# 4600 AC LOAD

# TRANSIENT MODE

**ADDENDUM**

**Part No. 09-0237**

**REVISION G**

**February 18, 1999**

**Document History**

| | | | |
|---|---|---|---|
| **Rev G** | **14857** | **2/18/1999** | **CAR** |

## Proprietary Rights Notice

# TABLE OF CONTENTS


**1. INTRODUCTION ..... 7**

**2. DESCRIPTION ..... 8**

2.1 TRANSIENT OPERATION ..... 8

2.2 TRANSIENT MODE SETTINGS ..... 9

2.2.1 TRANSIENT MODE OFF ..... 9

2.2.2 TRANSIENT MODE INITIATE ..... 9

2.2.3 TRANSIENT MODE ARMED ..... 9

2.2.4 TRANSIENT MODE CONTINUOUS ..... 9

2.2.5 GENERATE EXT. TRIGGER ..... 9

2.2.6 TRIG. BY EXT. TRIGGER ..... 9

2.2.7 TRIG. BY VOLTAGE TRANSITION ..... 9

2.2.8 TRIG. BY VOLTAGE PHASE ..... 9

2.2.9 RESET TRANSIENT MODE ..... 10

2.3 SET COMMANDS ..... 10

2.4 COMMAND QUEUE ..... 10

2.5 TRANSIENT MODE STATUS ..... 10

2.5.1 TRANSIENT MODE REGISTER ..... 10

2.5.2 LOAD TRIGGERED ..... 10

2.5.3 CMD BUFFER FULL ..... 10

2.5.4 TRIGGER THE PORT ..... 10

2.5.5 READ REGISTER ..... 10

2.6 ADVANCED SETTINGS ..... 11

**3. EXAMPLE ..... 12**

# 1. INTRODUCTION

This document is an addendum to the 4600 AC load users manual. The user must understand basic operation of the AC load before attempting transient operation.

Transient operation is useful for fast or time critical changes in load operation.

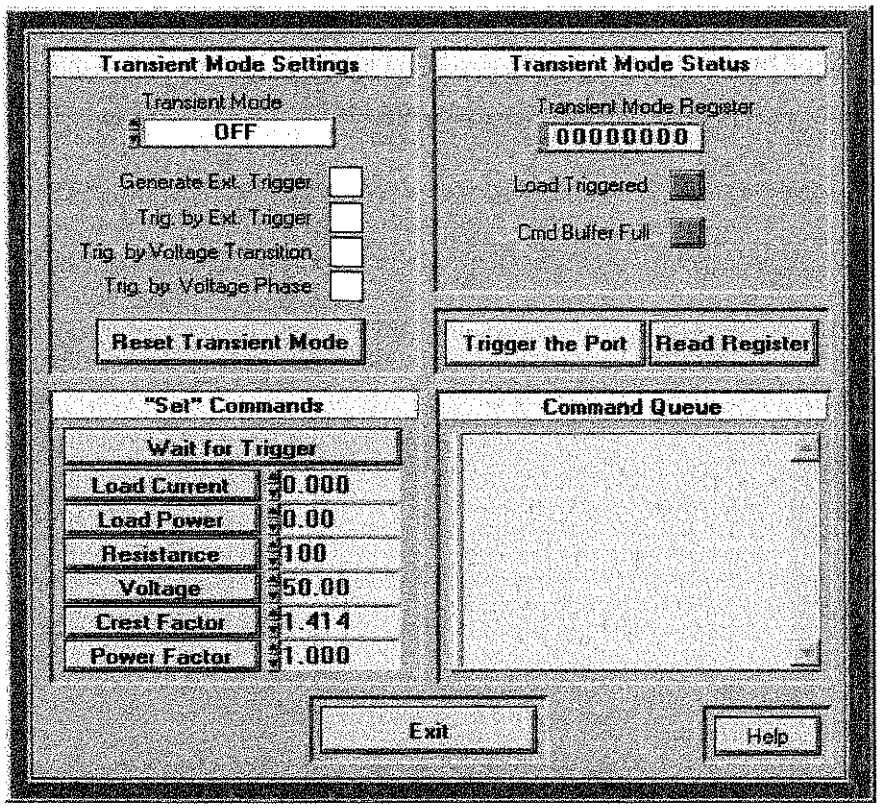
With normal operation, commands are executed as soon as they are received. During transient operation commands are queued and not executed until triggered. This allows very fast changes (every cycle if needed) in current which can reveal precious information about the regulation, output voltage and current, peak capabilities etc. of the UUT in just one test. The commands can be executed as a single shot or as a loop.

# 2. DESCRIPTION

## 2.1 Transient Operation

Transient Operation button.


Transient Operation window.



## 2.2 Transient Mode Settings

### 2.2.1 Transient Mode Off

The AC Load will execute commands as soon as received. Any triggers are ignored. This is normal operation.

### 2.2.2 Transient Mode Initiate

This is the programming mode. In this mode "Set" commands will be queued and NOT executed. Commands are stored for execution later. After Initiate mode is set select the "Set" Commands, you wish to program.

### 2.2.3 Transient Mode Armed

The load is waiting for a trigger signal to execute the next command previously queued. When all queued commands have been executed, returns to Transient Mode Off. This is a one shot transient.

### 2.2.4 Transient Mode Continuous

This is the same as armed except when all queued commands have been executed commands restart at the beginning of queue. The transient starts over again and repeats indefinitely.

### 2.2.5 Generate Ext. Trigger

When this box is selected, the load will generate trigger outputs on the Trig Out port when it is triggered. This is a negative true, TTL level signal.

### 2.2.6 Trig. By Ext. Trigger

When this box is selected the load will accept a trigger input from the "Trigger the Port" button or the Trig In port. The Trig In port requires a negative true TTL level signal and must be 50uS minimum in length.

### 2.2.7 Trig. By Voltage Transition

When this box is selected, the load will generate a trigger input when:

- The input voltage starts below the Turn-Off Volts then rises and exceeds the Turn-On Volts.
- The input voltage starts above the Turn-On Volts then falls below the Turn-Off Volts.

### 2.2.8 Trig. By Voltage Phase

When this box is selected, the load will generate a trigger input at a programmed voltage phase angle.

### 2.2.9 Reset Transient Mode

Clears the command queue and allows a new transient to be programmed.

### 2.3 Set Commands

Here is where the user builds the sequence of commands he wishes to execute later in real time. Up to 100 commands may be queued.

Set the Current, Power, Resistance, Voltage, Crest Factor and/or Power Factor you wish the load to change to when a trigger is received. One or multiple commands may be executed with a single trigger. The Wait for Trigger command causes the load to wait for the next trigger before executing the next command or group of commands.

### 2.4 Command Queue

The commands, which have been queued, are displayed here.

### 2.5 Transient Mode Status

### 2.5.1 Transient Mode Register

The value of the Transient Mode Register is displayed here.

| Bit | Name | Description |
|---|---|---|
| 0 & 1 | Mode | 00 – No transient operation.<br>01 – Initiate. Set type commands will be queued, but the module output is not modified until it is armed and it receives a trigger signal.<br>10 – Armed. The module is waiting for a trigger signal to execute the next command(s) previously queued. When all queued commands have been executed, returns to no transient operation.<br>11 - Continuous. Same as armed except when all queued commands have been executed, restarts at beginning of queue. |
| 2 | Enable Output | The module will generate trigger outputs. |
| 3 | Trigger Output | 0 - When enable output is 0.<br>1 - Latched with each trigger event, reset after read. |
| 4 | Trigger Input | Hardware trigger input enabled. |
| 5 | Voltage Input | Turn on/off voltage trigger enabled. |
| 6 | Phase Angle | Phase angle trigger enabled. |
| 7 | Queue Full | The transient command queue is full. |

### 2.5.2 Load Triggered

This will light when the load is triggered.

### 2.5.3 Cmd Buffer Full

This is an error, which indicates more than 100 commands have been sent to the load.

### 2.5.4 Trigger the Port

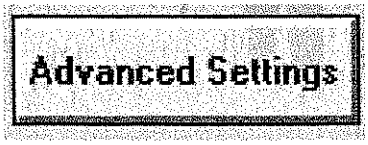
Sends a trigger to the load. Ext. Trigger must be enabled.

### 2.5.5 Read Register

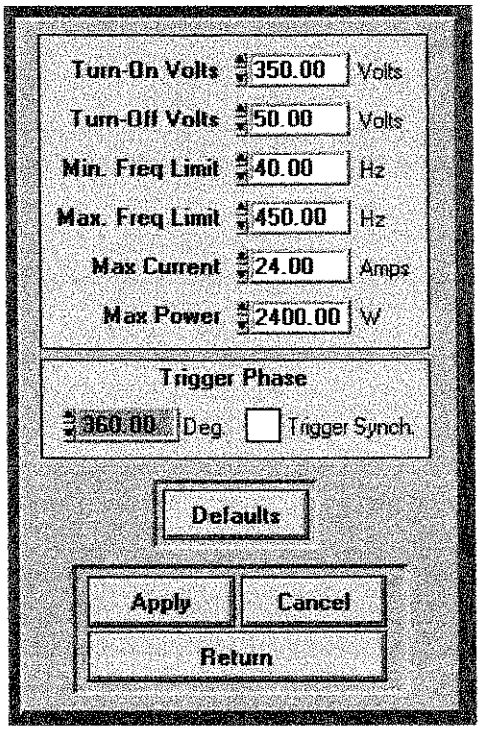
Reads the Transient Mode Register.

## 2.6 Advanced Settings

Advanced Settings Button.




Advanced settings window.




The Trig. By Voltage Transition may be programmed by the Turn-on and Turn-Off Voltages.

The Trig. By Voltage Phase may be programmed by selecting 0 to 359 Deg. and then enable the Trigger Synch.

## 3. EXAMPLE

The following is an example of turn on inrush current where the first cycle is 20A, the second cycle is 10A and the remaining cycles are 5A.

Click on the Advanced Settings Button. Set the Trigger Phase to 0 degrees and enable Trigger Synch. see section 2.6. This will cause the current to change at 0 degrees.

Click on the Transient Operation and set Transient Mode Initiate, see section 2.2.2.

Set load current to 20 Amps, see section 2.3. Observe "Set load current to 20 Amps" appear in the Command Queue window. See section 2.4.

Click on Wait for Trigger, observe "Wait for Trigger" appear in the Command Queue window.

Set load current to 10 Amps.

Click on Wait for Trigger.

Set load current to 5 Amps.

Click on Wait for Trigger.

Click on Wait for Trigger.

Click on Wait for Trigger.

Click on Trig. By Voltage Phase, see section 2.2.8.

Click on Transient Operation and set Transient Mode Continuous, see section 2.2.4.

With an oscilloscope and current probe, observe one cycle of current at 20A the next at 10A and several at 5A.

# 4600 AC LOAD

# USERS MANUAL

**Part No. 09-0237**

**REVISION G**

**February 18, 1999**

## Document History

| | | | |
|---|---|---|---|
| **Rev A** | **First printing** | **12/19/97** | **CAR** |
| **Rev B** | **Added calibration section** | **1/22/98** | **CAR** |
| **Rev C** | **Release ECO 14650** | **2/9/98** | **JW** |
| **Rev D** | **ECO 14684** | **4/16/98** | **CAR** |
| **Rev E** | **ECO 14756** | **6/26/98** | **CAR** |
| **Rev F** | **ECO 14803** | **10/8/98** | **VJB** |
| **Rev G** | **ECO 14857** | **021899** | **CAR** |

## Proprietary Rights Notice

# TABLE OF CONTENTS


**1. INTRODUCTION ..... 9**
1.1 BROAD OPERATING ENVELOPE ..... 9
1.2 NON LINEAR LOADING ..... 9
1.3 BROAD SPECTRUM OF EMULATION MODES ..... 9
1.4 HIGH ACCURACY MEASUREMENTS ..... 9

**2. SPECIFICATIONS ..... 11**
2.1 RATINGS ..... 11
2.2 PROGRAMMABLE FEATURES ..... 11
2.3 READBACK INSTRUMENTATION ..... 12
2.4 PROTECTION ..... 14
2.5 SUPPLEMENTAL CHARACTERISTICS ..... 14

**3. INSTALLATION ..... 15**
3.1 HARDWARE INSTALLATION ..... 15
3.1.1 FRONT VIEW ..... 16
3.1.2 REAR VIEW ..... 16
3.1.3 TOP VIEW ..... 17
3.1.4 SIDE VIEW ..... 17
3.1.5 CONNECTORS ..... 18
3.1.5.1 CONTROL POWER INPUT ..... 18
3.1.5.2 LOAD POWER INPUT ..... 18
3.1.5.3 RS232 9PIN CONNECTOR ..... 19
3.1.5.4 COMM IN/OUT ..... 20
3.1.5.5 TRIG IN/OUT ..... 21
3.1.5.6 HOLD IN/OUT ..... 21
3.1.6 AIRFLOW ..... 21
3.1.7 MASTER SLAVE INSTALLATION ..... 21
3.1.7.1 LOAD POWER INPUT ..... 22
3.1.7.2 COMPUTER CONNECTION ..... 22
3.1.7.3 HOLD CONNECTION ..... 22
3.2 SOFTWARE INSTALLATION ..... 22
3.2.1 SOFTWARE INSTALLATION FROM CD ROM ..... 22
3.2.2 SOFTWARE INSTALLATION FROM FLOPPIES ..... 22

**4. USER OPERATION ..... 23**
4.1 HARDWARE OPERATION ..... 23
4.1.1 CONTROL POWER SWITCH AND INDICATOR ..... 23
4.1.2 LOAD POWER CIRCUIT BREAKER ..... 23
4.1.3 S6K AD SWITCH ..... 23
4.1.4 FAULT INDICATOR ..... 23
4.1.5 STATUS INDICATOR ..... 24
4.1.6 ERROR INDICATOR ..... 24
4.1.7 TALK INDICATOR ..... 24
4.1.8 LISTEN INDICATOR ..... 24
4.2 SOFTWARE OPERATION ..... 24
4.2.1 ACCESSING HELP ..... 24
4.2.2 OFF ..... 26
4.2.3 LOAD MODES ..... 26
4.2.3.1 CONSTANT CURRENT ..... 27
4.2.3.2 CONSTANT POWER ..... 27
4.2.3.3 CONSTANT RESISTANCE ..... 27

4.2.3.4 CONSTANT VOLTAGE ..... 27
4.2.4 OTHER PROGRAMMABLE FEATURES ..... 28
4.2.4.1 CREST FACTOR ..... 28
4.2.4.2 POWER FACTOR ..... 28
4.2.4.3 SHORT CIRCUIT ..... 28
4.2.4.4 POWER FACTOR MODES ..... 29
4.2.5 STATUS ..... 29
4.2.6 DEVICE CAPABILITIES ..... 30
4.2.7 ADVANCED SETTINGS ..... 31
4.2.8 RESETTING ..... 32
4.2.9 TRANSIENT ..... 32
4.2.10 METERING ..... 33
4.2.10.1 READ BACK CAPABILITIES ..... 33
4.2.10.2 METERING MODES ..... 33
4.2.10.3 WAVEFORM CAPTURE ..... 34

**5. CALIBRATION ..... 37**
5.1 MAINTENANCE PANEL ..... 37
5.2 EQUIPMENT REQUIRED ..... 37
5.3 PROCEDURE ..... 37

**6. THEORY OF OPERATION ..... 39**
6.1 ARCHITECTURE ..... 39
6.2 MEMORY ..... 40
6.2.1 MEMORY MAP ..... 40
6.2.2 EPROM ..... 41
6.2.3 ANALOG TO DIGITAL CONVERTERS ..... 41
6.2.4 PERIPHERAL BUS ..... 41
6.2.5 UART ..... 41
6.2.6 DIGITAL INPUTS ..... 41
6.2.7 DIGITAL OUTPUTS ..... 41
6.2.8 FREQUENCY ..... 41
6.2.9 REFERENCE DIGITAL TO ANALOG CONVERTER ..... 41
6.2.10 INTERNAL RAM ..... 41
6.2.11 SRAM ..... 41
6.2.12 FLASH PROM ..... 42
6.2.13 WAVEFORM DIGITAL TO ANALOG CONVERTER ..... 42
6.3 RESET ..... 42
6.4 INTERRUPTS ..... 42
6.4.1 INT0 ..... 42
6.4.2 INT1 ..... 42
6.4.3 INT2 ..... 42
6.4.4 INT3 ..... 42
6.5 BLOCK DIAGRAM ..... 43
6.6 SYNCHRONIZATION ..... 43
6.7 FREQUENCY METERING ..... 43
6.8 VOLTAGE METERING ..... 43
6.9 CURRENT METERING ..... 43
6.10 HARDWARE CR MODE ..... 44
6.11 HARDWARE CC MODE ..... 44
6.12 CREST FACTOR AND POWER FACTOR RELATIONSHIP ..... 45
6.13 POWER SECTION ..... 45
6.14 PROTECTION CIRCUITRY ..... 46
6.14.1 CIRCUIT BREAKER ..... 46
6.14.2 OVERVOLTAGE ..... 46
6.14.3 OVERTEMPERATURE ..... 46
6.14.4 OVERPOWER ..... 46

6.14.5 NO SHARE ....46
6.14.6 SECOND BREAK LIMIT ....46

**7. MESSAGE FORMATS ....47**
7.1 COMMAND MESSAGE ....47
7.1.1 COMMAND TYPES ....48
7.2 RESPONSE MESSAGE ....48
7.2.1 STATUS RESPONSE MESSAGE ....48
7.2.2 ACKNOWLEDGE MESSAGE ....48
7.2.3 COMMAND SPECIFIC RESPONSE ....49

**8. COMMAND MESSAGE SET ....51**
8.1 GET STATUS ....51
8.2 RESET ....51
8.3 RESET/SELFTEST ....52
8.4 CLEAR ERRORS ....52
8.5 CLEAR INTERFACE ....53
8.6 SEND OWN ADDRESS (SOA) ....53
8.7 SET GROUP ADDRESS ....55
8.8 GET GROUP ADDRESS ....55
8.9 GET REGISTER ....56
8.10 SET COMMAND MODE ....57
8.11 GET COMMAND MODE ....57
8.12 SET LOAD MODE ....58
8.13 GET LOAD MODE ....58
8.14 SET MEASUREMENT MODE ....59
8.15 GET MEASUREMENT MODE ....59
8.16 SET TRANSIENT MODE ....60
8.17 GET TRANSIENT MODE ....60
8.18 READ MEMORY ....61
8.19 WRITE MEMORY ....62
8.20 GET VERSION NUMBER ....63
8.21 FLASH DOWNLOAD MODE ....64
8.22 WRITE FLASH ....65
8.23 WRITE CALIBRATION FACTORS ....66
8.24 RESET CALIBRATION FACTORS ....66
8.25 GET DEVICE CAPS ....67
8.26 CALIBRATE AC CURRENT GAIN ....69
8.27 CALIBRATE AC VOLTAGE GAIN ....70
8.28 QUERY MEASUREMENT ....71
8.29 SET MAXIMUM FREQUENCY LIMIT ....72
8.30 GET MAXIMUM FREQUENCY LIMIT ....73
8.31 SET MINIMUM FREQUENCY LIMIT ....74
8.32 GET MINIMUM FREQUENCY LIMIT ....75
8.33 SET MAXIMUM CURRENT LIMIT ....76
8.34 GET MAXIMUM CURRENT LIMIT ....77
8.35 SET MAXIMUM POWER LIMIT ....78
8.36 GET MAXIMUM POWER LIMIT ....79
8.37 SET CURRENT ....80
8.38 GET CURRENT ....81
8.39 SET CREST FACTOR ....82
8.40 GET CREST FACTOR ....83
8.41 SET POWER FACTOR ....84
8.42 GET POWER FACTOR ....85
8.43 SET RESISTANCE ....86
8.44 GET RESISTANCE ....87
8.45 SET POWER ....88

8.46 GET POWER ..... 89
8.47 SET VOLTAGE ..... 90
8.48 GET VOLTAGE ..... 91
8.49 WAIT FOR TRIGGER ..... 92
8.50 SET TURN ON VOLTAGE ..... 92
8.51 GET TURN ON VOLTAGE ..... 93
8.52 SET TURN OFF VOLTAGE ..... 94
8.53 GET TURN OFF VOLTAGE ..... 95
8.54 SET TRIGGER PHASE ..... 96
8.55 GET TRIGGER PHASE ..... 97
8.56 STORE WAVEFORMS ..... 98
8.57 GET WAVEFORMS ..... 99
8.58 WRITE CONFIGURATION DATA ..... 100
8.59 READ CONFIGURATION DATA ..... 101

**9. REGISTER DESCRIPTION ..... 103**
9.1 EVENT STATUS REGISTER ..... 103
9.2 HARDWARE FAULT REGISTER ..... 103
9.3 SELFTEST ERROR REGISTER ..... 104
9.4 DEVICE ERROR REGISTER ..... 104
9.5 OPERATIONAL ERROR REGISTER ..... 104
9.6 COMMAND MODE REGISTER ..... 105
9.7 LOAD MODE REGISTER ..... 105
9.8 MEASUREMENT MODE REGISTER ..... 106
9.9 TRANSIENT MODE REGISTER ..... 106

**10. TROUBLE SHOOTING ..... 107**
10.1 LOAD POWER CIRCUIT BREAKER TRIPS ..... 107
10.2 FAULT LAMP LIT ..... 107
10.3 STATUS LAMP NOT BLINKING ..... 107
10.4 ERROR LAMP LIT ..... 108
10.5 NO COMPUTER COMMUNICATION ..... 108
10.6 ZERO FREQUENCY ..... 108
10.7 NEGATIVE POWER DISPLAYED ..... 108
10.8 UNDER VOLTAGE ..... 108

**ADDENDUM**
TRANSIENT MODE ..... 109

# 1. INTRODUCTION

The Model 4600 family of AC Electronic Loads is designed to provide precise non-linear loading requirements for UPS and AC power supply test and evaluation applications. Manufacturers are now able to vary current, crest factor and power factor to ensure that their products are tested to worst case conditions encountered in the field. The Model 4600 offers more flexibility, enhanced reliability, less space and lower cost than an assortment of passive resistive loads.

## 1.1 Broad Operating Envelope

To cover the full spectrum of UPS and AC power supplies, the Model 4600 operates up to 3000W over a voltage range of 50 to 350Vac in a single-phase mode. The loading current waveform synchronizes to the voltage waveform for the set current, crest factor and power factor. Thus multiple Model 4600s can be connected in parallel for higher power loading or in single groups for multiphase systems.

## 1.2 Non Linear Loading

Programmable crest factor and power factor allows the Model 4600 to emulate a non-linear load such as a switching power supply. The Model 4600's capability to provide a variety of loads from sinusoidal to high crest factor allows manufacturers to characterize UUT's to worst case conditions.

## 1.3 Broad Spectrum of Emulation Modes

To allow UPS's and AC power supplies to be tested under a variety of loading conditions, the Model 4600 offers a broad spectrum of emulation modes. CC mode allows current to be drawn constantly, making it suitable for non-linear, linear and regulation loading. While CR mode allows the load to emulate a power resistor, CV allows it to emulate a shunt regulator. CP mode emulates a constant power load such as a switching power supply. Short circuit mode allows the load to test the UUT's short circuit protection capability. Unity power factor mode causes power factor to be as close as possible to unity, useful when the input voltage is non-sinusoidal. These capabilities makes the Model 4600 a universal load which replaces an assortment of resistive loads and short circuit relays used currently by manufacturers.

## 1.4 High Accuracy Measurements

The Model 4600 accomplishes high accuracy frequency, voltage, peak voltage, current, peak current, crest factor, apparent power, true power, peak power, reactive power, power factor and resistance measurements by combining high resolution measurements with precision ranging. The ability to make all measurements internally eliminates multiple external measurement instruments plus associated signal matrixing. In this manner the load provides for a more compact, less costly and considerably faster test system. Waveforms may be graphically displayed eliminating the need for an oscilloscope.

# 2. SPECIFICATIONS

## 2.1 Ratings

Power: 3000W 0 - 37° C, 2400W 38 - 50° C
Max. Peak power: 13kW (up to 20% duty cycle)

Current: 30A rms.
Max. Peak current: 90A

Voltage: 50 to 350V rms.
Max. Peak voltage: 500V

Frequency: 45 to 440Hz

## 2.2 Programmable Features

Constant Current Mode
Range: 0 to 30A rms.

Accuracy: 0.2% of full scale

Resolution: 0.05% of full scale

Constant Voltage Mode
Range: 50 to 350V rms.

Accuracy: 0.2% of full scale

Resolution: 0.05% of full scale

Constant Resistance Mode
Range: 2.5 to 100Ω, 100 to 1000Ω

Accuracy: 1% of full scale, 5% of full scale

Resolution: 0.05% of full scale

Constant Power Mode
Range: 3000W 0 - 37° C, 2400W 38 - 50° C

Accuracy: 0.5% of full scale

Resolution: 0.1% of full scale

Crest factor

Range: √2 to 3.5, limited to 90A peak

Accuracy: 1% of full scale

Resolution: 0.1% of full scale

Power factor

Range: 0 to 1 lead or lag limited by Crest factor settings

Accuracy: 1% of full scale

Resolution: 0.1% of full scale

Short circuit Mode

Max. Surge current: 300A peak, up to 50msec

Max. Continuous current: 30A rms.

Max. Voltage drop: 2.5Vr.m.s.

Maximum Set Resistance = 1 / (Frequency * 1.3e-5)

Minimum Set Current = Voltage / Maximum Set Resistance

### 2.3 Readback Instrumentation

Frequency

Range: 45 to 440Hz

Accuracy: 0.1% of full scale

Resolution: 0.05% of full scale

Voltage

Range: 50 to 350V rms.

Accuracy: 0.1% of full scale

Resolution: 0.05% of full scale

Peak Voltage

Range: 50 to 500V

Accuracy: 0.5% of full scale

Resolution: 0.1% of full scale

Current
Range: 0 to 30A rms.
Accuracy: 0.2% of full scale
Resolution: 0.1% of full scale

Peak Current
Range: 0 to 90A
Accuracy: 0.5% of full scale
Resolution: 0.1% of full scale

Crest factor
Range: $\sqrt{2}$ to 3.5
Accuracy: 0.5% of full scale
Resolution: 0.1% of full scale

Apparent Power
Range: 0 to 10,500VA
Accuracy: 0.3% of full scale
Resolution: 0.1% of full scale

True Power
Range: 0 to 10,500W
Accuracy: 0.3% of full scale
Resolution: 0.1% of full scale

Peak Power
Range: 0 to 45,000W
Accuracy: 1% of full scale
Resolution: 0.1% of full scale

Reactive Power
Range: 0 to 10,500VA
Accuracy: 0.3% of full scale
Resolution: 0.1% of full scale

Power factor

Range: 0 to 1

Accuracy: 0.5% of full scale

Resolution: 0.1% of full scale

Resistance

Range: 2.5 to 100Ω, 100 to 1000Ω

Accuracy: 1% of full scale, 5% of full scale

Resolution: 0.05% of full scale

## 2.4 Protection

Over Current

Limited by input Circuit Breaker

Limited to Set Maximum Current Limit in software

Over Voltage

Output protected for voltage transients in hardware

Over Power

Power limited at maximum average and peak rated power in hardware

Limited to Set Maximum Power Limit in software

Over Temperature

Monitors heat sink temperature in hardware

## 2.5 Supplemental Characteristics

Size

10.5"H x 16.88"W x 25"D, 40 lbs.

Remote Sensing:

Max. 2V drop between sense and load lines

Isolation

1000V between input and chassis ground

Operating temperature:

3000W 0 - 37° C, 2400W 39 - 50° C

Control power input:

Ordered from factory as either 115VAC ± 10%, 47 to 63Hz, 1.4A Max.
OR 230VAC ± 10%, 47 to 63Hz, 0.7A Max.

All specifications apply for 23°C ± 5°C

# 3. INSTALLATION

## 3.1 Hardware Installation

Unpack the load. Save the packing material if a need arises to return the load.

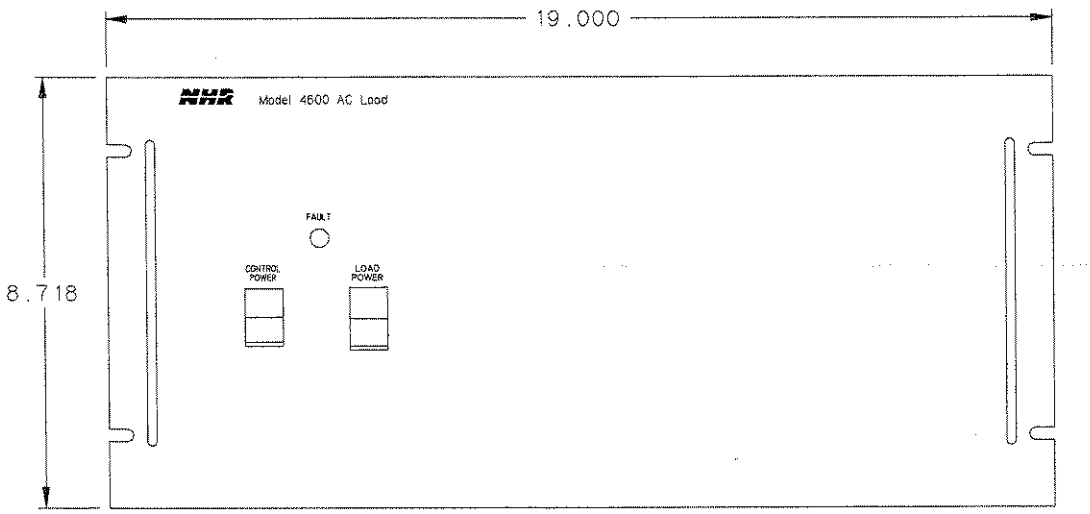
The load is designed to mount into a 19" rack. Optional slide rails are available.

Select a suitable location, which meets size, weight, temperature, airflow, control power input and load power input requirements.

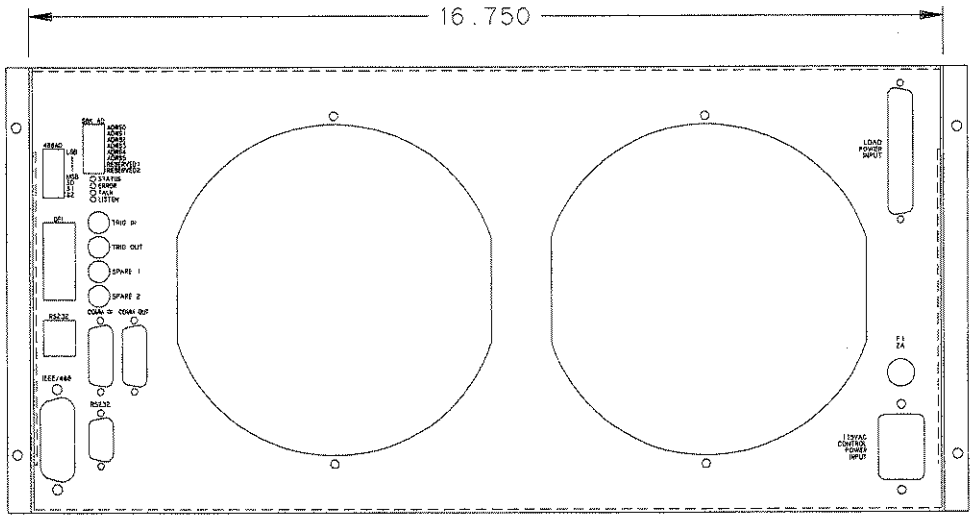
A computer to control the load must be located nearby. The length of the (RS232 or RS485) control cable limits the distance from the load to the computer. The controlling software must be set to the same computer communication port that is connected to the load. The controlling software must be set to the same address as the S6k AD switch on the load.

The remote sense wires must be connected at the power source for more accurate metering and to compensate for voltage drop across the load wires.

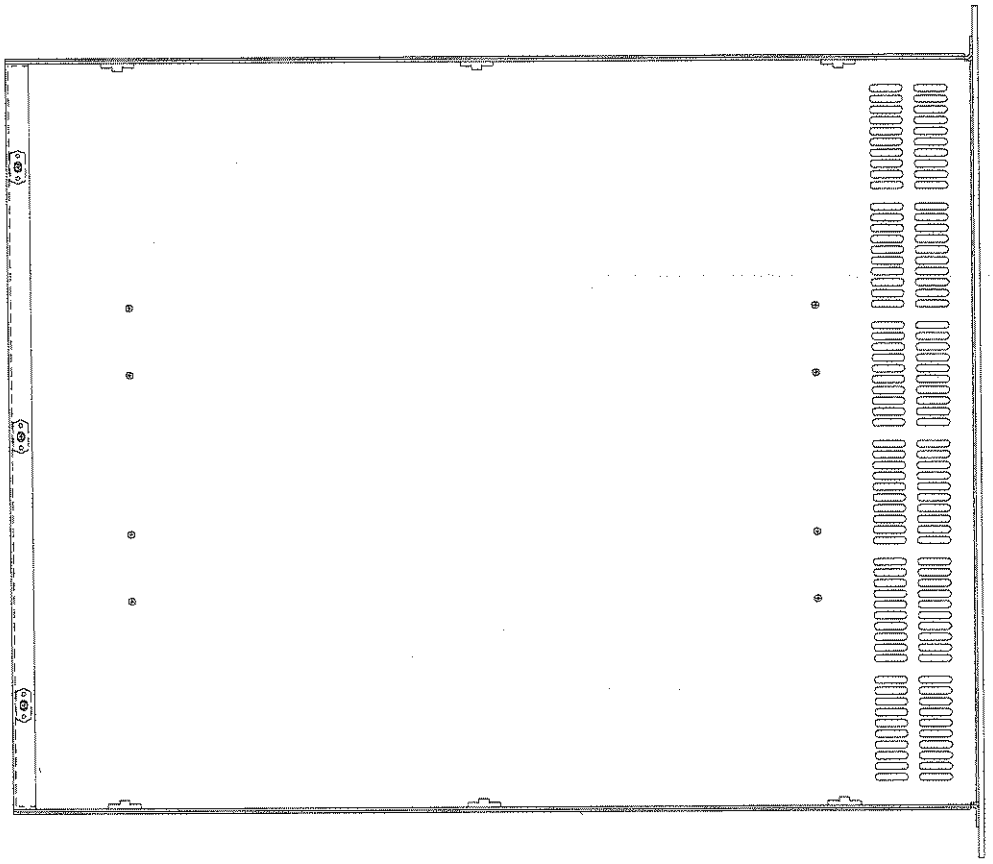
### 3.1.1 Front View



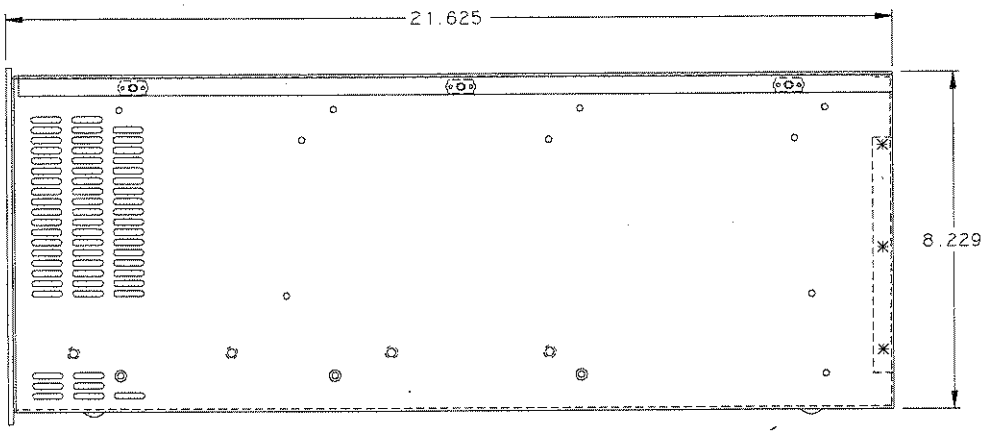

### 3.1.2 Rear View



### 3.1.3 Top View



### 3.1.4 Side View



### 3.1.5 Connectors

#### 3.1.5.1 Control Power Input

This supplies power to the fans and control circuits.

#### 3.1.5.2 Load Power Input

Single unit:

| Pin | Signal | Description |
|---|---|---|
| A1 | No Connection | |
| A2 | Neutral | Load power input |
| A3 | No Connection | |
| A4 | Line | Load power input |
| 1 | No Connection | |
| 2 | Neutral Sense | Remote voltage sense |
| 3-7 | No Connection | |
| 8 | Line Sense | Remote voltage sense |
| 9-17 | No Connection | |

The voltage sense wires are also located on this connector. The voltage sense wires must be connected to the load wires either at this connector or at the source. The load will not operate with these voltage sense wires disconnected. It will generate an undervoltage error.

Mating connector type is:

| NH Part # | Description | Commercial Part # | Manufacturer |
|---|---|---|---|
| 6200933 | DSUB 17 - 4 CO-AX | DCM-21 WA4S | ITT CANNON |
| 6200949 | DSUB contact 40 A | DM 53744-1 | ITT CANNON |
| 6200927 | DSUB shell | DCM 24660 | ITT CANNON |
| 6201309 | DSUB Screw Lock | D20419-21 | ITT CANNON |

### 3.1.5.3 RS232 9pin connector

| Pin | Description |
|---|---|
| 2 | TX |
| 3 | RX |
| 7 | RTS |
| 5 | GND |

Signal levels on this connector conform to RS232C signal levels.

Mating Connector type is:

| NH Part # | Description | Commercial Part # | Manufacturer |
|---|---|---|---|
| 6202014 | DSUB 9 Plug | DE9P | ITT CANNON |
| 6201698 | DSUB Shell | DE24657 | ITT CANNON |
| 6201309 | DSUB Screw Lock | D20419-21 | ITT CANNON |

This connector will mate with a PC compatible nine pin RS232 port if a one to one four wire cable is used. This connection may be used for control of the load in a test system.

### 3.1.5.4 Comm In/Out

| Pin | COMM OUT – FEMALE | Pin | COMM IN - MALE |
|---|---|---|---|
| 1 | TX_IN- | 1 | TX_IN- |
| 2 | TRIGIN+ | 2 | TRIGIN+ |
| 3 | GND | 3 | GND |
| 4 | TX_IN+ | 4 | TX_IN+ |
| 5 | INTLKIN+ | 5 | INTLKIN+ |
| 6 | INTLKIN- | 6 | INTLKIN- |
| 7 | LCLOUT0+ | 7 | LCLIN0+ |
| 8 | LCLOUT- | 8 | LCLIN0- |
| 9 | RX_IN- | 9 | RXOUT- |
| 10 | TRGOUT+ | 10 | TRGOUT+ |
| 11 | TRGOUT- | 11 | TRGOUT- |
| 12 | RX_IN+ | 12 | RXOUT+ |
| 13 | TRIGIN- | 13 | TRIGIN- |
| 14 | LCL1OUT+ | 14 | LCLIN1+ |
| 15 | LCL1OUT- | 15 | LCLIN1- |

Signal levels on this connector are differential with levels conforming to RS422 specification.

This connector will mate with NHR S6000 type modules. This connection may be used for control of the load in a test system. If Comm In is used, remove jumpers on J9, pins 9 to 10 and pins 11 to 12.

Mating connector type is:

| NH Part | Description | Commercial Part # | Manufacturer |
|---|---|---|---|
| 6200844 | DSUB 15 Socket (COMM IN) | DA15S | ITT CANNON |
| 6200799 | DSUB 15 Plug (COMM OUT) | DA15P | ITT CANNON |
| 6200800 | DSUB Shell | DA24658 | ITT CANNON |
| 6201309 | DSUB Screw Lock | D20419-21 | ITT CANNON |

### 3.1.5.5 Trig In/Out

| Connector | Description |
|---|---|
| Trigger In | Negative true TTL level signal with 1K Ohm pull up to +5V |
| Trigger Out | Negative true TTL level output with 39 Ohm series resistor |

These are the hardware trigger input and output connectors for use with transients.

Mating Connector type is:

| NH Part | Description | Commercial Part # | Manufacturer |
|---|---|---|---|
| 6200262 | SMB CO-AX 50 Ohm | 131-1403-016 | EF JOHNSON |

This connector is used with RG178 type 50-ohm CO-AXIAL cable.

### 3.1.5.6 Hold In/Out

| Connector | Description |
|---|---|
| Hold In/Out | Open collector output. |

Paralleled units wait or hold until all are ready to execute new commands simultaneously. Paralleled units will work with out this connection but may not execute commands simultaneously. Connect Hold Out to Hold In from one unit to the next in a daisy chain fashion for all loads in parallel. Do not connect anything else to this connector.

Mating Connector type is:

| NH Part | Description | Commercial Part # | Manufacturer |
|---|---|---|---|
| 6200262 | SMB CO-AX 50 Ohm | 131-1403-016 | EF JOHNSON |

This connector is used with RG178 type 50-ohm CO-AXIAL cable.

### 3.1.6 Airflow

The load will dissipate over 3kW of heat.

400CFM of air must be allowed to moving through the load.

Air enters through slots on top, bottom and both sides then exits through the rear.

### 3.1.7 Master Slave Installation

Slave units must be located next to the master.

### 3.1.7.1 Load Power Input

Load power input to master slave paralleling cable:

| Pin | Signal | Description |
|---|---|---|
| A1 | Neutral | Load power input unit #1 |
| A2 | Neutral | Load power input unit #2 |
| A3 | Line | Load power input unit #1 |
| A4 | Line | Load power input unit #2 |
| 1 | No Connection | |
| 2 | Neutral Sense | Remote voltage sense both units |
| 3-7 | No Connection | |
| 8 | Line Sense | Remote voltage sense both units |
| 9-17 | No Connection | |

Connect the master slave paralleling cable to the master and salve load power input connectors. Connect your source to this cable. The Master-Slave paralleling cable requires (neutral connection to pins A1 and A2 in parallel) and (line connection to pins A3 and A4 in parallel).

### 3.1.7.2 Computer Connection

Connect the controlling computer to the RS232 port or COMM IN on the master. If COMM IN is used, remove jumpers on J9, pins 9 to 10 and pins 11 to 12.
Connect COMM OUT from the master to COMM IN on the slave.

### 3.1.7.3 Hold Connection

Connect HOLD OUT from the master to HOLD IN on the slave.

## 3.2 Software Installation

### 3.2.1 Software Installation from CD ROM

Close all programs that are currently running in windows. Insert the CD into the drive and view the contents of the disk and double click on 'Setup' to start the installation. Follow the instructions on the screen.

### 3.2.2 Software Installation from Floppies

Close all programs that are currently running in windows. Insert disk #1 in the floppy drive. View the contents of the disk and double click on 'Setup' to start the installation. Follow the instructions on the screen.

# 4. USER OPERATION

## 4.1 Hardware Operation

### 4.1.1 Control Power Switch and Indicator

This switch/indicator is located on the front panel. When ON, this switch/indicator will light indicating fan and control power is applied.

### 4.1.2 Load Power Circuit Breaker

This circuit breaker is located on the front panel. When ON, this circuit breaker connects the load to the load power input terminals.

### 4.1.3 S6k AD Switch

The address switch on the rear of the load is used to set a unique communication address for the load on the S6000 family serial interface. Switch ADRS0 – ADRS5 are used to set a module address. Paralleled loads must have successive module addresses.

Switch GADR0 and GADR1 are used to set a group communication address. All paralleled loads must have the same group address other than 0xFF.

Example:

| Load | Description | Switch ADRS 543210 | Unique Address | Switch GADR 10 | Group Address |
|---|---|---|---|---|---|
| 1 | Master in parallel with load 2 | 000001 | 0x01 | 00 | 0xFC |
| 2 | Slave in parallel with load 1 | 000010 | 0x02 | 00 | 0xFC |
| 3 | Master in parallel with load 4 | 000011 | 0x03 | 01 | 0xFD |
| 4 | Slave in parallel with load 3 | 000100 | 0x04 | 01 | 0xFD |
| 5 | Master not paralleled | 000101 | 0x05 | 11 | 0xFF |

If all eight positions of this switch are off when the load is turned on, it will boot from firmware in EPROM and not from FLASH. This is useful if the firmware in FLASH has been corrupted.

### 4.1.4 Fault Indicator

The fault indicator is located on the front panel. A hardware fault (overtemp, overpower, no share) caused the hardware to shutdown. This indicator is cleared by a hardware reset, clear error, reset and selftest commands only after the fault is removed.

### 4.1.5 Status Indicator

This indicator is located on the rear panel. It should blink at a 1Hz rate indicating the internal DSP is operating.

### 4.1.6 Error Indicator

This indicator located on the rear panel indicates a software error has occurred. If lit when the load is initially turned on indicates self-test failed.

### 4.1.7 Talk Indicator

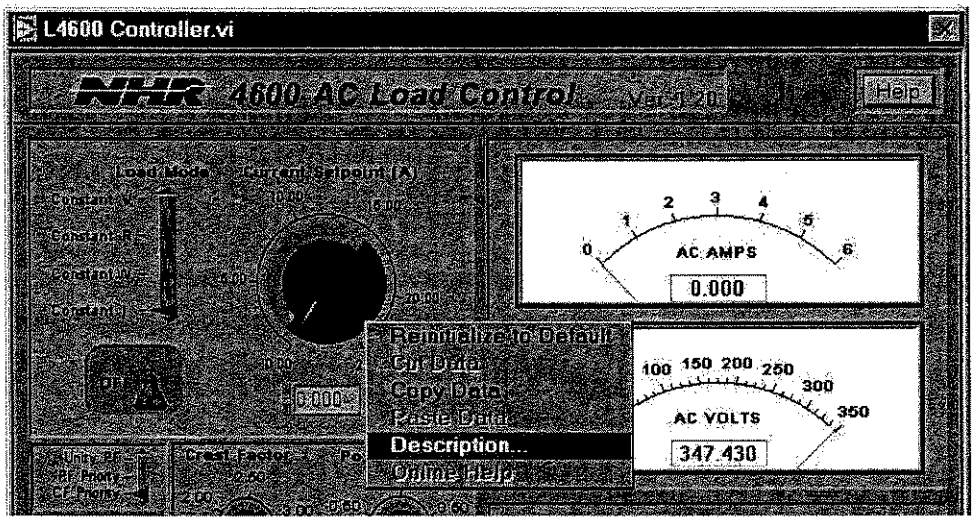
This indicator located on the rear panel will blink on when data is going from the load to the computer.

### 4.1.8 Listen Indicator

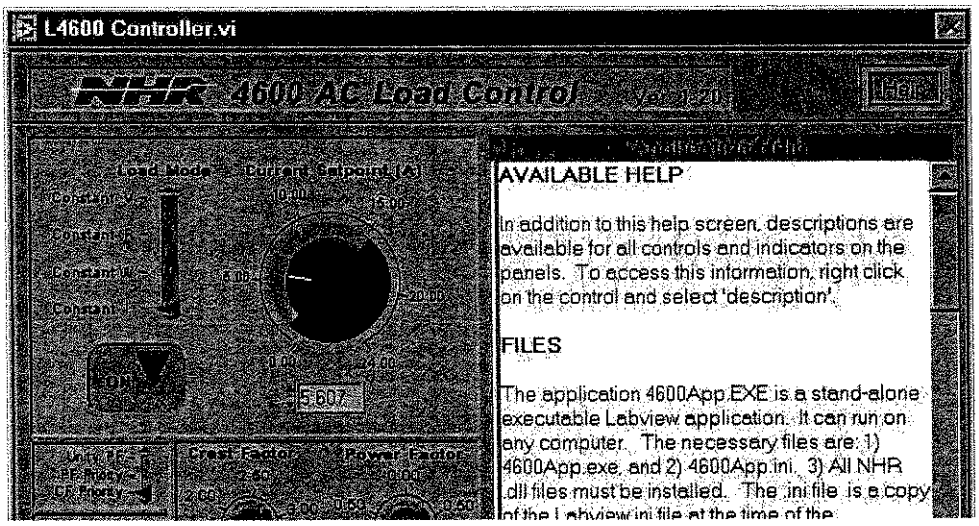
This indicator located on the rear panel will blink on when commands are going from the computer to the load.

## 4.2 Software Operation

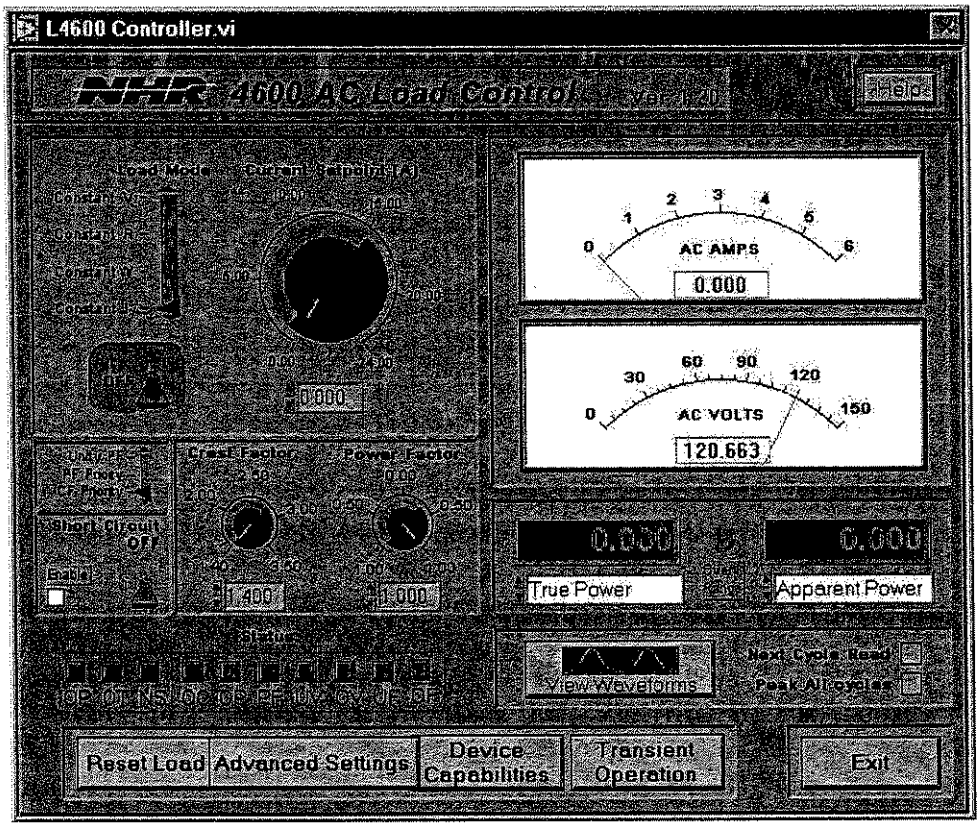
### 4.2.1 Accessing Help

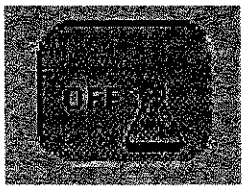



Right click on the control you're interested in then highlight 'Description…' to get help for that control.




When you click on the 'Help' button you will be provided with a general description of system requirements as well as some capability information.

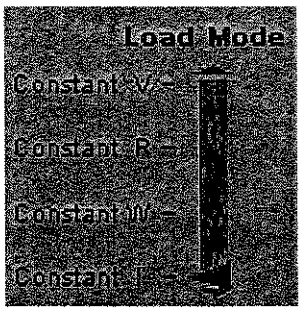



### 4.2.2 Off

The load will not draw any power when in the off state.

### 4.2.3 Load Modes




Use the red slider to select the mode of operation for the load.

#### 4.2.3.1 Constant Current

The amount of rms current drawn it is a constant, regardless of the input voltage. Crest Factor and Power Factor may also be programmed.

#### 4.2.3.2 Constant Power

Varies the amount of current drawn inversely proportional with the input voltage in order to maintain a constant power. By varying the Crest Factor and the Power Factor the load emulates a very wide variety of switching power supplies.

#### 4.2.3.3 Constant Resistance

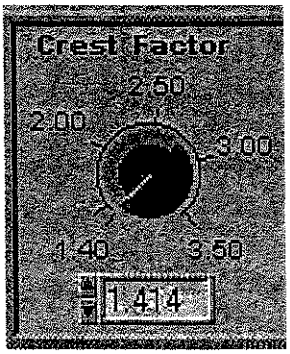
The amount of current drawn varies in direct proportion with the voltage. In this mode the load emulates a power resistor.

#### 4.2.3.4 Constant Voltage

Draws the necessary amount of current to maintain a constant voltage, emulates a shunt regulator.

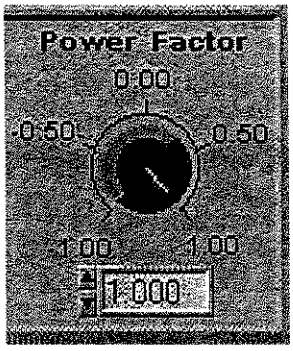
### 4.2.4 Other Programmable Features

#### 4.2.4.1 Crest Factor



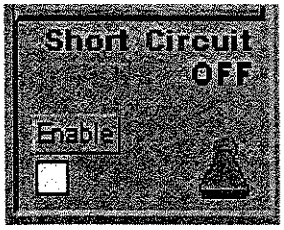

Emulates different types of load characteristics (i.e. switching supplies or other nonlinear loads) in Constant Power and Constant Current mode. Not programmable when unity power factor is selected.

#### 4.2.4.2 Power Factor



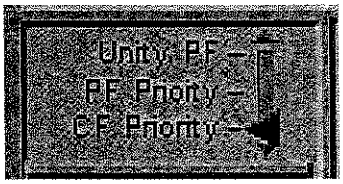

In conjunction with the crest factor it can be set from 0 to 1 (lead or lag) in Constant Power and Constant Current mode. Not programmable when unity power factor is selected. Limited by crest factor setting. See section 6.12 Crest Factor and Power Factor Relationship.

#### 4.2.4.3 Short circuit




Internal SCR's turn on to test the UUT short circuit protection capability.

### 4.2.4.4 Power Factor Modes




Unity Power Factor. (Unity PF)

Forces highest power factor. Programmable Crest Factor and Power Factor do not apply. Allows Constant Current and Constant Power to be programmed correctly with non-sinusoidal input voltages.

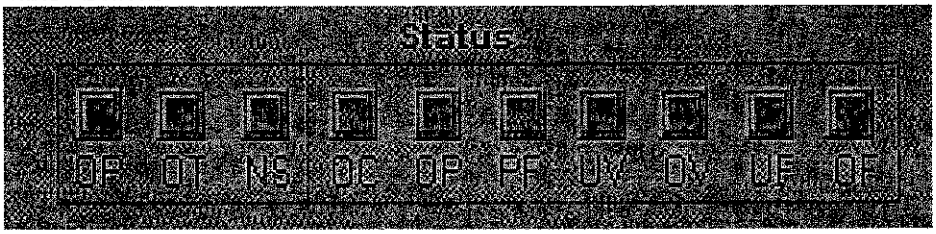
Power Factor Priority. (PF Priority)

Changes Crest Factor to obtain desired Power Factor without phase shifting current. Programmable Crest Factor and does not apply. More closely emulates a power supply type load.

Crest Factor Priority. (CF Priority)

Crest Factor and Power Factor are Programmable. See section 6.12 Crest Factor and Power Factor Relationship.

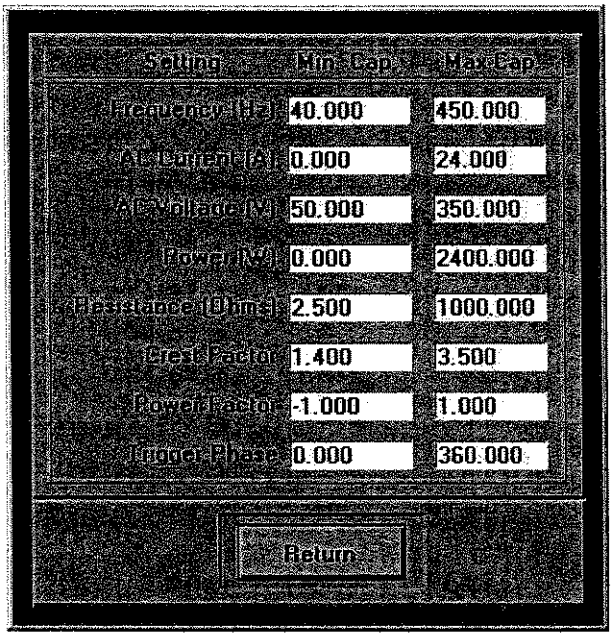
### 4.2.5 Status



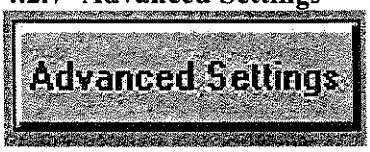

This status bar indicates instrument errors. The two letter descriptors stand for over power (OP), over temperature (OT), no sharing (NS), over current (OC), power factor (PF), under voltage (UV), over voltage (OV), under frequency (UF), and over frequency (OF). The status boxes will turn red if an error is detected. The status bar is separated into two regions. The left region of the status bar represents catastrophic hardware errors and the right represents operational errors.

### 4.2.6 Device Capabilities

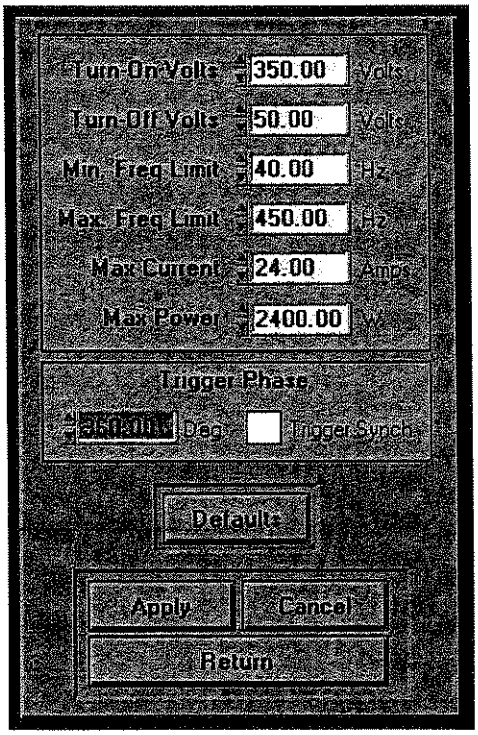

The device capabilities are the permissible operational ranges of the AC Load.



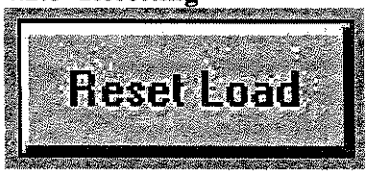
### 4.2.7 Advanced Settings




The advanced settings allow you to customize specific operational characteristics of the AC Load as well generate a trigger based on a phase angle.

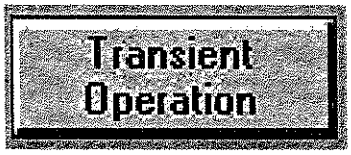


### 4.2.8 Resetting

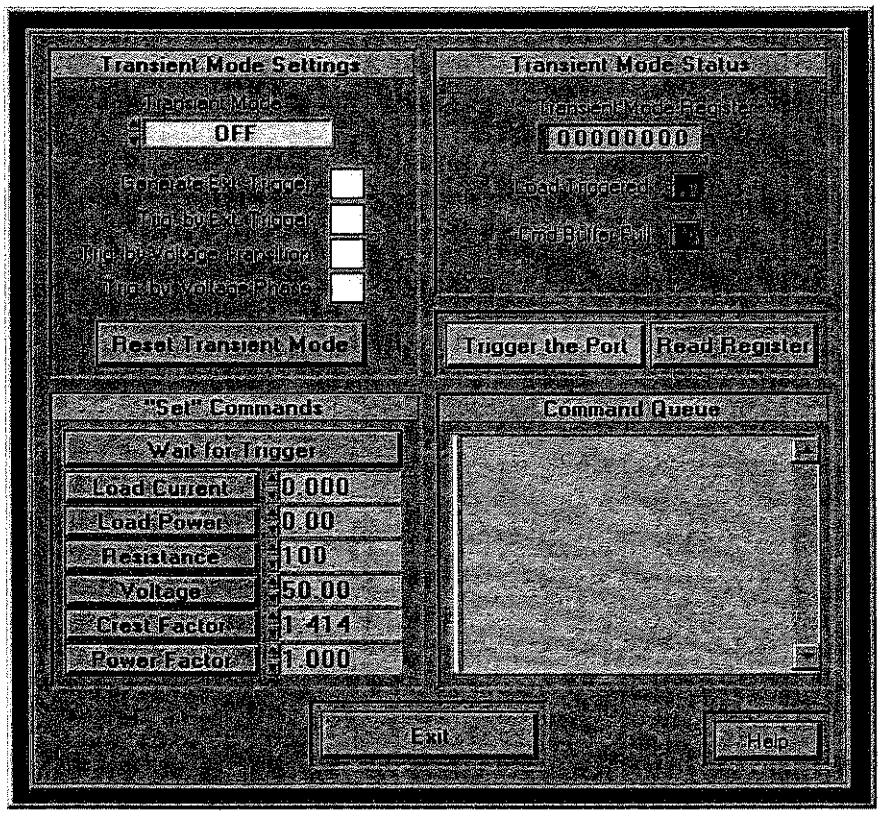



Resets the load hardware to default values.

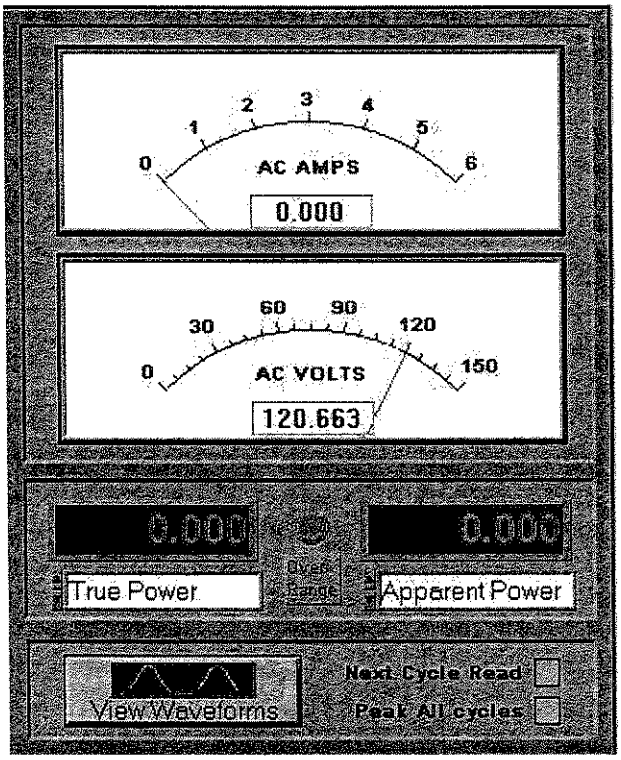
### 4.2.9 Transient




Queues up to 100 commands and when triggered executes them locally (internal DSP). This allows very fast changes (every cycle if needed) in current which can reveal precious information about the regulation, output voltage and current, peak capabilities etc. of the UUT in just one test. The commands can be executed as a single shot or as a loop.



### 4.2.10 Metering




The technique used for measurements is Synchronous Sampling. This method yields maximum speed and accuracy (one-cycle measurements).

#### 4.2.10.1 Read back Capabilities

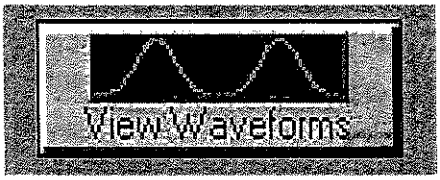

True RMS Current, True RMS Voltage, True Power, Peak Power, Crest Factor, Peak Current, Peak Voltage, Apparent Power, Resistance, Power Factor, Frequency and Reactive Power are all metered.

#### 4.2.10.2 Metering Modes

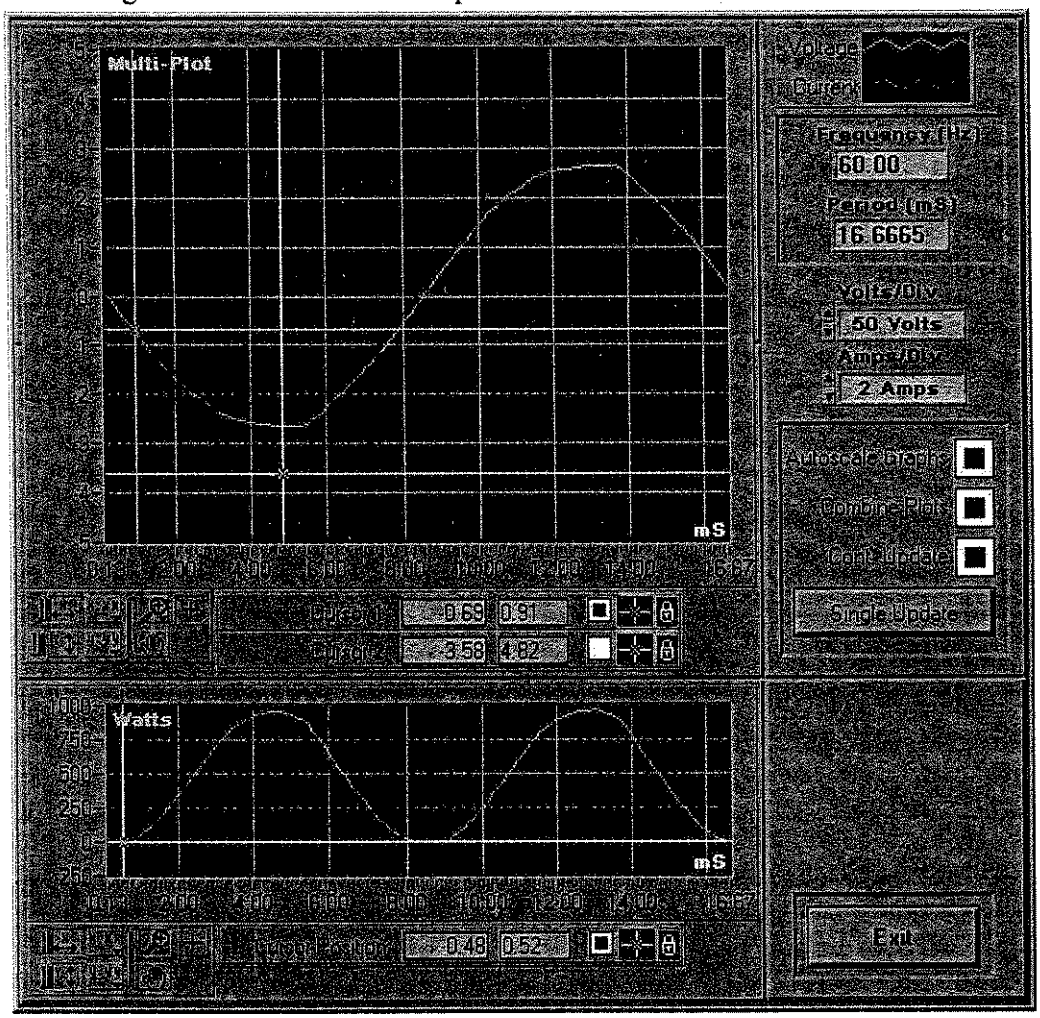

By default the last several measurements made are averaged and returned. This may be up to 2 cycles old, but is returned immediately. If Next Mode is selected, a new measurement is made and returned after the command is sent.

Peak measurements are reset each cycle. If Peak mode is selected, the largest peak measurement is saved. This is useful for inrush measurement.

### 4.2.10.3 Waveform Capture

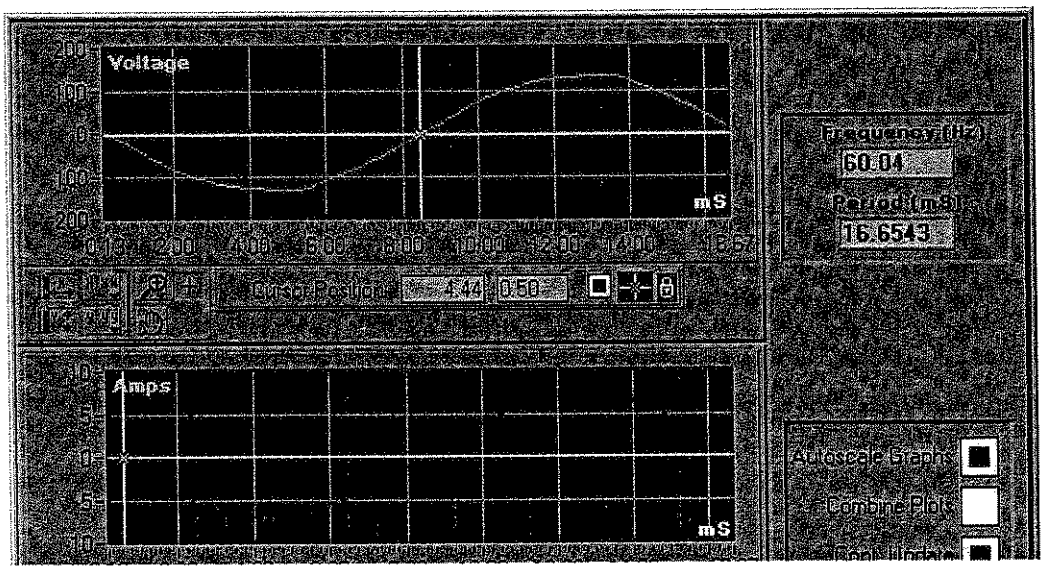



One cycle of current, voltage and power waveforms may be graphically displayed eliminating the need for an oscilloscope.



(Waveform Capture Cont.)

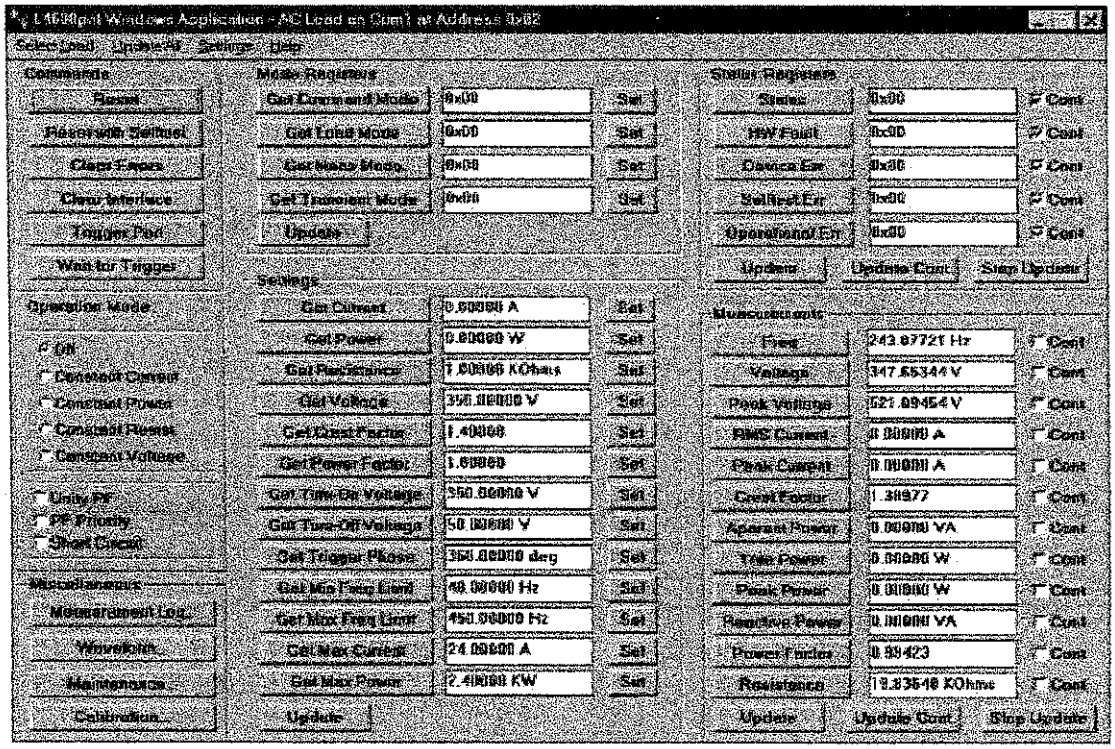
De-select the combine plots to view each individual waveform independently.



# 5. CALIBRATION

WARNING!!!!! THIS SECTION IS FOR EXPERIENCED USERS WITH A DETAILED UNDERSTANDING OF THE SYSTEM HARDWARE AND SOFTWARE. POSSIBLE IRREPAIRABLE UUT DAMAGE OR CORRUPTION OF THE LOADS FLASH MEMORY MAY RESULT FROM INAPPROPRIATE SETTINGS.

## 5.1 Maintenance Panel




## 5.2 Equipment Required

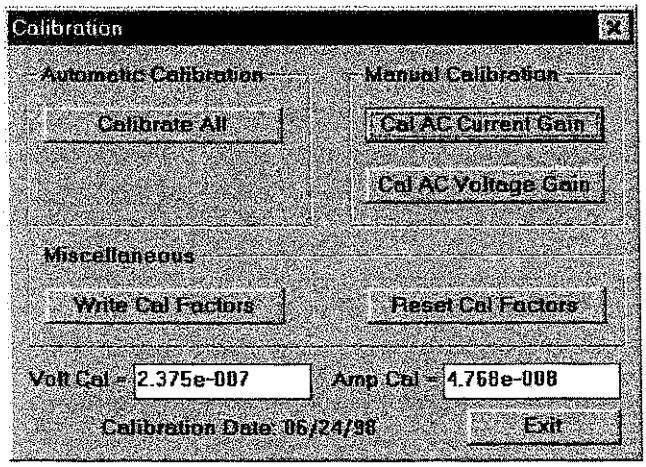
Xitron Power Analyzer model 2501AH with high accuracy option or Yokogawa Power Analyzer model WT2000 or equivalent.

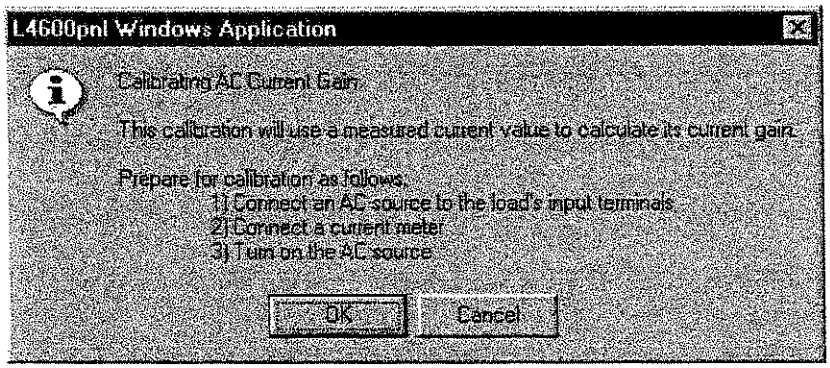
## 5.3 Procedure

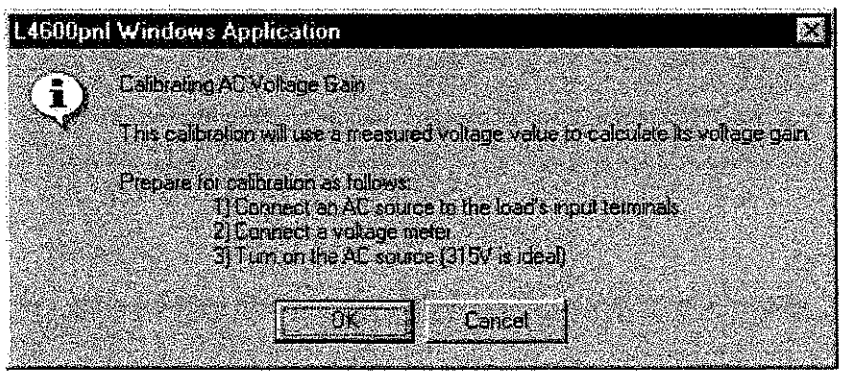
From the start menu 'programs' select 'NHResearch' Click on 'L4600 Maintenance Panel'. You have to select the com. port and the instrument address to obtain access to the maintenance panel.

Click on the calibration button to obtain the calibration panel.

Click on "Calibrate All" and follow instructions.




Set calibrating current and voltage to 90% of maximum rating.

Save the calibration data by writing the calibration factors to FLASH RAM.


Verify measured current and voltage is the same as actual ± metering accuracy.

Calibration is now complete.

# 6. THEORY OF OPERATION

## 6.1 Architecture

The load contains a Texas Instruments TMS320C32, a 32 bit floating point digital signal processor. The DSP with a Motorola MC68681 UART uses RS232 or RS485 serial ports for the command/response interface. The DSP uses FLASH PROM for code, calibration, configuration data, hardware control registers and DMA's for output waveform generation and measurement. The DSP boot kernel is in a "read only" EPROM separate from the FLASH memory. The DSP performs all setup, control, synchronization and measurement functions for the AC waveform, control hardware initialization and setup via memory mapped control/status registers.

The load accepts commands using the S6000 command protocol. Using the set commands and/or writing control words into the appropriate registers programs operation of the load. Reading the appropriate registers provides operational feedback.

To facilitate future firmware versions, all of the DSP code, configuration and calibration data is stored in FLASH memory, which can be downloaded over the serial interface.

High accuracy is obtained by the use of 16-bit instrument grade digital to analog converters and analog to digital converters.

## 6.2 Memory

### 6.2.1 Memory Map

| CPU Address | Memory | Data | Description |
|---|---|---|---|
| 000000-000FFF | | | Internal DSP boot loader |
| 001000-00FFFF | 32 | 32 | EPROM |
| 010000-03FFFF | 32 | 32 | Do not access, EPROM |
| 040000-07FFFF | 32 | 32 | Not used |
| 080000-1FFFFF | | | Do not access |
| 200000-23FFFF | 32 | 32 | Not used |
| 240000-27FFFF | 32 | 32 | Analog to digital converters |
| 280000-7FFFFF | | | Do not access |
| 800000-807FFF | | | Reserved |
| 808000-8097FF | 32 | 32 | Peripheral bus |
| 809800-80FFFF | | | Reserved |
| 810000-81000F | 32 | 32 | UART |
| 810010-811FFF | 32 | 32 | Do not access, UART |
| 812000-813FFF | 32 | 32 | Digital inputs |
| 814000-815FFF | 32 | 32 | Digital outputs |
| 816000-817FFF | 32 | 32 | Frequency register |
| 818000-819FFF | 32 | 32 | Reference DAC |
| 81A000-81BFFF | 32 | 32 | Not used |
| 81C000-81DFFF | 32 | 32 | Not used |
| 81E000-81FFFF | 32 | 32 | Not used |
| 820000-82FFFF | | | Do not access |
| 830000-87FDFF | 32 | 32 | Reserved |
| 87FE00-87FFFF | 32 | 32 | Internal RAM |
| 880000-887FFF | 32 | 32 | SRAM, 32k word by 32 bit |
| 888000-89FFFF | 32 | 32 | Do not access, RAM |
| 900000-90FFFF | 32 | 16 | SRAM, 64k word by 16 bit |
| 910000-97FFFF | 32 | 16 | Do not access, RAM |
| 980000-9FFFFF | 32 | 16 | Not used |
| A00000-A07FFF | 16 | 32 | Flash prom, 32k word by 32 bit |
| A08000-A3FFFF | 16 | 32 | Do not access, Flash prom |
| A40000-C7FFFF | 16 | 32 | Do not access |
| C00000-C0FFFF | 16 | 16 | Flash prom, 64k word by 16 bit |
| C10000-C3FFFF | 16 | 16 | Do not access, Flash prom |
| C40000-C7FFFF | 16 | 16 | Do not access |
| C80000-CFFFFF | 32 | 16 | Waveform DAC |
| D00000-FFFFFF | | | Do not access |

Memory is not fully decoded. Using a "do not access" address may access another device and cause undesired operation. CPU and external address may be different. "Memory" is memory width and "Data" is data size loaded into a STROB register.

### 6.2.2 EPROM

A single chip 64k by 8 bit EPROM is connected to data lines D7-0. It contains a full version of code.

### 6.2.3 Analog to Digital Converters

A 16-bit analog to digital converter used to measure voltage 'VADC' is connected to data lines D31-16. A 16-bit analog to digital converter used to measure current 'AADC' is connected to data lines D15-0. The DMA reads both the VADC and AADC simultaneously as one 32-bit word and writes the data into RAM.

### 6.2.4 Peripheral Bus

Internal to the DSP is DMA0, DMA1, timer0, timer1, serial port and external port registers.

### 6.2.5 UART

A Motorola MC68681 is connected to data lines D7-0. It is used for RS232 and RS485 serial communications. It is also used for triggering and fault detection.

### 6.2.6 Digital Inputs

A 16-bit register 'DIN' connected to data lines D31-16 is used for reading hardware status bits and the address switch.

### 6.2.7 Digital Outputs

A 16-bit register 'DOUT' connected to data lines D31-16 is used for writing hardware status bits.

### 6.2.8 Frequency

A 16-bit register 'FREQ' connected to data lines D31-16 writes to a 16-bit binary rate multiplier 'BRM'. This BRM generates the ADC_CLK and DAC_CLK. This clock is a power of 2 multiple of the load frequency.

### 6.2.9 Reference Digital to Analog Converter

A 16-bit digital to analog converter connected to data lines D31-16. Scales output waveform.

### 6.2.10 Internal RAM

The DSP contains internal RAM, which is 512-word by 32-bit. The stack starts here and may grow into external RAM.

### 6.2.11 SRAM

There are four 32k word by 8 bit SRAM chips. The same RAM may be accessed as a single 32-bit word or two separate 16-bit words depending upon the address. 32 bit is used for code and data. 16 bit is used for the output waveform.

### 6.2.12 Flash PROM

Two 64k by 8 bit Flash PROM chips are used. They are connected to data lines D15-0. They contain a full version of code and calibration factors.

### 6.2.13 Waveform Digital to Analog Converter

A 16-bit digital to analog converter connected to data lines D15-0 generates the output waveform. Data is copied from RAM to this DAC by a DMA.

## 6.3 Reset

During a reset the MCBL/MP* pin is high, this causes the DSP to enter boot loader mode. INT0 is low, INT1-3 is high, and this causes the boot loader to read code from EPROM and write it to RAM. Program execution begins in RAM. If Flash ROM checksum is correct, a newer version of code is copied from Flash ROM into RAM. By setting the address switch to 0, code will not be copied from Flash ROM to RAM.

## 6.4 Interrupts

### 6.4.1 INT0

A positive zero crossing on the load-input terminals causes an INT0 interrupt. The CPU measures phase error, uses timer0 to measure the period of input voltage waveform and synchronize the load current waveform to the input voltage waveform.

### 6.4.2 INT1

The BRM generates the DAC_CLK, which is connected to INT1. This interrupt causes DMA0 to read the VADC and AADC then copy the data to RAM and DMA1 to copy a new step of waveform data to the waveform DAC.

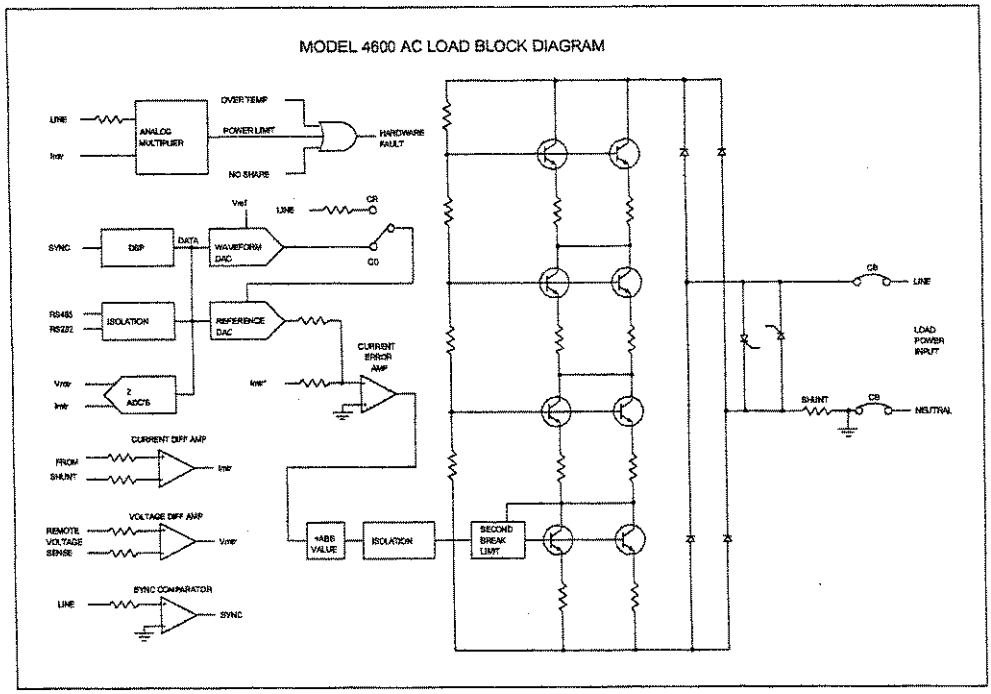
### 6.4.3 INT2

Not used.

### 6.4.4 INT3

The CPU handles communications, triggering and fault interrupts generated by the UART on INT3.

## 6.5 Block Diagram




## 6.6 Synchronization

The load power input voltage waveform is scaled down by 50 to 1 then converted to a square wave by a comparator. The output of this comparator is the sync signal.

## 6.7 Frequency Metering

The period of the sync signal is measured, inverted then displayed as frequency.

## 6.8 Voltage Metering

The voltage at the remote voltage sense terminals is scaled down 50 to 1 by a differential amplifier. This signal is then sent to the voltage 16bit analog to digital converter and sampled synchronously at a power of 2 multiple of the input frequency. The DSP then calculates AC rms voltage and other metering values.

## 6.9 Current Metering

The current through the shunt generates a voltage, which is scaled up 100 to 1 by a differential amplifier. This signal is then sent to the current 16bit analog to digital converter and sampled synchronously at a power of 2 multiple of the input frequency. The DSP then calculates AC rms current and other metering values.

## 6.10 Hardware CR Mode

The hardware emulates a resistor in this mode. The hardware is in this mode when constant resistance or voltage mode is programmed. The hardware is in this mode when constant current or constant power is programmed and unity power factor is on. The load does **not** respond to the programmed crest factor or power factor.

Voltage from the load power input is scaled down 50 to 1 and feed into the reference DAC. The reference DAC scales this signal to obtain the desired resistance.

The current error amp compares the output of the reference DAC to the metered current and generates the signal required to drive the power transistors.

## 6.11 Hardware CC Mode

The DSP generates a waveform with the desired crest factor and power factor in this mode. The hardware is in this mode when constant current or constant power is programmed and unity power factor is off.

The DSP generates a waveform at the output of the waveform DAC. This waveform synchronizes to the input voltage using the sync signal. The waveform is scaled by the reference DAC to obtain the desired current.

The current error amp compares the output of the reference DAC to the metered current and generates the signal required to drive the power transistors.

## 6.12 Crest Factor and Power Factor Relationship

This section discusses the relationship between crest factor and power factor. This only applies when the input voltage is sinusoidal, unity power factor is off and the load is in constant current or constant power mode. For non-sinusoidal input voltages select unity power factor mode.

Crest factor is peak current divided by rms current. When a crest factor of 1.414 is programmed, the DSP creates a sinusoidal current waveform. When a higher crest factor is programmed the DSP creates a modified sinusoidal current waveform with the correct crest factor. The DSP can directly create the desired crest factor.

Power factor is true power divided by apparent power. For a resistive load the power factor is 1. Assuming a constant voltage RMS and constant current RMS, as crest factor increases, power factor decreases because apparent power remains constant and true power decreases. True power decreases because current is not flowing during the entire cycle.

For a given crest factor there is only a limited range of possible power factors. The load cannot directly create the desired power factor; it can only attempt to meet the desired power factor. The programmed power factor is achieved by programming an appropriate crest factor and the DSP will phase shift the current. As crest factor increases the range of possible power factor decreases.

For example:

With a crest factor of 1.414, the only power factor allowed is 1.

With a crest factor of 2, the power factor may range from 0.6 to 0.8.

With a crest factor of 3, the power factor may range from 0.2 to 0.5.

If a higher power factor is desired, program a lower crest factor. If a lower power factor is desired, program a higher crest factor.

If the power factor programmed is positive it will be a leading power factor. If the power factor programmed is negative it will be a lagging power factor.

## 6.13 Power Section

The load power input is connected to a circuit breaker.

The circuit breaker is connected to the shorting SCR's and the AC side of a diode bridge.

The DC side of the Diode Bridge is connected the power transistor array.

The power transistor array consists of 4 load boards in series. Each load boards have 28 power transistors in parallel.

## 6.14 Protection Circuitry

The following protection is provided in hardware, and may also be redundant by the DSP.

### 6.14.1 Circuit Breaker

An input circuit breaker is provided. This CB will trip if input current is exceeds ratings.

### 6.14.2 Overvoltage

Overvoltage protection is provided is two stages.

During the first stage the load will turn on and clamp voltages above rating. The load will act like a zener diode.

If the energy is greater than the load can absorb, the second stage is turning on the shorting SCR's. This is an overvoltage crowbar.

### 6.14.3 Overtemperature

A temperature switch is located on each of the 4 load boards. Any one will shut down the load.

### 6.14.4 Overpower

The DSP will not allow the load to draw more than rated power. If the remote sense wires are not properly connected the load cannot calculate the actual power dissipated.

In hardware an analog multiplier creates an average true power signal which will shut down the load if rated input power is exceeded.

### 6.14.5 No Share

The 4 load boards should dissipate equal energy. If they are not close enough this circuit will shut down load.

### 6.14.6 Second Break Limit

The power transistors have an average and peak power rating. This circuit limits peak power dissipated to the peak power rating. This will **not** shut down the load; it will just limit peak power.

# 7. MESSAGE FORMATS

The S6000 command/response protocol is an RS485 multidrop protocol. Each device on the bus has a unique address in the range 1 through 63. Each device listens to the bus for the command address byte. If the address byte matches the device's address or is a broadcast address (0xFF), the device will process the command. The device will respond with an acknowledge byte to all commands except status and broadcast commands. The device will only send messages to the controller when the controller requests data.

## 7.1 Command Message

The command message will contain the following eight bit packets:

Address

Count

Command

0 to n message specific data packets

Checksum

The address packet is the module address. The module address is set via the switch block. The module will process any message with the correct address packet or if the command is a broadcast command. The address byte is distinguished from the other byte by the setting of the parity bit.

The count packet is the number of data packets in the command message, not including the address or checksum packets. The exception is the status message. The status message count will be zero and the message will contain only address and count packets.

The command packet is the ID of the command to be processed.

The data packets are command dependent.

The checksum is the bitwise exclusive or of all the message packets with 0xFF. The checksum is used to check for message transmission errors in place of parity checking.

If any errors are detected in the command message a command error will be generated and the command will not be processed. If any errors are detected while the command is being processed an execution error will be generated and the processing of the command will be stopped. The commands listed can only be sent to the device if they are legal for the given Command mode. Various state bits in the Command Mode Register determine the Command Mode.

### 7.1.1 Command Types

There are three types of commands:

Broadcast

Immediate

Query

If the address packet is 0xFF the command is a broadcast command. The module will process the command but not issue an acknowledge response message. The module will respond to the CPU with an acknowledge message upon receipt of all commands except for status or broadcast commands. The module will respond to the CPU with an acknowledge message plus data upon receipt of a query command.

Commands which respond with data (i.e. fetch) should not be sent as broadcast commands. Spurious data will be generated on the interface bus.

## 7.2 Response Message

There are three type of response message formats; the status response message, the acknowledge message, and the command specific response. Each response message will contain a message specific number of eight bit data packets.

### 7.2.1 Status Response Message

The module upon receipt of a status command will issue the status response message. The status response message has the following format:

Address

Contents of Event Status Register see section 9.1.

Checksum

The checksum is the bitwise exclusive or of all the message packets with 0xFF. The checksum is used to check for message transmission errors in place of parity checking.

### 7.2.2 Acknowledge Message

The acknowledge message will be issued upon receipt of all commands except the status command. The acknowledge message has the following format:

Bitwise inversion of address

### 7.2.3 Command Specific Response

The command specific response message will be issued upon completion of a query command. The command specific response message has the following format:

Address

Count

0 to n message specific data packets

Checksum

The count packet is the number of data packets in the command message, not including the address or checksum packets.

The data packets are command dependent.

The checksum is the bitwise exclusive or of all the message packets with 0xFF. The checksum is used to check for message transmission errors in place of parity checking.

# 8. COMMAND MESSAGE SET

## 8.1 Get Status

This message commands the module to return the contents of the Event Status Register. See section 9.1 for a description of the Event Status Register. The controller to get fast status information from the module should use it.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x00 |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Event status reg. | 0xnn |
| 3 | Checksum | 0xnn |

## 8.2 Reset

This message commands the module to return to the power-up state. All variables on the module are returned to their default values. All digital outputs and DACs are set to their power on state. This command is used to bring the module to the power-up mode. This command should be used after the controller detects a module error or as a fast way to bring the module to a fully reset state. Note that the error registers should be read before this command is sent.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x01 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.3 Reset/Selftest

The module resets and runs a selftest. See section 9.3 Selftest Error Register for a description of errors. All errors are cleared except those generated during this test.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x02 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.4 Clear Errors

This message commands the module to clear the Hardware Fault and Device Specific Error bits in the Event Status Register and all the bits in error registers. If a Hardware Fault is still true it cannot be cleared.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x03 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.5 Clear Interface

This message commands the module to clear the serial interface without resetting the module.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x04 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.6 Send Own Address (SOA)

The S6000/PC controller to perform auto configuration at power-up uses this command. This command will be used to open and close the daisy chain connection to the down stream modules, have the module respond with it's logical address, and ignore all messages until it receives the command to close the daisy chain connection.

At power-up the S6000/PC controller should:

1) Issue a broadcast SOA type 1

   This command will put all modules in SOA mode 1. The modules will open up the bus to the downstream modules.

2) Issue a broadcast SOA type 2

   This command will put all modules in SOA mode 2. All of the modules, except those locked out, will respond with their logical address and type. Since the downstream modules are disconnected from the response bus the S6000/PC controller will only receive a response from the most upstream module.

3) Issue an SOA type 3 command to the module to lock it out.

4) Repeat steps 2 through 3 until no modules respond.

5) Issue a broadcast SOA type 4 command to reset bus communication.

   At power up and reset the module serial bus is daisy chained from the CPU to the last module. If the module receives a RESET command while in SOA modes 1 through 4, it will reset to SOA mode 0 {normal operation} and connect the downstream modules. SOA type 1-3 sets the SOA bit of the Command Mode Register. SOA type 4 clears the SOA bit of the Command Mode Register. See section 9.6 for a description of the Command Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x03 |
| 3 | Command ID | 0x07 |
| 4 | Type | 0xnn |
| 5 | Checksum | 0xnn |

Response:

Type 1:

The module will not issue any response to this command. It will open up the serial bus.

Type 2:

The module will issue configuration data.

| Description | Module ID | System (Notebook) ID |
|---|---|---|
| 2.4kW AC Load | 51 | 2600 |
| 3.0kW AC Load Master | 52 | 2601 |
| 3.0kW AC Load Slave | 53 | 2602 |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x03 |
| 3 | Module Address | 0xnn |
| 4 | Module Type | 0x33 |
| 5 | Checksum | 0xnn |

Type 3:

The module will issue an acknowledge message and lock itself out from responding to any commands until it receives an SOA type 4 command. It will close up the serial bus to the next module.

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

Type 4:

The module will not issue any response to this command. It will return to normal communication mode.

### 8.7 Set Group Address

This command will setup a secondary address to which the module will accept commands. The module will treat any command received with this address as a broadcast command, i.e. the module will not issue an acknowledge response. This command will allow the controller to setup a subgroup to communicate with of all the modules on the bus. Only commands that do not generate responses should be used with the group address. At power-up the group address parameter will be set to 0xFF, the broadcast address. The range of possible group address is from 0xF0 to 0xFF. Remember that all modules belong to group (0xFF). If the group address switch is not set to 0xFF the group address may not be changed.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x03 |
| 3 | Command ID | 0x08 |
| 4 | Group address | 0xnn |
| 5 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.8 Get Group Address

This command will cause the module to respond with its group address parameter.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x09 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Group address | 0xnn |
| 4 | Checksum | 0xnn |

## 8.9 Get Register

This command returns the contents of the selected register. See section 8.55 for a description of the registers.

Registers:

| Index | Register description |
|---|---|
| 1 | Event Status |
| 2 | Hardware Fault |
| 3 | Selftest Error |
| 4 | Device Error |
| 5 | Operational Error |

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x03 |
| 3 | Command ID | 0x11 |
| 4 | Register index | 0xnn |
| 5 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Register data | 0xnn |
| 4 | Checksum | 0xnn |

### 8.10 Set Command Mode

This command will define the command mode. A byte is written to the Command Mode Register. To use this command, read the Command Mode Register change the bits required then write it back. See section 9.6 for a description of the Command Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x03 |
| 3 | Command ID | 0x12 |
| 4 | Byte | 0xnn |
| 5 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.11 Get Command Mode

This command returns the contents of the Command Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x13 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Register data | 0xnn |
| 4 | Checksum | 0xnn |

### 8.12 Set Load Mode

This command will define the load mode. A byte is written to the Load Mode Register. To use this command, read the Load Mode Register change the bits required then write it back. See section 9.7 for a description of the Load Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x03 |
| 3 | Command ID | 0x14 |
| 4 | Byte | 0xnn |
| 5 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.13 Get Load Mode

This command returns the contents of the Load Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x15 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Register data | 0xnn |
| 4 | Checksum | 0xnn |

### 8.14 Set Measurement Mode

This command will define how measurements are made. A byte is written to the Measurement Mode Register. To use this command, read the Measurement Mode Register change the bits required then write it back. See section 9.8 for a description of the Measurement Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x03 |
| 3 | Command ID | 0x16 |
| 5 | Byte | 0xnn |
| 6 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.15 Get Measurement Mode

This command returns the contents of the Measurement Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x17 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Register data | 0xnn |
| 4 | Checksum | 0xnn |

### 8.16 Set Transient Mode

This command will set transient mode, input and output triggers. A byte is written to the Transient Mode Register. To use this command, get the Transient Mode Register change the bits required then write it back. See section 9.9 for a description of the Transient Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x03 |
| 3 | Command ID | 0x18 |
| 4 | Byte | 0xnn |
| 5 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.17 Get Transient Mode

This command returns the contents of the Transient Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x19 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Register data | 0xnn |
| 4 | Checksum | 0xnn |

## 8.18 Read Memory

This command allows the S6000/PC controller to read any address location in the module. This command should be only used for testing. No error checking on the data is performed.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Command ID | 0x1A |
| 4 | Address byte 0 LSB | 0xnn |
| 5 | Address byte 1 | 0xnn |
| 6 | Address byte 2 MSB | 0xnn |
| 7 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Data byte 0 LSB | 0xnn |
| 4 | Data byte 1 | 0xnn |
| 5 | Data byte 2 | 0xnn |
| 6 | Data byte 3 MSB | 0xnn |
| 7 | Checksum | 0xnn |

## 8.19 Write Memory

This command allows the S6000/PC controller to write to any address in the module. This command should be only used for testing. No error checking on the data is performed.

This command will cause an execution error if:
The debug bit is not set in the Command Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x09 |
| 3 | Command ID | 0x1B |
| 4 | Address byte 0 LSB | 0xnn |
| 5 | Address byte 1 | 0xnn |
| 6 | Address byte 2 MSB | 0xnn |
| 8 | Data byte 0 LSB | 0xnn |
| 9 | Data byte 1 | 0xnn |
| 10 | Data byte 2 | 0xnn |
| 11 | Data byte 3 MSB | 0xnn |
| 12 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.20 Get Version Number

This command will return the firmware version number of FLASH if executing from FLASH or EPROM if executing from EPROM.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x1C |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

## 8.21 Flash Download Mode

This command, in conjunction with the Write Flash command, is used to download new DSP firmware.

Starts Download Mode will set the download bit in the Command Mode Register, and prevent execution from FLASH at next hardware reset. End Download Mode will clear the download bit in the Command Mode Register, calculate and save firmware checksum, then allow execution from FLASH at next hardware reset.

Mode:

| Mode | Description |
|---|---|
| 0 | Abort |
| 1 | Start Download |
| 2 | End Download |

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x03 |
| 3 | Command ID | 0x1D |
| 4 | Mode | 0xnn |
| 5 | Packet Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.22 Write Flash

This command, in conjunction with the Flash Download Mode command, is used to download new DSP firmware. The command consists of the address and 128 bytes of data to store starting at the address.

The FLASH must be written to in 256 byte blocks, 64 32bit words, or one page at a time. Therefore this command must be issued in multiples of 2. The first packet address must be on a page boundary, a 32bit address on multiples of 0x100. The second packet address must be on ½ page boundary, the first address plus 0x80. Addresses are divided by 4 (byte to word address conversion) when loaded into SRAM. After the second packet the 256-byte block will be written to FLASH. All 256 bytes of data must be defined even if they are not used.

A hardware reset must occur for new parameters to take effect.

This command will cause an execution error if:
The download bit is not set in the Command Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x86 |
| 3 | Command ID | 0x1E |
| 4 | Address byte 0 LSB | 0xnn |
| 5 | Address byte 1 | 0xnn |
| 6 | Address byte 2 | 0xnn |
| 7 | Address byte 3 MSB | 0xnn |
| 8 | Address 1 data byte 0 LSB | 0xnn |
| 9 | Address 1 data byte 1 | 0xnn |
| 10 | Address 1 data byte 2 | 0xnn |
| 11 | Address 1 data byte 3 MSB | 0xnn |
| … | Address n data byte 0 | 0xnn |
| … | Address n data byte 1 | 0xnn |
| … | Address n data byte 2 | 0xnn |
| … | Address n data byte 3 | 0xnn |
| 136 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.23 Write Calibration Factors

This command is used to write calibration factors and configuration data to flash. All calibration factors and configuration data in SRAM are written into FLASH.

This command will cause an execution error if:
The download bit is not set in the Command Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x1F |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.24 Reset Calibration Factors

This command is used to reset calibration factors in SRAM to EPROM defaults. Calibration factors are NOT written into FLASH. Defaults may be written to FLASH with the write calibration factors command after this command. This command NOT needed during normal calibration. Hardware reset is required to use FLASH calibration factors.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x20 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.25 Get Device Caps

This command will return the device maximum and minimums capacities. A set type command outside of these limits will cause an execution error. The following structure is returned.

```
Struct 4600CAPS
{
        FLOAT32 fMinFreq;
        FLOAT32 fMaxFreq;
        FLOAT32 fMinACCurrent;
        FLOAT32 fMaxACCurrent;
        FLOAT32 fMinCrestFactor;
        FLOAT32 fMaxCrestFactor;
        FLOAT32 fMinPowerFactor;
        FLOAT32 fMaxPowerFactor;
        FLOAT32 fMinResistance;
        FLOAT32 fMaxResistance;
        FLOAT32 fMinPower;
        FLOAT32 fMaxPower;
        FLOAT32 fMinACVoltage;
        FLOAT32 fMaxACVoltage;
        FLOAT32 fMinTrigPhase;
        FLOAT32 fMaxTrigPhase;
};
```

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x21 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x42 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| … | … | … |
| 64 | Float byte 60 LSB | 0xnn |
| 65 | Float byte 61 | 0xnn |
| 66 | Float byte 62 | 0xnn |
| 67 | Float byte 63 exponent | 0xnn |
| 68 | Checksum | 0xnn |

## 8.26 Calibrate AC Current Gain

To use this command place the load in AC Constant Current Mode, crest factor 1.414 and power factor 1. Set load current to 90% of maximum value. Send the actual current. This command will cause the load to calculate and store its own current gain. Set Measurement Mode to last, which is the default.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x22 |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.27 Calibrate AC Voltage Gain

To use this command place the load in AC mode, connect 90% of maximum AC voltage to the voltage sense terminals. Send the actual voltage. This command will cause the load to calculate and store its own voltage gain. Set Measurement Mode to last, which is the default.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x23 |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.28 Query Measurement

This command will return the selected measurement. If the measurement is out of range 3.4e38 is returned.

Measurement:

| Index | Measurement description |
|---|---|
| 1 | Frequency |
| 2 | Volts |
| 3 | Peak Volts |
| 4 | Current |
| 5 | Peak Current |
| 6 | Current Crest Factor |
| 7 | Apparent Power |
| 8 | True Power |
| 9 | Peak Power |
| 10 | Reactive Power |
| 11 | Power Factor |
| 12 | Resistance |

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x03 |
| 3 | Command ID | 0x24 |
| 4 | Measurement index | 0xnn |
| 5 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

## 8.29 Set Maximum Frequency Limit

This is the maximum operating frequency. Reset frequency is Get Device Caps fMaxFreq. Range is Minimum Frequency Limit to fMaxFreq.

This command will cause an execution error if the:
Frequency is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x25 |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.30 Get Maximum Frequency Limit

This command will return the set maximum frequency limit as programmed by the Set Maximum Frequency Limit command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x26 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

### 8.31 Set Minimum Frequency Limit

This is the minimum operating frequency. Reset frequency is Get Device Caps fMinFreq. Range is Maximum Frequency Limit to fMinFreq.

This command will cause an execution error if the:
Frequency is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x27 |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.32 Get Minimum Frequency Limit

This command will return the set minimum frequency limit as programmed by the Set Minimum Frequency limit command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x28 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

## 8.33 Set Maximum Current Limit

This is the maximum current in any mode. Reset current is Get Device Caps fMaxACCurrent. Range is fMinACCurrent to fMaxACCurrent.

This command will cause an execution error if the:
Current is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x29 |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.34 Get Maximum Current Limit

This command will return the maximum current as programmed by the Maximum Current Limit command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x2A |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

### 8.35 Set Maximum Power Limit

This is the maximum power in any mode. Reset power is Get Device Caps fMaxPower. Range is fMinPower to fMaxPower.

This command will cause an execution error if the:
Power is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x2B |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.36 Get Maximum Power Limit

This command will return the maximum power as programmed by the Maximum Power Limit command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x2C |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

## 8.37 Set Current

This is the set current in Constant Current Mode. This command places the load in Constant Current Mode and enabled as defined by the Load Mode Register. Reset current is Get Device Caps fMinACCurrent. Range is fMinACCurrent to fMaxACCurrent.

This command will cause an execution error if the:
Current is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x2D |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.38 Get Current

This command will return the set current as programmed by the Set Current command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x2E |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

## 8.39 Set Crest Factor

This is set current waveform crest factor. This waveform is used in Constant Current and Constant Power Modes. At reset crest factor is Get Device Caps fMinCrestFactor. Crest factor range is fMinCrestFactor to fMaxCrestFactor.

This command will cause an execution error if the:
Crest factor is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x2F |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.40 Get Crest Factor

This command will return the set crest factor as programmed by the Set Crest factor command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x30 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

## 8.41 Set Power Factor

This is set load power factor. This is used in Constant Current and Constant Power Modes. Default power factor is Get Device Caps fMaxPowerFactor. Range is fMinPowerFactor to fMaxPowerFactor. Power factor range varies with crest factor and input voltage waveform. The load will attempt to meet the programmed power factor.

This command will cause an execution error if the:
Power factor is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x31 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

## 8.42 Get Power Factor

This command will return the set power factor as programmed by the Set Power factor command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x32 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

### 8.43 Set Resistance

This is the set resistance in Constant Resistance Mode. This command places the load in Constant Resistance Mode and enabled as defined by the Load Mode Register. Reset resistance is Get Device Caps fMaxResistance. Range is fMinResistance to fMaxResistance.

This command will cause an execution error if the:
Resistance is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x33 |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.44 Get Resistance

This command will return the set resistance as programmed by the Set Resistance command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x34 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

### 8.45 Set Power

This is the set power in Constant Power Mode. This command places the load in Constant Power Mode and enabled as defined by the Load Mode Register. Reset power is Get Device Caps fMinPower. Range is fMinPower to fMaxPower.

This command will cause an execution error if the:
Power is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x35 |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.46 Get Power

This command will return the set power as programmed by the Set Power command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x36 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

### 8.47 Set Voltage

This is the set voltage in Constant Voltage Mode. This command places the load in Constant Voltage Mode and enabled as defined by the Load Mode Register. Reset is Get Device Caps fMaxACVoltage. Range is fMinACVoltage to fMaxACVoltage. The load is put in Constant Resistance Mode and the resistance is varied to keep the voltage constant. The load operates as a shunt regulator.

This command will cause an execution error if the:
Voltage is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x37 |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.48 Get Voltage

This command will return the set voltage as programmed by the Set Voltage command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x38 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

### 8.49 Wait For Trigger

This message commands the module to wait for a trigger before executing the next queued command.

This command will cause an execution error if the:
Mode is anything except initiate in the Transient Mode Register.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x39 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

### 8.50 Set Turn On Voltage

When RMS voltage exceeds this value the load is enabled. Reset is Get Device Caps fMinACVoltage plus 10 volts. Range is Set Turn Off Voltage to Get Device Caps fMaxACVoltage.

If voltage is below the turn off voltage, then a rise to exceed this turn on voltage, a trigger is generated when enabled.

This command will cause an execution error if the:
Voltage is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x3A |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.51 Get Turn On Voltage

This command will return the set turn on voltage as programmed by the Set Turn On Voltage command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x3B |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

## 8.52 Set Turn Off Voltage

When RMS voltage is below this value the load is disabled. Reset is Get Device Caps fMinACVoltage. Range is fMinACVoltage to Set Turn On Voltage.

If voltage is above the Set Turn On Voltage, then drops below this Set Turn Off Voltage, a trigger is generated when enabled.

This command will cause an execution error if the:
Voltage is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x3C |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.53 Get Turn Off Voltage

This command will return the set turn off voltage as programmed by the Set Turn Off Voltage command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x3D |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

### 8.54 Set Trigger Phase

This is the input voltage phase angle when current will change. Reset is Get Device Caps fMaxTrigPhase, current changes randomly, as soon as possible, and no trigger is generated. If less than fMaxTrigPhase current will change and a trigger is generated, if enabled, on every cycle at that phase angle. Range is fMinTrigPhase to fMaxTrigPhase.

This command will cause an execution error if the:
Phase is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x06 |
| 3 | Command ID | 0x3E |
| 4 | Float byte 0 LSB | 0xnn |
| 5 | Float byte 1 | 0xnn |
| 6 | Float byte 2 | 0xnn |
| 7 | Float byte 3 exponent | 0xnn |
| 8 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

## 8.55 Get Trigger Phase

This command will return the trigger voltage phase angle as programmed by the Set Trigger Phase command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x3F |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x05 |
| 3 | Float byte 0 LSB | 0xnn |
| 4 | Float byte 1 | 0xnn |
| 5 | Float byte 2 | 0xnn |
| 6 | Float byte 3 exponent | 0xnn |
| 7 | Checksum | 0xnn |

## 8.56 Store Waveforms

The previous cycle of current, voltage and wattage waveforms are captured and stored. The sample rate and number of samples per cycle are returned for use with the Get Waveform command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x40 |
| 5 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x0A |
| 4 | Samples rate float byte 0 LSB | 0xnn |
| 5 | Samples rate float byte 1 | 0xnn |
| 6 | Samples rate float byte 2 | 0xnn |
| 7 | Samples rate float byte 3 exponent | 0xnn |
| 8 | Number of samples INT32 byte 4 LSB | 0xnn |
| 9 | Number of samples INT32 byte 5 | 0xnn |
| 10 | Number of samples INT32 byte 6 | 0xnn |
| 11 | Number of samples INT32 byte 7 MSB | 0xnn |
| 12 | Checksum | 0xnn |

### 8.57 Get Waveforms

One cycle of current, voltage or wattage waveforms are returned which may be graphically displayed.

Waveform number 1 is current, 2 is voltage and 3 is watts.

Many packets are required to display one waveform. All packets need not be retrieved and or may be retrieved in any order or interlaced with other commands. The required number of packets is the number of samples, returned by the Store Waveform command, divided by 32 samples per packet. For example, packets number 1-4 are required to display a 128 sample waveform.

This command will cause an execution error if the:

Packet number is out of range.

Waveform number is out of range.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x04 |
| 3 | Command ID | 0x41 |
| 4 | Waveform Number | 0xnn |
| 5 | Packet Number | 0xnn |
| 6 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x81 |
| 3 | Sample number 1 float byte 0 LSB | 0xnn |
| 4 | Sample number 1 float byte 1 | 0xnn |
| 5 | Sample number 1 float byte 2 | 0xnn |
| 6 | Sample number 1 float byte 3 exponent | 0xnn |
| ... | ... | ... |
| 127 | Sample number 32 float byte 124 LSB | 0xnn |
| 128 | Sample number 32 float byte 125 | 0xnn |
| 129 | Sample number 32 float byte 126 | 0xnn |
| 130 | Sample number 32 float byte 127 exponent | 0xnn |
| 131 | Checksum | 0xnn |

### 8.59 Read Configuration Data

This command is used to read configuration data. The first float is the voltage gain calibration factor. The second float is the current gain calibration factor. Data bytes 0 – 127 are returned as written by the Write Configuration Data command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x02 |
| 3 | Command ID | 0x43 |
| 4 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

| Byte | Description | Value |
|---|---|---|
| 1 | Source address | 0xnn |
| 2 | Count | 0x88 |
| 3 | Voltage gain float byte 0 LSB | 0xnn |
| 4 | Voltage gain float byte 1 | 0xnn |
| 5 | Voltage gain float byte 2 | 0xnn |
| 6 | Voltage gain float byte 3 exponent | 0xnn |
| 7 | Current gain float byte 0 LSB | 0xnn |
| 8 | Current gain float byte 1 | 0xnn |
| 9 | Current gain float byte 2 | 0xnn |
| 10 | Current gain float byte 3 exponent | 0xnn |
| 11 | Configuration Data byte 0 | 0xnn |
| 12 | Configuration Data byte 1 | 0xnn |
| 13 | Configuration Data byte 2 | 0xnn |
| ... | Configuration Data byte n | 0xnn |
| 138 | Configuration Data byte 127 | 0xnn |
| 139 | Checksum | 0xnn |

# 9. REGISTER DESCRIPTION

## 9.1 Event Status Register

| Bit | Name | Description |
|---|---|---|
| 0 | Hardware Fault | A hardware fault (overtemp, overpower, no share) caused the hardware to shutdown. This bit is cleared by a hardware reset, clear error, reset and selftest commands after the fault is removed. |
| 1 | Device Specific Error | A device specific operation generated an error. Device specific errors also set bits in error registers. Hardware reset, clear error, reset and selftest clear this bit commands. |
| 2 | Command in progress | 0 - all commands have totally finished execution, including any metering and transients.<br>1 - a command is in process. When a command is removed from the input buffer for parsing, this bit is set. |
| 3 | Operational Error | Parameters are out of range. |
| 4 | Not used | |
| 5 | Not used | |
| 6 | Not used | |
| 7 | Not used | |

## 9.2 Hardware Fault Register

| Bit | Name | Description |
|---|---|---|
| 0 | Over Temperature | A heatsink has exceeded rated temperature. |
| 1 | Over Power | Input power has exceeded rated limits. |
| 2 | No Share | Power transistors are not sharing. |
| 3 | Not used | |
| 4 | Not used | |
| 5 | Not used | |
| 6 | Not used | |
| 7 | Not used | |

### 9.3 Selftest Error Register

| Bit | Name | Description |
|---|---|---|
| 0 | EPROM | Executing firmware from ERPOM. |
| 1 | Firmware | Firmware checksum error. |
| 2 | Calibration | Calibration and configuration data checksum error. |
| 3 | RAM | RAM test failed. |
| 4 | Not used | |
| 5 | Not used | |
| 6 | Not used | |
| 7 | Not used | |

### 9.4 Device Error Register

| Bit | Name | Description |
|---|---|---|
| 0 | Checksum | Command checksum error. |
| 1 | Command | Command is not recognized. |
| 2 | Input buffer | Input buffer overrun. |
| 3 | Execution | Set parameter is out of range or can not be executed. |
| 4 | Not used | |
| 5 | Not used | |
| 6 | Not used | |
| 7 | Not used | |

### 9.5 Operational Error Register

| Bit | Name | Description |
|---|---|---|
| 0 | Under Frequency | Frequency is too low. |
| 1 | Over Frequency | Frequency is too high. |
| 2 | Under Voltage | Voltage is too low. |
| 3 | Over Voltage | Voltage is too high. |
| 4 | Power Factor | Power factor is out of range. |
| 5 | Over Current | Current is too high. |
| 6 | Not used | |
| 7 | Over Power | Power is too high. |

### 9.6 Command Mode Register

| Bit | Name | Description |
|---|---|---|
| 0 | SOA | The module is in send own address mode. This mode is used at startup by the control PC to determine the number and type of S6000 modules connected to the communication port. |
| 1 | Download | The FLASH memory is being updated. |
| 2 | Debug | Enables commands that can write directly to hardware potentially damaging unit. |
| 3 | Transient | Transient Initiate Mode. Set type commands will be queued not executed. Other commands are executed normally. |
| 4 | Not used | |
| 5 | Not used | |
| 6 | Not used | |
| 7 | Not used | |

### 9.7 Load Mode Register

| Bit | Name | Description |
|---|---|---|
| 0 | Not Used | |
| 1 | Not Used | |
| 2, 3 | Power Factor | 00 –Crest Factor Priority. Crest Factor and Power Factor are Programmable. See section 6.12 Crest Factor and Power Factor Relationship.<br>01 – Power Factor Priority. Changes Crest Factor to obtain desired Power Factor without phase shifting current. Programmable Crest Factor and does not apply. More closely emulates a power supply type load.<br>10 – Unity Power Factor. Forces highest power factor. Programmable Crest Factor and Power Factor do not apply. Allows Constant Current and Constant Power to be programmed correctly with non-sinusoidal input voltages.<br>11 – Reserved |
| 4, 5, 6 | Mode | 000 - Off<br>001 - Constant Current<br>011 - Constant Power<br>100 - Constant Resistance<br>110 - Constant Voltage |
| 7 | Short | Short with SCR. |

### 9.8 Measurement Mode Register

| Bit | Name | Description |
|---|---|---|
| 0 | Next | 0 - the last several measurements made are averaged and returned. This may be up to 2 cycles old, but is returned immediately.<br>1- Next, a new measurement is made and returned. This may take as long as 2 cycles. |
| 1 | Peak | 0 - resets peak measurements each cycle.<br>1 - saves largest peak measurements. |
| 2 | Not Used | |
| 3 | Not Used | |
| 4 | Not Used | |
| 5 | Not Used | |
| 6 | Not Used | |
| 7 | Not Used | |

### 9.9 Transient Mode Register

| Bit | Name | Description |
|---|---|---|
| 0 & 1 | Mode | 00 - No transient operation.<br>01 - Initiate. Set type commands will be queued, but the module output is not modified until it is armed and it receives a trigger signal.<br>10 - Armed. The module is waiting for a trigger signal to execute the next command(s) previously queued. When all queued commands have been executed, returns to no transient operation.<br>11 - Continuous. Same as armed except when all queued commands have been executed, restarts at beginning of queue. |
| 2 | Enable Output | The module will generate trigger outputs. |
| 3 | Trigger Output | 0 - When enable output is 0.<br>1 - Latched with each trigger event, reset after read. |
| 4 | Trigger Input | Hardware trigger input enabled. |
| 5 | Voltage Input | Turn on/off voltage trigger enabled. |
| 6 | Phase Angle | Phase angle trigger enabled. |
| 7 | Queue Full | The transient command queue is full. |

# 10. TROUBLE SHOOTING

## 10.1 Load Power Circuit Breaker Trips

This circuit breaker will trip when:

Input current is exceeded during short mode. Reduce short circuit current.

The over voltage protection crowbar turned on. Reduce input voltage.

The diode bridge or power transistor array has shorted. Return for repair.

## 10.2 Fault Lamp Lit

This lamp is lit when one of the following hardware faults has occurred:

Overtemperature, one of the 4 load boards has overheated. Allow more and cooler air to flow through the load. If the load is clogged with dirt, vacuum the dirt out.

Overpower, the hardware analog multiplier detected an average true power greater than rated input power. The remote sense wires may not be connected correctly and the DSP cannot calculate power correctly. The load may need to be calibrated.

No share, the load boards are not sharing power equally. A load board may be shorted or an internal wiring error. Return for repair.

When the hardware fault has been removed and clear errors command is issued, the lamp will go out.

## 10.3 Status Lamp Not Blinking

Verify that the control power switch/lamp is on and lit. This indicates control power is present at the control board.

If control power is present and the status lamp is not blinking at a 1 hertz rate, the DSP is not functioning properly.

Try switching all eight positions of the "S6k AD" switch to the off position. Remove and reapply control power. This will cause a reboot from EPROM. If the status lamp is still not blinking, return for repair.

## 8.58 Write Configuration Data

This command is used to store configuration data in SRAM. The configuration data is NOT written into FLASH. The configuration data may be written to FLASH with the Write Calibration Factors command, after this command.

Command:

| Byte | Description | Value |
|---|---|---|
| 1 | Destination address | 0xnn |
| 2 | Count | 0x81 |
| 3 | Command ID | 0x42 |
| 4 | Data byte 0 | 0xnn |
| 5 | Data byte 1 | 0xnn |
| 6 | Data byte 2 | 0xnn |
| ... | Data byte n | 0xnn |
| 131 | Data byte 127 | 0xnn |
| 132 | Checksum | 0xnn |

Response:

| Byte | Description | Value |
|---|---|---|
| 1 | Acknowledge byte | 0xnn |

```
################################################################
################################################################
##                                                            ##
##        NH Research CD-ROM Installation and Setup           ##
##                                                            ##
################################################################
################################################################
```

This CD-ROM contains one or more of the following:

- On-line documentation
- NH System Software
- NH Instrumentation Software

What is on this CD is dependent upon which System or Software you have purchased.

As with all software installations, you should backup your system and data files prior to installing any of the software on this CD.

Please refer to the appropriate sections below for installation instructions.

NOTE:
In the following instructions, "D:" refers to the CD-ROM drive. If your CD-ROM drive is NOT "D:", please substitute the appropriate letter for "D:" in all instructions below.

## General Installation Instructions

Most of the software contained on this CD are installed as described in this section. You should, however, look through this entire document to see if there are special installation requirements for the software you are installing.

### INSTALLATION FROM WINDOWS 3.1x

1) From the Program Manager, select the file menu and choose RUN. Type "D:\SETUP" and press enter.

2) Follow the on-screen instructions.

### INSTALLATION FROM WINDOWS 95/NT 4.x

1) Select the Start button then choose RUN. Type "D:\SETUP" and press enter.

2) Follow the on-screen instructions.

## MAKING INSTALLATION FLOPPY DISK SETS

==========

Normally, the software contained on this CD is installed directly from the CD. However, if you need to, you may make floppy based installation disk sets by performing the following procedure:

1) At a DOS prompt type "D:" and press enter to change the current path to the CD-ROM drive.

2) Type "CD \SW\190xxxx" (substitute the desired part number for 190xxxx) and press enter to change the current path to the software directory.

3) Type "DIR" to see a list of files and directories.

4) Have enough blank formatted floppies available (one for each sub directory call DISKn).

4) Type "nDISK2A.BAT" (where n is number of disks) and follow the directions on the screen.

==========

## On-line Documentation

==========

The On-line documentation is in PDF format and can be viewed with Adobe Acrobat Reader software. The Adobe software is provided on this CD and can be installed along with the On-line documentation.

The On-line documentation and reader is WINDOWS, WINDOWS 95, and WINDOWS NT compatible. It will NOT run under DOS.

==========

## Notebook System Software

==========

The Notebook System Software may be installed directly from this CD, or you may create a floppy disk set and install from it.

Detailed computer setup instructions (as well as Notebook installation instructions) can be found in NHR document #09-0224a (Windows 3.1x) and #09-0224b (Windows 95).

==========

## PowerFlex 5x5 System Software

==========

The PowerFlex 5x5 System Software is DOS based and MUST be installed from DOS.

You may install directly from CD or you may create a floppy disk set and install from it.

!!!!!!! WARNING !!!!!!!
Installed from Win3.XX environment, the installation process for PowerFlex will REPLACE your CONFIG.SYS and your AUTOEXEC.BAT during installation. The installation program will back up your current CONFIG.SYS and AUTOEXEC.BAT and report what name it saved them as ( Usually *.NHR ). If you need some of the features (device drivers, environment settings, etc.) of your current CONFIG.SYS or AUTOEXEC.BAT, you will need to manually edit the files to include what you need from both the newly installed files and the backed-up versions.
Installed from the Win95 GUI environment, if the installation program detects AUTOEXEC.DOS or CONFIG.DOS, the installation program will back up your current CONFIG.DOS and AUTOEXEC.DOS and report what name it saved them as ( Usually *.NHR ). If you need some of the features (device drivers, environment settings, etc.) of your current CONFIG.DOS or AUTOEXEC.DOS, you will need to manually edit the files to include what you need from both the newly installed files and the backed-up versions.
Installed from the Win95 DOS environment, ( from floppies ) the installation process for PowerFlex will REPLACE your CONFIG.SYS and your AUTOEXEC.BAT during installation.
The installation program will back up your current CONFIG.SYS and AUTOEXEC.BAT and report what name it saved them as ( Usually *.NHR ). If you need some of the features (device drivers, environment settings, etc.) of your current CONFIG.SYS or AUTOEXEC.BAT,you will need to manually edit the files in the Win95 DOS environment to include what you need from both the newly installed files and the backed-up versions.

---
INSTALLATION DIRECTLY FROM CD-ROM
---

1) At the DOS prompt (not a DOS shell) type "D:\INSTALL D:" and press enter.

2) Follow the on-screen instructions.

3) Edit the AUTOEXEC.BAT and CONFIG.SYS files to add necessary features of the previous versions. See WARNING above.

---
UNINSTALLING POWERFLEX SOFTWARE
---

1) At the DOS prompt type "C:" (or whatever drive PowerFlex was installed onto) and press enter to change the current path to the PowerFlex installation drive.

2) Type "CD \" and press enter to change the current path to the root directory.

3) Type "SUBST J: /D" and press enter to remove the DOS drive substitution for "J:".

4) Type "SUBST L: /D" and press enter to remove the DOS drive substitution for "L:".

5) Type "SUBST M: /D" and press enter to remove the DOS drive substitution for "M:".

6) Type "DELTREE PWRFLEX" and press enter to remove the PWRFLEX directory and all its subdirectories.

7) Type "DELTREE PFLEX" and press enter to remove the PFLEX directory and all its subdirectories.

8) Type "DEL PWRFLEX.CFG" and press enter to remove the config file.

9) Restore the AUTOEXEC.BAT and CONFIG.SYS files from the previously backed up files (usually named AUTOEXEC.00x and CONFIG.00x). For example:
   Type "COPY AUTOEXEC.002 AUTOEXEC.BAT" and press enter.
   Type "COPY CONFIG.002 CONFIG.SYS" and press enter.

==========
PowerFlex DOS System Software
==========

The PowerFlex DOS System Software may be installed directly from this CD, or you may create a floppy disk set and install from it.

---
INSTALLATION DIRECTLY FROM CD-ROM
---
If you are installing from Windows 3.1x:
1) From the Program Manager, select the file menu and choose RUN. Type "D:\SETUP" and press enter.

-or-

If you are installing from Windows 95:
1) Select the Start button then choose RUN. Type "D:\SETUP" and press enter.

2) Setup will run the NH Research Master Installation program. Press the button labeled "Install PowerFlex DOS" and follow the on-screen instructions.

3) If the Master Installation program indicates that there is a Installation Update for DOS Diagnostics on the CD, run the update program by pressing the button labeled "Install Installation Update for DOS Diagnostics". It is important that this update be installed AFTER the PowerFlex DOS installation. This program runs with no operator intervention.

**TECHNICAL NOTE: 08-0383 Rev B**
**DATE: 08/25/99**
**SUBJECT: MODEL 4600 AC LOAD SETUP.**

This technical note describes the setup of the SOFTWARE and HARDWARE of the MODEL 4600 AC LOAD.

## SOFTWARE SETUP.

### IMPORTANT:

The AC Load software can only be installed on the following operating systems:

- Windows 95 with Internet Explorer 4 or later installed.
- Windows 98
- Windows 98 SE
- Windows NT 4 with service pack 3 or later

The AC Load software CANNOT be installed on Windows 2000.

1. Close all programs that are currently running in windows. Insert the CD into the drive and view contents of disk and double click on Setup to start installation. Follow the instructions on the screen.
2. During setup, the Port Configuration Utility will be displayed. You must configure the port that your AC Load is connected to.
   - Click the "New" button and select the com port that will be used for the AC Load.
   - Verify that the I/O address and IRQ selected is correct for your port. They should be correct for Com1 and Com2, but Com3 and up are not standardized so consult with your PC documentation.
   - Select the correct protocol for your AC Load. This will be either "S6K type at 19200 bps" or "S6K type at 38400 bps" depending on the baud rate that your AC Load is set to. The default is "S6K type at 19200 bps".

## HARDWARE SETUP REAR PANEL CONNECTIONS.

1. Connect Control Power Input plug this supplies power to the fans and control circuits. Check label at rear panel for your power requirements 115VAC or 230VAC.
2. Connect Load Power Input connector, the voltage sense wires are also located on this connector. The voltage sense must be connected to the load wires either at this connector or at the source. The load will not operate with these voltage sense wires disconnected. It will generate an undervoltage error.

3. Connect the RS232 cable at the rear of the load. This cable will mate with a PC compatible nine pin RS232 port if a one to one four wire cable is used.
4. For connector pin outs and any additional information please refer to user manual P/N 09-0237.