queue overflow"	Message queue full.	Too many message. Read status using SYST:ERR query until 0, "No Error" is received indicating queue empty.
-400	"Query error"	Unable to complete query.	Check programming manual for correct query format and parameters
-410	"Query INTERRUPTED"	Query issued but response not read.	Check application program for correct flow. Response must be read after each query to avoid this error.
-420	"Query UNTERMINATED"	Query incomplete.	Check for terminator after query command.
-430	"Query DEADLOCKED"	Query cannot be completed	Check application program for multiple queries
-440	"Query UNTERMINATED"	Query incomplete.	Check for terminator after query command.
0	"No error"	No errors in queue	
2	" Non-volatile RAM CONFIG section checksum failed"	Controller failure during Self-test.	Contact CI service department at support@programmablepower.com
3	" Non-volatile RAM CAL section checksum failed"	Controller failure during Self-test.	Contact CI service department at support@programmablepower.com
4	" Non-volatile RAM WAVEFORM section checksum failed"	Controller failure during Self-test.	Contact CI service department at support@programmablepower.com
10	"Ram self test	Controller failure during Self-test.	Contact CI service department at support@programmablepower.com
40	"Voltage self test error, output 1	No. 1/A amplifier in Master source has no output during Self-test.	Contact CI service department at support@programmablepower.com
41	"Voltage self test error, output 2	No. 2/B amplifier in Master source has no output during Self-test	Contact CI service department at support@programmablepower.com

Number	Message String	Cause	Remedy
42	"Voltage self test error, output 3	No. 3/C amplifier in Master source has no output during Self-test	Contact CI service department at support@programmablepower.com
43	"Current self test error, output 1	No. 1/A amplifier in Aux. Source has no output during Self-test.	Contact CI service department at support@programmablepower.com
44	"Current self test error, output 2	No. 2/B amplifier in Aux. Source has no output during Self-test.	Contact CI service department at support@programmablepower.com
45	"Current self test error, output 3	No. 3/C amplifier in Aux. Source has no output during Self-test.	Contact CI service department at support@programmablepower.com
216	" RS-232 receiver framing error"	Communication failure.	Check RS232 port settings and cable.
217	" RS-232 receiver parity error"	Communication failure.	Check RS232 port settings and cable.
218	" RS-232 receiver overrun error"	Communication failure.	Check RS232 port settings and cable.
402	"CAL password is incorrect"	Calibration password does not equal high voltage range value.	Re-enter correct password.
403	"CAL not enabled"	No password entered for calibration	Enter correct CAL password.
600	"Systems in mode:list have different list lengths"	Transient lists have unequal lengths	Check list settings and correct to same no of data points.
601	"Requested voltage and waveform exceeds peak voltage capability"	Wave shape selected and RMS voltage combine to exceed peak voltage capability.	Reduce RMS or crest factor of wave shape.
602	"Requested voltage and waveform exceeds transformer volt-second rating"	The selected wave shape exceeds output transformer capability.	The volt-second product of he wave form (magnitude and time in the + and – half of wave form).
603	"Command only applies to RS-232 interface"	Command not relevant for GPIB interface.	Do not use command.
604	"Trigger received before requested number of pre-trigger readings"	Data acquisition pre-trigger buffer not filled yet.	Hold off trigger or reduce pre-trigger delay.
605	"Requested RMS current too high for voltage range"	Max RMS current is function of voltage range selected.	Reduce programmed RMS current limit or select low voltage range.
606	"Waveform data not defined"	No waveform name specified	Specify waveform name before sending waveform data.
607	"VOLT,VOLT:SLEW, and FUNC:SHAPe modes incompatible"	Conflict between wave shape and programmed slew	Reduce slew or change waveform type.

Number	Message String	Cause	Remedy
608	"Measurement overrange"	Measurement data out of range.	
609	"Output buffer overrun"	Too much data in output buffer.	Check receive mode on application program. Program is not reading data sent by AC source.
610	"Command cannot be given with present SYST:CONF setting"	Command conflicts with available hardware or firmware option settings.	Check configuration for available options and features.
801	"Output voltage fault"	- Output voltage exceeds max compliance voltage set. - Open circuit	Check load connection. Load impedance may be too high for programmed current level causing compliance voltage to exceed set limit.
802	"Current limit fault"	Maximum available current exceeded.	Load exceeds current limit and unit is in Constant Voltage (CV) mode of operation. Reduce load or increase CL setting
803	"Temperature fault"	Amplifier heat sink temp. too high.	Reduce load. Ensure proper air flow and exhaust clearance. Check fan(s) for operation.
804	"External sync error"	Could not sync to external sync signal.	External sync signal missing, disconnected or out of range.
805	"Initial memory lost"	Initial settings could not be recalled at power-up.	Save power on settings again to overwrite old content.
806	"Limit memory lost"	Hardware configuration settings could not be recalled at power-up.	Contact CI service department at support@programmablepower.com to obtain instructions on restoring configuration data.
807	"System memory lost"	Memory corrupted during power-up.	Recycle power.
808	"Calibration memory lost"	Calibration data lost during power-up.	Contact CI service department at support@programmablepower.com to obtain instructions on restoring calibration data or recalibrate unit.
813	"Missing list parameter"	One or more transient list parameters missing.	Check programmed lists.
814	"Voltage peak error "	Peak voltage exceeds internal bus voltage	This error may occur when selecting user defined wave shapes with higher crest factors. Reduce programmed RMS value.
815	"Slew time exceed dwell"	Time needed to slew to final value is less than dwell time.	Check dwell times in transient list settings. Increase dwell time or change slew rate for affected parameter.
816	"Illegal during transient"	Operation requested not available while transient is running.	Wait till transient execution is completed or abort transient execution first.
817	"Output relay must be closed"	Transient programmed with output relay open.	Close relay before attempting transient operation.

Number	Message String	Cause	Remedy
819	"Clock and sync must be internal"	Operation not possible with external clock	Switch to internal sync. (Default)
820	"Input buffer full"	Too much data received.	Break up data in smaller blocks.
821	"Amplifier unbalance"	Hardware error. An amplifier has an overload condition.	Check amplifier balance adjustment. If error persists contact CI service at support@programmablepower.com .
822	"Waveform harmonics limit"	Harmonic contents of user defined wave shape is too high and could damage amplifier output stage.	Reduce harmonic content or reduce fundamental frequency programmed.
823	"Amplifier fault"	An amplifier failure. Can be reported at any time.	Determine which amplifier is at fault with self-test or checking LED on Relay Board. Replace amplifier.
824	“Auxiliary down”	One or more auxiliary units is not powered up or not working.	Turn on all auxiliary units.
825	“Over voltage prot trip”	Over voltage detected on output	Check output voltage for correct RMS value.
826	“Peak current prot trip”	Peak current limit exceeded.	Peak current exceeded. Could be caused by switching EUT on or off.
827	“Frequency error”	Frequency error during self-test.	Correct frequency was not measured during self-test. May be result of 801 error.
828	“Phase error”	Self test error phase angle	Correct phase angle was not measured during self-test. May be result of 801 error.
829	“Dc component exceed limit”	Too much DC content in loaded ARB waveform.	Check waveform programming.

Table 8-1: Error Messages

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