4700 DC Load Family
User Manual

Part No. 09-0281

REVISION N

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1. DESCRIPTION

The Model 4700 electronic programmable DC load family includes many different size and power configurations. This document mainly describes the most popular configuration; a single master chassis with one Control circuit card and six Load Power circuit cards, comprising a 6 KW load instrument. Information for other configurations is noted as appropriate.

1.1 Model Variation

The 10.5" high chassis can hold a Controller circuit card, and from one to six Load Power circuit cards (each rated at 1KW capacity). The 5.25" high chassis can hold one Controller and up to two Load Power circuit cards. Different models are available with ratings of 1KW through 6KW in a single Master Chassis. Chassis with no Controller circuit card (Auxiliary Chassis) are also available.

Up to six chassis may be hardware-paralleled using external control cabling to construct a single 36KW load instrument. In this configuration, there is one Controller circuit card in the Master Chassis and five Auxiliary Chassis with no Controller circuit cards. A single load configured in this way appears to the software and the source under test as a single load. Transitions in load current are as tightly synchronized as possible across multiple Load Power circuit cards with hardware-paralleling.

To allow increased flexibility for the user, Master Load instruments, either in single or multiple chassis, can be software-paralleled under program control. This capability allows is a more dynamic configuration as the user's requirements change. Multiple Master loads are paralleled in software using a group addressing method to insure multiple Controller circuit cards execute commands simultaneously. Transitions in load current across multiple Load Power circuit cards are not as tightly synchronized as with hardware-paralleling, but more than adequate for the majority of applications.

1.2 4700 Load Family Common Features

Programmable Modes	Auto CC, CR, CV and CP OVPS relay, slew-rate, transient mode
Measurements	Voltage and current
Protection	Over voltage, current, power, temperature, reverse voltage
Parallel-able	Multiple chassis may be paralleled in hardware for higher power and/or lower resistance

1.3 4700 Load - 1KW Features

Power	1000W continuous
Current	200A @ 1V, reduced current to 0.15V
Resistance	5mΩ to 180 ohms
Voltage	0.15 to 120V
Size	5.25 inch chassis

1.4 4700 Load - 2KW Features

Power	2000W continuous
Current	400A @ 1V, reduced current to 0.15V
Resistance	2.5mΩ to 90 ohms
Voltage	0.15 to 120V
Size	5.25 inch chassis

1.5 4700 Load - 3KW Features

Power	3000W continuous
Current	600A @ 1V, reduced current to 0.15V
Resistance	1.67mΩ to 60 ohms
Voltage	0.15 to 120V
Size	10.5 inch chassis

1.6 4700 Load - 6KW Features

Power	6000W continuous
Current	1200A @ 1V, reduced current to 0.15V
Resistance	833μΩ to 30 ohms
Voltage	0.15 to 120V
Size	10.5 inch chassis

1.7 4700 Load - 9KW Features

Power	9000W continuous
Current	1800A @ 1V, reduced current to 0.15V
Resistance	556μΩ to 20 ohms
Voltage	0.15 to 120V
Size	21 inch rack height one Master 10.5 inch chassis, and one Auxiliary 10.5 inch chassis

1.8 4700 Load - 12KW Features

Power	12000W continuous
Current	2400A @ 1V, reduced current to 0.15V
Resistance	417μΩ to 15 ohms
Voltage	0.15 to 120V
Size	21 inch rack height one Master 10.5 inch chassis, and one Auxiliary 10.5 inch chassis

1.9 4700 Load – 18KW Features

Power	18000W continuous
Current	3600A @ 1V, reduced current to 0.15V
Resistance	278μΩ to 10 ohms
Voltage	0.15 to 120V
Size	31.5 inch rack height one Master 10.5 inch chassis, and two Auxiliary 10.5 inch chassis

1.10 4700 Load - 24KW Features

Power	24000W continuous
Current	4800A @ 1V, reduced current to 0.15V
Resistance	208μΩ to 7.5 ohms
Voltage	0.15 to 120V
Size	42 inch rack height one Master 10.5 inch chassis, and three Auxiliary 10.5 inch chassis

1.11 4700 Load - 30KW Features

Power	30000W continuous
Current	6000A @ 1V, reduced current to 0.15V
Resistance	167μΩ to 6 ohms
Voltage	0.15 to 120V
Size	52.5 inch rack height one Master 10.5 inch chassis, and four Auxiliary 10.5 inch chassis

1.12 4700 Load - 36KW Features

Power	36000W continuous
Current	7200A @ 1V, reduced current to 0.15V
Resistance	139μΩ to 5 ohms
Voltage	0.15 to 120V
Size	63 inch rack height one Master 10.5 inch chassis, and five Auxiliary 10.5 inch chassis

1.13 4750 Load - 1KW Features

Power	1000W continuous
Current	50A @ 7V, reduced current to 1V
Resistance	0.20 to 6000 ohms
Voltage	1 to 500V
Size	5.25 inch chassis

1.14 4750 Load - 2KW Features

Power	2000W continuous
Current	100A @ 7V, reduced current to 1V
Resistance	0.10 to 3000 ohms
Voltage	1 to 500V
Size	5.25 inch chassis

1.15 4750 Load - 3KW Features

Power	3000W continuous
Current	150A @ 7V, reduced current to 1V
Resistance	.0667 to 2000 ohms
Voltage	1 to 500V
Size	10.5 inch chassis

1.16 4750 Load - 6KW Features

Power	6000W continuous
Current	300A @ 7V, reduced current to 1V
Resistance	.0333 to 1000 ohms
Voltage	1 to 500V
Size	10.5 inch chassis

1.17 4750 Load - 9KW Features

Power	9000W continuous
Current	450A @ 7V, reduced current to 1V
Resistance	0.0222 to 666 ohms
Voltage	1 to 500V
Size	21 inch rack height one Master 10.5 inch chassis, and one Auxiliary 10.5 inch chassis

1.18 4750 Load - 12KW Features

Power	12000W continuous
Current	600A @ 7V, reduced current to 1V
Resistance	0.0167 to 500 ohms
Voltage	1 to 500V
Size	21 inch rack height one Master 10.5 inch chassis, and one Auxiliary 10.5 inch chassis

1.19 4750 Load - 18KW Features

Power	18000W continuous
Current	900A @ 7V, reduced current to 1V
Resistance	0.0111 to 333 ohms
Voltage	1 to 500V
Size	31.5 inch rack height one Master 10.5 inch chassis, and two Auxiliary 10.5 inch chassis

1.20 4750 Load - 24KW Features

Power	24000W continuous
Current	1200A @ 7V, reduced current to 1V
Resistance	8.33mΩ to 250 ohms
Voltage	1 to 500V
Size	42 inch rack height one Master 10.5 inch chassis, and three Auxiliary 10.5 inch chassis

1.21 4750 Load - 30KW Features

Power	30000W continuous
Current	1200A @ 7V, reduced current to 1V
Resistance	6.66mΩ to 200 ohms
Voltage	1 to 500V
Size	52.5 inch rack height one Master 10.5 inch chassis, and four Auxiliary 10.5 inch chassis

1.22 4750 Load - 36KW Features

Power	36000W continuous
Current	1800A @ 7V, reduced current to 1V
Resistance	5.55mΩ to 166 ohms
Voltage	1 to 500V
Size	63 inch rack height one Master 10.5 inch chassis, and five Auxiliary 10.5 inch chassis

2. SPECIFICATIONS

Accuracies apply when settings and/or measurements are greater than 10% of the range.

2.1 Configuration

Chassis with Controller circuit cards are designated Master Loads. Chassis with no Controller cards are designated Auxiliary Loads.

A Master Load chassis can connect to up to six Auxiliary Load chassis to form a single hardware-paralleled instrument. External cabling is required between chassis to implement hardware paralleling.

Multiple Master Load chassis can be software-paralleled to form a single load instrument. Load commands are sent using a group-address scheme over the communication bus. This scheme allows the user more flexibility to change configurations, but does not have the optimum transient step synchronization offered by hardware-paralleling.

The 10.5 chassis can contain a Controller circuit card and from one to six Load Power circuit cards, each capable of 1KW loading.

The 5.25 chassis can contain a Controller circuit card and one or two Load Power circuit cards, each capable of 1KW loading.

2.2 Sizes

10.5 inch chassis: 19 inches wide, 10.5 inches high, 22 inches deep

5.25 inch chassis: 19 inches wide, 5.25 inches high, 22 inches deep

2.3 Weight

10.5 inch chassis with 6 1KW Load Power boards: 100 lbs.

10.5 inch chassis with 3 1KW Load Power boards: 75 lbs.

5.25 inch chassis with 2 1KW Load Power boards: TBD lbs.

2.4 Communication

Command set conforms to the NH S6000 instrument command protocol.

Control Interface Options;

- RS232 direct to PC using standard 9 pin peripheral cable (RX/TX cross)
- 100BaseT Ethernet direct to PC using network Cross-over cable or using network switch and standard network patch cable.
- NH S6000 RS485 Master/Slave bus protocol COMM IN and COMM OUT connectors

Hardware Paralleling; Standard 25 pin DSUB one-to-one cables with proprietary bus

2.5 Program Control

An *em**Power***® driver is used to control this load in a system.

2.6 Robustness

Over-voltage and reverse-voltage protection is provided in hardware by the avalanche rated body diode in the power MOSFETs. Over-voltage protection is also provided by constant voltage programming, which will be current limited. Excessive over-voltage or reverse-voltage will cause fuses to blow.

Over-current and over-power protection is provided in hardware. Over-current and over-power protection is also provided in firmware by constant current and constant power programming.

Over-temperature protection is provided by thermal sensors.

If an individual FET shorts two fuses will blow disconnecting two FETs but the remaining FETs on that Load Power circuit card will continue to function. An LED will indicate a failure on a Load Power circuit card.

2.7 Isolation

1000VAC between control power and load or chassis ground. ± 1000VDC between load and chassis ground.

2.8 Calibration

Closed cover, all adjustment done in software. Controller circuit card calibration factors are stored in FLASH. Individual Load Power circuit card calibration factors are stored in EEPROM.

2.9 Self-test

Power-up self-test is implemented in firmware and will report comprehensive error messages about the status of the input, output, and control board and protection mechanism.

2.10 Performance Monitoring

Performance monitoring is performed continuously by the 4700 DC Load Controller. In case of measurement ambiguities, over/under range conditions, heat sink temperature limits reached, an appropriate error or warning is sent to the controlling device.

2.11 Temperature

Operating from 0 to 40°C at full power, 70% duty cycle.

Specifications apply at 23°C ±5°C after 10-minute warm-up

2.12 Remote Sense

2VDC max drop between sense and load input.

2.13 Supply Power

Operational from 115/230VAC ± 10% (non-destructive ± 25%), 47-63Hz, switch selectable.

Operation from 100/200/215VAC ± 10% (non-destructive ± 25%), 47-63Hz, is selectable with internal jumper options – consult the factory.

2.14 4700 1KW Configuration Programmable Features

Constant Current	Range Accuracy Resolution	0 to 20A, 0 to 200A 0.12% of set +0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	0.15 to 6.6V, 0.15 to 20V, 0.15 to 66V, 0.15 to 120V, 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 1KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	15% to 3000% of Voltage range divided by Current range * 2% of set **	
Short Circuit	Range Resistance Current	20A 50milliΩ max 33A max	200A 5milliΩ max 333A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	20A 2A/µS	200A 20A/µS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40µSec to 20 Sec 20µSec to 20 Sec 5µSec 1% ± 5µSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	1A/Sec to 20A/µSec < 5µSec 1% ± 5µSec	

2.15 4700 1KW Configuration Measurements

Current	Range Accuracy Resolution	0 to 20A, 0 to 200A 0.12% of reading, + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 6.6V, 0 to 66V, 0 to 166V, 0.01% of reading, + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Range: Not less than 126 milliohms

** CR Accuracy: Set 15% to 500% of range = 2% accuracy
Set 500% to 3000% of range = 10% accuracy

2.16 4700 2KW Configuration Programmable Features

Constant Current	Range Accuracy Resolution	0 to 40A, 0 to 400A 0.12% of set +0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	0.15 to 6.6V, 0.15 to 20V, 0.15 to 66V, 0.15 to 120V, 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 2KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	15% to 3000% of Voltage range divided by Current range * 2% of set **	
Short Circuit	Range Resistance Current	40A 25milliΩ max 67A max	400A 2.5milliΩ max 667A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	40A 4A/µS	400A 40A/µS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40µSec to 20 Sec 20µSec to 20 Sec 5µSec 1% ± 5µSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	2A/Sec to 40A/µSec < 5µSec 1% ± 5µSec	

2.17 4700 2KW Configuration Measurements

Current	Range Accuracy Resolution	0 to 40A, 0 to 400A 0.12% of reading, + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 6.6V, 0 to 66V, 0 to 166V, 0.01% of reading, + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Range: Not less than 63 milliohms

** CR Accuracy: Set 15% to 500% of range = 2% accuracy
Set 500% to 3000% of range = 10% accuracy

2.18 4700 3KW Configuration Programmable Features

Constant Current	Range Accuracy Resolution	0 to 60A, 0 to 600A 0.12% of set +0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	0.15 to 6.6V, 0.15 to 20V, 0.15 to 66V, 0.15 to 120V, 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 3KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	15% to 3000% of Voltage range divided by Current range * 2% of set **	
Short Circuit	Range Resistance Current	60A 17milliΩ max 100A max	600A 1.7milliΩ max 1000A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	60A 6A/µS	600A 60A/µS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40µSec to 20 Sec 20µSec to 20 Sec 5µSec 1% ± 5µSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	3A/Sec to 60A/µSec < 5µSec 1% ± 5µSec	

2.19 4700 3KW Configuration Measurements

Current	Range Accuracy Resolution	0 to 60A, 0 to 600A 0.12% of reading, + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 6.6V, 0 to 66V, 0 to 166V, 0.01% of reading, + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Range: Not less than 42 milliohms

** CR Accuracy: Set 15% to 500% of range = 2% accuracy
Set 500% to 3000% of range = 10% accuracy

2.20 4700 6KW Configuration Programmable Features

Constant Current	Range Accuracy Resolution	0 to 120A, 0 to 1200A 0.12% of set +0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	0.15 to 6.6V, 0.15 to 20V, 0.15 to 66V, 0.15 to 120V, 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 6KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	15% to 3000% of Voltage range divided by Current range * 2% of set **	
Short Circuit	Range Resistance Current	120A 8.33milliΩ max 200A max	1200A 833μΩ max 2000A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	120A 12A/μS	1200A 120A/μS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40μSec to 20 Sec 20μSec to 20 Sec 5μSec 1% ± 5μSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	6A/Sec to 120A/μSec < 5μSec 1% ± 5μSec	

2.21 4700 6KW Configuration Measurements

Current	Range Accuracy Resolution	0 to 120A, 0 to 1200A 0.12% of reading, + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 6.6V, 0 to 66V, 0 to 166V, 0.01% of reading, + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Range: Not less than 21milliohms

** CR Accuracy: Set 15% to 500% of range = 2% accuracy
Set 500% to 3000% of range = 10% accuracy

2.22 4700 9KW Configuration Programmable Features

Constant Current	Range Accuracy Resolution	0 to 180A, 0 to 1800A 0.12% of set +0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	0.15 to 6.6V, 0.15 to 20V, 0.15 to 66V, 0.15 to 120V, 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 9KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	15% to 3000% of Voltage range divided by Current range * 2% of set **	
Short Circuit	Range Resistance Current	180A 5.6milliΩ max 300A max	1800A 556μΩ max 3000A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	180A 18A/μS	1800A 180A/μS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40μSec to 20 Sec 20μSec to 20 Sec 5μSec 1% ± 5μSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	9A/Sec to 180A/μSec < 5μSec 1% ± 5μSec	

2.23 4700 9KW Configuration Measurements

Current	Range Accuracy Resolution	0 to180A, 0 to 1800A 0.12% of reading, + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 6.6V, 0 to 66V, 0 to 166V, 0.01% of reading, + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Range: Not less than 14 milliohms

** CR Accuracy: Set 15% to 500% of range = 2% accuracy
Set 500% to 3000% of range = 10% accuracy

2.24 4700 12KW Configuration Programmable Features

Constant Current	Range Accuracy Resolution	0 to 240A, 0 to 2400A 0.12% of set +0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	0.15 to 6.6V, 0.15 to 20V, 0.15 to 66V, 0.15 to 120V, 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 12KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	15% to 3000% of Voltage range divided by Current range * 2% of set **	
Short Circuit	Range Resistance Current	240A 4.17milliΩ max 400A max	2400A 417μΩ max 4000A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	240A 24A/μS	2400A 240A/μS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40μSec to 20 Sec 20μSec to 20 Sec 5μSec 1% ± 5μSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	12A/Sec to 240A/μSec < 5μSec 1% ± 5μSec	

2.25 4700 12KW Configuration Measurements

Current	Range Accuracy Resolution	0 to 240A, 0 to 2400A 0.12% of reading, + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 6.6V, 0 to 66V, 0 to 166V, 0.01% of reading, + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Range: Not less than 10.5 milliohms

** CR Accuracy: Set 15% to 500% of range = 2% accuracy
Set 500% to 3000% of range = 10% accuracy

2.26 4700 18KW Configuration Programmable Features

Constant Current	Range Accuracy Resolution	0 to 360A, 0 to 3600A 0.12% of set +0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	0.15 to 6.6V, 0.15 to 20V, 0.15 to 66V, 0.15 to 120V, 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 18KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	15% to 3000% of Voltage range divided by Current range * 2% of set **	
Short Circuit	Range Resistance Current	360A 2.78milliΩ max 600A max	3600A 278μΩ max 6000A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	360A 36A/μS	3600A 360A/μS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40μSec to 20 Sec 20μSec to 20 Sec 5μSec 1% ± 5μSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	18A/Sec to 360A/μSec < 5μSec 1% ± 5μSec	

2.27 4700 18KW Configuration Measurements

Current	Range Accuracy Resolution	0 to 360A, 0 to 3600A 0.12% of reading, + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 6.6V, 0 to 66V, 0 to 166V, 0.01% of reading, + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Range: Not less than 7 milliohms

** CR Accuracy: Set 15% to 500% of range = 2% accuracy
Set 500% to 3000% of range = 10% accuracy

2.28 4700 24KW Configuration Programmable Features

Constant Current	Range Accuracy Resolution	0 to 48A, 0 to 4800A 0.12% of set +0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	0.15 to 6.6V, 0.15 to 20V, 0.15 to 66V, 0.15 to 120V, 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 24KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	15% to 3000% of Voltage range divided by Current range * 2% of set **	
Short Circuit	Range Resistance Current	480A 2.08milliΩ max 792A max	4800A 208μΩ max 7920A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	480A 48A/μS	4800A 480A/μS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40μSec to 20 Sec 20μSec to 20 Sec 5μSec 1% ± 5μSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	24A/Sec to 480A/μSec < 5μSec 1% ± 5μSec	

2.29 4700 24KW Configuration Measurements

Current	Range Accuracy Resolution	0 to 480A, 0 to 4800A 0.12% of reading, + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 6.6V, 0 to 66V, 0 to 166V, 0.01% of reading, + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Range: Not less than 5.25 milliohms

** CR Accuracy: Set 15% to 500% of range = 2% accuracy
Set 500% to 3000% of range = 10% accuracy

2.30 4700 30KW Configuration Programmable Features

Constant Current	Range Accuracy Resolution	0 to 600A, 0 to 6000A 0.12% of set +0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	0.15 to 6.6V, 0.15 to 20V, 0.15 to 66V, 0.15 to 120V, 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 30KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	15% to 3000% of Voltage range divided by Current range * 2% of set **	
Short Circuit	Range Resistance Current	600A 1.67milliΩ max 990A max	6000A 167μΩ max 9900A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	600A 60A/μS	6000A 600A/μS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40μSec to 20 Sec 20μSec to 20 Sec 5μSec 1% ± 5μSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	30A/Sec to 600A/μSec < 5μSec 1% ± 5μSec	

2.31 4700 30KW Configuration Measurements

Current	Range Accuracy Resolution	0 to 600A, 0 to 6000A 0.12% of reading, + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 6.6V, 0 to 66V, 0 to 166V, 0.01% of reading, + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Range: Not less than 4.2 milliohms

** CR Accuracy: Set 15% to 500% of range = 2% accuracy
Set 500% to 3000% of range = 10% accuracy

2.32 4700 36KW Configuration Programmable Features

Constant Current	Range Accuracy Resolution	0 to 720A, 0 to 7200A 0.12% of set +0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	0.15 to 6.6V, 0.15 to 20V, 0.15 to 66V, 0.15 to 120V, 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 36KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	15% to 3000% of Voltage range divided by Current range * 2% of set **	
Short Circuit	Range Resistance Current	720A 1.39milliΩ max 1188A max	7200A 139μΩ max 11880A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	720A 72A/μS	7200A 720A/μS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40μSec to 20 Sec 20μSec to 20 Sec 5μSec 1% ± 5μSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	36A/Sec to 720A/μSec < 5μSec 1% ± 5μSec	

2.33 4700 36KW Configuration Measurements

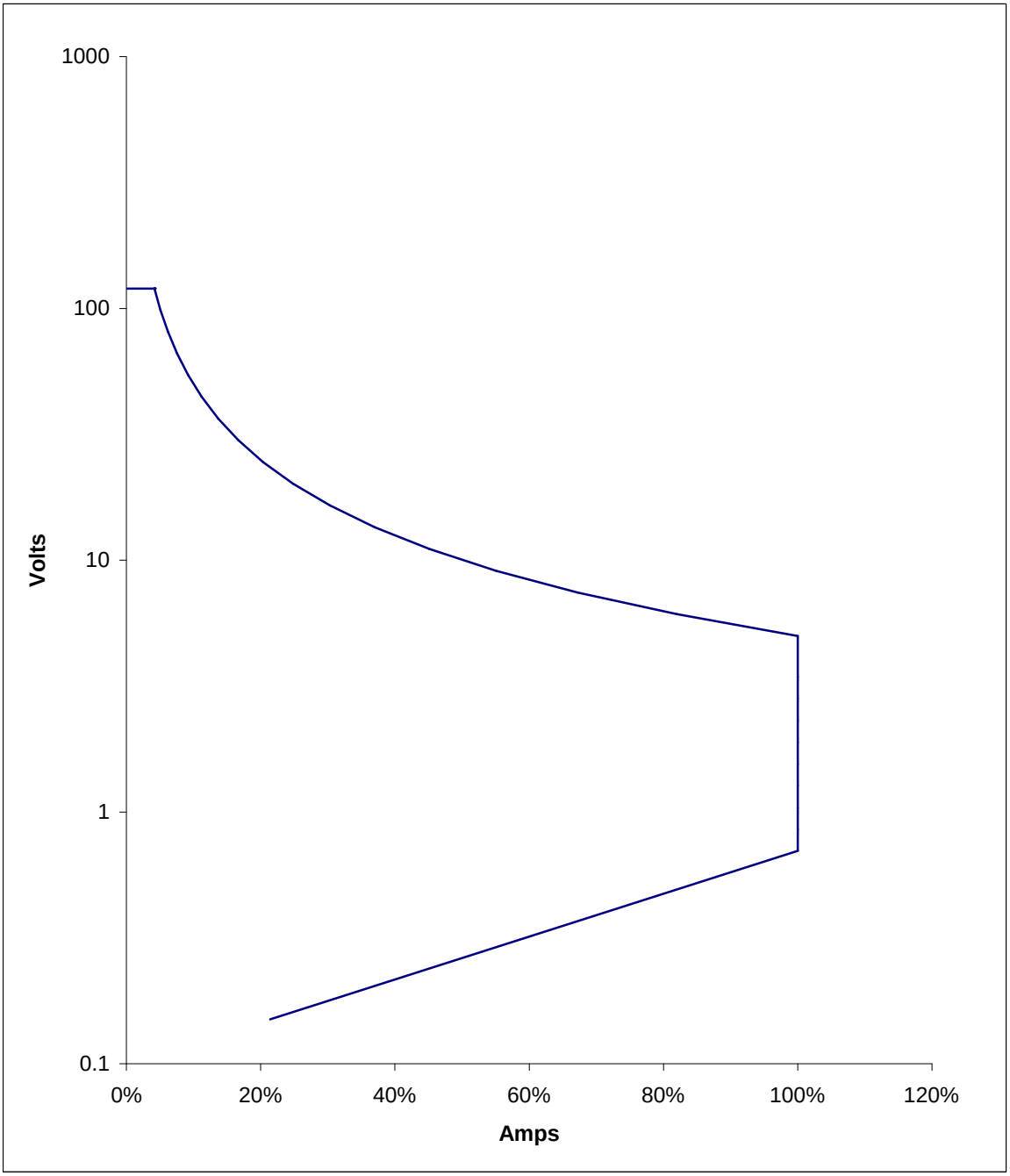
Current	Range Accuracy Resolution	0 to 720A, 0 to 7200A 0.12% of reading, + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 6.6V, 0 to 66V, 0 to 166V, 0.01% of reading, + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Range: Not less than 3.5 milliohms

** CR Accuracy: Set 15% to 500% of range = 2% accuracy
Set 500% to 3000% of range = 10% accuracy

2.34 4700 Operating Envelope



4700 Operating Envelope

2.35 4750 1KW Programmable Features

Constant Current	Range Accuracy Resolution	0 to 5A, 0 to 50A 0.12% of set + 0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	1 to 20V, 1 to 200V, 1 to 500V 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 1KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	50% to 6000% of Voltage range divided by Current range 2% of set *	
Short Circuit	Range Resistance Current	5A 2Ω max 8A max	50A 0.2Ω max 80A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	5A 0.5A/µS	50A 5A/µS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40µSec to 20 Sec 20µSec to 20 Sec 5µSec 1% ± 5µSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	0.25A/Sec to 5A/µSec < 5µSec 1% ± 5µSec	

2.36 4750 1KW Measurements

Current	Range Accuracy Resolution	0 to 5A, 0 to 50A 0.12% of reading + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 20V, 0 to 200V, 0 to 500V 0.01% of reading + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Accuracy: Set 50% to 1000% of range = 2% accuracy
Set 1000% to 6000% of range = 10% accuracy

2.37 4750 2KW Programmable Features

Constant Current	Range Accuracy Resolution	0 to 10A, 0 to 100A 0.12% of set + 0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	1 to 20V, 1 to 200V, 1 to 500V 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 2KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	50% to 6000% of Voltage range divided by Current range 2% of set *	
Short Circuit	Range Resistance Current	10A 1Ω max 16A max	100A 0.1Ω max 160A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	10A 1A/μS	100A 10A/μS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40μSec to 20 Sec 20μSec to 20 Sec 5μSec 1% ± 5μSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	0.5A/Sec to 10A/μSec < 5μSec 1% ± 5μSec	

2.38 4750 2KW Measurements

Current	Range Accuracy Resolution	0 to 10A, 0 to 100A 0.12% of reading + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 20V, 0 to 200V, 0 to 500V 0.01% of reading + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Accuracy: Set 50% to 1000% of range = 2% accuracy
Set 1000% to 6000% of range = 10% accuracy

2.39 4750 3KW Programmable Features

Constant Current	Range Accuracy Resolution	0 to 15A, 0 to 150A 0.12% of set + 0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	1 to 20V, 1 to 200V, 1 to 500V 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 3KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	50% to 6000% of Voltage range divided by Current range 2% of set *	
Short Circuit	Range Resistance Current	15A 0.67Ω max 24A max	150A 0.067Ω max 240A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	15A 1.5A/μS	150A 15A/μS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40μSec to 20 Sec 20μSec to 20 Sec 5μSec 1% ± 5μSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	0.75A/Sec to 15A/μSec < 5μSec 1% ± 5μSec	

2.40 4750 3KW Measurements

Current	Range Accuracy Resolution	0 to 15A, 0 to 150A 0.12% of reading + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 20V, 0 to 200V, 0 to 500V 0.01% of reading + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Accuracy: Set 50% to 1000% of range = 2% accuracy
Set 1000% to 6000% of range = 10% accuracy

2.41 4750 6KW Programmable Features

Constant Current	Range Accuracy Resolution	0 to 30A, 0 to 300A 0.12% of set + 0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	1 to 20V, 1 to 200V, 1 to 500V 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 6KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	50% to 6000% of Voltage range divided by Current range 2% of set *	
Short Circuit	Range Resistance Current	30A 0.33Ω max 48A max	300A 0.033Ω max 480A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	30A 3A/µS	300A 30A/µS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40µSec to 20 Sec 20µSec to 20 Sec 5µSec 1% ± 5µSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	1.5A/Sec to 30A/µSec < 5µSec 1% ± 5µSec	

2.42 4750 6KW Measurements

Current	Range Accuracy Resolution	0 to 30A, 0 to 300A 0.12% of reading + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 20V, 0 to 200V, 0 to 500V 0.01% of reading + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Accuracy: Set 50% to 1000% of range = 2% accuracy
Set 1000% to 6000% of range = 10% accuracy

2.43 4750 9KW Programmable Features

Constant Current	Range Accuracy Resolution	0 to 45A, 0 to 450A 0.12% of set + 0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	1 to 20V, 1 to 200V, 1 to 500V 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 9KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	50% to 6000% of Voltage range divided by Current range 2% of set *	
Short Circuit	Range Resistance Current	45A 0.222Ω max 72A max	450A 0.0222Ω max 720A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	45A 4.5A/µS	450A 45A/µS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40µSec to 20 Sec 20µSec to 20 Sec 5µSec 1% ± 5µSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	2.25A/Sec to 45A/µSec < 5µSec 1% ± 5µSec	

2.44 4750 9KW Measurements

Current	Range Accuracy Resolution	0 to 45A, 0 to 450A 0.12% of reading + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 20V, 0 to 200V, 0 to 500V 0.01% of reading + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Accuracy: Set 50% to 1000% of range = 2% accuracy
Set 1000% to 6000% of range = 10% accuracy

2.45 4750 12KW Programmable Features

Constant Current	Range Accuracy Resolution	0 to 60A, 0 to 600A 0.12% of set + 0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	1 to 20V, 1 to 200V, 1 to 500V 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 12KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	50% to 6000% of Voltage range divided by Current range 2% of set *	
Short Circuit	Range Resistance Current	60A 0.167Ω max 96A max	600A 0.0167Ω max 960A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	60A 6A/μS	600A 60A/μS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40μSec to 20 Sec 20μSec to 20 Sec 5μSec 1% ± 5μSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	3A/Sec to 60A/μSec < 5μSec 1% ± 5μSec	

2.46 4750 12KW Measurements

Current	Range Accuracy Resolution	0 to 60A, 0 to 600A 0.12% of reading + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 20V, 0 to 200V, 0 to 500V 0.01% of reading + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Accuracy: Set 50% to 1000% of range = 2% accuracy
Set 1000% to 6000% of range = 10% accuracy

2.47 4750 18KW Programmable Features

Constant Current	Range	0 to 90A, 0 to 900A	
	Accuracy	0.12% of set + 0.08% of range	
	Resolution	0.025% of range	
Constant Voltage	Range	1 to 20V, 1 to 200V, 1 to 500V	
	Accuracy	0.05% of set + 0.05% of range	
	Resolution	0.025% of range	
Constant Power Limited to 18KW	Range	Current range times Voltage range	
	Accuracy	1% of set + 1% of range	
	Resolution	0.025% of range	
Constant Resistance	Range	50% to 6000% of Voltage range divided by Current range	
	Accuracy	2% of set *	
Short Circuit	Range	90A	900A
	Resistance	0.111Ω max	0.0111Ω max
	Current	144A max	1440A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range	90A	900A
	Max di/dt	9A/µS	90A/µS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings	100	
	Total Period	40µSec to 20 Sec	
	Delay	20µSec to 20 Sec	
	Resolution	5µSec	
	Accuracy	1% ± 5µSec	
	Modes	Single burst or continuous	
Slew Rate	Range	4.5A/Sec to 90A/µSec	
	Resolution	< 5µSec	
	Accuracy	1% ± 5µSec	

2.48 4750 18KW Measurements

Current	Range	0 to 90A, 0 to 900A
	Accuracy	0.12% of reading + 0.06% of range
	Resolution	0.0015% of range
Voltage	Range	0 to 20V, 0 to 200V, 0 to 500V
	Accuracy	0.01% of reading + 0.02% of range
	Resolution	0.0015% of range
DSO Voltage and current waveform capture	Bandwidth	DC to (¼ of sample rate)
	Accuracy	1% of range
	Channels	1 or (2 muxed)
	Digitizing rate	100 to 100k Samples/Second
	Memory	16k Samples
	Resolution	0.0015% of range
	Triggering	S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Accuracy: Set 50% to 1000% of range = 2% accuracy
Set 1000% to 6000% of range = 10% accuracy

2.49 4750 24KW Programmable Features

Constant Current	Range Accuracy Resolution	0 to 120A, 0 to 1200A 0.12% of set + 0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	1 to 20V, 1 to 200V, 1 to 500V 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 24KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	50% to 6000% of Voltage range divided by Current range 2% of set *	
Short Circuit	Range Resistance Current	120A 0.0833Ω max 192A max	1200A 0.00833Ω max 1920A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	120A 12A/µS	1200A 120A/µS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40µSec to 20 Sec 20µSec to 20 Sec 5µSec 1% ± 5µSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	6A/Sec to 120A/µSec < 5µSec 1% ± 5µSec	

2.50 4750 24KW Measurements

Current	Range Accuracy Resolution	0 to 120A, 0 to 1200A 0.12% of reading + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 20V, 0 to 200V, 0 to 500V 0.01% of reading + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Accuracy: Set 50% to 1000% of range = 2% accuracy
Set 1000% to 6000% of range = 10% accuracy

2.51 4750 30KW Programmable Features

Constant Current	Range Accuracy Resolution	0 to 150A, 0 to 1500A 0.12% of set + 0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	1 to 20V, 1 to 200V, 1 to 500V 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 30KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	50% to 6000% of Voltage range divided by Current range 2% of set *	
Short Circuit	Range Resistance Current	150A 0.0667Ω max 240A max	1500A 0.00667Ω max 2400A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	150A 15A/µS	1500A 150A/µS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40µSec to 20 Sec 20µSec to 20 Sec 5µSec 1% ± 5µSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	7.5A/Sec to 150A/µSec < 5µSec 1% ± 5µSec	

2.52 4750 30KW Measurements

Current	Range Accuracy Resolution	0 to 150A, 0 to 1500A 0.12% of reading + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 20V, 0 to 200V, 0 to 500V 0.01% of reading + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

* CR Accuracy: Set 50% to 1000% of range = 2% accuracy
Set 1000% to 6000% of range = 10% accuracy

2.53 4750 36KW Programmable Features

Constant Current	Range Accuracy Resolution	0 to 180A, 0 to 1800A 0.12% of set + 0.08% of range 0.025% of range	
Constant Voltage	Range Accuracy Resolution	1 to 20V, 1 to 200V, 1 to 500V 0.05% of set + 0.05% of range 0.025% of range	
Constant Power Limited to 36KW	Range Accuracy Resolution	Current range times Voltage range 1% of set + 1% of range 0.025% of range	
Constant Resistance	Range Accuracy	50% to 6000% of Voltage range divided by Current range 2% of set *	
Short Circuit	Range Resistance Current	180A 0.0556Ω max 290A max	1800A 0.00556Ω max 2900A max
Loop Response Over-shoot 10% max with less than 1Vp-p ripple	Range Max di/dt	180A 18A/µS	1800A 180A/µS
Transient Mode Only one mode (CC, CR, CP or CV) at a time may be programmed in a transient.	Settings Total Period Delay Resolution Accuracy Modes	100 40µSec to 20 Sec 20µSec to 20 Sec 5µSec 1% ± 5µSec Single burst or continuous	
Slew Rate	Range Resolution Accuracy	9A/Sec to 180A/µSec < 5µSec 1% ± 5µSec	

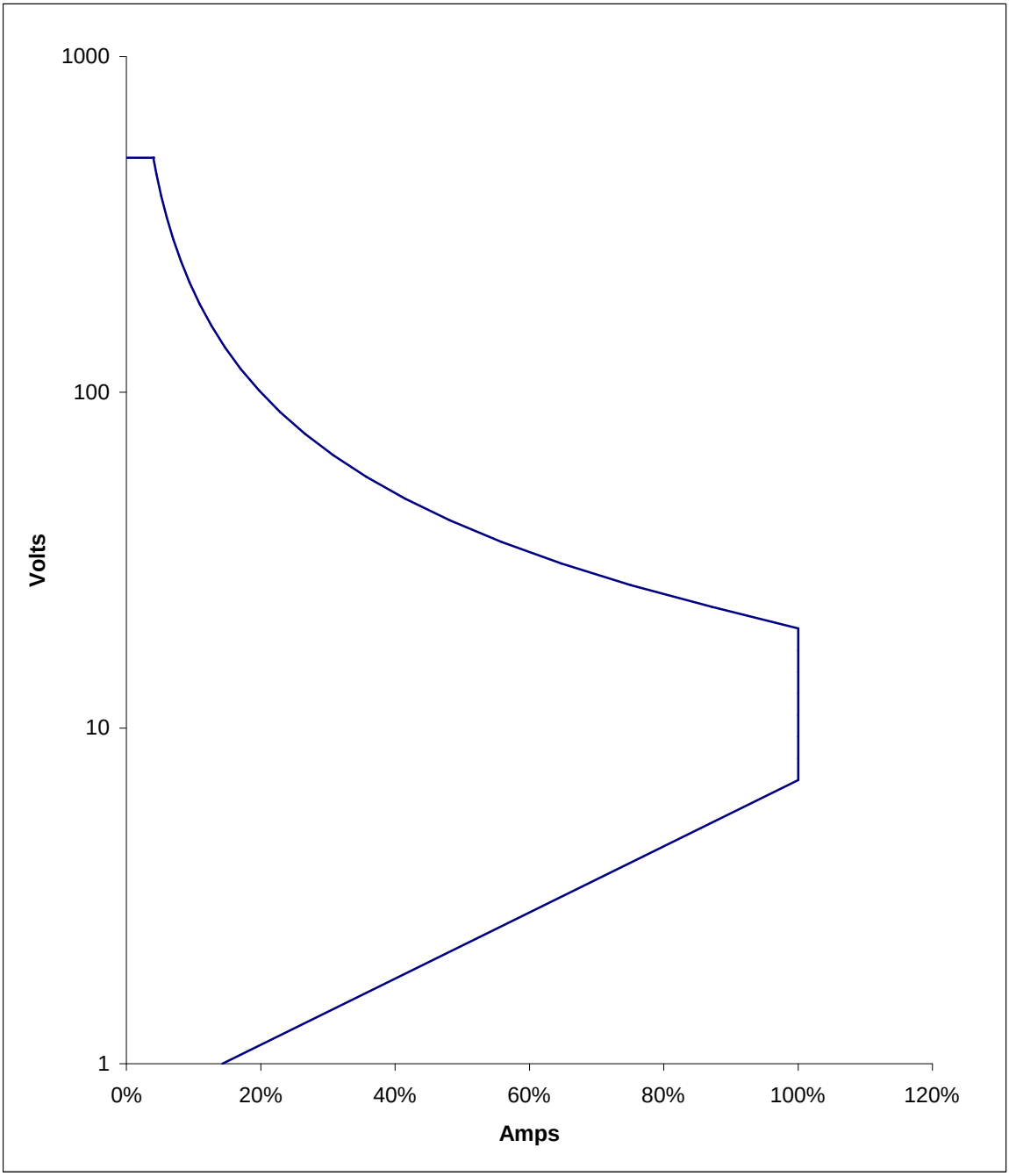
2.54 4750 36KW Measurements

Current	Range Accuracy Resolution	0 to 180A, 0 to 1800A 0.12% of reading + 0.06% of range 0.0015% of range
Voltage	Range Accuracy Resolution	0 to 20V, 0 to 200V, 0 to 500V 0.01% of reading + 0.02% of range 0.0015% of range
DSO Voltage and current waveform capture	Bandwidth Accuracy Channels Digitizing rate Memory Resolution Triggering	DC to (¼ of sample rate) 1% of range 1 or (2 muxed) 100 to 100k Samples/Second 16k Samples 0.0015% of range S6K Trigger In

DSO Range is the same as Current or Voltage being measured.

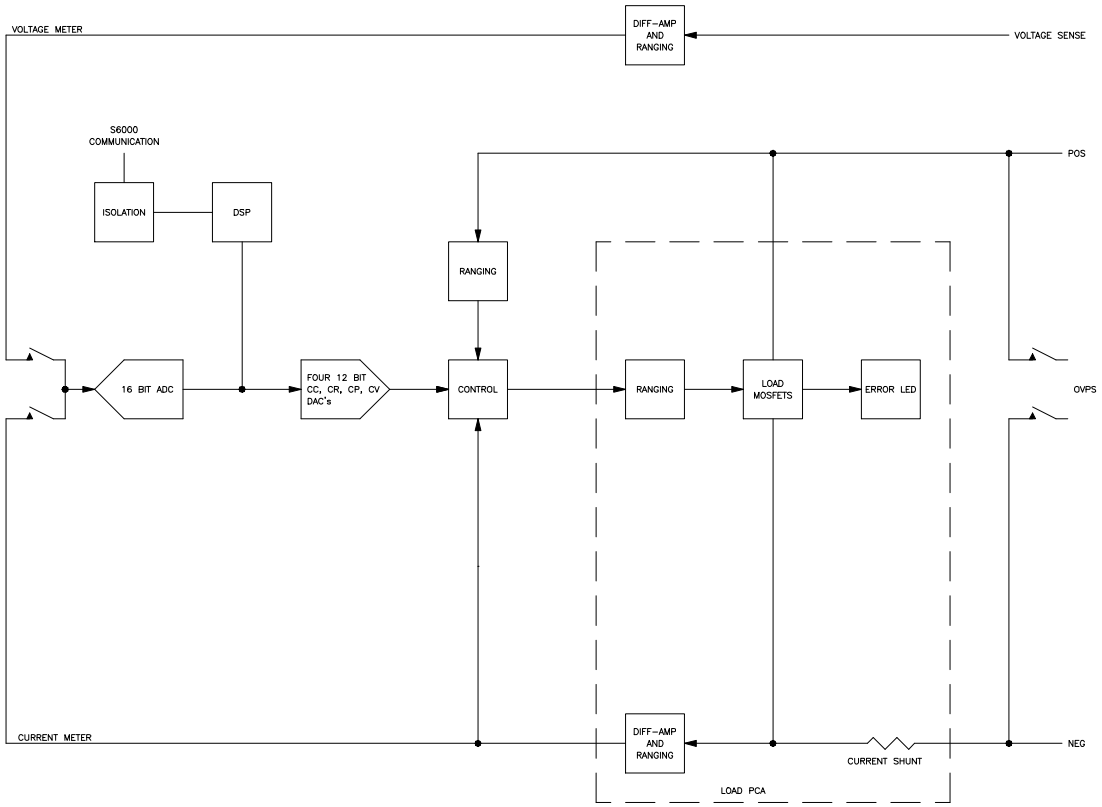
* CR Accuracy: Set 50% to 1000% of range = 2% accuracy
Set 1000% to 6000% of range = 10% accuracy

2.55 4750 Operating Envelope



4750 Operating Envelope

2.56 Block Diagram



4700 DC Load Block Diagram

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 for the 10.5 inch chassis. The 5.25 inch chassis can be mounted on right angle slide brackets.

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

3.1.1 Voltage Select Switch

This switch/indicator is located on the rear panel, selects 115V or 230V AC input power. This switch must be set to the applied input voltage or damage to the load will occur.

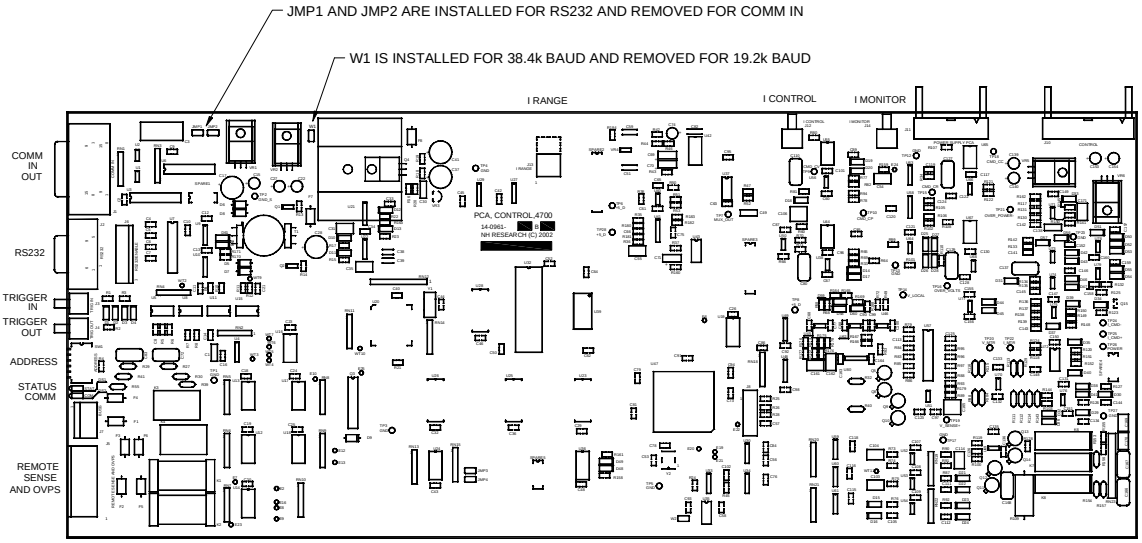
3.1.2 Serial Port Communication

3.1.2.1 Baud Rate

A baud rate of 19.2k or 38.4k may be selected. In most cases, 38.4k (factory default) will be used, however, if you want to change the desired baud rate, select with jumper W1 on the Controller circuit card as shown below.

3.1.2.2 RS-232 or COMM IN

The load can be hooked up to a PC using the RS-232 or COMM IN connector. The COMM IN is an NHR proprietary version of an RS-485 serial port. It allows multiple NHR products to be connected to a single COM port on the PC. In most cases, the RS-232 (factory default) will be used. To change the desired communication port to COMM IN, select with jumpers on the Controller circuit board as shown below.



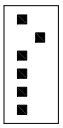
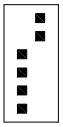
3.1.2.3 Connecting to a PC

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 NH Research emPower Configurator Software is used to select the desired PC COM port, and can perform an Autofill function to find all instruments on that COM port using their unique 6-bit address value.

The 6-bit 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. The controlling software must be set to the same address as the ADDRESS switch on the load. The address switch on the load CANNOT be the same as any other device on that port.

This address switch setting determines a 6-bit binary address. The LSB is on top, near the Trigger Out connector. The MSB is on the bottom, near the Status LED. When a switch bit is moved toward the outside of the chassis, the bit is set to 0. When a switch bit is moved toward the fan, the bit is set to 1. This switch is only read once at power up. If this switch is changed, the load must be turned off and on again for the new switch setting to take effect. If all six 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.

Examples:

ADDRESS SWITCH POSITION	COMMUNICATION ADDRESS
	0X00
	0X01
	0X02
	0X03

3.1.3 Ethernet Port Communication

3.1.3.1 Connection

The Ethernet port option provides a 100BaseT LAN connection in place of the RS232 connection. As with any Ethernet network device, there are a variety of ways to connect to a Windows PC, and a variety of ways to assign an Ethernet address (IP address) to the device.

To connect the Load directly to a Windows PC, an Ethernet crossover cable will be required (Belkin Part Number A3X126-14-YLW-M or equivalent). If the Load is connected to a network switch or router that is connected to the Windows PC, a standard 100BaseT network patch cable can be used.

3.1.3.2 IP Addressing

The Load can obtain an Ethernet IP address in two ways; It will be assigned an address dynamically using Ethernet DHCP protocol if there is a router or other DHCP server in the connection network, or it will auto-assign itself an address after 30 seconds.

The Load will only request a dynamic address on power up, plugging and un-plugging the Ethernet cable has no effect.

If the Load auto-assigns an address, it will be in the domain 192.168.0000.nnn with subnet mask 255.255.255.000. The nnn value will be the modulo 256 sum of the lower three bytes of the device MAC value. The MAC value is a factory assigned six byte value unique to every networked device.

To talk to a Load that has auto-assigned an address, the PC network interface must be in the same domain. This may require going to the Windows, Settings, Network and Dial Up Connections control panel for the Network Interface. Under the IP properties, the IP

address will have to be changed to a fixed address such as 192.168.000.001 or 192.168.000.002.

All of this setup and connection must be done before launching the NH software, which will find networked devices that are in the same IP address domain as the PC network interface. Please see Appendix A for a more detailed discussion of Ethernet setup and configuration options.

3.1.3.3 Additional Devices

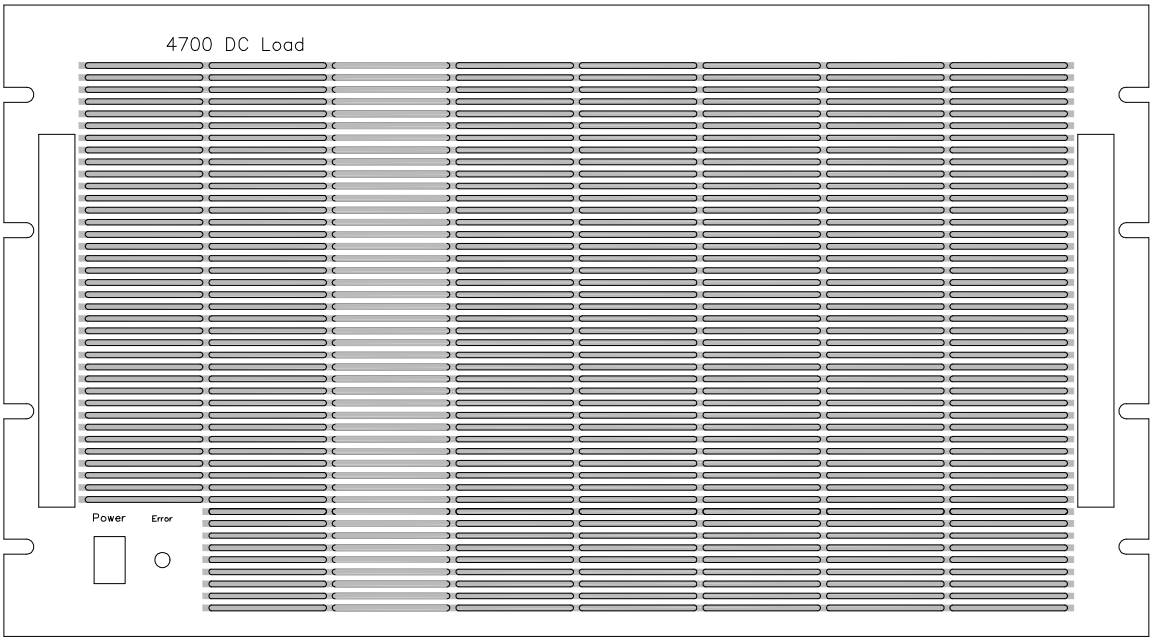
The COMM OUT connector from the Master Load chassis with the Ethernet port can be used to communicate with other Loads or NH Instruments that have the S6000 Bus COMM IN connectors. Any additional devices connected using this S6000 Bus chain must have unique 6-bit Address values set on the rear panel Address switch. See the description of this switch in the Serial Port section for setting instructions.

3.1.4 Airflow

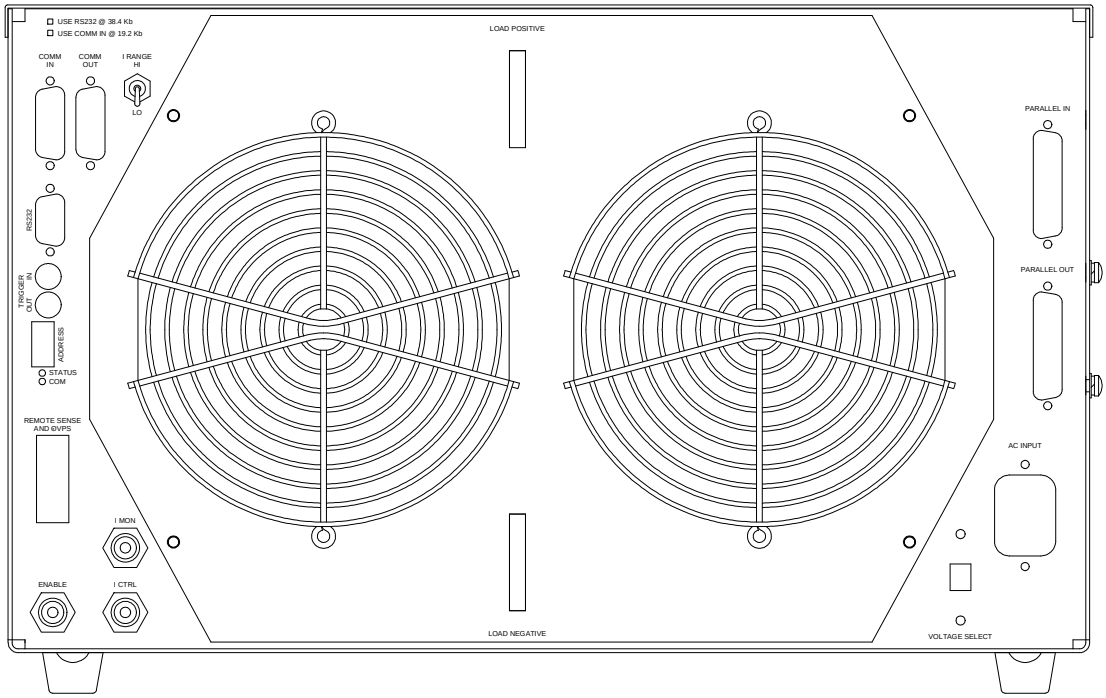
The load will dissipate over 6KW of heat per chassis.

Allow for 600CFM, per chassis, of air to enter the front and exit the rear of the load. This must be fresh cool air and not hot re-circulated air.

3.1.5 Front View



3.1.6 Rear View



3.2 Connectors

3.2.1 AC Input

Located on the rear panel, supplies AC input power to the fans and control circuits.

Mating cable type is:

NH Part #	Description	Commercial Part #	Manufacturer
8030041	CABLE, AC PWR 14X3/10'/NEMA-IEC	17505	BELDEN/VOLEX

3.2.2 Remote Sense and OVPS

Located on the rear panel, provides remote voltage sense and Over Voltage Power Supply connections.

Remote voltage sense wires may be connected to the DC source for more accurate voltage metering. If remote sense is used it must be selected in software.

Over Voltage Power Supply wires may be connected to the Over Voltage DC source for over voltage testing. An internal over voltage relay may be selected in software to connect the OVPS input to the load positive and negative inputs.

Pin	Description
1	VOLTAGE SENSE POSITIVE
3	VOLTAGE SENSE NEGATIVE
6	OVER VOLTAGE POSITIVE
8	OVER VOLTAGE NEGATIVE

Mating connector type is:

NH Part #	Description	Commercial Part #	Manufacturer
6300080	CONN, 8 PIN HOUSING .156 CTRS	09-50-3081	MOLEX
6300107	CONN, TERMINAL 22-18 AWG .156 CTRS	08-50-0106	MOLEX

3.2.3 Trig In/Out

Located on the rear panel, these are the hardware trigger input and output connectors.

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

Mating Connector type is:

NH Part	Description	Commercial Part #	Manufacturer
6000262	SMB CO-AX 50 Ohm	131-1403-016	EF JOHNSON

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

3.2.4 Load Positive and Negative

Located on the rear panel, is the load power input connections.

3.2.5 RS232 9pin Connector (Replaced by RJ45 for Ethernet Option)

Located on the rear panel, this connector will mate with a PC compatible nine pin RS232 port if a one to one cable is used. This connection may be used for control of the load in a test system. When this input is used, JMP1 and JMP2 must be in place on the Controller circuit card. Refer to Serial Port Communication section.

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

Mating cable type is:

NH Part #	Description	Commercial Part #	Manufacturer
8030596	CABLE, RS232, DB9 M/F 10' MOLDED	F2N209-10-T	BELKIN

3.2.6 Ethernet Connector (Replaced by DSUB 9 Pin for RS232 Option)

Standard Ethernet 100BaseT RJ45 8 pin connector

Mating cable type is:

NH Part #	Description	Commercial Part #	Manufacturer
8364363	Ethernet Network Cross-over Cable	A3X126-14-YLW-M	BELKIN
-	Ethernet Network Standard Patch Cable	A3L791-14	BELKIN

3.2.7 COMM In/ COMM Out

Located on the rear panel, this connector will mate with NHR S6000 Bus type modules. This connection may be used for control of the load in a test system. If Comm In is used, remove jumpers on JMP1, and JMP2 on the Controller circuit card. Refer to Serial Port Communication section.

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.

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

3.2.8 Parallel In

Located on the rear panel, is used to parallel more than one chassis. Connect to Parallel Out of the previous chassis.

Mating cable type is:

NH Part #	Description	Commercial Part #	Manufacturer
8030657	CABLE, DB25 M/M 6FT SERIAL	BC00703	BLACK BOX

3.2.9 Parallel Out

Located on the rear panel, is used to parallel more than one chassis. Connect to Parallel In of the next chassis.

Mating cable type is:

NH Part #	Description	Commercial Part #	Manufacturer
8030657	CABLE, DB25 M/M 6FT SERIAL	BC00703	BLACK BOX

3.2.10 External Current Control Enable Input

A logic signal input to enable and disable the use of the external current control input (see 3.2.11). If this signal is a HIGH or disconnected at power up, it will NOT enable the external current control input until it is set to a LOW then back to a HIGH.

LOW (0 to 1.5v) = DISABLE external current control input
HIGH (3.5 to 5.0V) = ENABLE external current control input
NOTE: TTL ground reference must be common with serial connector (PC) ground.

3.2.11 Ext Range Switch

This selects the current range when External Current Control Enable is ENABLED. This switch has NO effect when the load has been under the control of the PC.

3.2.12 Ext Current Control Voltage Input

When External Current Control Enable is ENABLED, the Constant Current #2 setpoint is set proportional to the voltage on this input.

There are five programmable setpoints for the 4700 load. Constant Current #1, Constant Power, Constant Voltage, Constant Resistance, and Constant Current #2. None, one, some, or all may be enabled at any one time. The first four modes mentioned are controlled by the computer interface port. Constant Current #2 is controlled by the External Current Control Enable input and the Ext Current Control Voltage Input. Of ALL the enabled modes, the one that is most restrictive to current flow will prevail.

0V = 0A
10V = 100%A of the current range.

NOTE: The voltage must be common with the load input negative bus bar.

3.2.13 Current Monitor Output

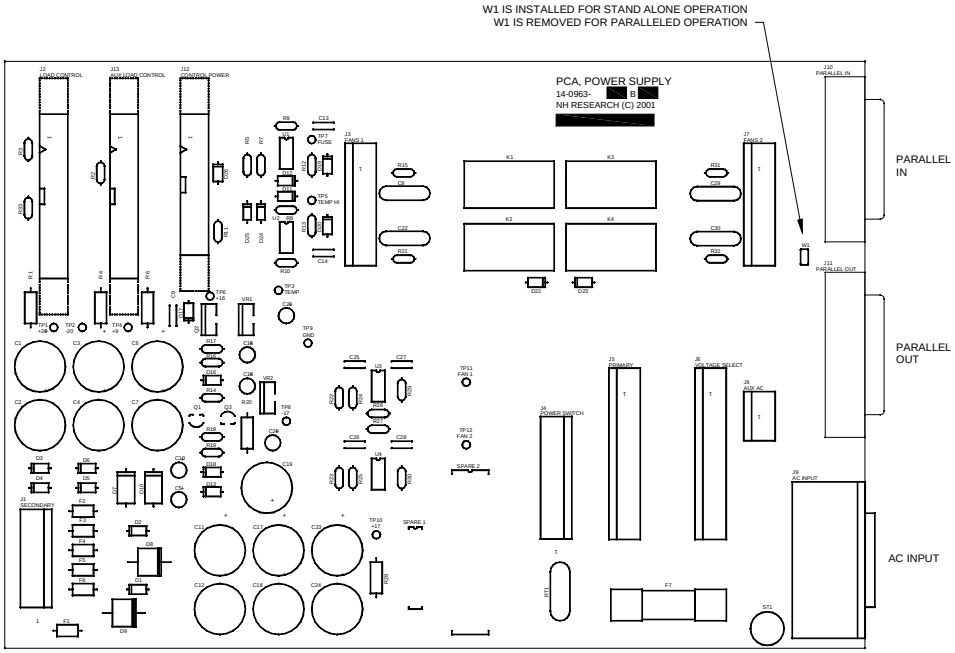
This output voltage is a voltage proportional to the amount of current through the load.

0V = 0A
10V = 100%A of the current range.
NOTE: The voltage output is common with the load input negative bus bar.

3.3 Paralleled System

One master and up to five auxiliary chassis may be paralleled. The master is on top, auxiliary 1 under the master, auxiliary 2 under auxiliary 1 and so on to the last auxiliary on the bottom.

Only a master has a Controller circuit card. When a master is operating stand alone, W1 on the Power Supply circuit card must be installed. Auxiliary chassis do not have a Controller circuit card and cannot operate stand-alone.

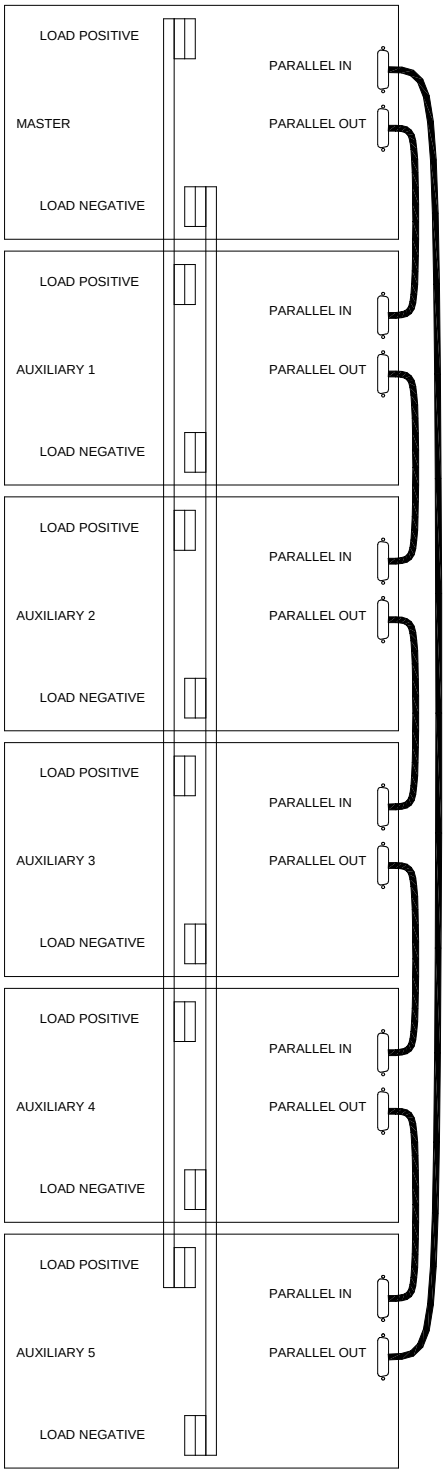


When a master or auxiliary chassis is operating in parallel:

1) W1 on the Power Supply circuit card must be removed.
2) Both Parallel In and Parallel Out must be connected.
3) All “Load Positive” connections must be tied together.
4) All “Load Negative” connections must be tied together.

Connect Parallel Out of the master to Parallel In of auxiliary one. Connect Parallel Out of auxiliary 1 to Parallel In of auxiliary 2 and so on to the last auxiliary chassis. Connect Parallel Out of the last auxiliary to Parallel In of the master.

3.3.1 Paralleled System Rear View



3.3.2 Paralleled Connection and Wiring

Each 4700/4750 load is capable of extreme current. The loads must be wired appropriately to prevent wire damage. Appendix B shows how to wire the 4700/4750 loads taking advantage of the full current rating of the load. As shown, the wires must be distributed along all the buss bars. If the current is limited by the DC Source(UUT) then there is no need to wire for full load current. **WARNING: Using a higher current rated DC Source than the system is wired for may damage external load wiring.** Use the National Electric Code Ampacity tables to select wire type and size.

The physical location of the loads is critical. Master and Auxiliary load boxes must be mounted directly above and below each other using the buss bar technique as in Appendix B. Communication from one load box to the next via the parallel cable may be disrupted if the buss bar from load to load is not used. P/N 1109207 BUSS BAR KIT

3.4 Software Installation

3.4.1 Software Installation from DVD

Close all programs that are currently running in windows. Insert the DVD into the drive, if your drive is configured for Autoplay the setup program should start. If Autoplay is not enabled, you will need to view the contents of the disk and double click on 'Setup' to start the installation.

Follow the prompts on the screen to install. You will need to reboot during the process.

4. USER OPERATION

4.1 Control Power Switch and Indicator

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

4.2 Error Indicator

The error indicator is located on the front panel and indicates either a fuse has blown or the load has detected an over temperature condition.

4.3 Status Indicator

This indicator is located on the rear panel. This LED blinks at a one hertz rate during normal operation. This LED blinks at an 8-hertz rate during an error condition. If the LED is not blinking, remains off or on, the CPU is not operating.

4.4 COM Indicator

This indicator located on the rear panel will blink when the computer is communicating with the load. If it remains off, the load is not receiving commands at its address. If it remains on, the load received its address with an incomplete communication packet.

4.5 Ethernet Connector Indicators (with Ethernet Option)

Green Link LED indicates network link is established. Lights when both ends of network cable are connected to powered-on 100BaseT devices.

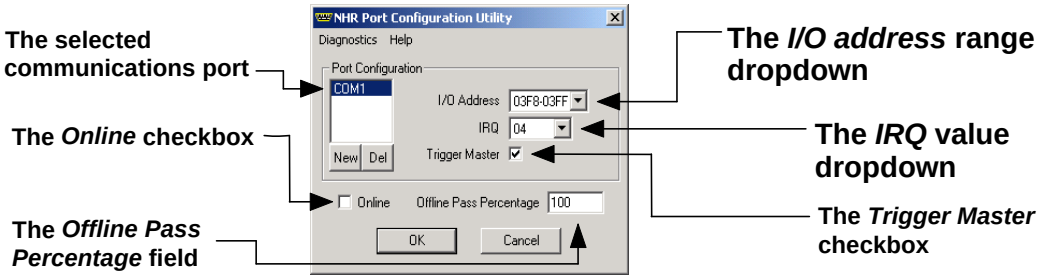
Yellow Activity LED indicates any input or output occurring on the network.

4.6 Ext. Range Switch

This selects the Current range when External Current Control Enable is ENABLED. This switch has NO effect when the load has been under the control of the PC.

4.7 Port Configurator – Serial RS232 COM Interface

In the NHR Port Configuration Utility, you describe/re-describe to the software the serial and Ethernet communication ports it has available for communicating with hardware devices. The NHR Port Configuration Utility can only be used to configure/re-configure the standard serial communications ports.



4.7.1 Port Configurator – Ethernet Interface

Please see Appendix A describing Ethernet communications.

4.7.2 Toggling the Online/Offline mode.

With this checkbox unchecked, the software will run in the Offline mode, and will not attempt to interact with any hardware devices. When the software is installed, its default mode is Online.

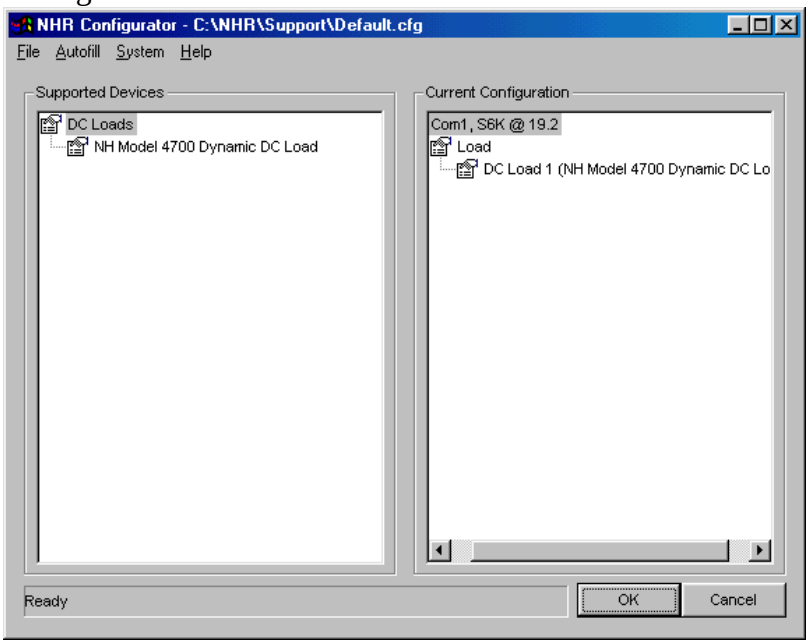
Check or uncheck the online checkbox, as you require.

NOTE: The Offline Pass Percentage field has no effect on stand-alone instruments.

4.8 Configure Hardware

Pressing configure hardware will display a dialog that allows you to modify your hardware configuration.

The NHR Configurator has two frames, the Supported Devices frame, and the Current Configuration frame



The Supported Devices frame contains the list of all NHR supported hardware drivers installed on your PC. This may only list a single device type like the NHR 4700 DC Load or it may include other NHR supported hardware.

The Current Configuration frame shows the list of implemented device drivers in the Current Configuration file, usually named default.cfg. This configuration file can be customized to meet your requirements.

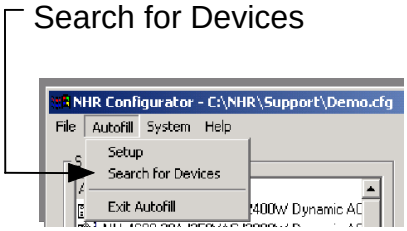
You will notice that the hardware devices listed in the Current Configuration frame are listed by logical names such as DC Load 1, with their more descriptive name in parentheses following it. The logical names are how you will refer to this specific piece of hardware from this point on.

4.8.1 Adding New Devices

If you hook up additional NHR supported hardware to the system (like a second load), the use of the Search for Devices option in the Autofill menu of NHR Configurator is the recommended method for adding new hardware device drivers to the Configuration file.

4.8.2 Autofill – Online mode only

The Search for Devices option **ONLY** works on NHR hardware devices connected to the serial and Ethernet communication ports; and only when in Online mode. Using this method Configurator does most of the work for you; it "autofills" much of the setup information that the software would otherwise ask you to supply. It does this because the configurator can find, and ask the NHR hardware devices about themselves.



Search for Devices in the Autofill menu

4.8.3 Updating Device Firmware

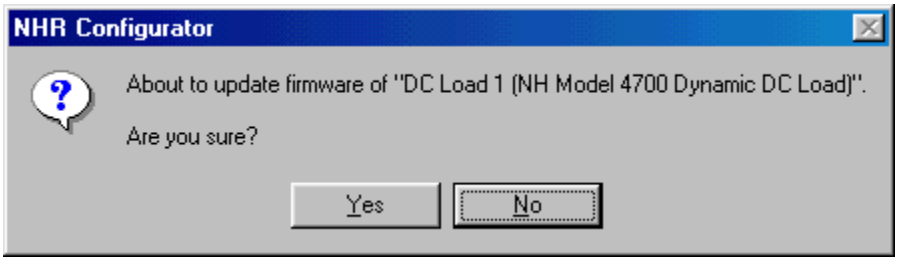
The firmware is really software that "lives" on a computer chip built into an NH Research hardware device. Some of NH Research's hardware devices allow you to update the firmware.

Since updating firmware is an interactive process, you can only update firmware while on-line.

Right-click the name of hardware device you want to update – the hardware device menu opens.

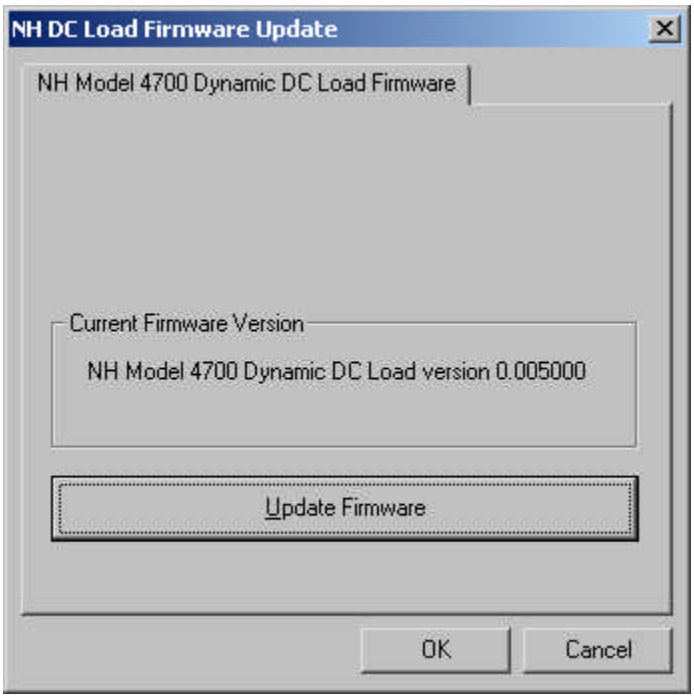
If the menu item Update Firmware is enabled, then the hardware device you right-clicked can have, its firmware updated; if the menu item Update Firmware… is disabled then the hardware device cannot have its firmware updated.

Select Update Firmware…



Click the Yes button.

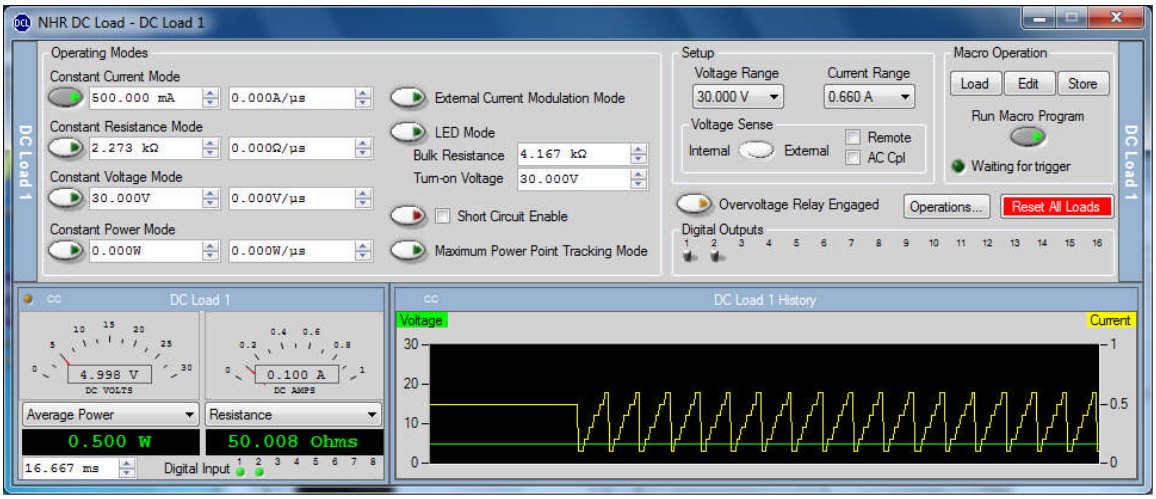
This will take you into a dialog that shows the current firmware version and if you press "Update Firmware", you will be prompted for the new .hex file. Once downloading is begun, do not interrupt the process.



4.9 NHR IVI Instrument Panel

The NHR IVI Instrument Panel (referred to as the softpanel) can be started from the desktop icon or the start menu in the NH Research program group.

The panel should look like this after loading…



Important note: Some of the modes and features presented in screen shots and text within this document may not be available with your particular load.

The soft panel can control many different load models, and the capabilities of each load vary from model to model. If a capability is not supported, the feature will be disabled on the soft panel.

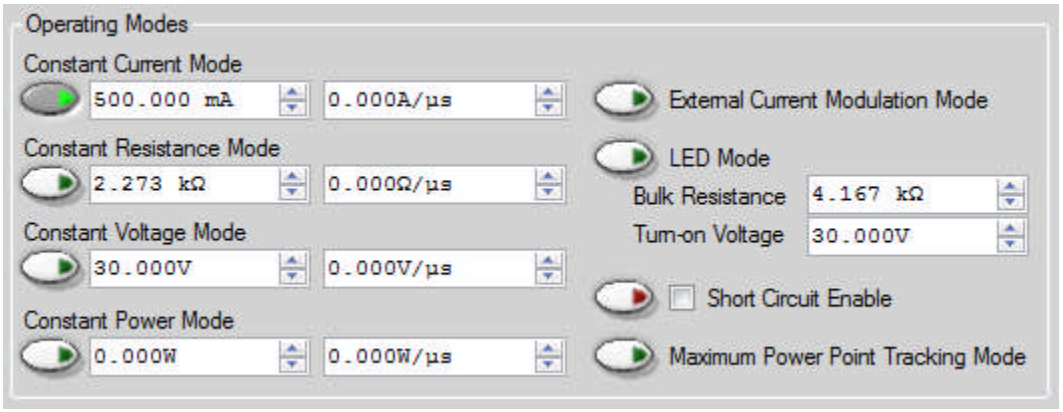
Please refer to the Specification section to determine the capabilities of your load model.

If there is more than one load in your configuration, the softpanel will adjust itself to maximize the number of loads visible at one time. Depending on your configuration and computer monitor, your softpanel may appear slightly different, but the operations remain the same.

The title bar and side bars contain the logical name of the DC Load you are currently controlling. This softpanel can control any number of physical loads, including NHR loads of different types. Use the Control section to set the various features of the selected load. To switch loads, simply click anywhere within the measurement or history window of the desired load. Switching from one load to another does NOT affect the settings. The Control section is automatically updated to reflect the state of the selected load.

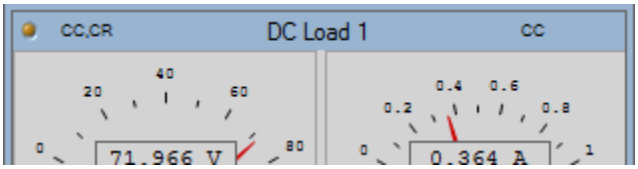
The panel allows full control of the DC load. The panel is divided into 8 sections.

4.9.1 Operating Modes Section



This is the section used to control the principal operating characteristics of the load. This load supports any number of modes enabled at a time. To enable a mode, press the corresponding switch. If all the switches are off, the load is off (high impedance). In the sample above, Constant Current mode is enabled.

The measurement section of each load contains information indicating which modes are enabled for the load, and which of the enabled modes is the active one. The text near the left-hand measurement active LED indicates which modes are enabled: CC for constant current, CR for constant resistance, etc. On the right-hand of the title bar the active mode is indicated (note: not all load models support the reporting of the active mode):



The active mode is the mode that is the most restrictive of the current being drawn. It is dynamic and will change based on the conditions present. For example, suppose you have a 12V 100A source hooked up to the load. The following table shows a few examples of how the various modes would interact.

Enabled Modes	Active Mode	UUT Volts	UUT Amps
CC at 50A	CC	12	50
CR at 1ohm	CR	12	12
CP at 1000W	CP	12	83.33
CV at 10V	CV	10	110
CC at 50A CR at 1ohm	CR	12	12
CC at 50A CR at 1ohm CP at 100W	CR	12	12
CC at 50A CR at 1ohm CP at 1000W CV at 10V	CR	12	12
CC at 50A CP at 1000W CV at 10V	CC	12	50
CP at 1000W CV at 10V	CP	12	83.33
CV at 10V	CV	10	105

When the External Current Modulation Mode is enabled, the load will attempt to draw a constant current proportional to the voltage on the External Current Control Voltage input. When the input is at zero volts, the load will be set to zero amps; 10 volts equals a current draw of 100% of the current range.

Short circuit mode is higher priority than the other modes. If it is enabled the load will go into short circuit mode regardless of the other modes that are enabled. Because of this, activating the short circuit mode requires two actions. First, arm the mode by checking the Short Circuit Enable checkbox. Second, click the button to the left of the

enable (the one with the red LED). The short will be applied for as long as the button remains down. Click the button again to release the short circuit mode.

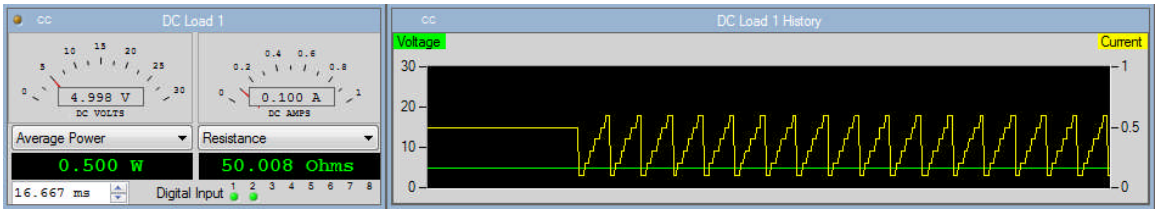
The slew rate for each mode can be set and applies only when a programmed value is changed. For example (assuming a 12V 100A UUT):

1) The load is set in CR mode at 1ohm with a 1ohm/s slew rate; the load will be drawing 12A.
2) Set the load to 2ohms. The load will decrease the current from 12A to 6A linearly over a period of one second.

When the slew rate is set to zero, the load will transition to the new state as fast as possible.

NOTE: Slew rates do NOT apply when the load is reacting to a change in the UUT.

4.9.2 Measurement Section



If enabled, the load will make measurements over a period defined by the aperture. To reduce the effect of noise, increase the aperture; to make faster, less accurate measurements, reduce the aperture. The aperture window is located in the lower-left corner of the measurement section. Each load can define its own aperture size.

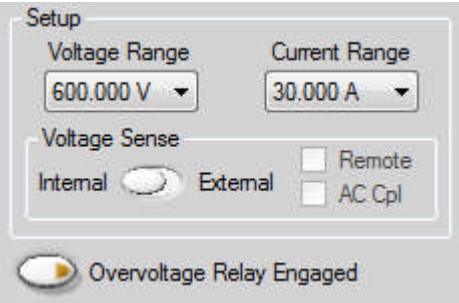
Each time a measurement is taken, the load will display the active voltage and current in the analog gauges. Two additional measurements are available in the digital gauges. Use the dropdown lists above each digital gauge controls to select the desired additional measurements.

The amber LED in the upper-left corner flashes whenever a measurement is active. You can click this light to disable the measurements. Click again to re-enable.

The measurement history chart displays the past voltage and current measurements. It is ONLY updated when measurements are active. Depending on the number of loads in your configuration, there may not be enough screen space to display the history chart all the time. In this situation, the history chart shares screen space with the measurement window and a "+" sign will be visible in the upper-right corner. Pressing the "+" button will toggle between the measurement window and the history chart.

If the load supports Digital Inputs (DINs), the state of each input is displayed via an LED. When the LED is lit, the DIN is high; when off, the DIN is low.

4.9.3 Setup Section



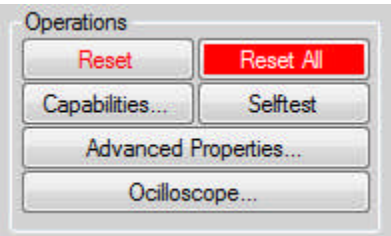
This section sets up the load's operating ranges and controls whether the external sense is enabled and whether the overvoltage relay is engaged.

The voltage and current ranges affect the operating range of the hardware. When either is changed, the load will go to the off state, and the settings and slew go to their default state for that range. Changing the range has the same effect as RESET.

Switching voltage sense to external will cause the load to use the voltage present on the external sense connector for all metering. If the external sense is not connected, you will measure 0V. Some load models support AC coupling and "remote" measurements. When remote is selected, the load will disregard all voltage measurements and restrict its operating mode to constant current. This allows external voltages to be monitored by the load measurement circuitry without affecting the behavior of the load itself.

Selecting overvoltage relay engaged will activate the internal relay, which causes the overvoltage input to be connected in parallel with the load. CAUTION: This relay is only rated for 10A. If the load is drawing more than 10A, the panel will prevent you from engaging the relay. However, there is no additional protection and if you try to draw more than 10A damage to the relay may result.

4.9.4 Operations Section



4.9.4.1 Reset

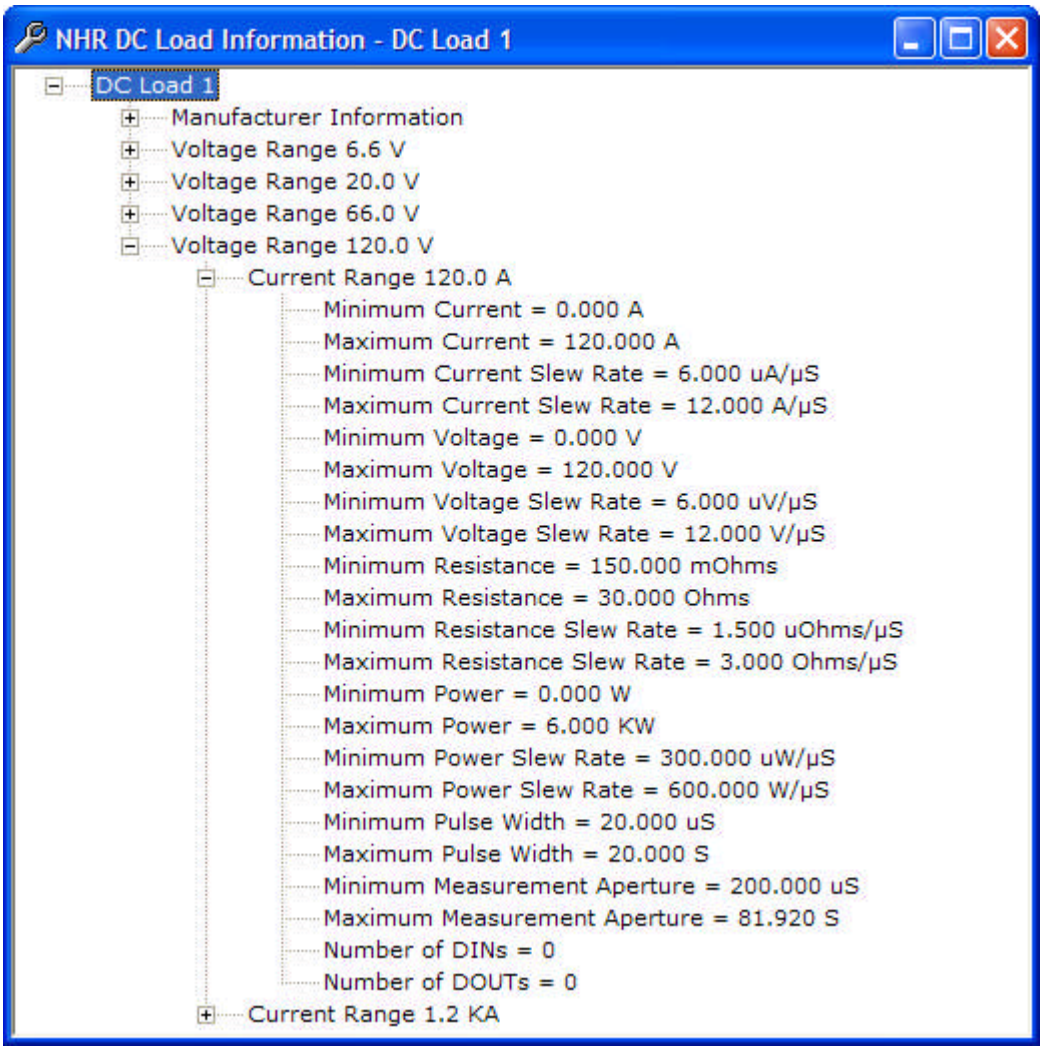
Pressing reset will reset the selected load and set all settings back to default. After reset, the load will be off.

4.9.4.2 Reset All

This button will reset all the modules in the panel to their default settings.

4.9.4.3 Capabilities

Pressing capabilities will display a dialog that allows you to see the minimum and maximum settings for all values of the selected load for any range you choose.



The Manufacturer Information section contains useful data such as the load's serial number, hardware and firmware revision numbers, and date of last calibration.

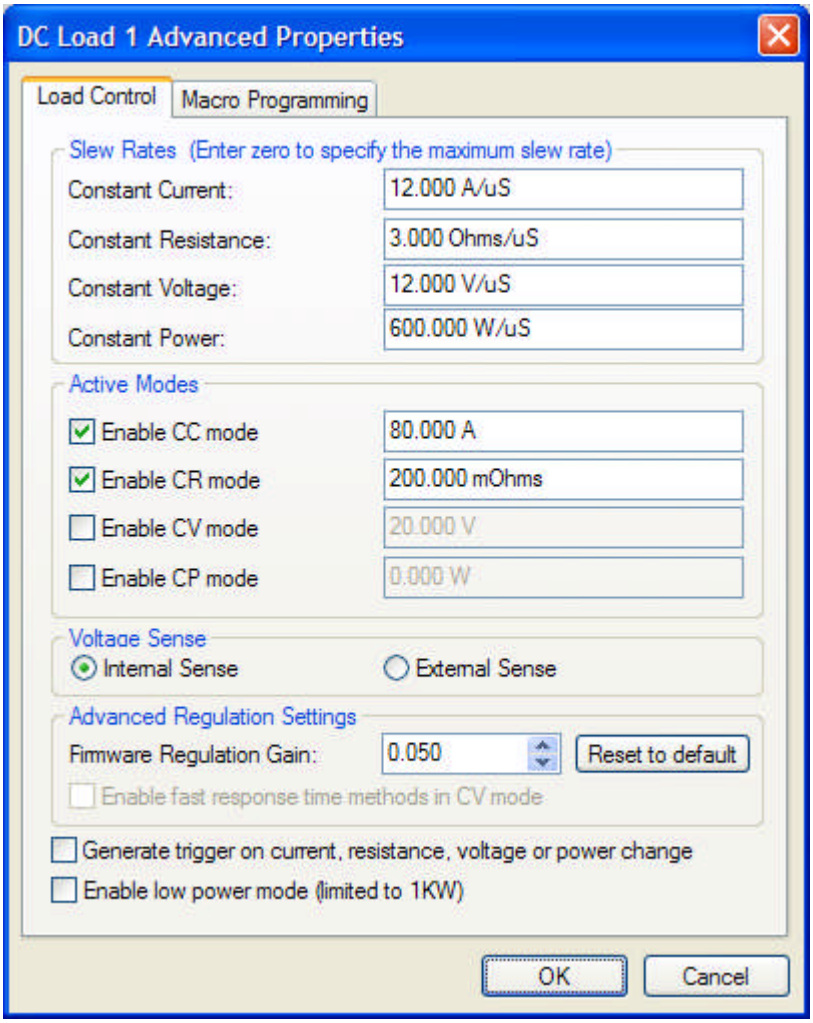
4.9.4.4 Selftest

Pressing self-test will reset the selected load then perform a built-in test. After the test is complete, a pop-up dialog appears informing the results of the test.

4.9.4.5 Advanced Properties

Pressing advanced properties will display a dialog that allows you to set properties that, while rarely used, can be beneficial when operating the load.

From the dialog below, you can see that the advanced property dialog contains fields that duplicate those found on the softpanel itself. When OK is pressed, the softpanel will refresh itself to reflect any changes made within the advanced property dialog.



If an advanced property is disabled, that feature is not available on the selected load hardware. The unique advanced properties are listed below.

4.9.4.5.1 Firmware Regulation Gain

Regulation gain is used to control the rate at which the load attempts to regulate based on the loads measurements.

This value is the percent (expressed as a decimal such that 1.00 = 100%, 0.15 = 15%, etc.) change the load will allow in each measurement sample while attempting to correct an error between the set and measured value. Setting this value higher will make faster corrections at the risk of oscillations.

For example, if the regulation gain is set to 0.30, 30% of the difference between set and measure will be done each sample. Therefore, the correction could look like this:

Programmed set = 10A CC
Sample 1: Internal set = 10.000A, measure 9.980A
Sample 2: Internal set = previous set + 0.3 * (10.000 - 9.980) = 10.006, measure 9.986A
Sample 3: Internal set = previous set + 0.3 * (10.000 - 9.986) = 10.010, measure 9.990A
Sample 4: Internal set = previous set + 0.3 * (10.000 - 9.990) = 10.013, measure 9.993A

4.9.4.5.2 Enable Fast Response Time Methods in CV Mode

This property Controls the loop response rate of the load when constant voltage is the active mode. When enabled, the load will increase the speed at which it adjusts the voltage level. The fast loop response mode is more susceptible to oscillations.

4.9.4.5.3 Generate Trigger on Current, Resistance, Voltage or Power Change

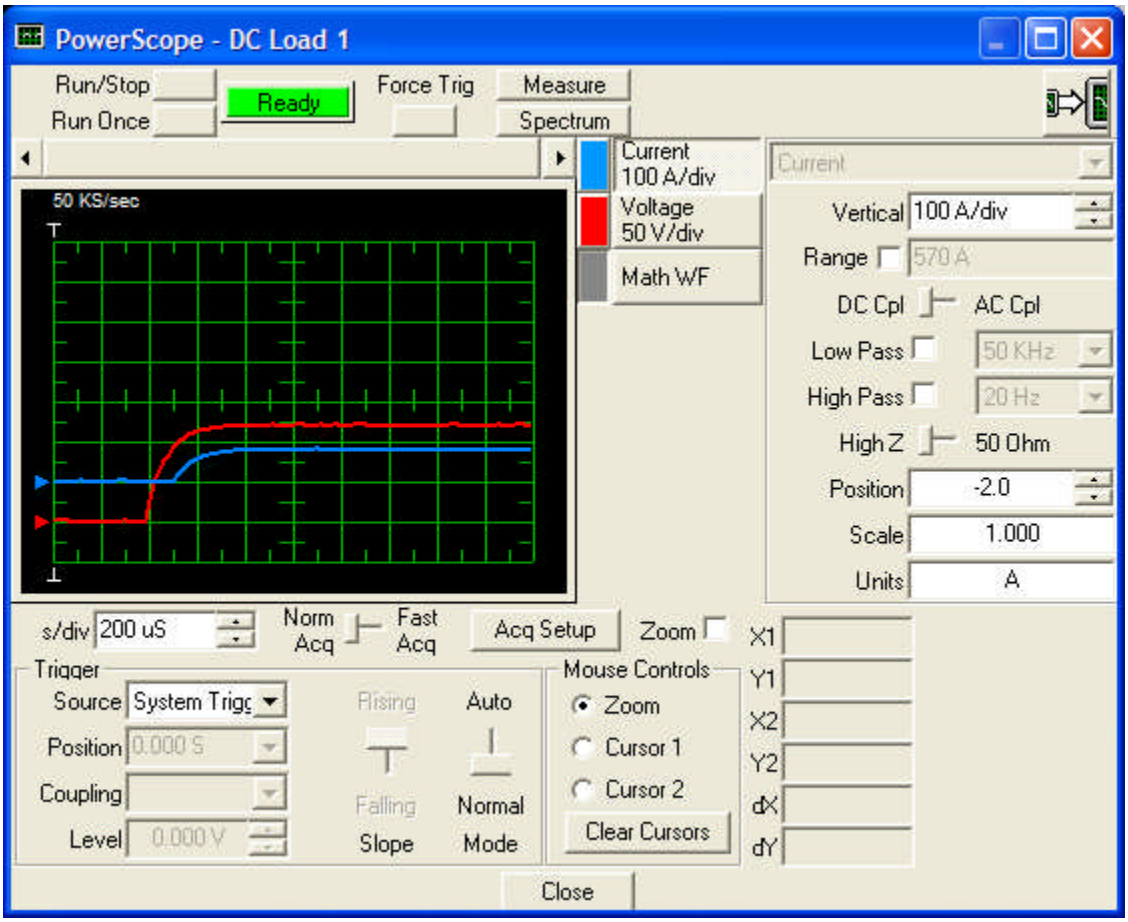
When enabled, a trigger pulse will be sent on the communications line whenever a current, resistance, voltage or power value is sent to the load. Due to the design of the softpanel, this will generate a continuous trigger pulse stream when enabled. The use of this property is more practical when you are creating your own instrumentation software using the supplied instrument driver.

4.9.4.5.4 Enable Low Power Mode

This mode restricts the load hardware to use a single internal power board, which is capable of a maximum of 1KW, increasing the resolution and accuracy of the load in low power situations. With this mode enabled, the load can draw up to 20 amps in the low current range and 200 amps in the high current range. The voltage capabilities remain unaffected.

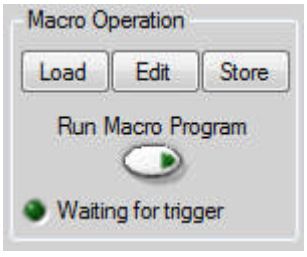
4.9.4.6 Oscilloscope

To display the oscilloscope panel for the selected load, press the Oscilloscope button. When you do, this panel is displayed.

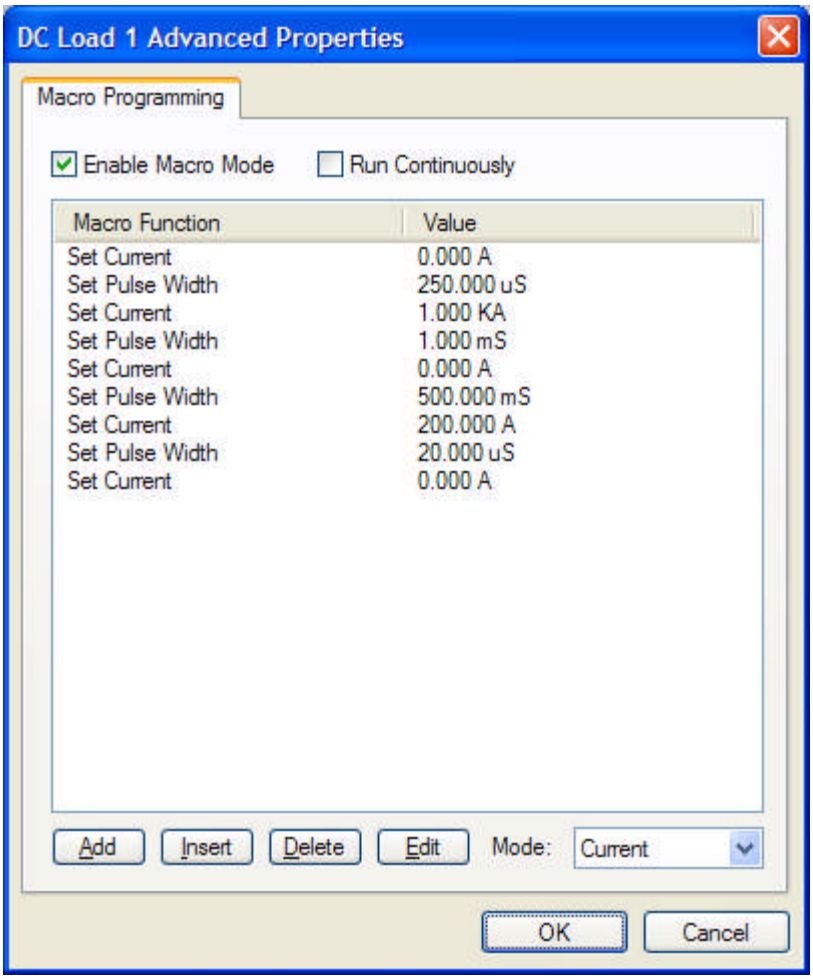


Operation of the oscilloscope panel is similar to a traditional scope. It is, however, limited to the capabilities of the load hardware.

4.9.5 Macro (Transient) Operation Section



Macro programs are sequences of load settings which can be played back to create a sophisticated pattern with precise timing. For example, if you want to create a 0 to 1000A pulse 250uS wide then 1mS later a 0 to 200A pulse 500mS wide you would press the Edit button and create a sequence like this…

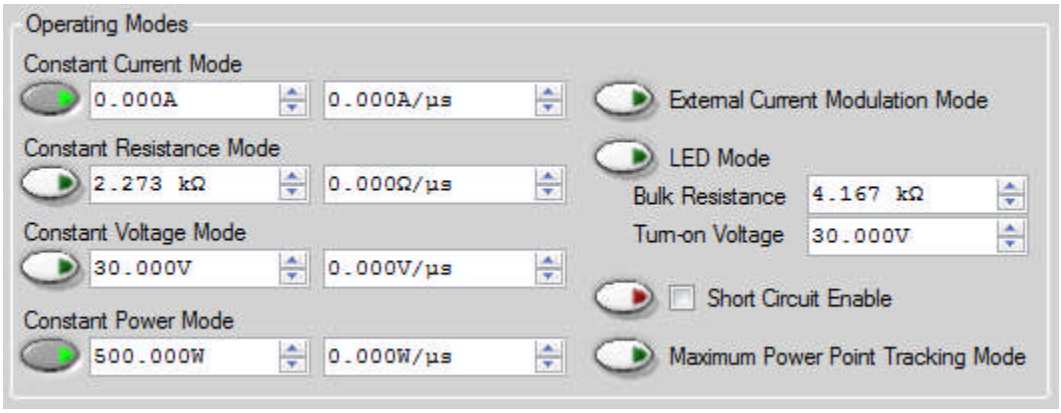


If you want the sequence to repeat continuously, check the “Run Continuously” checkbox and it will continually repeat as long as the “Run Macro Program” button is pressed. If it is not checked, the sequence will run once each time the “Run Macro Program” button is pressed.

If the macro program contains a wait for trigger command, the sequence will pause at that step and wait for a system trigger to occur. The “Waiting for trigger” LED will light and a Force Trigger button will appear so you can manually generate the trigger should the need arise.

The macro program requires the selected mode to be active in order to run. In the above example, we created a Constant Current program. If constant current mode is not enabled, a software fault will inform you that it must be enabled before the program can be run.

When running the macro program, all settings are in effect. In this example, if the settings look like this…

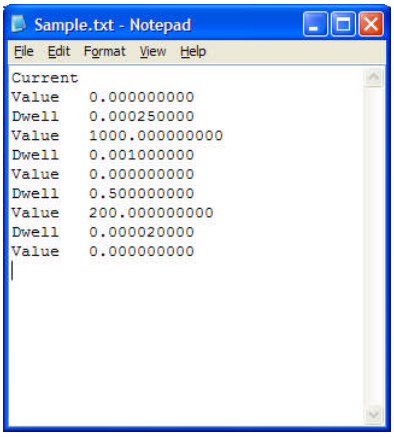


…then the maximum power will be limited to 500W regardless of the current setting in the transient program.

The Load and Store buttons allow you to save macro sequences and recall them for use at a later time. The file format is an ASCII file as follows:

- The first line indicates the active mode ("Current", "Resistance", "Power" or "Voltage"). Only the first letter is required ("C", "R", "P" or "V").
- The following lines indicate the desired commands and associated values. Commands and values are separated by spaces or tabs:
  - "Value", or V, is the "set" value for the active mode
  - "Slew", or S, is the rate of change for the value
  - "Dwell", or D, is the pulse width
  - "Trigger", or T, is used to indicate that the macro should wait for a trigger before continuing execution. There is no "value" associated with a trigger.

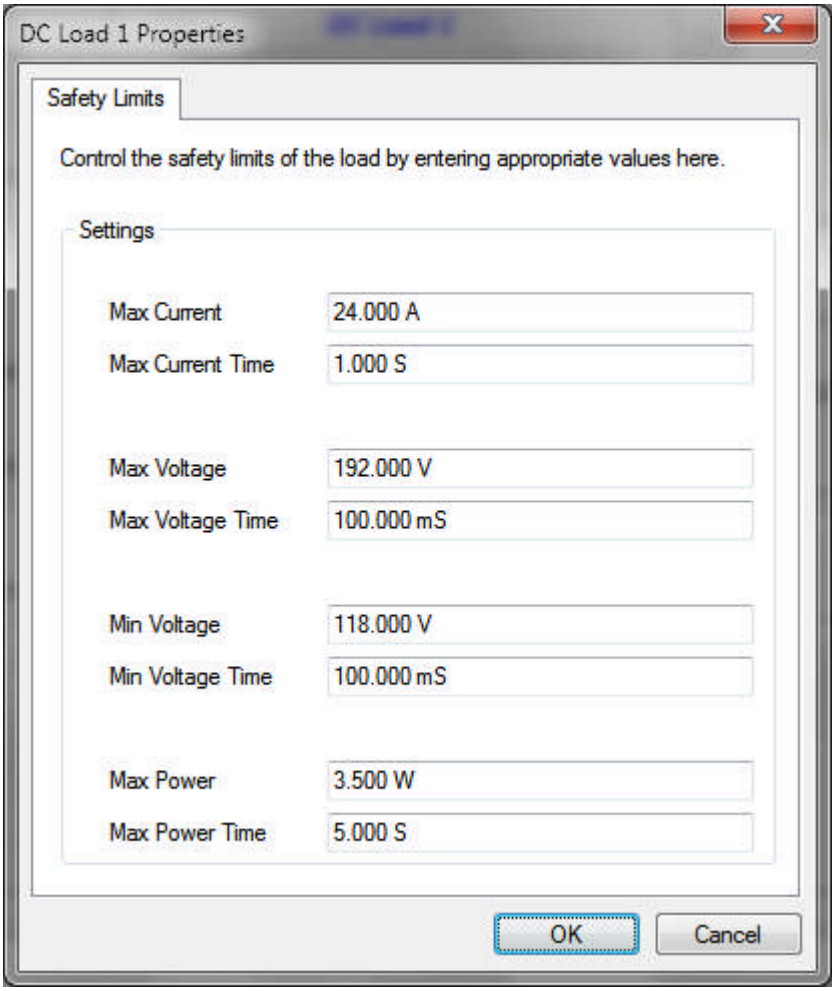
A macro can contain up to 100 command/value pairs. This is the sample defined above:



4.9.6 Safety Section

(Note: depending on your monitor resolution, this section may be part of the Operations pop-up dialog.)

On loads that support Safety Limits, pressing the “Limits” button displays the Safety setup page:

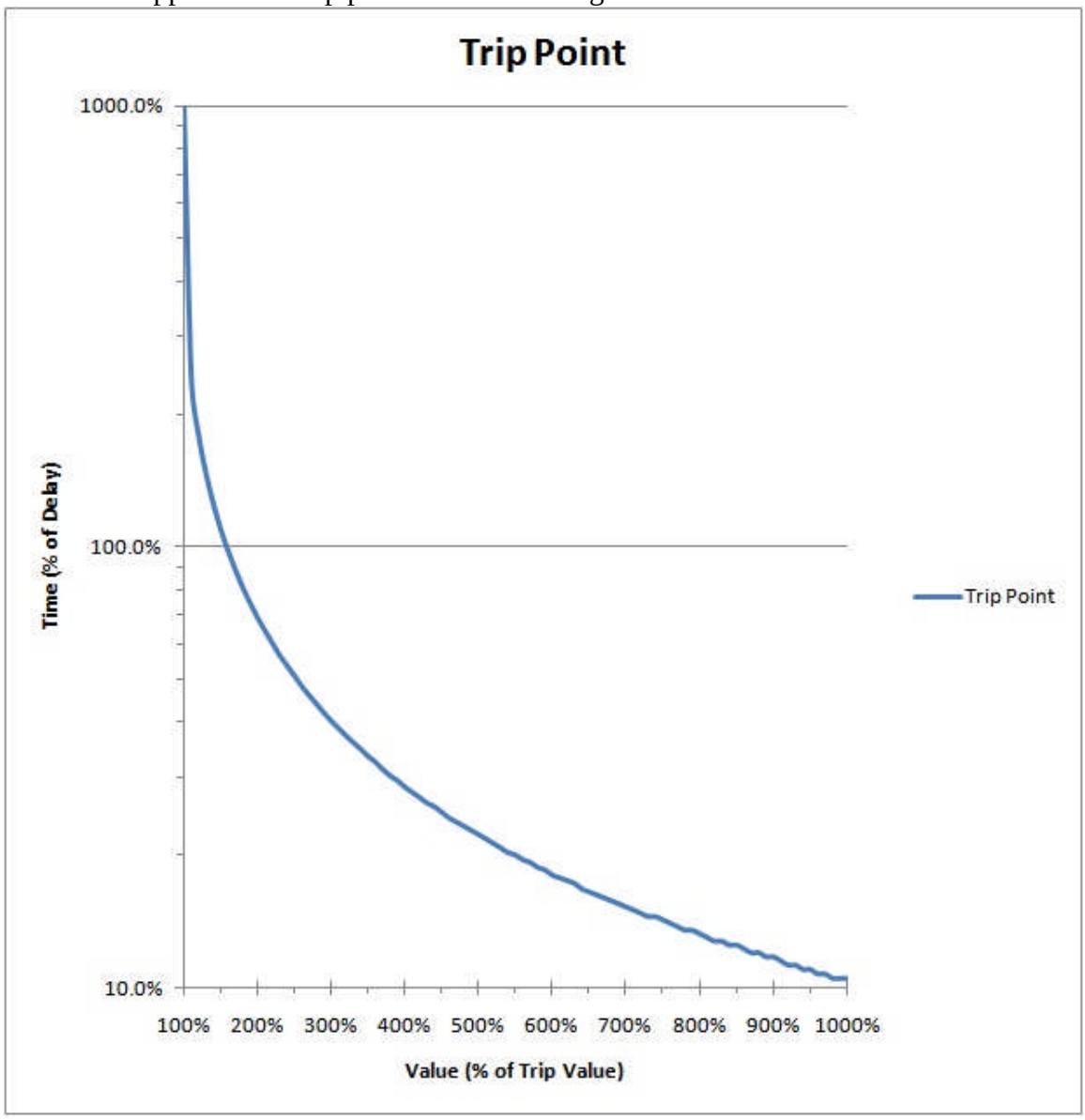


The safety setup page allows you to set safety trip points. In essence, you are defining a “programmable circuit breaker” for current, voltage, and power. You will define a value and a time for each characteristic. Note, if you set the time value to zero, it will act as an instantaneous fuse. That is, it will trip off the instant it sees a value that exceeds the programmed setting. This often leads to false trips due to high frequency noise spikes. It

is usually better to set a small (non-zero) time to avoid false trips but still provide fast trip response.

The safety trip algorithm mimics the behavior of a circuit breaker. Like a circuit breaker, the algorithm will not be affected by noise and the trip point delay will vary with the amount of overload. That is, the higher the overload, the faster the trip. The parameters that can be set are the trip value and the time value.

Here is the approximate trip point curve of the algorithm.



For example, for a 10A maximum current safety trip point and a time value of 5 seconds:

If the load draws 20A (200% of trip value) it will trip off in about 3 s (65% of time value)
If the load draws 15A (150% of trip value) it will trip off in about 5 s (100% of time value)
If the load draws 12A (120% of trip value) it will trip off in about 9 s (180% of time value)

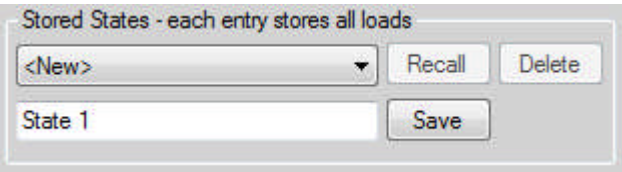
To set the load to default to the programmed safety limits, use the “Save Safety Settings as Default” button in the “Save/Recall Settings” section.

4.9.7 Digital Output Section

Many NHR load models provide general-purpose Digital Outputs, useful for fixture control. The state of the digital output matches that of the corresponding toggle switch. To set the digital high, simply move the switch to its up position (as shown in #2 above); move the switch to its down position for a digital low.

4.9.8 Stored States Section

(Note: depending on your monitor resolution, this section may be part of the Operations pop-up dialog.)



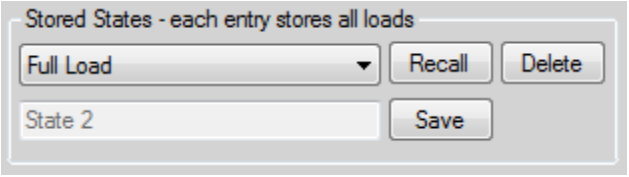
As a convenience, all load settings can be saved to the hard disk for later recall. You can save as many different states as you have room on your hard drive (for all intents and purposes unlimited). All load settings are saved including the transient program. Each state stores the settings for all loads being controlled by the softpanel (one state saves all).

To save the current settings to a new state description

1. Set up all load settings as desired.
2. Select <New> in the “Stored States” selection box.
3. Modify the description if desired (the default will be “State #” which will be a unique name).
4. Press the “Save” button.

To recall a saved state

1. Select the desired state to restore in the “Stored States” selection box. In this example, “Full Load” was chosen.



2. Press the “Recall” button. ***WARNING!*** The saved state will be restored and become active immediately! If the state was stored with short circuit turned on, a short will be applied as soon as you press recall.

5. PROGRAMMING

5.1 General

NH Research provides an IVI-compliant instrument driver with the softpanel, along with support files for various popular development environments. The driver contains functions for selecting, configuring, taking measurements from and controlling the instrument.

Complete, context-sensitive help is provided for every method and property via a compiled HTML help file, `NHRDCLoad.chm`, which is located in `C:\Program Files\IVI Foundation\IVI\Drivers\NHRDCLoad`.

Samples are located in the `C:\NHR\Samples\NHR DC Load` folder.

5.2 Microsoft .NET Languages

You use the IVI-COM instrument driver to control the load in a .NET program. Interop assemblies are used in .NET environments, such as C# and VB.NET, to access COM components. The necessary interop assembly is deployed and registered on the system during software installation. The "Samples" folder contains a C# program that illustrates the use of the load driver in the .NET environment, as well as the source code for the softpanel.

5.3 Microsoft Visual Basic 6.0

You use the IVI-COM instrument driver to control the load in a VB6 program. References to COM drivers are used in VB6 to gain access to the load hardware. The necessary driver is deployed and registered on the system during software installation. The "Samples" folder contains a VB6 program that illustrates the use of the load driver in this environment.

5.4 National Instruments LabVIEW

A palette set providing direct access to each of the instrument driver functions is included with the software installation. NOTE: for LabVIEW to see the palette, you must copy or move the `NHRDCLoad` folder located in `C:\NHR\Samples\NHR DC Load\LabVIEW\instr.lib` into the LabVIEW instrument sub-folder, which is usually located in `C:\Program Files\National Instruments\LabVIEW X.X\instr.lib`.

From a LabVIEW block diagram, traverse the Instrument I/O and Instrument Driver menus to find the NHR DC Load palette.

Alternately, a LabVIEW programmer can access the IVI-COM driver directly using LabVIEW's support for ActiveX drivers.

5.5 National Instruments LabWindows/CVI

A function panel providing access to the driver is included with the software installation. The “Samples” folder contains a LabWindows program that illustrates the use of the load driver in this environment. NOTE: depending upon where you install the files, you may have to browse for the instrument function panel (`NHRDCLoad.fp`, usually located in `C:\Program Files\IVI Foundation\IVI\Drivers\NHRDCLoad`) before the sample will compile.

APPENDIX A – ETHERNET COMMUNICATION

Windows Configuration

The setup required in Windows will depend on the physical connection made to the instrument. Please refer to the following diagrams to determine which setup you will need. Screen shots may show Windows 2000 or XP, but functions are the same.

Computer with Two Network Interfaces

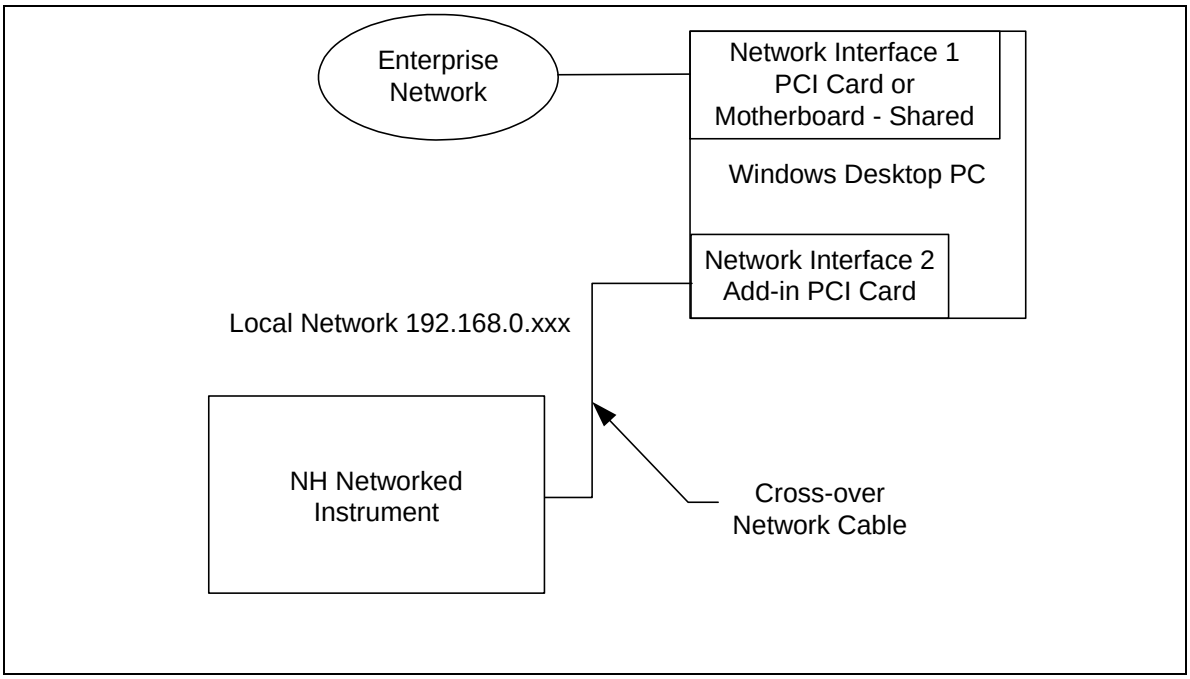


Figure 1 – Direct connection to a PC with Two Network Interfaces

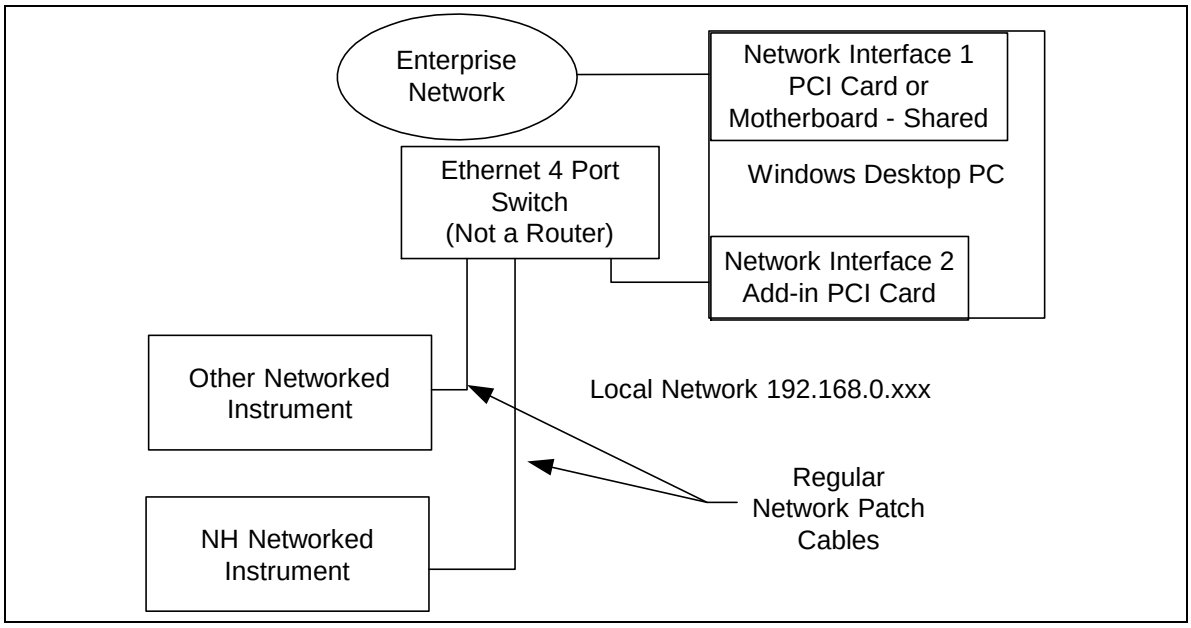
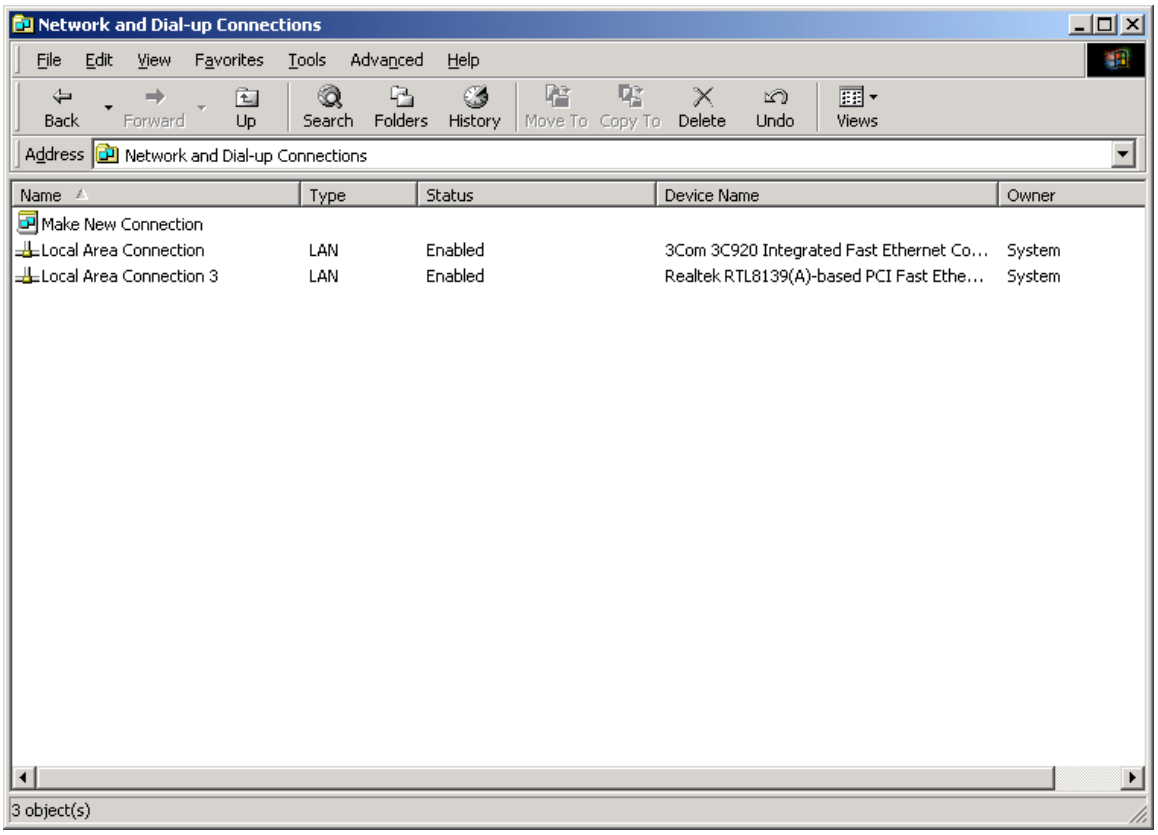


Figure 2 - Switch Connection to PC with Two Network Interfaces

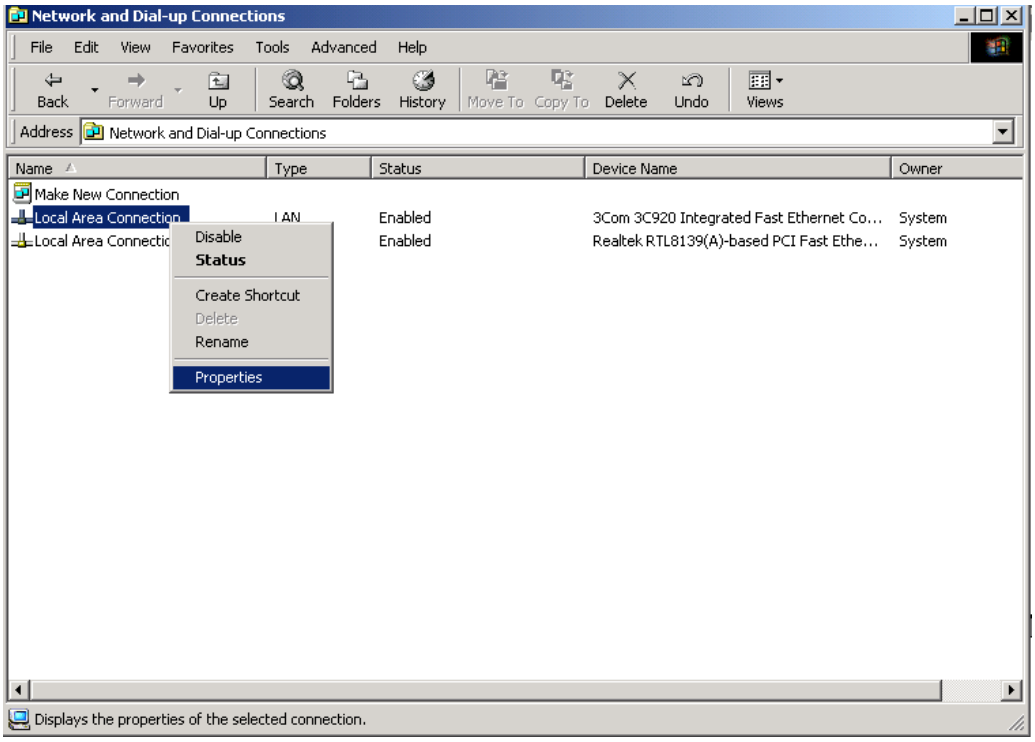
Configuration for PC with Two Network Interfaces (Direct or with Switch)

After installing add-in card, Windows should install necessary drivers on power-up. An instrument or one port of the Network Switch must be plugged into the second PC Ethernet port before proceeding to configure the network sharing. This configuration only has to be performed once; it is then saved in Windows and will remain regardless of whether the computer is powered up with or without something connected.

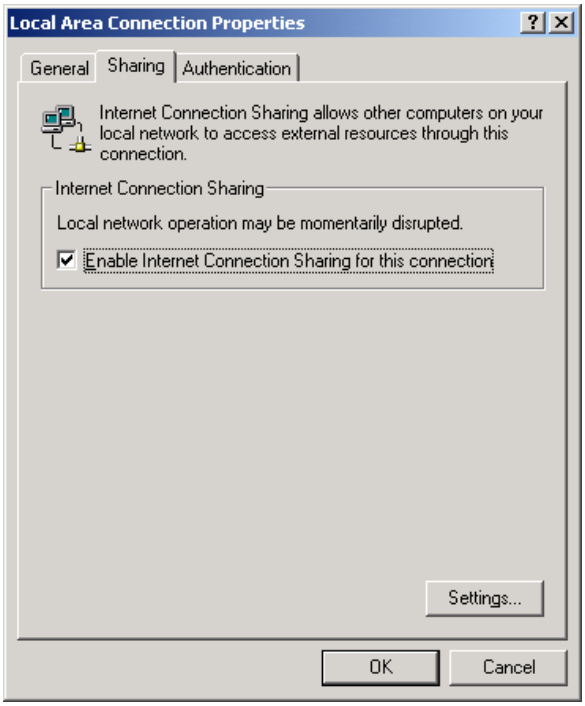
Using Windows Control Panel, open Network and Dial up Connections window. Set the Windows Views option to Detailed. Verify that two local area connections are present and both are enabled. Instruments must be powered up for the enabled status to appear. The next sharing step won't work if both connections are not enabled.



Right-click on the Local Area Connection NOT connected to the networked instrument. This is the one typically connected to the company network. Select Properties.

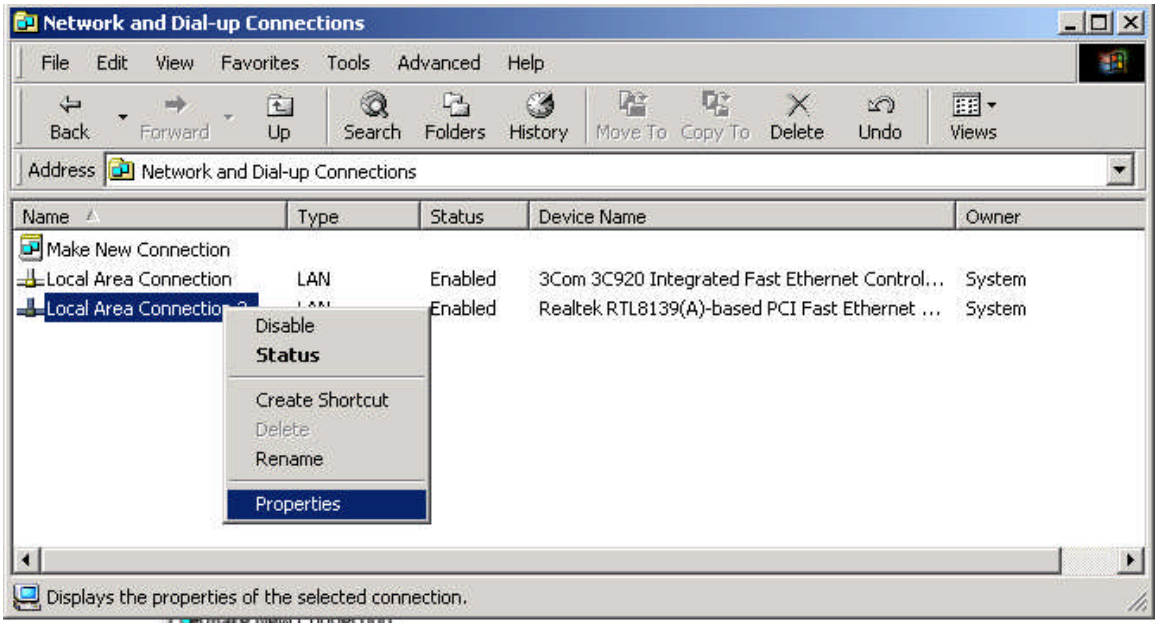


Select the Sharing tab in the Properties window and check Enable Internet Connection Sharing for this connection.

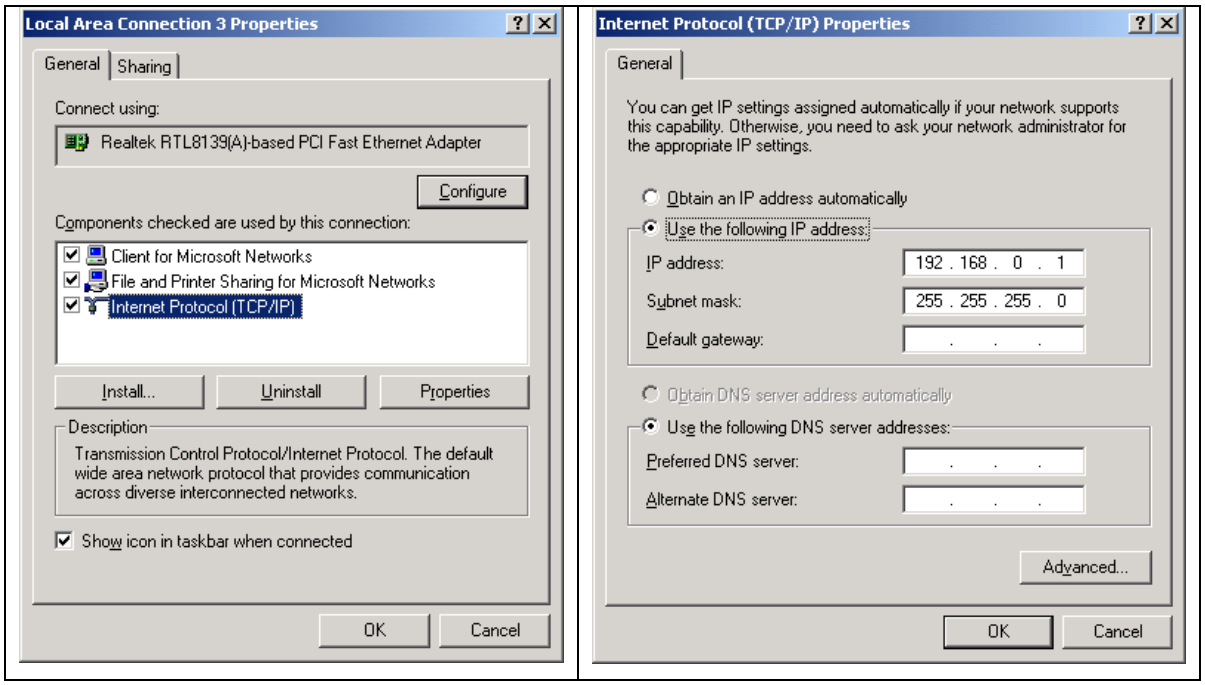


If a warning appears about changing the IP address, select Yes to share connection.

Using the Windows Control Panel; open Network and Dial up Connections window again, right-click on the OTHER Local Area Connection - the one to be connected to the Networked Instrument, then select Properties.



Under the General tab, highlight the Internet Protocol TCP/IP component, and select the Properties. Verify that the Use IP Address selection has been set to address 192.168.0.1. Don't modify the DNS server selections.



Computer with One Network Interface

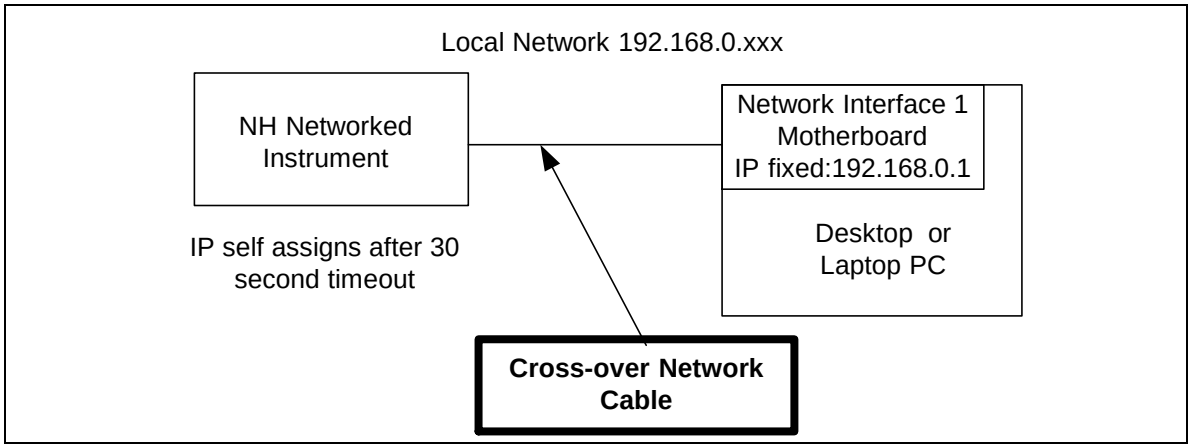
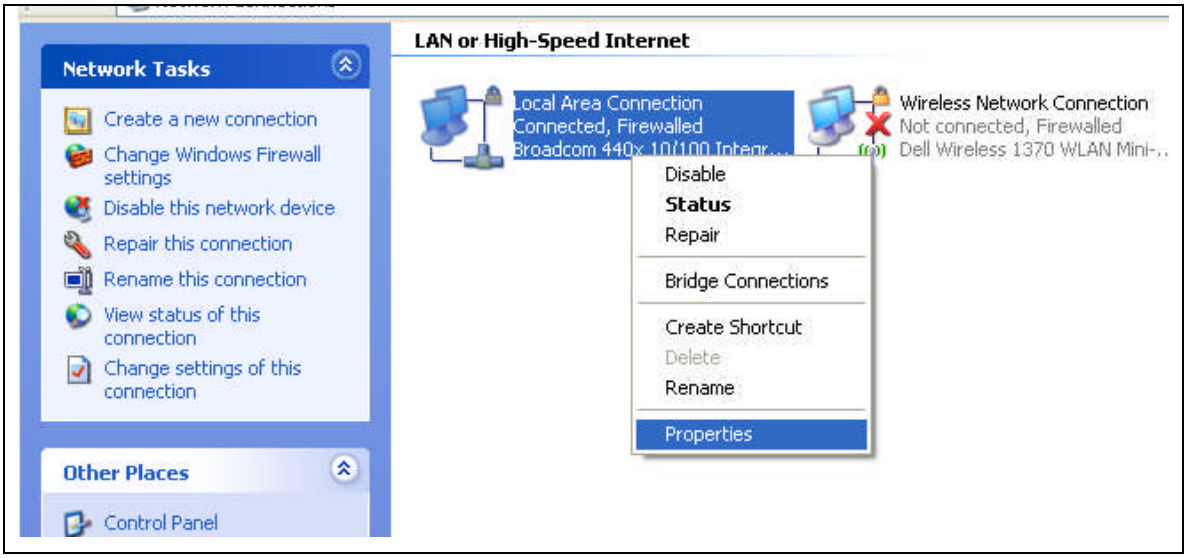


Figure 3 - Direct Connection to PC with One Network Interface

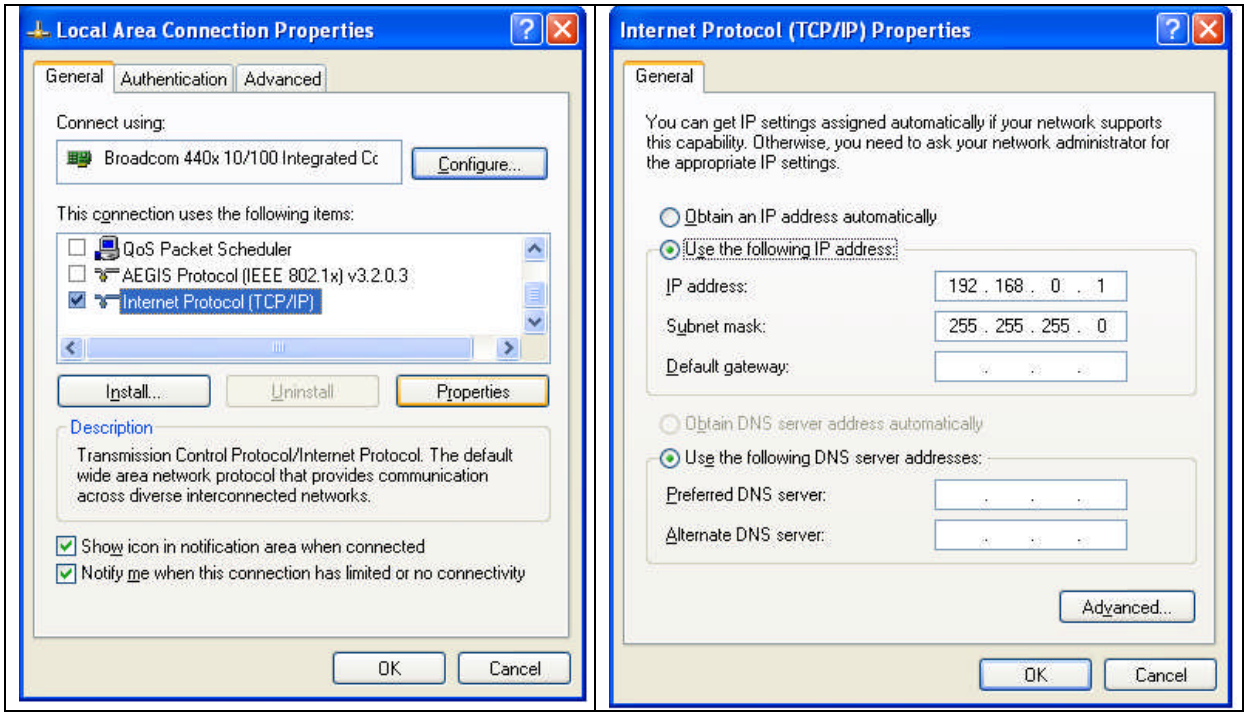
Configuration for Direct Connection for PC with One Network Interface

Using the Windows Control Panel; open Network and Dial up Connections window, right-click on the Local Area Connection (the one wired to the instrument, not the Wireless Network), then select Properties.



Under the General tab, highlight the Internet Protocol TCP/IP component, and select the Properties. Select Use The Following IP Address, and enter 192.168.000.001, then hit the Tab on the keyboard to fill in the subnet mask automatically (255.255.255.0). Don't modify the DNS server selections.

NOTE: Using this mode of operation, the NHR Instrument will need to be turned on for at least 30 seconds before it self-assigns an IP address in the 192-168.0.xxx range. Don't start any software that attempts to communicate with it until this timeout expires.



Computer with One Network Interface and Router

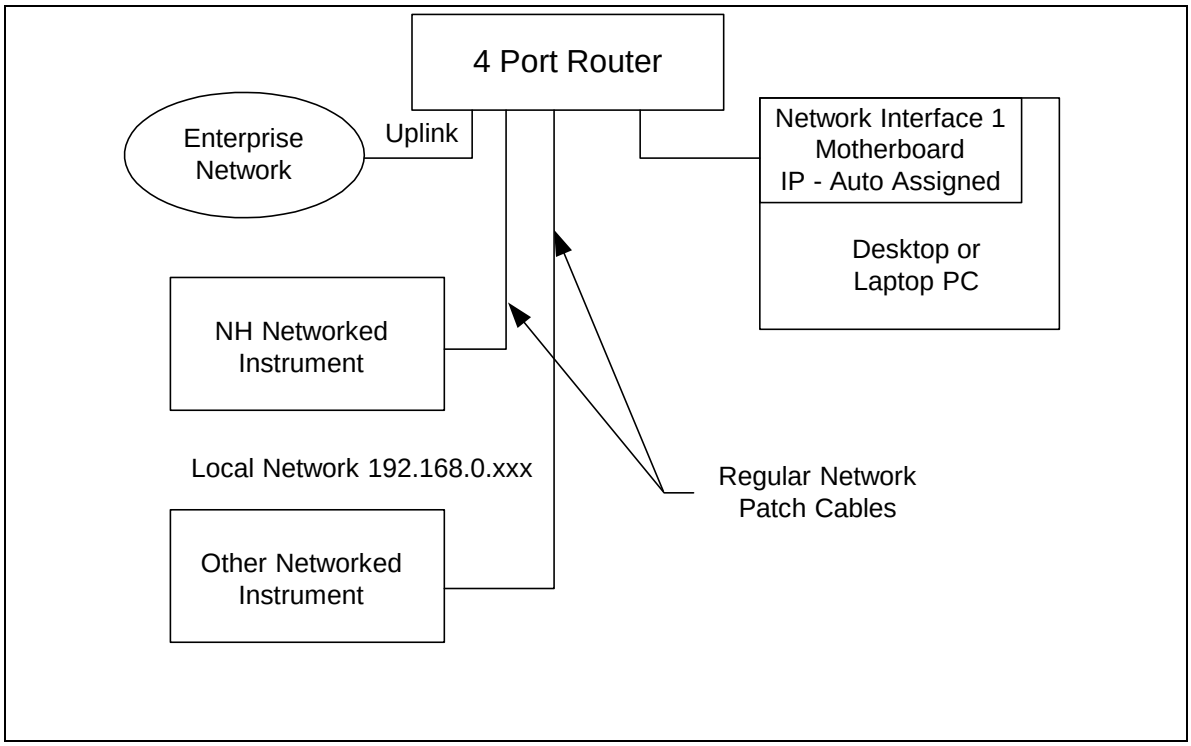
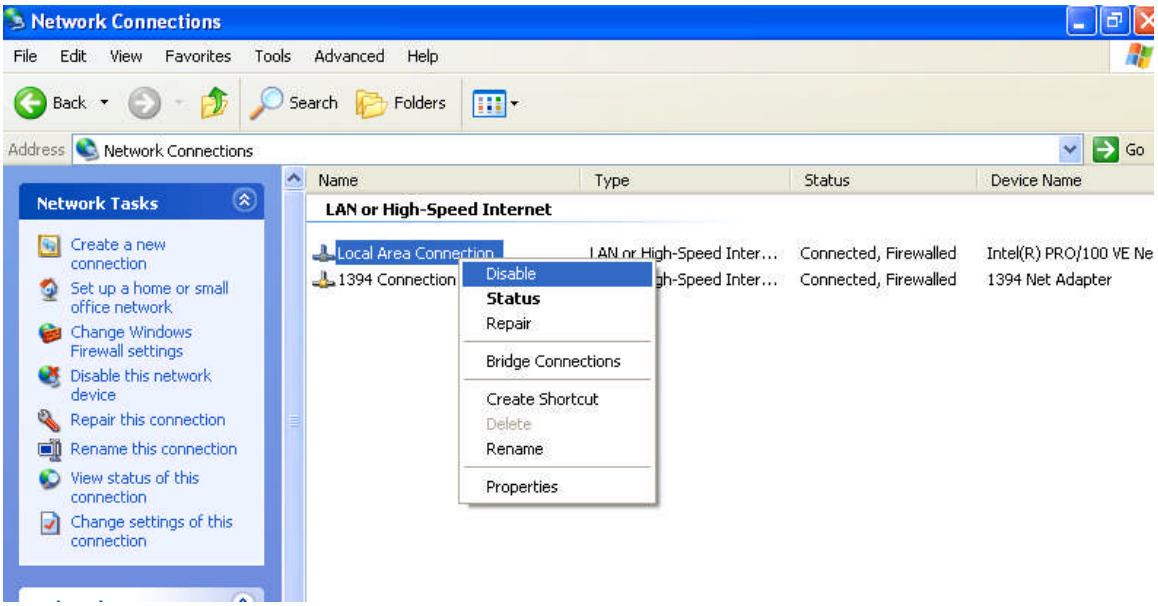


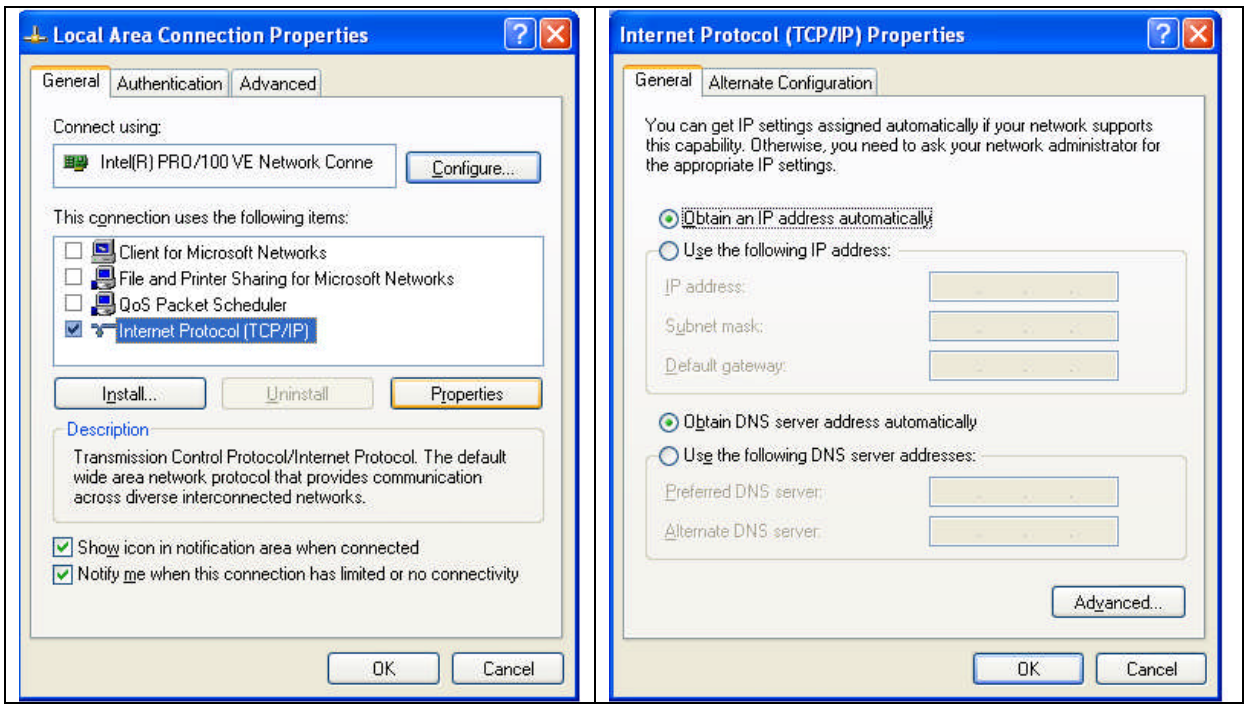
Figure 4 - Router Connection to PC with One Network Interface

Configuration for Router Connection to PC with One Network Interface

Using the Windows Control Panel; open Network and Dial up Connections window, right-click on the Local Area Connection (the one wired to the instrument, not the Wireless Network), then select Properties.



Under the General tab, highlight the Internet Protocol TCP/IP component, and select the Properties. Verify that Select Obtain an IP Address Automatically is active. Don't modify the DNS server selections.



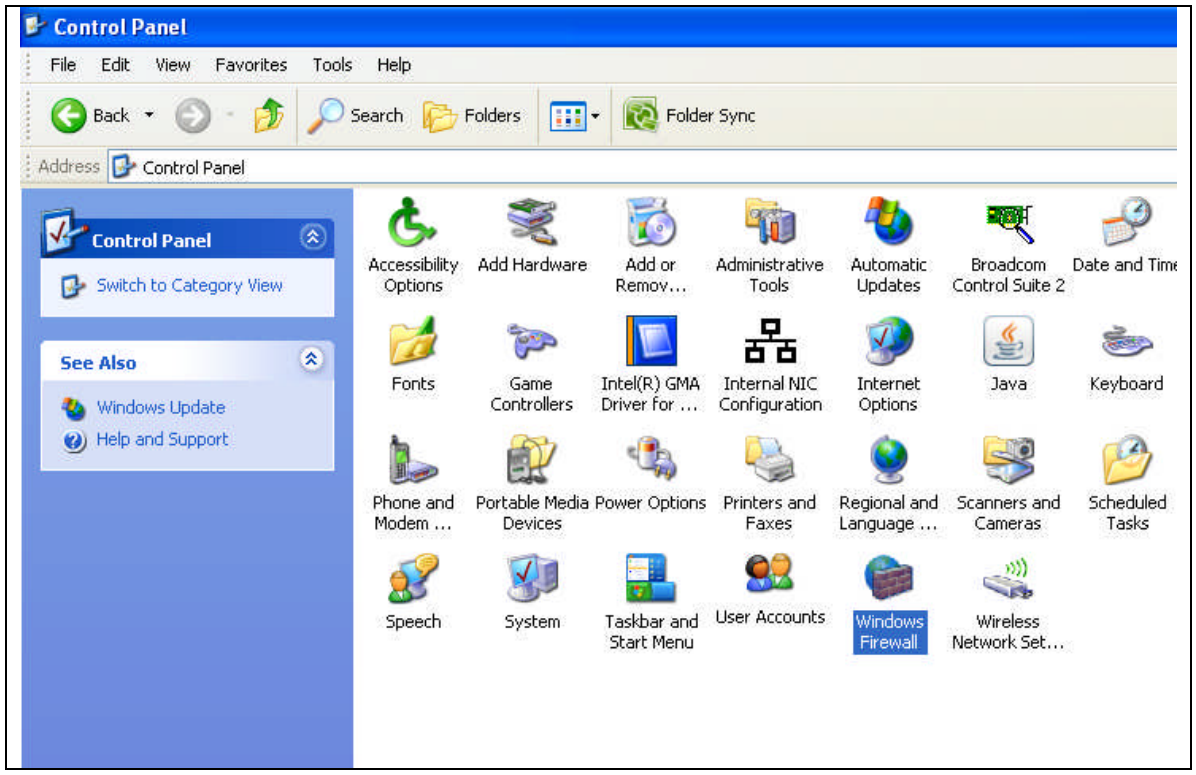
Depending on security settings and other options, some routers may not assign instrument addresses within the 30-second timeout period. If that timeout elapses, the instrument will self assign an IP address in the local network IP range 192.168.0.2 – 192.168.0.254.

Most routers have a browser based control panel for enabling options like DHCP server functions and address assignment ranges. Usually opening the Windows internet browser and entering 192.168.0.1 will bring up the control panel for the router. Unless defaults have been changed, they often require a default user name of “admin”, and a password of “password”. If you have trouble with the router assigning the IP address using this mode of operation, the NHR Instrument will need to be turned on for at least 30 seconds before it self-assigns an IP address. Don’t start any software that attempts to communicate with it until this timeout expires.

Windows Firewall Configuration

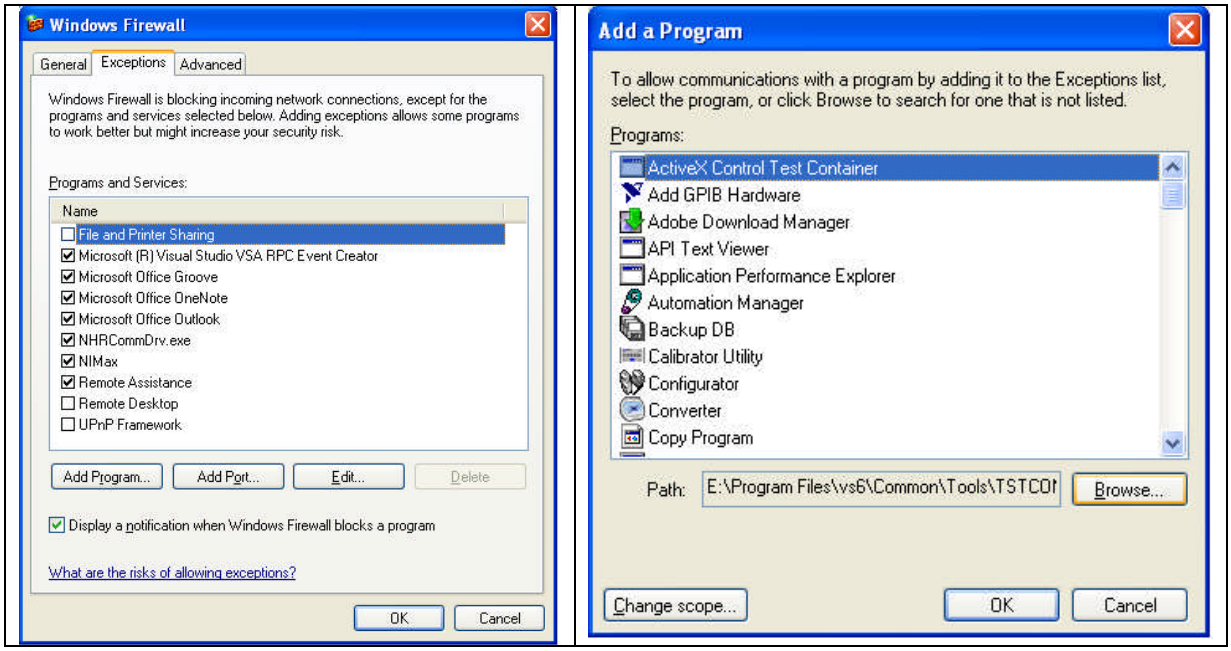
The Windows XP built in firewall, as well as third party firewall software, may keep the computer from communicating with networked instruments. To make sure the firewall software allows communication, the following setup is required in Windows.

Open the Control Panel, select Windows Firewall, and Open

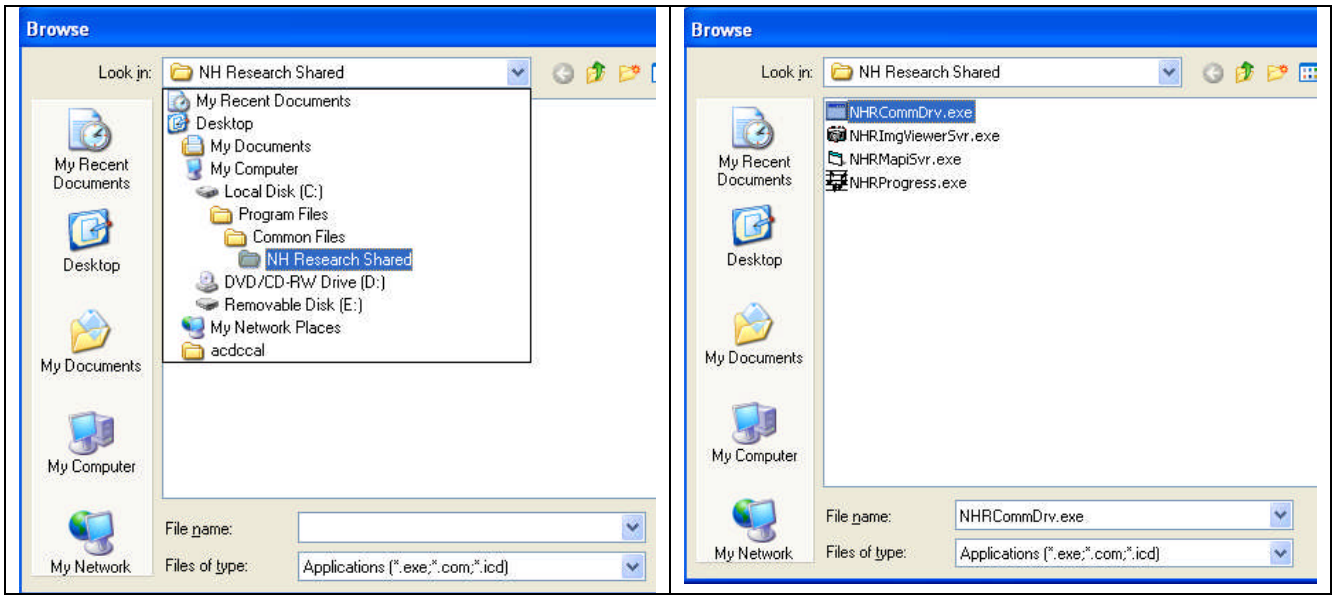


Select the Exceptions Tab in the Firewall control, and then the Add Program button.

In the Add a Program window, select the Browse option at the bottom and find the NH Research Shared folder. The usual path is C:\Program Files\Common Files\ .



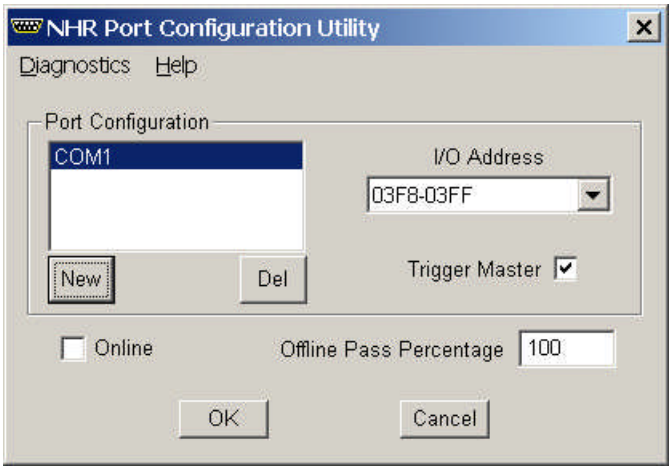
In that folder, select NHRCommDrv.exe file, and click Open. This should allow NHR instrument drivers to communicate through the firewall.



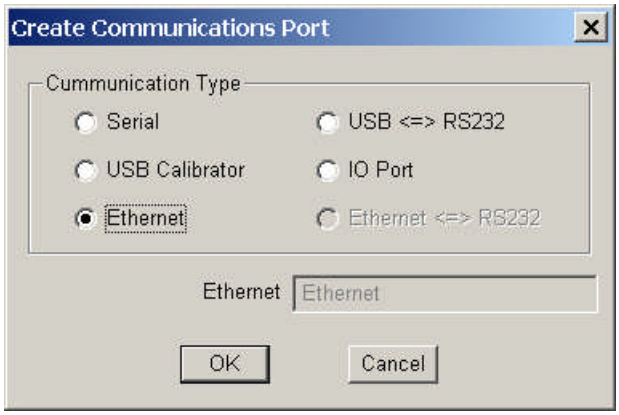
NH Research Port Configuration

NH Research software requires instruments to be correctly configured in a driver database to select the correct instrument driver and communication method. The following steps show how to install an NH Research networked 4700 DC Load.

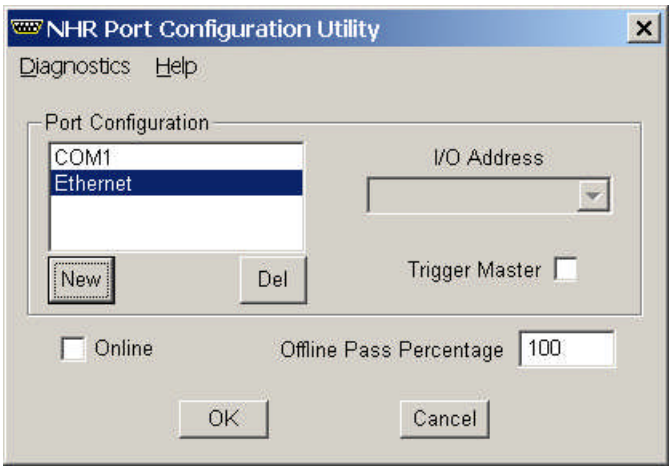
The install program should have created an NH Research folder in the Windows Start menu. Run the PortConfig application in that folder to configure the communication drivers. Starting the program will open the Configuration Utility window.



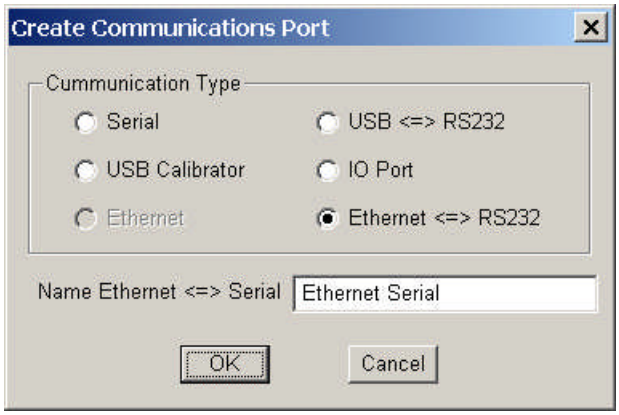
Select New and add the Ethernet Communications port.



Click OK to return to the Port Configuration window.



Click on New again, and add another port called Ethernet ⇔ RS232



Return to the Port Configuration Utility window, verify that the Online and Trigger Master boxes are checked, click OK to leave window and PortConfig.

The software will now prompt to reboot computer.

After reboot, your NHR instrument is ready for use.

As an example, the NHR DC Load Softpanel program can be started to control the load interactively. The program should appear on the screen when started.

Network Addressing

Instruments on a network have individual IP (Internet Protocol) addresses so they can be controlled individually, even though they share an interface. These IP addresses must be assigned somehow; either automatically assigned by software, entered through a front panel interface, or stored in non-volatile memory on the instrument.

The software function that automatically assigns each instrument an IP address when requested is referred to as a DHCP server. This software is typically found on a network router, but a scaled down version of the software is also available in Windows. The Windows version is only activated when a network connection sharing option is selected.

You can verify the IP address assigned to the network interfaces in the PC by using a DOS command utility called “ipconfig”. Run this utility by entering DOS using the Windows Start, Run window and entering cmd, and clicking Open (you may need to type Exit to escape DOS). Enter ipconfig at the DOS prompt to display the IP address assigned to each network interface. At least one must be in the range 192.168.0.1 – 192.168.0.254 to communicate with NHR instruments.

If there is no DHCP server anywhere in the network, instruments may wait for a time-out period, then assign themselves a default IP address. NHR instruments use the IP addresses reserved for private networks ranging from 192.168.0.2 to 192.168.0.254.

Here is how the IP address is assigned in the various network configurations shown:

Configuration	DHCP Server	Address Assigned
PC with two network interfaces, either direct or with network switch	Windows internet sharing function	192.168.0.2 – 192.168.0.254
PC direct with single network interface	None – Instrument times out after 30 seconds and self-assigns. PC network interface must be fixed at 192.168.0.1	192.168.0.nnn nnn = modulo 256 sum of lower 3 bytes of instrument MAC address
Local network router	Router – enabled for DHCP server function with default local network address range (Router takes 192.168.0.1)	192.168.0.2 – 192.168.0.254 Note: If router address not accepted by instrument, self assigns after 30 seconds.

Troubleshooting

Connection Problems

Check the following to verify a good connection:

As soon as a network cable that is connected to computer or router is plugged into a powered-on Network Instrument, the green Link Active LED in the Ethernet connector should light. If it doesn't, one end of the cable may be disconnected, the cable may be bad, or it may be a straight-through cable when a cross-over cable is required.

A cross-over cable is required only when connecting the instrument directly to a network connector on a PC. Cross-over cables are usually clearly marked as such on both ends.

If the connection is Good, and communication is not working:

Make sure the Networked Instrument is powered up for at least 30 seconds before attempting to communicate. This is the timeout period before the instrument assigns itself an IP address in the 192.168.0.xxx range. This self-assignment is necessary when the instrument is connected directly to a PC network connector, or if connected to a router that for some reason can't correctly assign an IP address to the instrument.

If the instrument still doesn't communicate:

Verify that the computer network interface that is attempting to communicate with the instrument is in the same IP address "domain". This can be checked by using the ipconfig DOS utility as described in the Network Addressing section above. The IP address of the computer network interface should be in the range 192.168.0.1 – 192.168.0.254.

Windows Firewall:

Some Windows XP installations and third party software packages have settings to block unknown programs from accessing the network. See the Windows Firewall Configuration section of this document for instructions on adding program exceptions.

Verify Instrument Activity:

If the instrument is communicating, each command processed will cause the Yellow Activity LED in the Ethernet connector to flash.

Operational Problems

Some Networked Instruments have an address dipswitch on the rear panel to select unique addresses. These are usually shipped at address value 01 (hex) for stand-alone instruments. Each position on the switch represents a single bit in a hexadecimal value, and a switch in the up position represents a “one” bit.

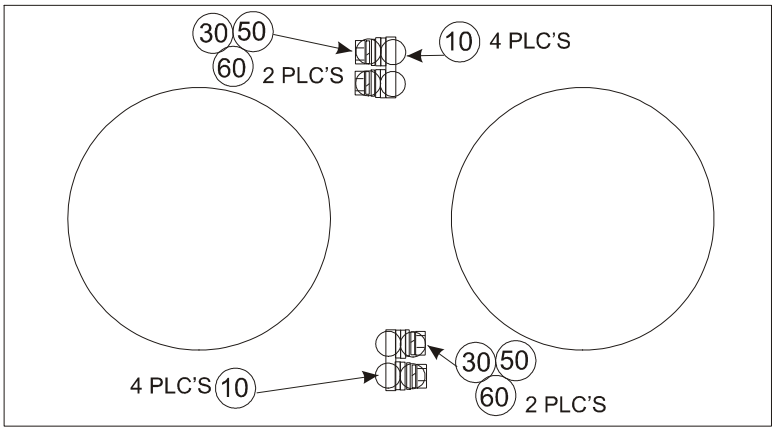
If the switch position has changed since the original software configuration of the instrument, it will stop communicating.

If the instrument is communicating, each command processed will cause the Yellow Activity LED in the Ethernet connector to flash.

APPENDIX B – MULTILOAD CONNECTION & WIRING

ONE LOAD

DESCRIPTION	QTY WIRES	WIRE AWG
3KW 4750 150A	2	#2
6KW 4750 300A	4	#2
3KW 4700 600A	4	2/O
6KW 4700 1200A	8	2/O

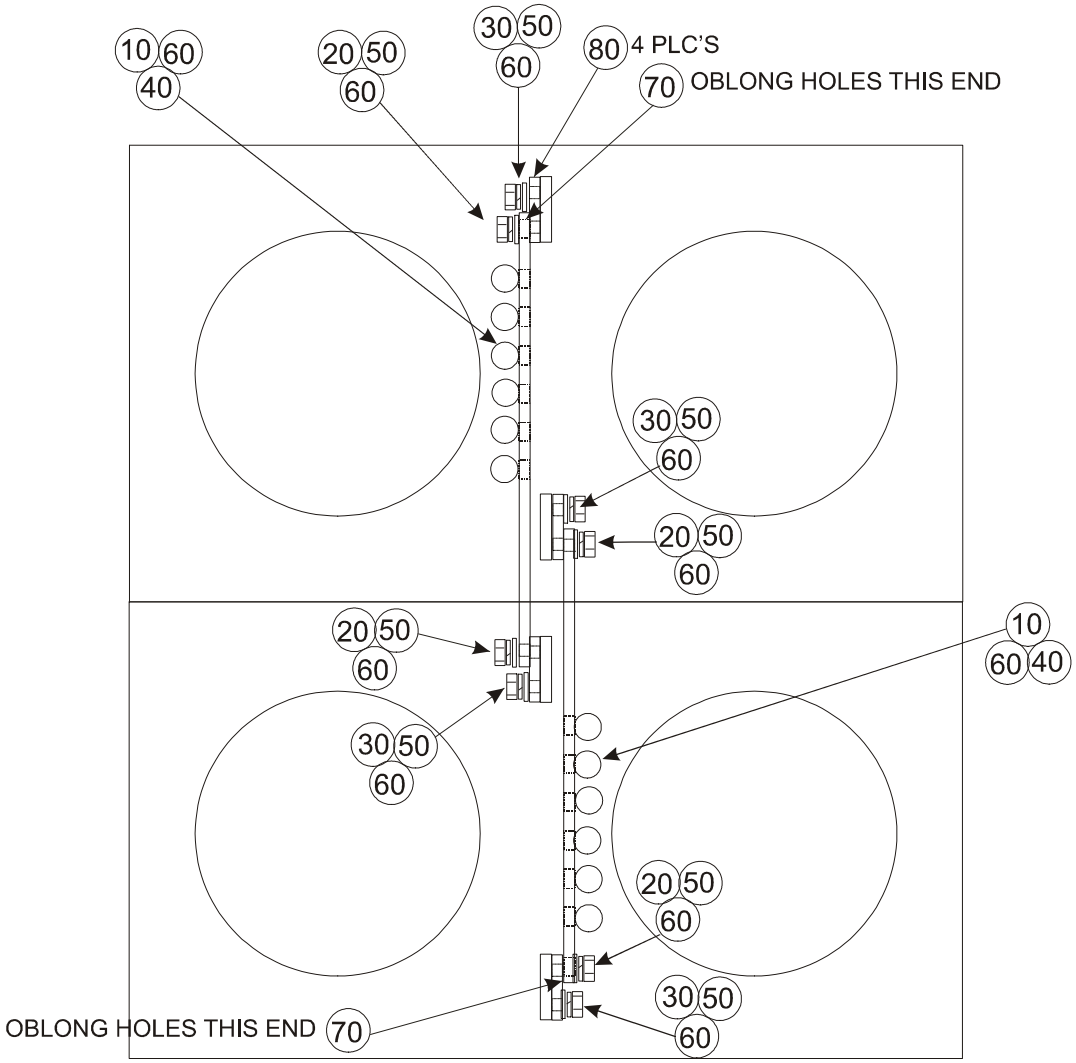


10 LUG 1/4" X 2/O AWG or #2 AWG SEE TABLE QTY & AWG
30 BOLT 1/4-20 x 0.625" BRASS QTY 4
50 WASHER FLAT 1/4 BRASS QTY 4
60 WASHER LOCK SPLIT 1/4 BRASS QTY 4

FIGURE 1

TWO LOADS

DESCRIPTION	QTY WIRES	WIRE AWG
6KW 4750 300A	4	#2
12KW 4750 600A	6	#2
6KW 4700 1200A	8	2/O
12KW 4700 2400A	12	2/O

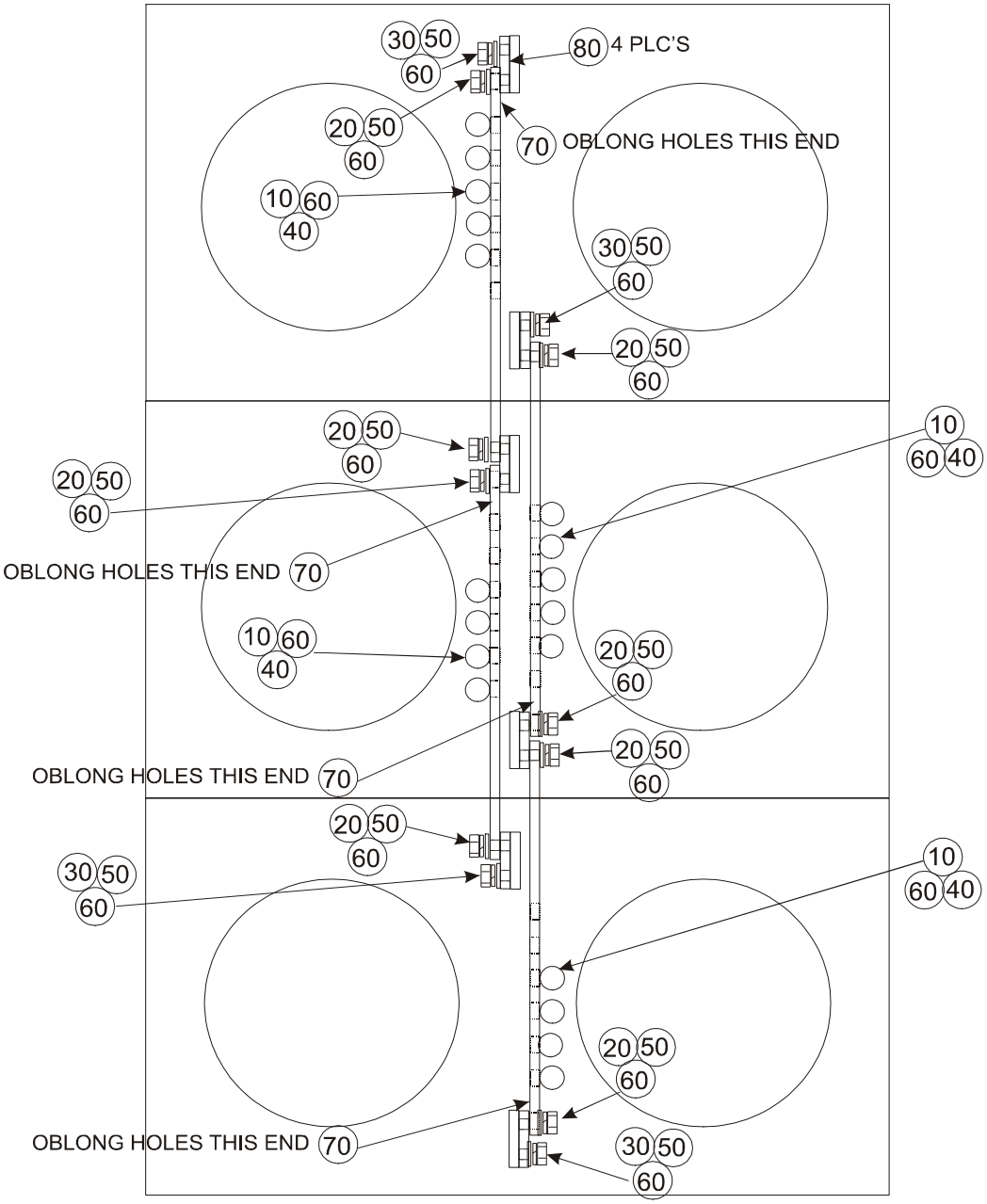


10 LUG 1/4" X 2/O AWG or #2 AWG SEE TABLE QTY & AWG
20 BOLT 1/4-20 x 0.875" BRASS QTY 8
30 BOLT 1/4-20 x 0.625" BRASS QTY 8
40 BOLT 1/4-20 x 0.50" BRASS QTY 12
50 WASHER FLAT 1/4 BRASS QTY 16
60 WASHER LOCK SPLIT 1/4 BRASS QTY 28
70 BUS BAR 02-3344 QTY 2
80 BUS BAR SPACER 4 HOLE 02-3161 QTY 4

FIGURE 2

THREE LOADS

DESCRIPTION	QTY WIRES	WIRE AWG
9KW 4750 450A	6	#2
18KW 4750 900A	10	#2
9KW 4700 1800A	12	2/O
18KW 4700 3600A	24	2/O

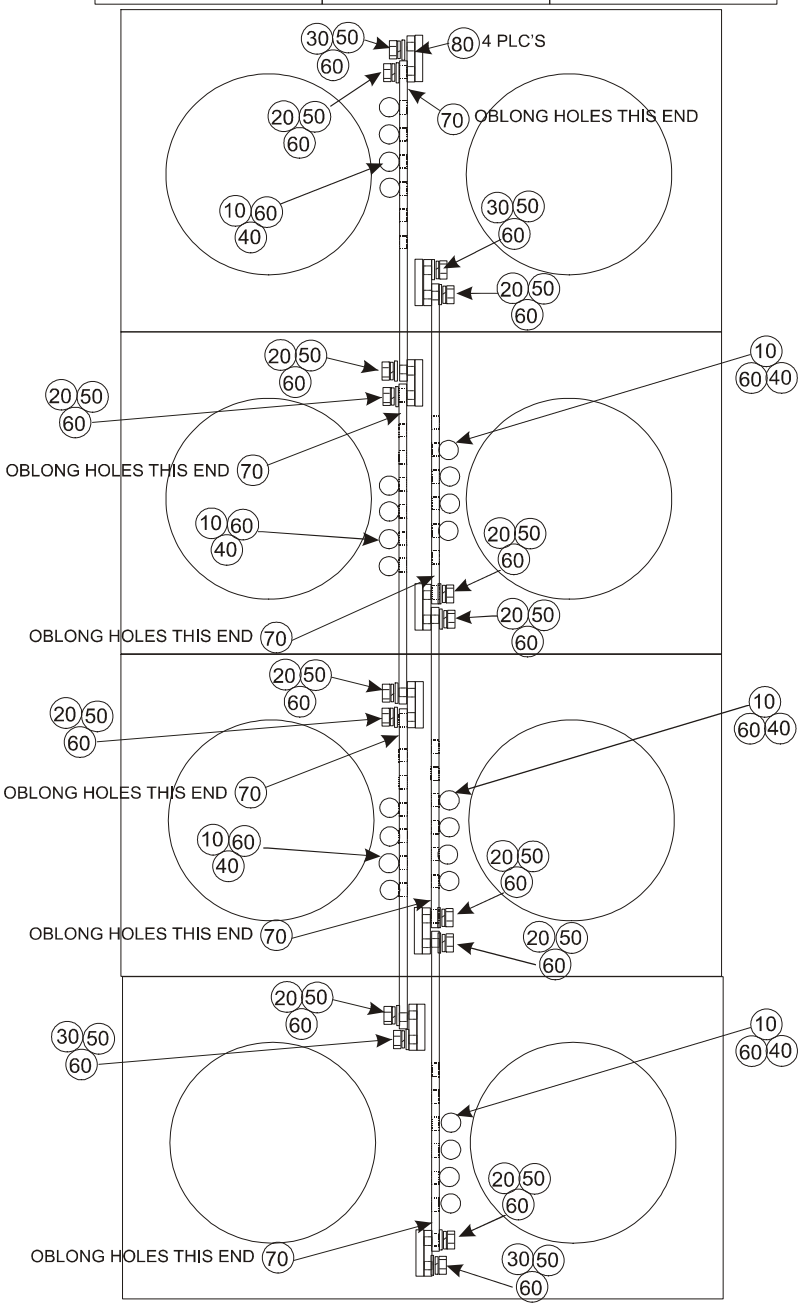


10	LUG 1/4" X 2/O AWG	SEE TABLE QTY & AWG
20	BOLT 1/4-20 x 0.875" BRASS	QTY 16
30	BOLT 1/4-20 x 0.625" BRASS	QTY 8
40	BOLT 1/4-20 x 0.50" BRASS	QTY 18
50	WASHER FLAT 1/4 BRASS	QTY 24
60	WASHER LOCK SPLIT 1/4 BRASS	QTY 42
70	BUS BAR 02-3344	QTY 4
80	BUS BAR SPACER 4 HOLE 02-3161	QTY 6

FIGURE 3

FOUR LOADS

DESCRIPTION	QTY WIRES	WIRE AWG
12KW 4750 600A	6	#2
24KW 4750 1200A	12	#2
12KW 4700 2400A	18	2/O
24KW 4700 4800A	30	2/O

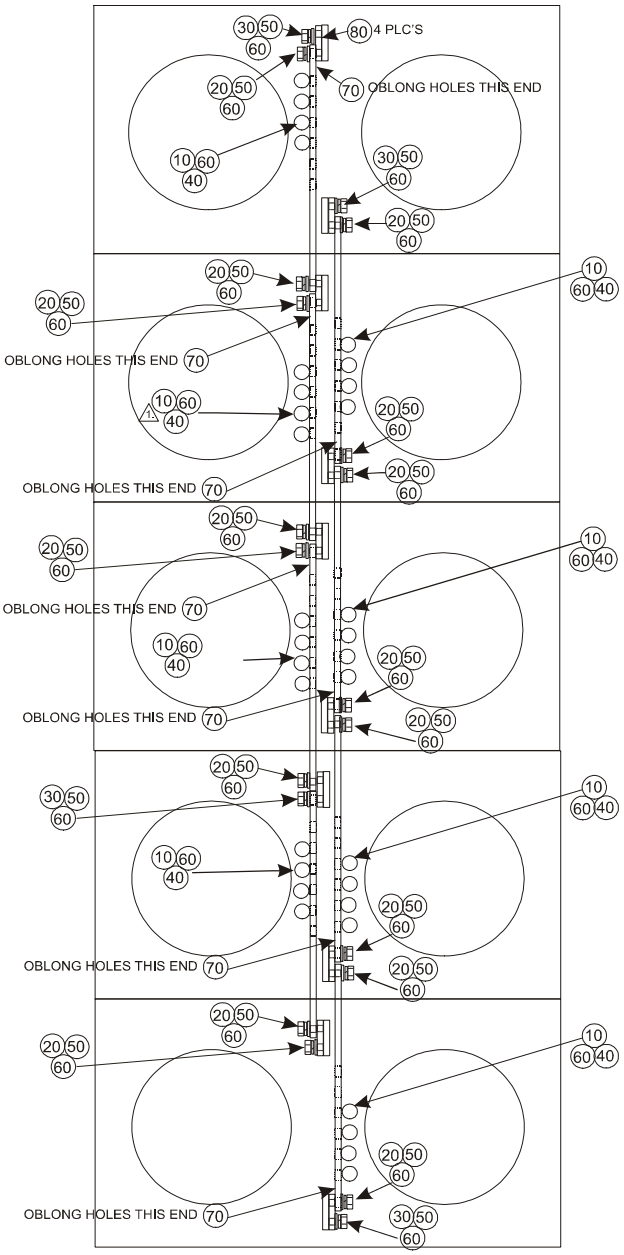


10	LUG 1/4" X 2/O AWG	SEE TABLE QTY & AWG
20	BOLT 1/4-20 x 0.875" BRASS	QTY 24
30	BOLT 1/4-20 x 0.625" BRASS	QTY 8
40	BOLT 1/4-20 x 0.50" BRASS	QTY 24
50	WASHER FLAT 1/4 BRASS	QTY 32
60	WASHER LOCK SPLIT 1/4 BRASS	QTY 56
70	BUS BAR 02-3344	QTY 6
80	BUS BAR SPACER 4 HOLE 02-3161	QTY 8

FIGURE 4

FIVE LOADS

DESCRIPTION	QTY WIRES	WIRE AWG
15KW 4750 750A	8	#2
30KW 4750 1500A	16	#2
15KW 4700 3000A	24	2/O
30KW 4700 6000A	40	2/O

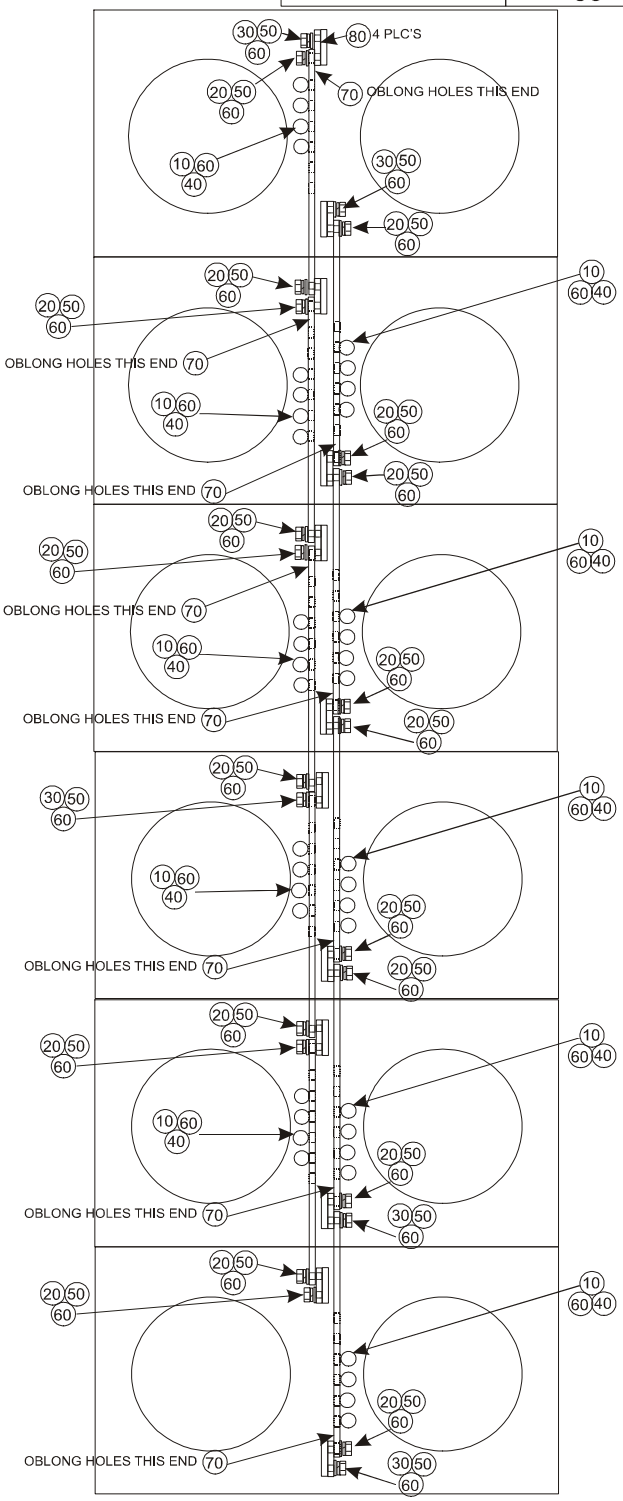


10	LUG 1/4" X 2/O AWG	SEE TABLE QTY & AWG
20	BOLT 1/4-20 x 0.875" BRASS	QTY 32
30	BOLT 1/4-20 x 0.625" BRASS	QTY 8
40	BOLT 1/4-20 x 0.50" BRASS	QTY 30
50	WASHER FLAT 1/4 BRASS	QTY 40
60	WASHER LOCK SPLIT 1/4 BRASS	QTY 88
70	BUS BAR 02-3344	QTY 8
80	BUS BAR SPACER 4 HOLE 02-3161	QTY 10

FIGURE 5

SIX LOADS

DESCRIPTION	QTY WIRES	WIRE AWG
18KW 4750 900A	10	#2
36KW 4750 1800A	20	#2
18KW 4700 3600A	30	2/O
36KW 4700 7200A	50	2/O



10 LUG 1/4" X 2/O AWG — SEE TABLE QTY & AWG
20 BOLT 1/4-20 x 0.875" BRASS — QTY 40
30 BOLT 1/4-20 x 0.625" BRASS — QTY 8
40 BOLT 1/4-20 x 0.50" BRASS — QTY 36
50 WASHER FLAT 1/4 BRASS — QTY 48
60 WASHER LOCK SPLIT 1/4 BRASS — QTY 120
70 BUS BAR 02-3344 — QTY 10
80 BUS BAR SPACER 4 HOLE 02-3161 — QTY 12

FIGURE 6