NHR 9400 Series
Regenerative Bi-Directional AC

USER'S MANUAL

Part No. 09-0329

REVISION C

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Document History

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1. GENERAL

1.1 Models

This manual applies to the following hardware modules provided by NH Research.

9410 Regenerative Grid Simulator			
Model	Maximum Power	Channel Count	Footprint
9410-04	4kW / 8 kVA	1 Channel	19” Rack-mountable Module
9410-08	8kW / 16 kVA	2 Channels	
9410-12	12kW / 24kVA	3 Channels	
9410-24	24kW / 48kVA	3 Channels	43” Tall Cabinet
9410-36	36kW / 72kVA		78” Tall Cabinet
9410-48	48kW / 96kVA		78” Tall Cabinet
9410-60	60kW / 120kVA	3 Channels	Dual Bay 78” Cabinet
9410-72	72kW / 144kVA		
9410-84	84kW / 168kVA		
9410-96	96kW / 192kVA		

This manual will also apply to new product variations released by NH Research.

Complete model lists and their associated specifications is available models is available from NH Research upon request.

1.2 Symbols Used

Warnings, cautions, & notes will be highlighted within this document with the following symbols.

	**Failure to observe warning(s) may cause life threatening danger Please use extreme caution**
	**General safety warnings - Failure to observe warning(s) may cause bodily harm or equipment damage.**
	**General notes or keys for operation**

1.3 Warranty

NH Research provides a one (1) year standard warranty for hardware test equipment products.

Details, limitations, and other information are included within the general terms and conditions provided with the product quote.

1.4 Intended Usage

The 9400 Series provides AC or DC bi-directional power control and measurement. It is primarily used in the evaluation, performance, functional, & endurance testing for either AC or DC products.

Operators of the equipment should be trained in safety procedures. Any damage caused by non-intended usage is not covered under warranty.

1.5 Safety Notice – No User Serviceable Parts Inside

The 9400 series contains no internally replaceable or serviceable parts.

Internal adjustment or component replacement is only permitted by qualified NH Research personnel. No internal adjustments or system access should be attempted by non-NH Research personnel.

Safety Notice For Qualified Technician:

- Remove all external voltage sources
- Disconnect power cord
- Wait a minimum of 1 minute to discharge internal circuits
- Verify circuits are fully discharged

1.6 General Safety Notices

The following are general notices which should be observed by the operator

Potential for Mortal Hazard:

- Internal access should be avoided – No serviceable parts
- All connections should be carried out under 0V conditions
- All connections should be properly terminated leaving no exposed wires which could present an electrical shock hazard
- Always assume the output has potential even when “OFF”

Additional Notes

- The test equipment should only be used by trained personnel or under the direct supervision of trained personnel.
- Do not insert any object through the air intake
- Avoid use of liquids near the test equipment when possible
- Ensure proper polarity is observed when connecting the equipment to the unit under test. Reverse polarity can damage either the equipment or the UUT.

1.7 Important Terminology

1.7.1 Unit-Under-Test (UUT)
The Unit-Under-Test (or UUT) is the device which is being tested

1.7.2 Input
Input is the generic term applied to the connection from the 9400 to the Facility Power. The 9400 system is bi-directional allowing power to flow in either direction. As such the use of the term input does not imply power flow direction.

1.7.3 Output
Output is the generic term applied to the connection from the 9400 to the UUT. The 9400 system is bi-directional allowing power to flow in either direction. As such the use of the term output does not imply power flow direction.

1.7.4 Channel
A channel is comprised of a master output and each auxiliary output (if installed). Each channel may be configured for AC or DC operation as well as be configured to operate together to produce a single larger channel.

1.7.5 Module or Power Module
A Module is the generic name for one of the 9400 systems. There are two primary versions including a “Master” and an “Auxiliary”.

1.7.6 Auxiliary (Module) or Auxiliary (Power Module)
A master module includes only the power electronics needed to supplement a master modules power. It does not contain the control and communications components needed to operate as a standalone system. These parts are only installed in a master module.

1.7.7 Master (Module) or Master (Power Module)
A master module includes the control and communications hardware along with one or more output channels. Master module current as well as power is expandable by connecting an appropriate auxiliary module.

1.7.8 Instrument
The instrument is an abstraction term allowing one or more channels to be treated as a logical group. For example, when the 9400 is configured for single 1-phase or 3-phase operation, all of the channels will be grouped together into a single instrument. By comparison, if three separate channels are configured the system will address this as three separate instruments.

1.7.9 Units

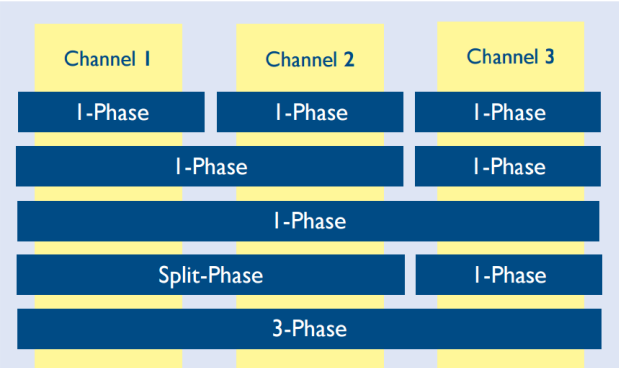
Unless otherwise stated, units are as follows:

Voltage	Volts (V)
Current	Amperes (A)
Resistance	Ohms (Ω)
True power	Watts (W)
Apparent power	Volt-Amperes (VA)
Frequency	Hertz (Hz)
Energy	Ampere-Hours (Ah), Kilowatt-Hours (kWh), Kilovolt-Ampere-Hours (kVAh)
Angles	degrees (°)
Time	seconds (s)

2. TECHNICAL OVERVIEW

2.1 System Description

This system description is provided clarify the technical specifications section which follows. The 9400 Series, depending on model selected, provides one (1), two (2), or three (3) power control channels which are configured through software in order to provide any combination of AC and DC test channels.



For example, the 9410-12 provides three (3) $310V_{ACRMS}$, 30A, 4kW/8kVA channels. These channels may be configured to operate as separate AC channels, combined in order to provide a higher single output channel (8kW or 12kW), or combined to provide multi-phase output (split -phase or 3-phase). Each channel supports both AC & DC operation making the 9400 Series a very flexible, regenerative, bi-directional power test system.

The power and current capability of each channel is expanded by adding an auxiliary. For example a 9410-24 uses a master module and a slave auxiliary module. In this case, each of the three (3) channels is capable of $310V_{ACRMS}$, 60A, 8kW/16kVA.

Systems may be ordered with a reduced channel count providing only one (1) or two (2) channels. For example, the 9410-4 includes one channel whereas the 9410-8 includes 2 channels. These product versions still provide the same power and current capability of $310V_{ACRMS}$, 30A, 4kW/8kVA per channel.

These details will be helpful in understanding the following technical specification tables.

2.2 Output Specifications

9410 Series Regenerative Grid Simulator								
Model	**9410-4**	**9410-8**	**9410-12**	**9410-24**	**9410-36**	**9410-48**	**9410-72**	**9410-96**
AC Output Specifications								
Number of channels	1	2	3					
Phases / Output Channels	1	1 or 2	1, 2 or 3					
Max Power (Total) Current Ranges (max 1ϕ) Current Ranges (per ϕ)	4kW/8kVA 6A, 30A 6A, 30A/ϕ	8kW/16kVA 12A, 60A 6A, 30A/ϕ	12kW/24kVA 18A, 90A 6A, 30A/ϕ	24kW/48kVA 36A, 180A 12A, 60A/ϕ	36kW/72kVA 54A, 270A 18A, 90A/ϕ	48kW/96kVA 72A, 360A 24A, 120A/ϕ	72kW/144kVA 108A, 540A 36A, 180A/ϕ	96kW/192kVA 144A, 720A 48A, 200A/ϕ
Peak Current	3x Max RMS Current							
Voltage Ranges Accuracy Resolution	155, 310V_{rms} (400V_{rms} Option) 0.2% setting + 0.2% range 0.005% range							
Frequency	30 – 100Hz							
Distortion	< 1% @ 50/60Hz (full power into resistive load @ 480$V_{rms\ l\text{-}l}$							
Output Wave Shapes	Sine, n-Step Sine, Triangle, Clipped-Sine, Arbitrary (user-defined)							
Phase Angle Control	0 ^{o} to 359 ^{o} / 1 ^{o} resolution							
DC Output Specifications								
Max Power (Total) Current Ranges (max 1ch) Current Ranges (per ch)	4kW 6A, 30A 6A, 30A/ch	8kW 12A, 60A 6A, 30A/ch	12kW 18A, 90A 6A, 30A/ch	24kW 36A, 180A 12A, 60A/ch	36kW 54A, 270A 18A, 90A/ch	48kW 72A, 360A 24A, 120A/ch	72kW 108A, 540A 36A, 180A/ch	96kW 144A, 720A 48A, 200A/ch
Voltage Ranges Accuracy Ripple	200, 400V_{dc} 0.2% setting + 0.2% range < 800mV							

2.3 Measurement Specifications

9410 Series Regenerative Grid Simulator								
Model	**9410-4**	**9410-8**	**9410-12**	**9410-24**	**9410-36**	**9410-48**	**9410-72**	**9410-96**
AC & DC Measurements								
Peak Voltage	250V, 500V							
Accuracy (AC_{rms})	0.1% reading + 0.06% range							
Accuracy (DC)	0.1% reading + 0.10% range							
Accuracy (Peak)	0.5% reading + 0.20% range							
Resolution	0.005% range							
Peak Current (per ch)	20A / 100A	20A / 100A	20A / 100A	40A / 200A	60A / 300A	80A / 400A	120A / 600A	160A / 800A
Accuracy (AC_{rms})	0.2% reading + 0.06% range							
Accuracy (DC)	0.2% reading + 0.06% range							
Accuracy (Peak)	0.5% reading + 0.20% range							
Resolution	0.005% range							
Peak Power	V range * I range							
Accuracy (kW / kVA)	0.3% reading + 0.025% range							
Resolution	0.005% range							
Additional Measurements	Energy (Ah, kWh, kVAh), AC Crest Factor, AC Power Factor, Waveform Capture							
Waveform Digitizer	Output Voltage & Current							
Sample Rate	125k Samples / Second							
Memory Depth	64k Samples							
Aperture Time	1 cycle to 64 seconds							
Accuracy	0.5% reading							
Resolution	0.05% range							

2.4 Facility & Mechanical Specifications

9410 Series Regenerative Grid Simulator								
Model	**9410-4**	**9410-8**	**9410-12**	**9410-24**	**9410-36**	**9410-48**	**9410-72**	**9410-96**
Physical Characteristics								
Output Connections	Terminal Block			Bus Bar				
Form Factor	Single Module			Single Cabinet			Double Cabinet	
Dimensions (WxDxH)	19” x 24” x 15¾“ (9U)			23”x30”43”	23”x30”x78”		46”x30”x78”	
Weight	105 lbs	120 lbs	135 lbs	370 lbs	505 lbs	855 lbs	1340 lbs	1610 lbs
Operating Temp	0°C to 35°C							
Isolation	Facility to Chassis – 1000V, Output to Chassis – 500V, Facility to Output Internal Isolation – 2000V							
Input Characteristics								
Voltage	Universal Input – 380V to 480V ± 10% (L-L, 3 Phase, 50/60Hz)							
Efficiency	Greater than 85% (typical)							
Facility Power Factor	Greater than 0.95							
Power Utilization	Energy (Ah, kWh, kVAh), AC Crest Factor, AC Power Factor, Waveform Capture							
Input per ϕ @ 380V	9A	17A	25A	49A	73A	97A	144A	192A
Input per ϕ @ 400V	9A	17A	24A	47A	69A	92A	137A	183A
Input per ϕ @ 480V	8A	14A	20A	39A	58A	77A	114A	152A

Input Power Utilization refers only to the amount of power drawn during operation. See the installation section for breaker and facility wiring recommendations

2.5 Key Features

2.5.1 Flexible Hardware Operating Modes

The 9400 supports multiple hardware directed operation modes including various combinations of AC & DC output channels. When configured, the interface automatically adapts to show measurements and settings commonly used for single phase & multi-phase operation. See the appendix sections for "Hardware Modes" for any of the configurations directly supported by the 9400 system.

2.5.2 Isolated Outputs

Each output channel of the 9400 is isolated from the input (facility power), chassis, communications interfaces, & the other output channels. This permits the 9400 to be used with multiple separate ground references and maximizes the configuration flexibility for the system.

2.5.3 Bi-Directional 4-Quadrent Operation

The 9400 is bi-directional and permits full 4-quadrent output capabilities while maintaining near unity power transfer to and from the facility. The bi-directional design manages the power flow between the facility and the UUT in either direction with minimal power loss. This results in low waste heat generation and cooling requirements when compared with linear power sources or electronic loads.

2.5.4 Near Unity Power Factor Regeneration

The 9400 ensures that current (and therefore power) being drawn or returned to the facility precisely matches the existing voltage waveform very close to unity. This ensures that the power being consumed or returned is clean and free from unwanted disturbances which could affect other equipment used within the facility.

2.5.4.1 All Digital Control and Firmware Upgradable

The output control is performed by upgradable, onboard DSP devices for fast measurement and command response times. All the micro code for the DSPs and the communication microcontroller is stored in FLASH memory so that firmware upgrades can be performed in the field by downloading over the control interface.

2.5.4.2 Programmable Limits

The 9400 series Power Module has programmable current, voltage, and power limits.

2.5.4.3 Safety Features to Protect the Operator

- **Interlock Connector:** Each 9400 Power Module provides a separate interlock input. If the interlock signal loop becomes open, the output relay will open immediately and the system will give the interlock error and perform the normal output off sequence.
- **Emergency Off Connector:** There is an Emergency Off connector available for each 9400 power module. Pin 1 and 2 of the connector has to be shorted to turn on the unit. This allows the user to have a circuitry with immediately shut down Emergency Off Button.

2.5.4.4 Safety Features to Protect the UUT

There are 6 types of safety features available in each power module:

- Protection from an AC grid voltage or frequency excursion beyond preset limits
- Programmable limits to the output current, voltage and power
- Programmable safety trip to the output current, voltage and power
- Protection from a PC or touch-panel failure
- Ability to shut down based on an outside fault
- A hardware emergency-off circuitry

2.6 System Size

Smaller systems are provided as rack mountable modules. These systems may be expanded in the field by ordering auxiliary modules with the same number of installed channels as the master. For larger systems (which use both master & auxiliary modules), NH Research installs these in a cabinet and pre-wires the input and output to a common connection point.

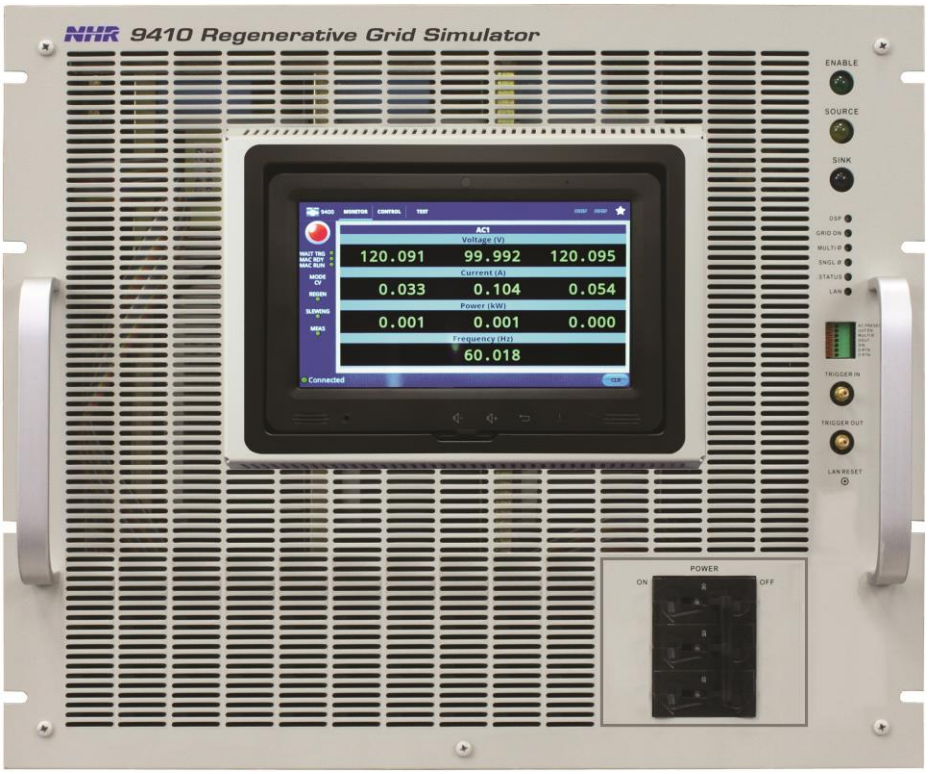
19" Rack Mountable Module (19" x 24" x 15¾")			
Model	Maximum Power	Channel Count	Height
9410-04	4kW / 8 kVA	1 Channel	15¾" (9U)
9410-08	8kW / 16 kVA	2 Channels	
9410-12	12kW / 24kVA	3 Channels	

Single Cabinet (28" x 30" x H)			
Model	Maximum Power	Channel Count	Height
9410-24	24kW / 48kVA	3 Channels	43" Tall Cabinet
9410-36	36kW / 72kVA	3 Channels	78" Tall Cabinet
9410-48	48kW / 96kVA		

2-Bay Cabinet (46" x 30" x H)			
Model	Maximum Power	Channel Count	Height
9410-60	60kW / 120kVA	3 Channels	78"
9410-72	72kW / 144kVA		
9410-84	84kW / 168kVA		
9410-96	96kW / 192kVA		

2.6.1 Module Front View

The Front of the system module includes a touch panel interface, output & status indicators, Digital IO, Trigger ports, and a circuit breaker. Air intake is from the front.

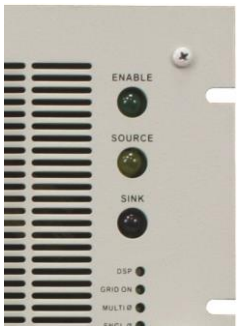


Touch Panel Interface

This interface provides direct manual control of the system without requiring an external PC or control device. In addition, it serves as a monitor for voltage, current, power, frequency, and other measurements while the system is under local control.

For additional details, refer to the using the touch panel control section.

Output Status Indication



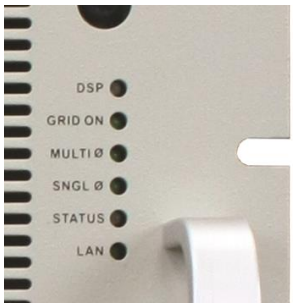
The three indicators in the upper left provide a visual indication

- Enable – Output Contactors are connected (closed)
  Enable does not imply that voltage is being produced or indicate direction of power flow
- Source – All channel powers are summed & Net Power is flowing from the 9400 to the UUT
- Sink – All channel powers are summed & Net Power is flowing from the UUT to the 9400

	**Always assume electrical connections may have voltage especially when the Enabled light is illuminated.**
	The source & sink lights may NOT illuminate when the arithmetic sum of all channel power is near zero. For example, if two channels are sourcing 2kW each and another is sinking 4kW the sum is near zero and neither light will be illuminated even though significant power is flowing on a per channel basis. Never use Source & Sink as a safety indication.

System Status Indicators

The three indicators in the upper left provide a visual indication



- DSP – Status indication for the internal processor
- Grid On – Illuminates when internal power reaches normal operational levels.
- Multiϕ – Indicates multiple phases are active
- Singleϕ – Indicates a single phase is active
- Status – Status indication for the communications processor
- LAN – Illuminated when good network connection is established

LED Pattern	DSP Meaning	Status Meaning
Blinking Green	Normal Operation	Not applicable
Blinking Yellow	Non-fatal error occurred	Normal Operation
Blinking Red	Not Configured, safety limit, or fatal error occurred	Not applicable
Alternating yellow – red	Not applicable	Hardware, DSP communication, or command execution error
Alternating green – yellow	Not applicable	External communication (Normal Operation)
Solid or Off	Incorrect operation (requires reset)	Incorrect operation (requires reset)

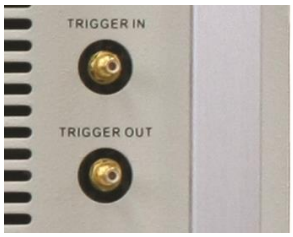
Digital IO Interface

This interface uses a wire terminal block with release level. This interface provides an open collector input/output with internal pull up indicating status and may be used for external device control.

- AC PRESENT –
  Indicates the presence of AC at the output terminals
- UUT EN –
  Indicates the output contactor state
- Multiϕ –
  Indicates the output is operating in multiϕ
- DOUT – General Purpose Digital Out
- DIN – General Purpose Digital input
- D RTN – Return signal / reference for digital IO interface.

Trigger In / Out

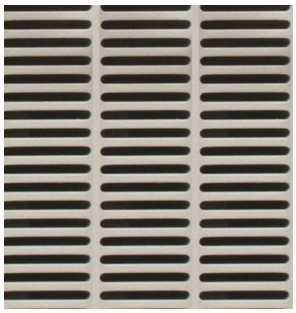
This interface uses a SMB connector and provides Trigger In and Trigger Out controls.



- Trigger In –
  Generally used to start or advance a macro sequence
- Trigger Out –
  Indicates each command as it is applied

Air Intake

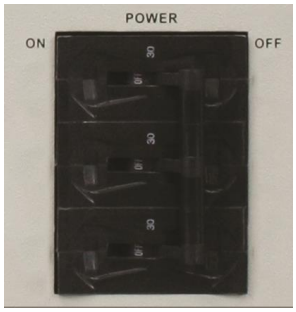
The system is cooled with ambient air. Cooling air is drawn from the front of the unit and exhausted out of the rear.



Never insert tools or metal objects into the air intake slots

Circuit Breaker

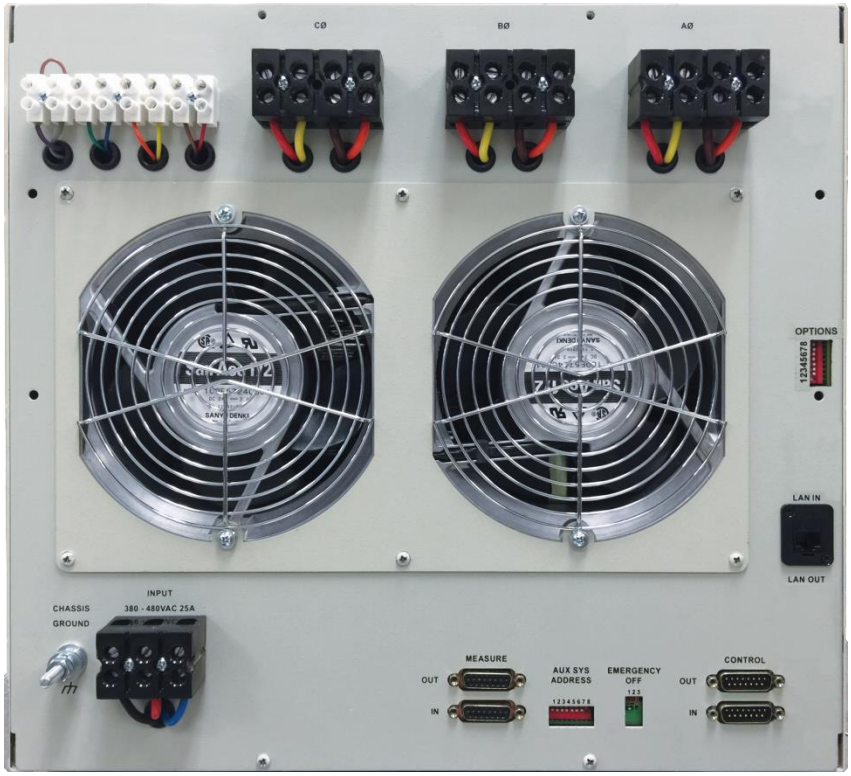
Each master & auxiliary module provides a 30A main circuit breaker. This is used to protect the internal wiring and power stage against internal failures. See the installation section for recommendations about sizing a breaker to power a 9410 system.



See the installation section for breaker and facility wiring recommendations

2.6.2 Module Rear View

The rear of the system includes connections for interlocks, power (facility & UUT), communication, and system expansion.



Facility Power & Safety Ground

The power module uses a universal input accepting 3-Phase voltages between $380V_{l\text{-}l}$ and $480V_{l\text{-}l}$. The connection is 4-wire (3-phase + safety ground) and has no phase rotation dependency.

Each module provides a separate 30A breaker protecting itself from internal wiring failures. Refer to the installation section for more details and recommended wiring gauges.

	**Connection of the system to a three phase AC Line should be made by an electrician or other qualified personnel** **Never wire a system directly to a live power feed.** **All wiring should be conducted in a 0V / No Power state.**
	**There is a potential shock hazard if the system is not connected to safety ground via the provided terminal.** **Ensure all wires are properly terminated with tight connections.** **Improper termination may result in exposed conductors.**
	**See the installation section for breaker and facility wiring recommendations**

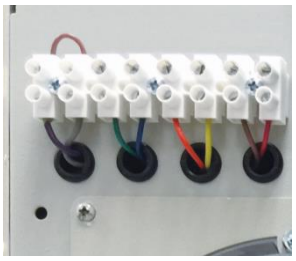
UUT Power Connections

UUT Power connections are made in the rear of the module. Each output is isolated and needs to be wired based on the desired operating mode.

See the Hardware Operating Modes in the appendix sections for recommendations in wiring these outputs.

	**Never wire a system when either the system or UUT is powered. Ensure all wires are properly terminated with tight connections.**
	**The three (3) output channels are isolated from each other and from chassis ground. Please refer to the recommended wiring diagrams in the Hardware Operating Modes section.**

Remote Sense & Interlock



Remote sense connections compensate for wire losses between the Power Module and the UUT. These connections are made only to the master module and must be connected for proper operation.

See the Hardware Operating Modes in the appendix sections for recommendations in wiring these connections.

The interlock connection is the left most terminal. These terminals must be shorted for proper operation and provide an external signal which can be used to disable the power module.

Emergency Off (E-Stop)

Emergency Off turns off the system and will require software reset command before the unit is able to return to an operating state.

Pins 1 & 2 must be connected for normal operation. When pin1 & 2 are disconnected, all input and output relays will open and the internal power electronics will stop switching.

	**See the Installation section for recommendations for wiring E-Stop.**

LAN Communications Port

The 9400 Series modules provide a standard Ethernet 100BaseT RJ-45 8 pin connector with auto-MDIX. This interface does not require a crossover cable to enable communications.

Mating Cable Type:		
Standard Ethernet Cable	Belkin	A3L791-14 (or equivalent)

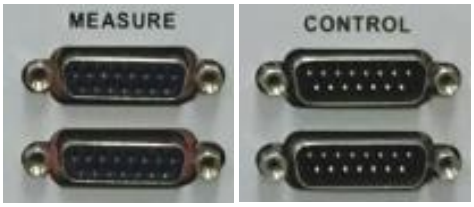
See the changing the IP address section for information about configuring the IP address.

Options Dip-Switches

Options dip switches should not be changed unless specifically instructed to by NH Research customer support or by a programming update procedure. The only exception to this statement is Switch #1 which may be used to force the IP address of the unit to 192.168.0.2 for configuration purposes.

See the changing the IP address section for more information about how to use Switch #1.

Paralleling Interface



A standalone master should have a terminator installed on the control IN connector. This terminator is either pre-installed or can be found in the supplied accessory kit shipped with the unit.

This interface is used to add an auxiliary module to a system master in order to expand current capabilities.

Only NH Research supplied cables should be used to make this connection.

Mating Cable Type:		
Control Paralleling Cable	NHR	P/N: By Request
Terminator	NHR	P/N: By Request

Contact NH Research for more information adding an auxiliary module

Aux Sys Address Dip-Switches

Aux Sys Address dip switches should not be changed unless specifically instructed to by NH Research customer support. These switches are used to identify the address of an auxiliary which is connected to a master.

Contact NH Research before beginning a field installation of an Auxiliary module.

2.6.3 Cabinet Systems

Photos and connector descriptions will be added as soon as available

3. INSTALLATION

3.1 Unpacking the 9400 Series System

Prior to shipment, The 9400 System was inspected and found to be free of mechanical or electrical defects. Upon unpacking, inspect for any damage or shock watch sensors which may indicate that the unit was potentially damaged during transit.

If damage is detected, file a claim with the carrier immediately and notify NH Research Customer Support. Keep all packing materials in case the system will be returned to NH Research.

Do not proceed with installation if damaged during shipping.

3.2 Location Mounting and Cooling

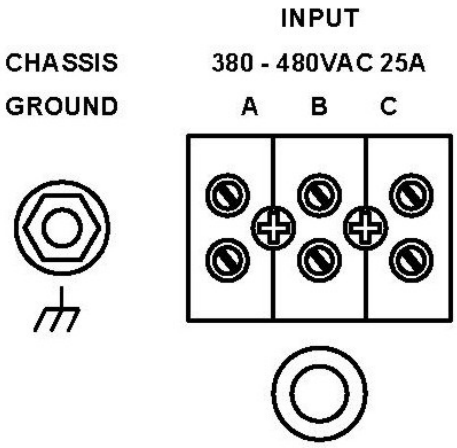
This unit is air-cooled and uses fans. The air intake is from the front of the module (or cabinet) and exhausts to the rear of the module (or cabinet).

For all systems, NH Research recommends 24 inches (60cm) of unrestricted air space in front of the unit and 30 inched (76cm) of unrestricted airspace to the rear of the unit.

3.3 Connecting AC Facility Power

	**Connecting the system to a three phase AC line should be made by an electrician or other qualified personnel.**
	**There is a potential for electrical shock if the system is not properly connected to a safety ground connection.**
	**NH Research is only able to provide general recommendations. It is the responsibility of the user to ensure that wiring, breaker sizing, and associated power connections meet local ordinances.**

For individual modules, the three phase AC Line connects to the system via a terminal block located at the rear of the unit as per the attached drawing. For larger systems, the three phase AC line connects the system via a terminal block located in the rear of the cabinet as shown below.



Module Facility Power Connection

Photo provided when available

Chassis Power Connection

3.4 Recommended Breaker & Facility Wiring

The recommended wiring is based on 30A facility power per module (master or auxiliary). The Facility breaker is intended to protect the wiring from the service panel to the unit only. Each module protects itself internally with a separate 30A breaker.

NH Research can only make general recommendations. Please consult local electricians for local wiring ordinances.

Breakers and Facility Power should be at least 20% higher than the maximum power draw of the unit to prevent trips.

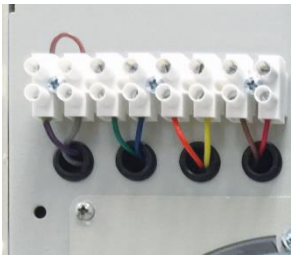
9410 System	Recommended Panel Breaker	Recommended Wire Gauge
9410-4 9410-8 9410-12	30A	AWG 10
9410-24	60A	AWG 6
9410-36	90A	AWG 4
9410-48	120A	TBD
9410-60	150A	TBD
9410-72	180A	TBD
9410-84	210A	TBD
9410-96	240A	TBD

Note: Additional product variations will be added as released to the above table

3.5 Emergency-OFF Connector Setup

User need to jumper pin1 and pin2 of the Emergency-Off connector to turn on the system. This connector provides a way to quickly turn off the system with an outside switch at emergency. When pin1 and pin2 are disconnected, all the input relay and output relay will open, and all the semi-conductors will stop switching. System will generate an Emergency Off error and be latched off even if the jumper is back. Recycle power or a reset command can clear the error.

3.6 Interlock



User need to jumper the interlock pins found at the far left of the external sense connector block. When these pins are disconnected, the output relay will open, and all the semi-conductors will stop switching. System will generate an error if an set operation command (i.e. OUTP:ON) is sent and these pins are not connected. A power cycle or reset is NOT required to clear this error.

3.7 UUT Wiring

The UUT Wiring will depend on the operating mode. Additionally, NH Research offers an Auto Transformer option for 400V Line-Neutral test capability. This should be installed and wired in a zero-volt state before activating the module.

Refer to the output operating mode section in the appendix for UUT wiring recommendations.

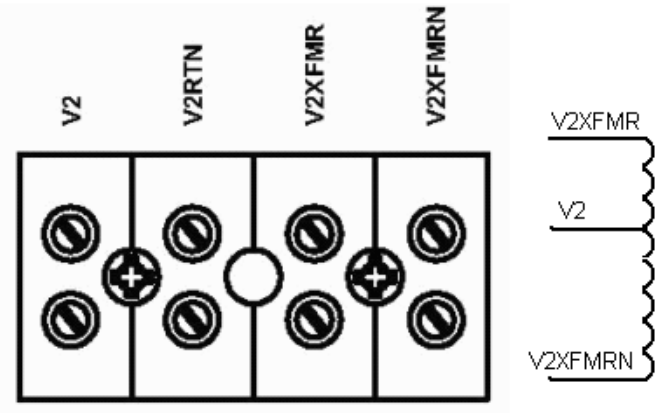
3.7.1 External Sense

External sense is a required connection. The sense leads must be connected at either the UUT or module output connections for proper operation.

3.7.2 400VAC Optional Voltage Support

While a single system provides a maximum output voltage of 310VACrms$_{(l\text{-}n)}$, NH Research offers a modular option to boost the output voltage to 400VACrms$_{(l\text{-}n)}$. The system is designed to measure the output voltage as well as the current and properly scale the measurements and settings using NH Research supplied options.

The voltage boost circuit is based on an auto transformer.
The following figure shows how to connect this option to the rear of the system.



When 400VAC option is used, the output (VxXFMR) and output_return (VnXFMRN) are used as the UUT connections.

THE 400VAC OPTION HAS TO BE SPECIALY DESIGNED TO AVOID SATURATION AND IS ONLY USED FOR AC OUTPUT MODES.
THE 400VAC OPTION SHOULD NOT BE USED FOR DC OPERATION AS IT WILL RESULT IN THE OUTPUTS BEING SHORT CIRCUITED

3.8 Turn On Checklist

3.8.1 Prior to applying external power to the unit

- Verify external door is closed (if equipped)
- Verify the front/rear have enough spacing for air cooling
- Verify e-Stop is unlocked and in ready position (if equipped)
- Verify Interlock is connected
- Verify all system breakers are in the "Off" Position (switched to the right)
- Verify all Options dipswitches (section 2.5.2) are in "off" position
- Verify all power and communications cable connections are tight
- Verify terminator is installed

3.8.2 Powering up the system

- Turn on facility 3-phase power
- Switch all auxiliary breakers to the on position (switched to the left)
- Switch on the master breaker to the on position (module with the touch panel)
- The Touch Panel will automatically start into the monitoring application
- Ensure Grid-On & LAN LEDs are lit before attempting PC communications.

3.9 Configuring the IP Address

The 9400 Series uses standard 100BaseT Ethernet for external control.

There are a large number of potential configurations which should be discussed with your local information technology (IT) department.

NH Research generally recommends either static IP addressing or DHCP where the MAC addresses are assigned to a fixed address to prevent confusion in later use.

Each system shipped with a label containing the MAC addresses and IP addresses contained in the system. These may be changed by the user.

Each 9400 system has an IP address for the master module as well as the touch panel (if equipped). Both of these addresses as well as any controlling PC will need to be in the same broadcast domain. All addresses must be unique.

If we assume the touch panel was configured with an IP address of 192.168.0.1 & the master module was configured with the IP address of 192.168.0.2, Any additional PC's or modules should have a unique address in the range of 192.168.0.3 to 192.168.0.254.

3.9.1 Connect a computer with a web browsing application

Changing the IP address will require a PC or other web-browser capable computer. This external PC must have a similar but different IP address as the manual. (for example, if the system if 192.168.0.2 then the system the PC would need to have an ip address between 192.168.0.1 and 192.168.0.254 with the exception of module.)

Standalone Module LAN Connection

Photo provided when available

Chassis LAN Connection

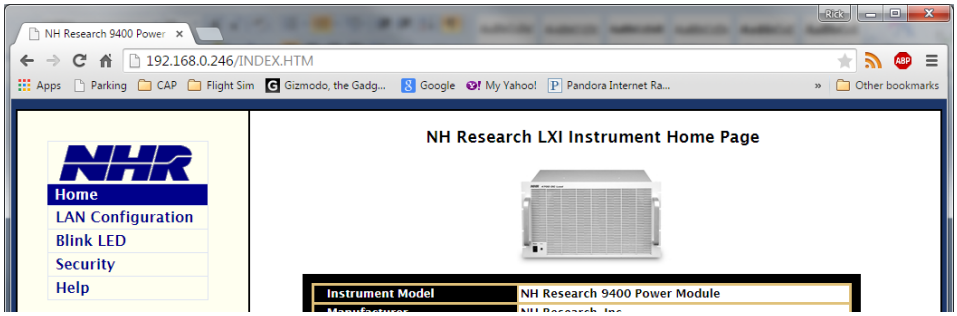
3.9.2 Configuring the master modules IP address

If the Module IP address is unknown

Turn off the master module's breaker and switch the options switch (#1) to the ON position then turn the module's breaker back on. This will force the module to use a fixed IP address of 192.168.0.2. This is a temporary configuration intended to allow the system's IP address to be known for the purposes of configuration. Continue with the known IP addressing setup as follows.

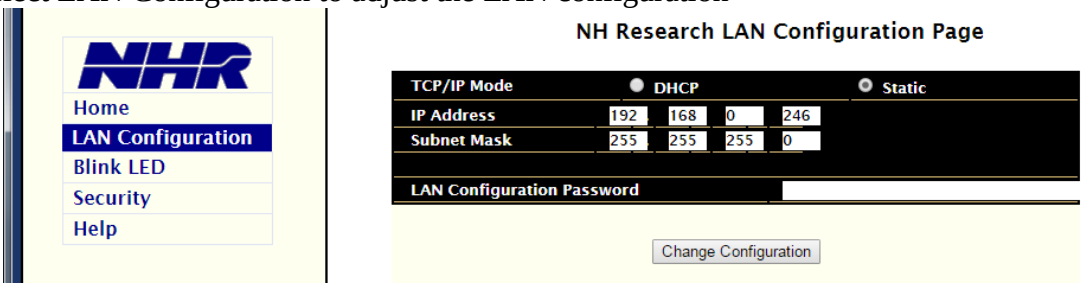
If the Module IP address is known

Open a web browser and browse to http://(IP_ADDRESS) where the IP address is the master modules address (for example http://192.168.0.2). This will open the configuration screen as shown.



Selecting "Blink LED" in the left menu will cause the module to blink the LAN LED. This may be used to ensure the proper module has been selected before making a change.

Then select LAN Configuration to adjust the LAN configuration



Here a static IP or DHCP configuration may be made. If DHCP is selected, NH Research recommends IT assigning the modules MAC address to a static DHCP address for proper operation. Be sure to record the new IP address as it will be required by the touch panel.

The default security password is password

If you set the switch on the rear panel to force a 192.168.0.2 address be sure to return this switch to the off position before cycling power.

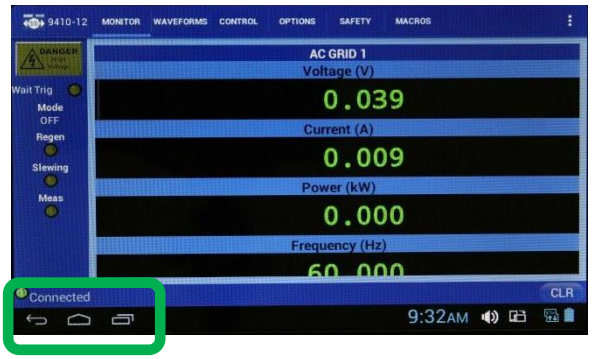
Restart the module and continue with the touch panel configuration.

3.9.3 Configuring the Touch Panel's IP address

The touch panel has two separate IP configurations required:

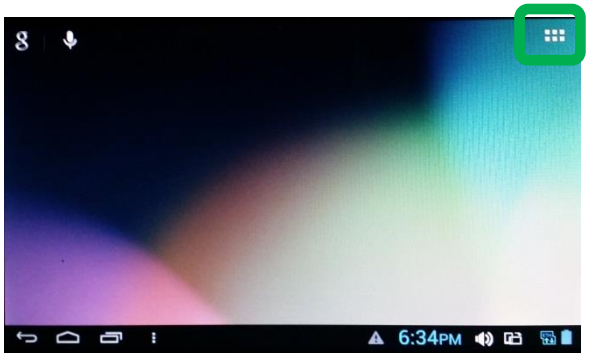
Configuring the Panel's IP Address

To configure the panel's IP address,
First, click the "Home" button
Located at the lower left of the panel
This will return you to the Android Screen

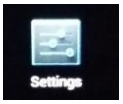


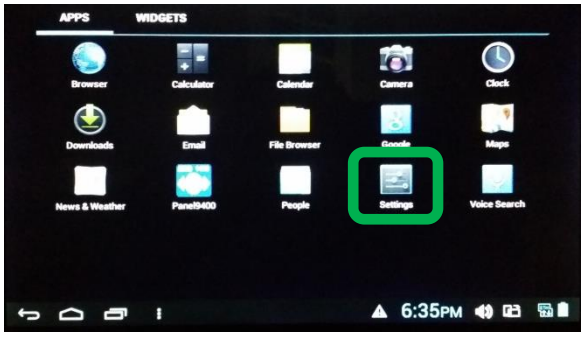
Then Select The Menu Button

This is found in the Upper Left



Then Select Settings
from the list of options



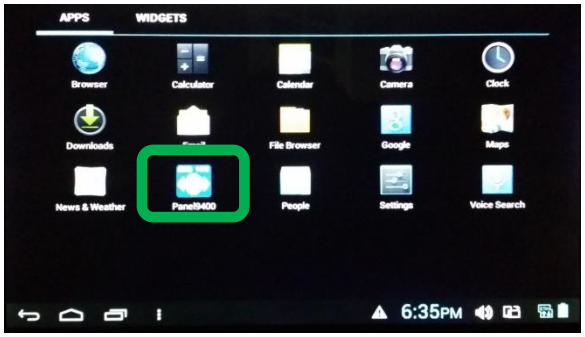


The panel's ethernet IP address settings are located under the Ethernet Tab.

Be sure to assign a unique IP address that will be used by the touch panel.

Consult your IT administrator

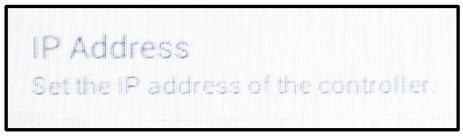
Click the Home button to restart the Panel
The application will be on the home screen
or under the “Apps”  menu

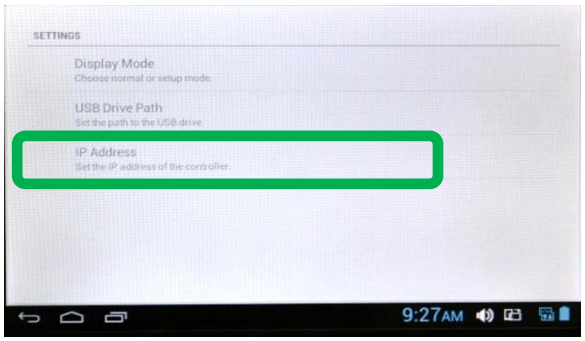


Then Select The Menu Button

This is found in the Upper Left

Then Select IP Address Option





Provide the Controller’s IP Address
This is the address set in section 3.9.1

Note: This is not the panel’s address
but the address assigned to the
9400 Master Module.

3.9.4 Connecting with an external application

External applications will use the Master's IP address and port number 5025.

For VISA Devices the resource ID string is typically:
TCPIP::IPADDRESS::5025::SOCKET

For NH Research PC tools the resource ID string is typically:
TCPIP::IPADDRESS

3.10 Powering down the system

- Turn off the outputs
- Stop and close any external control software (if used)
- Turn off the master module's circuit breaker
- Turn off the remaining auxiliary module(s) circuit breaker(s)

The modules use internal contactors to isolate themselves from Facility Power when a fault occurs or when the system is powered off.

- Turn off external power (optional)

4. TOUCH PANEL CONTROL

The Power Module can be controlled through the supplied front panel touch control.

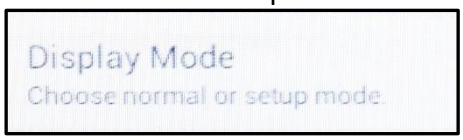
4.1 Setting the operating mode

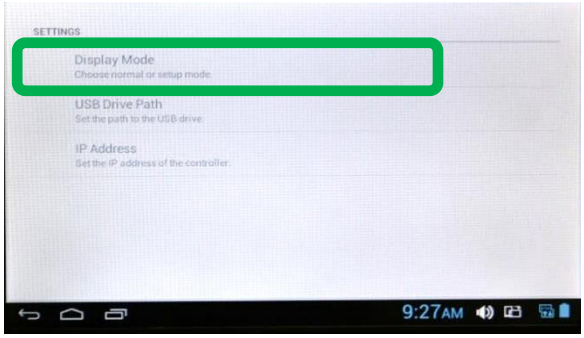
The 9400 series contains a number of hardware operating modes. These modes provide a simpler programming interface as well as displaying line-line values for multi-phase operation. To select a hardware operating mode follow the steps below

Then Select The Menu Button

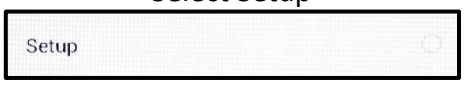
This is found in the Upper Left

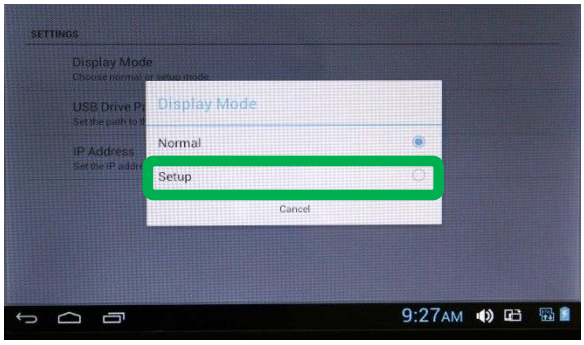
Then Select Display Mode to change from normal to setup screen view.



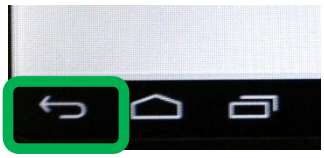


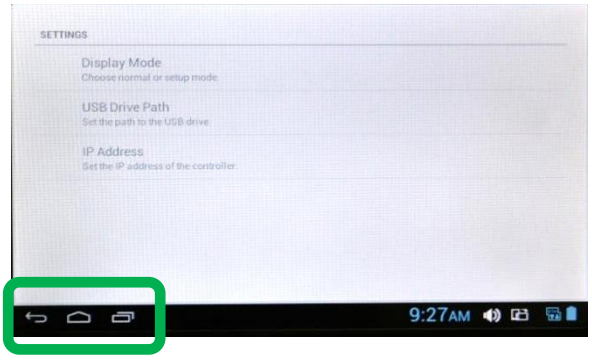
Select Setup



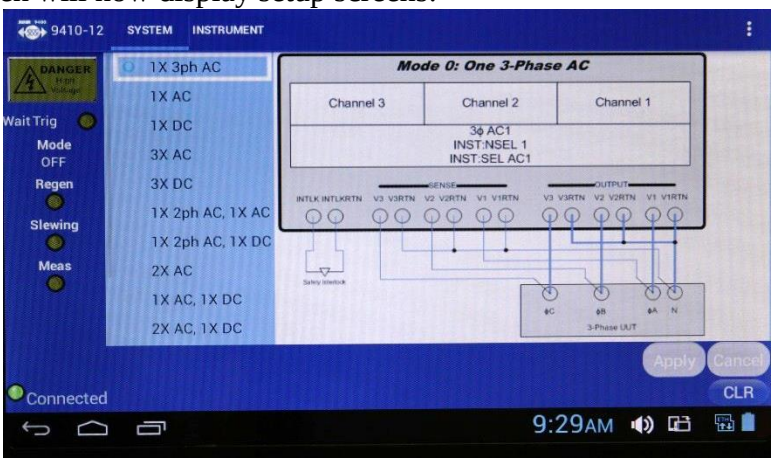


Press the return arrow to exit from the menu screens.



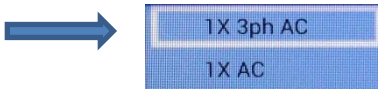


The touch screen will now display setup screens:

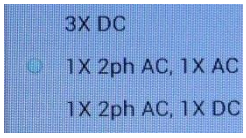


Any operating mode may be viewed along with NH Research's recommended wiring. The menu is scrollable by swiping (up/down) on the operating mode list. Any operating modes may be viewed and will not be activated until the apply button is pressed.

The active hardware mode is circled as shown



Any selected hardware operating mode as well as the wiring associated with this mode is indicated with a dot icon as shown.



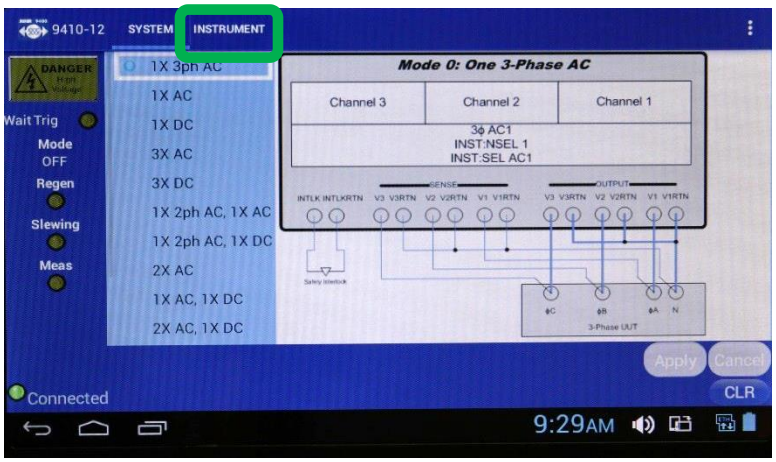
Pressing apply will send the configuration commands to the hardware

Changes to the operating mode may require output wiring changes.

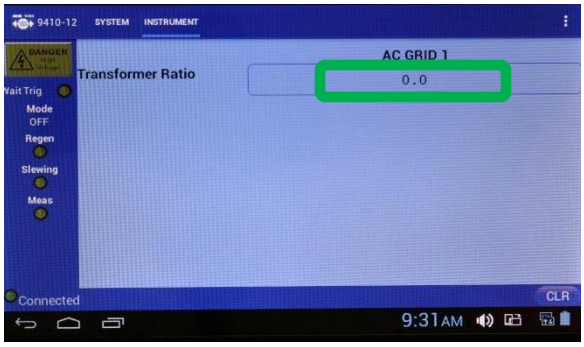
Changes to operating mode disable previous safety limit settings.

4.2 Configuring an Auto-Transformer

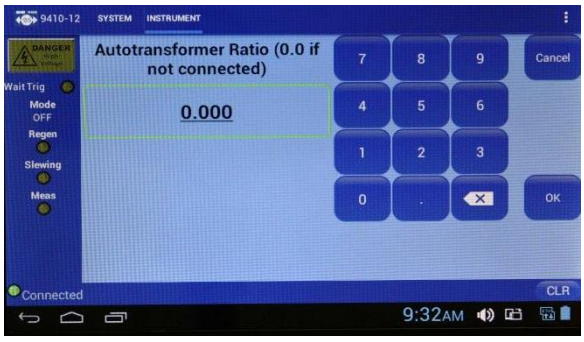
The 9400 is able to support as well as directly measure and control the output of an auto-transformer for higher output voltage up to 400VAC$_{rms(l-n)}$ per phase.
After configuring the hardware mode, the turns-ratio of an external auto-transformer is programmed under the instrument tab.



Tap the value field under the the configured instrument which an auto transformer has been installed.



Enter the turns ratio and press the OK button



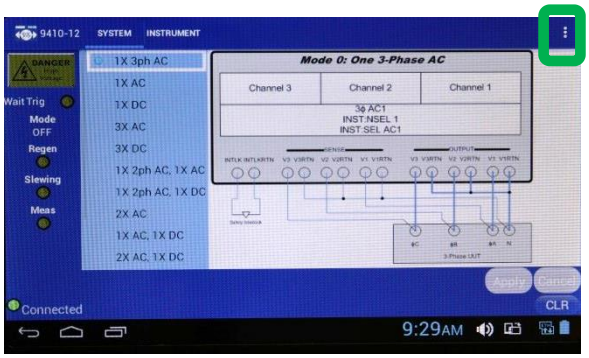
See the installation section for wiring guidance to connect an auto-transformer to a 9400 system.

4.3 Exiting System Setup Screen

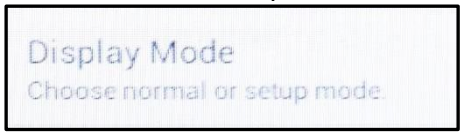
Use the following steps to return to normal display mode after setup is complete.

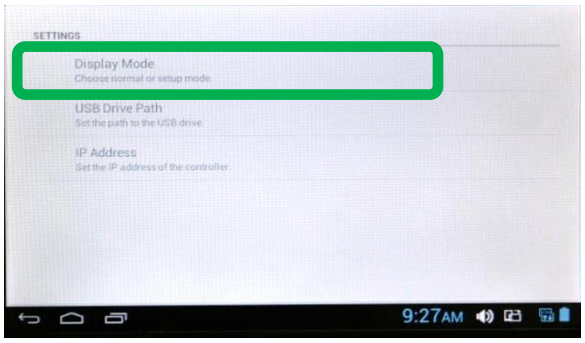
Then Select The Menu Button

This is found in the Upper Left

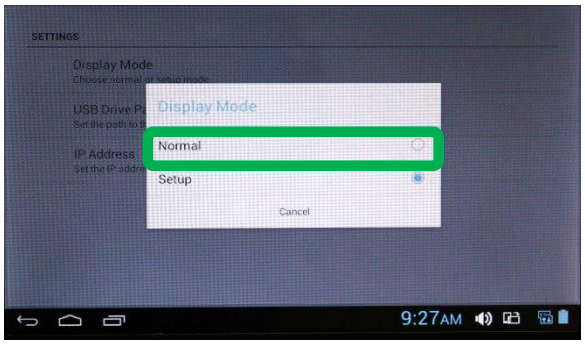


Then Select Display Mode to change from normal to setup screen view.

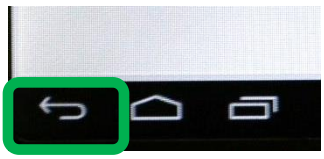


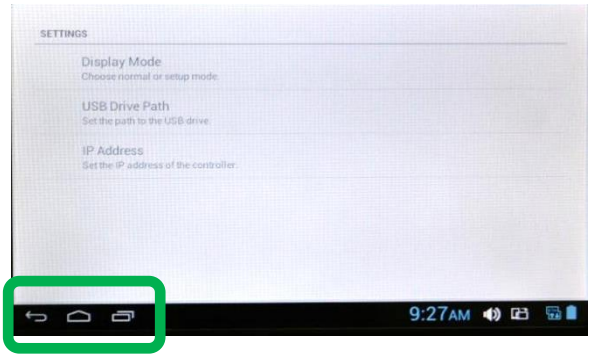


Select Normal



Press the return arrow to exit from the menu screens.





4.4 Touch Screen Overview

The touch screen includes a number of tabs and indicators. The touch panel may be locked out preventing manual changes when the system is being operated remotely such as the NHR 9400 panel. The monitor tab and the error clear buttons are the only active fields when the panel has been locked by a remote application.

Panel is Primary Controller

Panel is Locked Out (remote controller)

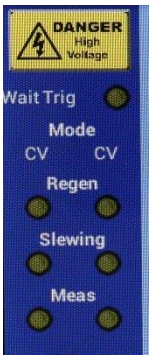
4.5 Indicators

The 9400 supplies a number of indicators which are displayed to the left at all times.

The number of indicators shown will depend on the number of logical instrument as configured by the hardware operating mode. For example a 3-ϕ AC output is a single logical instrument whereas three separate 1-ϕ AC outputs would be three channels.

These are ordered left to right.

Examples
9410: 1x 1-ϕ AC or DC
9410: 3-ϕ



Examples
9410: 2-ϕ + AC or DC
9410: 2x AC or DC

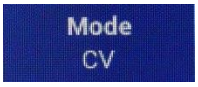
Examples
9410: 3x 1-ϕ AC
9410: 3x DC

Indicators below are described from top to bottom

When lit, the output of one or more channels is active.
This button may be pressed to turn all channels off.
This feature is locked out in remote lockout mode.

⚠ Always assume voltage may be present at the output

Indicates the system is waiting for a trigger before performing the next action such as taking a measurement or executing a macro step



Indicates the current regulation mode (per instrument)

Indicates the power the UUT is being converted into facility power

Indicates one or more phases of are slewing to a new set value.

Indicates a measurement is in progress

Indicates the macro is executing (i.e. local high-speed control is active.)

Only displayed when a macro has been downloaded to the system.

A macro run button may also appear when the system is under touch panel control.

More information about building and using macros can be found in later sections.

4.6 System Status

The upper left hand corner displays the system model number and size. The system size is automatically updated based on the number of auxiliary modules which have been identified at system power up.

Additionally, this field indicates if the system is currently being controlled remotely and the panel has been locked out by the remote application (such as the NHR 9400 Panel).

Panel is Primary Controller

Panel is Locked Out (remote controller)

The lower portion of the screen includes a status bar including an indicator 

The indicator shows a communications status (heart beat) as well as error status.

- Blinking Yellow – Normal status & communicating with system
- Blinking Red – An Error has been detected
- Solid (any color: on or off) – Communication with the system has failed
  (A reset or power cycle may be required)

Immediately to the right of this indicator is a status message.
This message shows either "Connected" or an error message (if present)

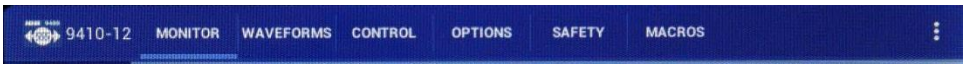
The displayed error (if present) may be cleared by pressing 

found to the right.

The time clock is the local time as determined by the Android operating system for the touch panel. Adjusting the time clock is possible under the android tablet settings which is accessed in the same was as in the "Configuring the Touch Panel's IP Address" section.

4.7 Screen Selection Tabs

The multiple control screens are selected using the tabs at the top of the touch panel. he current selected tab is indicated by a blue underline as shown below



All control screens are available when the system is under touch panel control.

The monitor tab is the only screen available when the touch screen is locked out. The other tabs (circled below) are removed thereby preventing local changes which may affect the testing results.

Control tabs are described from left to right

MONITOR	The monitor tab provides digital measurements for each instrument. For multi-phase instruments, tap any measurement to switch between per phase (l-n) and multi-phase (l-l) views
WAVEFORMS	Provides a waveform view of the current output (voltage & current)
CONTROL	Provides set control for single values (voltage, current, frequency, etc) Like the monitor tab, tap the measurements to switch between per phase (l-n) and multi-phase (l-l) control views
OPTIONS	Provides access to additional set controls (ranges, waveshapes, etc)
SAFETY	Provides access to the safety limit settings
MACROS	Provides access to the internal local high-speed control system
⋮	Used to access setup menu For more information see “Setting the operating mode” section

4.7.1 Monitor Screen

The Monitor screen provides measurements for each configured instrument.
For 1-ϕ and DC these measurements are always referenced to neutral (l-n).
For multi-ϕ modes, the measurements are available as line-line or per-phase (l-n).

This monitor screen is available at all times even when the system is being controlled externally with another application (such as the NHR 9400 Panel software)

Monitor Screen for a split phase (2-ϕ) + 1 AC (1-ϕ) Configuration

4.7.1.1 Instrument Labels

The monitor screen provides the instrument names based on the hardware configuration.

These are placed atop of the measurements as shown.

The background of the instrument label changes to YELLOW when the output is active.
This indication is in addition to the left indicators which are displayed across all screens.

Channel is Active (ON)

Channel is Inactive (OFF)

4.7.1.3 Switching between line-line and line-neutral views

For multi-phase outputs, tap any measurement toggles between multi- & per-phase views

Line-Line view for 2-ϕ instrument

Per Phase (L-N) view for 2-ϕ instrument

Multi-Phase view takes into account the relative phase angles of the phases when displaying the equivalent line-line voltage. The following table provides some additional details

Hardware Mode	Per Phase View (only)
DC Output **Single Phase (1-ϕ)**	Voltage Shown as L-N Actual line currents Power (kW) Energy (Ah) Energy (kWh) Apparent Power (VA)

Hardware Mode	Multi-Phase View	Per Phase View
Multi-Phase	Voltage shown as L-L Average of line currents	Voltage Shown as L-N Actual line currents per phase
Split Phase (2-ϕ) **Three Phase (3-ϕ)**	Total Power (kW) Total Energy (Ah) Total Energy (kWh) Total Apparent Power (VA)	Power (kW) per phase Energy (Ah) per phase Energy (kWh) per phase Apparent Power (VA) per phase

+Peak and –Peak voltage, current, & power are always displayed per ϕ.

Frequency is indicated for instruments configured for AC outputs.

4.7.1.4 Scrolling for additional measurements

The system reports more measurements than can be shown on the screen at one time. The touch screen takes advantage of Androids swipe capability allowing the entire list of measurements to be viewed. To see the additional measurements, keep touching the screen and scroll up & down to see the additional available measurements.

Scrolling for more measurements on AC GRID 3

Scrolling for more measurements on AC GRID 3

4.7.2 Waveform Screen

The waveform screen provides a graphical representation of the voltage & current for any or all of the configured instruments. The displayed waveform synchronizes to the 0^{o} start angle of the output and displays one cycle (AC) or 10mS (DC).

To access this feature, select the waveforms tab then check the desired instruments.

Split Phase (2-ϕ) shown with A-Phase using a n-Step sine output

4.7.3 Control Screen

The control screen allows single value updates to any instrument. In single phase, this may be voltage, frequency, or any other single parameter. In multi-phase, the adjustment can be to all phases (such as returning to a balanced voltage) or on a per-phases basis.

Macros (described later) are available to adjust multiple phases simultaneously as well as provide timed or cycle count based changes to settings.

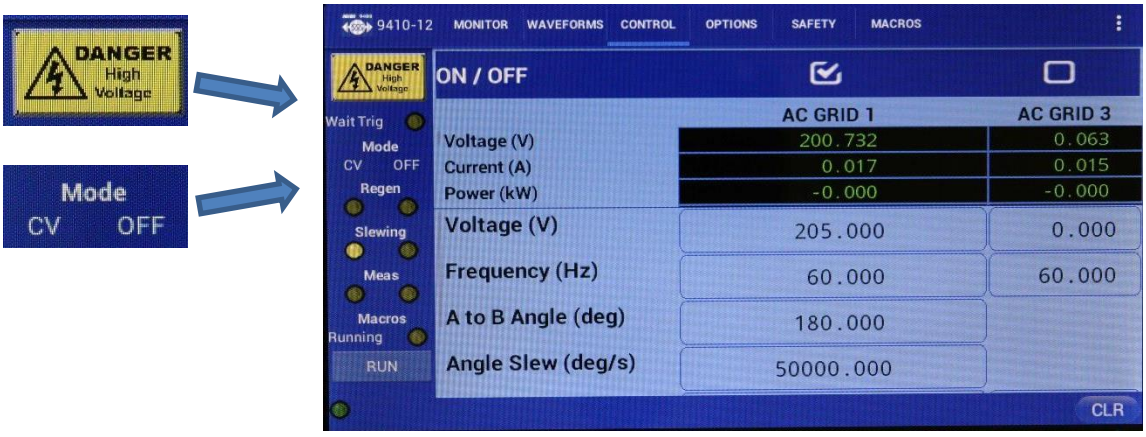
Control Screen for a split phase (2-ϕ) + 1 AC (1-ϕ) Configuration

4.7.3.1 Turning the Output On/Off

An output is turned on/off by taping the check box directly above the instrument label. This check-box is in addition to the left indicators which are displayed across all screens as well as the active measurements directly below.

Channel is Active (ON)

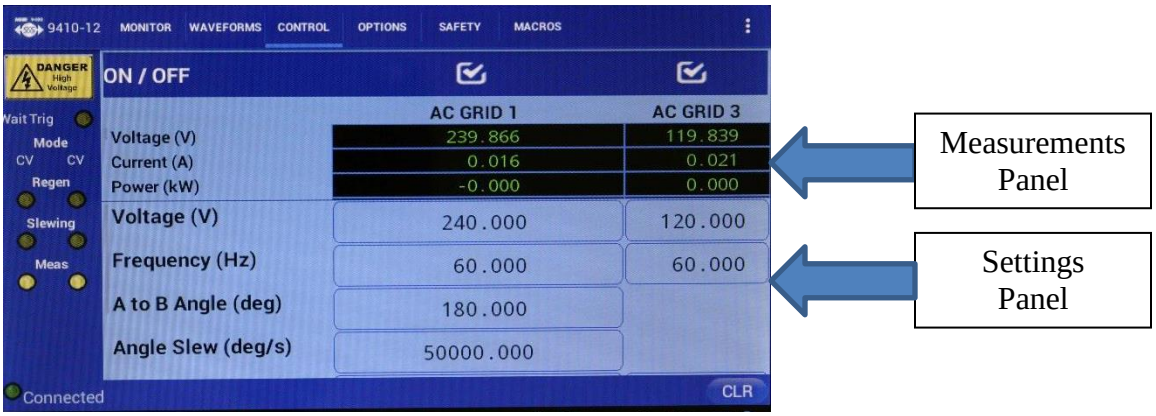
Channel is Inactive (OFF)



4.7.3.2 Measurements & Settings Panels

Directly below the On/Off checkbox control is a measurements panel. This provides similar functionality as the monitor screen including taping for multi- versus per-phase views as well as scrolling the measurements to see other values which do not fit on the screen. The only significant difference is both instruments will scroll together rather than separately as is available in the monitor screen.

The settings panel is used to select which setting will be adjusted.



4.7.3.3 Switching control from line-line to line-neutral

Similar to the monitor panel, the control panel allows a single tap in the measurements panel to switch between multi- & per-phase views. The control options follow the mult- or per-phase setting controls as shown below.

Line-Line control for 2-ϕ instrument

Per Phase (L-N) control for 2-ϕ instrument

Multi-Phase programming uses line-line values for voltage whereas per-phase and single channels use line-neutral programming values.

The example above shows a $240VAC_{rms(l-l)}$ split phase in multi-phase control which is identical to $120VAC_{rms(l-n)}$ per phase with a A to B phase angle of 180^{o}. By comparison, The additional single phase (AC GRID 3) maintains the same view and is programmed in line-neutral in both screens.

4.7.3.4 Scrolling for additional settings

Similar to the monitor panel, the number of possible settings is greater than the number that can be shown on the screen at one time. The touch screen takes advantage of Androids swipe capability allowing the entire list of settings to be viewed or selected. To see the additional settings, keep touching settings area and scroll up & down to see the additional available set options.

Scrolling up for more settings (3-ϕ shown)

Scrolling up for more settings (3-ϕ shown)

4.7.3.5 Adjusting Output Settings

Tapping on a setting opens a control allowing the setting to be changed.

The setting may be adjusted by direct value entry or using a live-update feature which emulates up & down buttons supplied by other equipment manufacturers.

Only the available settings will be displayed which are appropriate for the hardware operating mode selected.

For example: in Split-ϕ + 1 AC the single AC channel has no phase angle relationship.

Adjusting through direct value entry

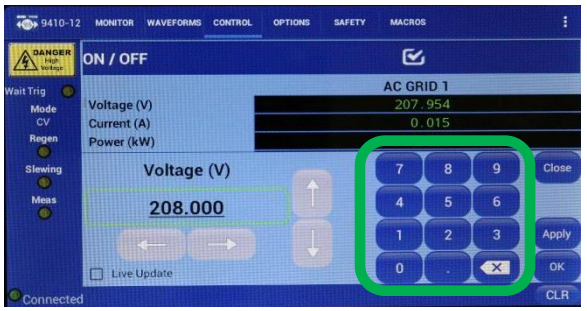
Taping the value field opens a control panel allowing for direct numerical entry.

Tap on the measurement value
That is to be adjusted.

Click on 208V.

Note: for multi-ϕ, this is line-line (voltage)
for single-ϕ & per-ϕ, this is line-neutral

Enter the new setting
using the numeric keypad

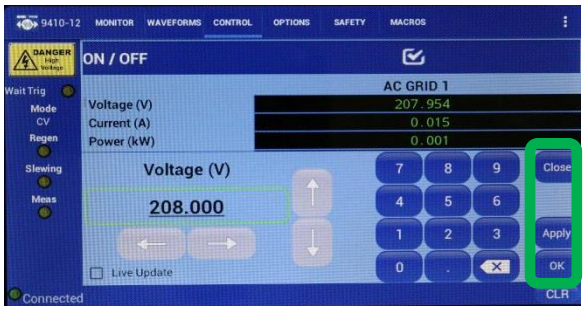


Then select close, apply, or OK

Close — Closes the entry screen and cancels the setting (NOT applied)

Apply — Applies the new setting and allows additional entries for the setting

OK — Closes the entry screen and applies the new setting



Switching between Multi-Phase and Per phase views occurs before selecting the setting to be adjusted. For more information, see the previous "Switching control from line-line to line-neutral" section

Single phase and per phase view settings are always entered as line-neutral

Multi-phase settings (such as voltage) are generally entered as line-line

Adjusting using an Up/Down value modification

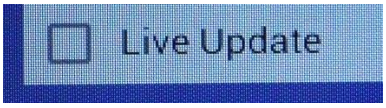
The NHR 9400 Panel allows a value to be adjusted using an up/down button approach.

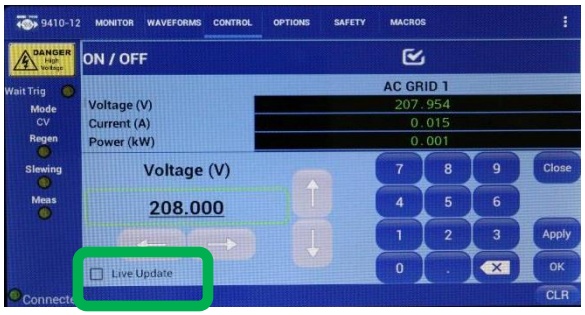
Tap on the measurement value
That is to be adjusted.

Click on 208V.

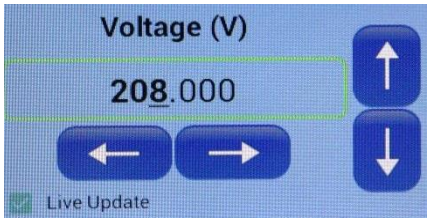
Note: for multi-ϕ, this is line-line (voltage)
for single-ϕ & per-ϕ, this is line-neutral

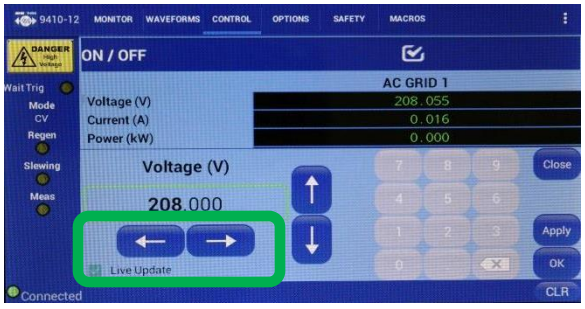
Check the Live Update Checkbox



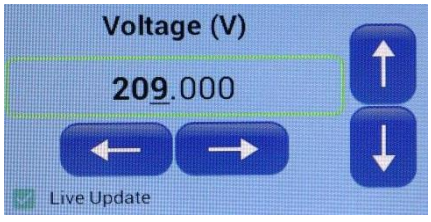


Use the left & right arrows to
select which digit will be adjusted





Use the up & down arrows to
Increase or decrease the selected digit



Note: Settings are applied immediately using this method.

4.7.4 Options Screen

The options screen provides settings which accept one or more fixed values rather than user-specified values like the control screen. This screen operates in a similar way as the control screen except that a selected value provides a menu choice rather than a value entry screen.

All of these settings may also be adjusted using macros similar to the control screen.

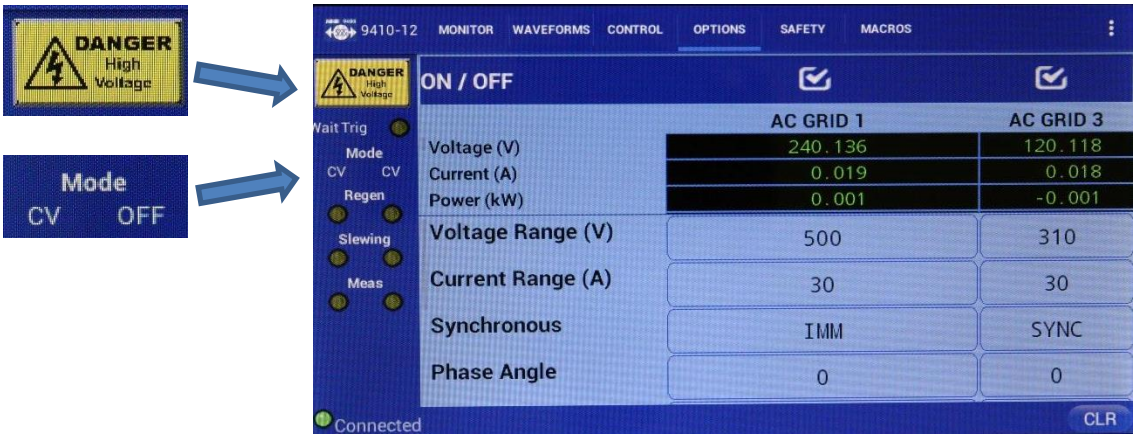
Control Screen for a split phase (2-ϕ) + 1 AC (1-ϕ) Configuration

4.7.4.1 Turning the Output On/Off

Similar to the control screen, an output is turned on/off by taping the check box directly above the instrument label. This check-box is in addition to the left indicators which are displayed across all screens as well as the active measurements directly below.

Channel is Active (ON)

Channel is Inactive (OFF)



4.7.4.2 Scrolling for additional settings

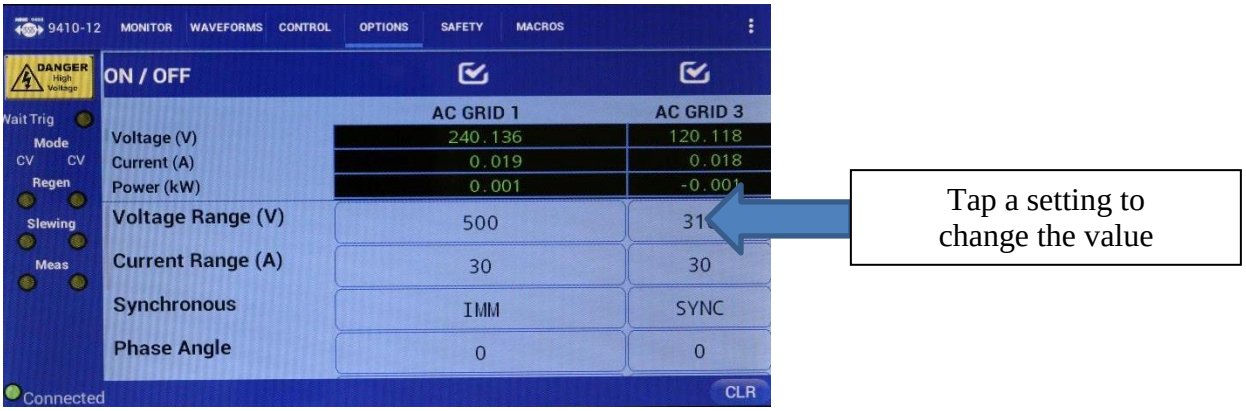
Similar to the control panel, the number of possible settings is greater than the number that can be shown on the screen at one time. The touch screen takes advantage of Androids swipe capability allowing the entire list of settings to be viewed or selected. To see the additional settings, keep touching settings area and scroll up & down to see the additional available set options.

Scrolling up for more settings (2-ϕ + AC shown)

Scrolling up for more settings (2-ϕ + AC shown)

4.7.4.3 Adjusting Output Settings

Similar to the control screen, Tapping on a setting opens a control allowing the setting to be changed. When selected, a menu option will pop up providing a selection option..



Voltage Range is always displayed as line-line for multi-ϕ instruments and line-neutral for single-ϕ instruments. The panel does permit switching between multi-ϕ and per-ϕ views (similar to the control screen) which is useful for applying a user-wave shape to an individual phase.

4.7.4.4 Clearing Accumulated measurements

Options to clear accumulated measurements such as peak voltage, current, power as well as energy is found at the bottom of the options screen.

Tap to clear instruments accumulated measurements

When pressed, the touch panel requests confirmation before clearing the measurements .

4.7.4.5 Performing a Hardware Reset

A hardware reset may be requested from the options screen.

Tap to request a hardware reset

When pressed, the touch panel requests conformation before applying a hardware reset.

Hardware resets will turn off all outputs and return the system to a power up state. This sets all wave shapes back to the pre-programmed wave shapes, ranges to default, and settings to default.

Safety limits are preserved through reset. It is generally advised to ensure the system is fully prepared including ranges, safety limits, and operating modes before turning on the output again.

Always assume the voltage is present at the output even after performing a hardware reset.

4.7.5 Safety Screen

The safety screen provides programmable safety limits intended to limit UUT damage due to operator errors. Safety limits act like a programmable fuse and will disable and disconnect the system from the UUT when the programmed level is exceeded for the time specified. Like a fuse or circuit breaker, the setting value should be greater than the nominal expected and will trip faster when the actual value exceeds the threshold by a larger value.

Safety limits are sent to the hardware when another screen is selected.

Provide the desired changes and then select another screen

Changing hardware operating modes disables all safety limits values. Ensure safety limits are implemented before turning on the output.

4.7.5.1 Scrolling for additional settings

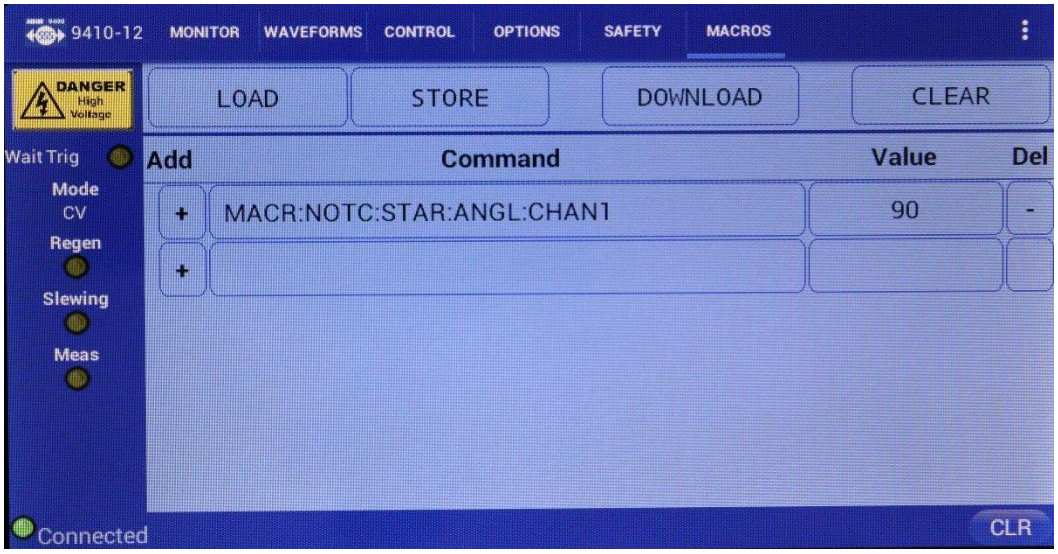
Similar to other screens, the number of possible settings is greater than the number that can be shown on the screen at one time. The touch screen takes advantage of Androids swipe capability allowing the entire list of settings to be viewed or selected. To see the additional settings, keep touching settings area and scroll up & down to see the additional available set options.

Scrolling up for more settings (3-ϕ shown)

Scrolling up for more settings (3-ϕ shown)

4.7.6 Macro Editor Screen

Macros are pre-programed sequences which are downloaded and executed locally on the hardware in order to provide direct cycle and sub-cycle control. Marcro's provide deterministic cycle-based and time-based changes to settings across all instrument channels, to any phase, to wave-shape selection, and any other programmable setting
.



Button Options below are described from left to right

LOAD	Retrieves a previously generated and stored macro file
STORE	Saves the current macro file for later use
DOWNLOAD	Downloads the current macro file to the hardware
CLEAR	Clears the macro editor screen (and macro loaded in hardware_
+	Inserts a new macro step above the current step
	Selectable entry field
-	Deletes the selected macro step

More information and usage examples can be found in the
"MARCOS & USAGE EXAMPLES" section below

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5. SOFTWARE (PC TOOLS) CONTROL

NH Research provides a number of PC-Based tools along with each 9400 System. One of these is the NHR 9400 Panel which permits manual control of the hardware. Alternatively, the Power Module can be controlled through communications terminals (like HyperTerminal) using SCPI commands, or through any software package which is able to issue SCPI commands, use an IVI-C/IVI-COM driver, or LabVIEW.

All of the provided utilities

Start → All Programs → NH Research → 9400 Series

Or on the local hard drive under

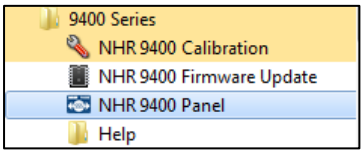
"C:\Program Files (x86)\NH Research\NHR 9400 Utilities\"

IVI is a windows only driver. The LabVIEW VIs and SCPI language should be used for non-windows control.

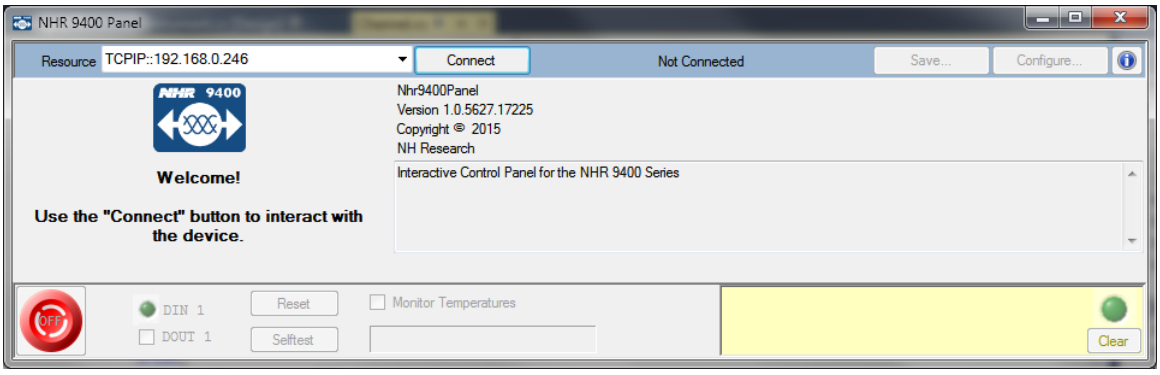
5.1 Launching the NHR 9400 Panel

The 9400 Panel software can be found under

Start → All Programs → NH Research → 9400 Series



After selecting the NHR 9400 Panel, the program will open with the following screen.

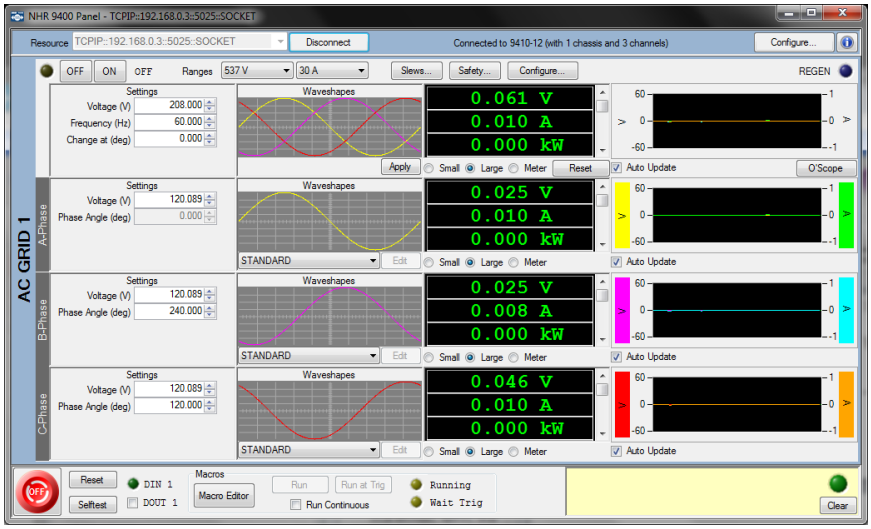


The IP address of the Module will need to be typed into the resource field in the upper left. This IP address is the one assigned in the "Configuring the Master Module" section from above and should use the format "TCPIP::(IP_ADDRESS)" as shown.

Supply the IP address and press the "Connect" button

5.2 The NHR 9400 Panel Overview

Once the software connects to the hardware you will see the main panel open.



The connection does NOT reset the hardware and will display the current settings and operating state of the hardware. Please ensure that you observe the current operating state before making applying any new settings.

5.3 NHR 9400 Panel - System Level Controls

The 9400 Panel includes a number of controls which apply to the entire system. Please read this section to ensure these controls are well understood including how they may affect other outputs.

5.3.1 Changing the Hardware Operating Modes

Hardware operating modes affects the entire chassis. The 9400 Series includes a number of operating modes which are intended to simplify programming and overall user experience. The Apendix provides a complete list of hardware operating modes as well as recommended UUT wiring.

Please ensure you are refering to the correct model trype as well as number of output channels to ensure the correct documentation is used for the rest of this process.

Changing the operating mode will typically require changes in the output connections to the UUT. Please read this section completely before proceeding.

To change the hardware operating mode using the 9400 Panel, first connect to the unit as described in the Launching the 9400 Panel section from above.

The main panel will load and show active measurments

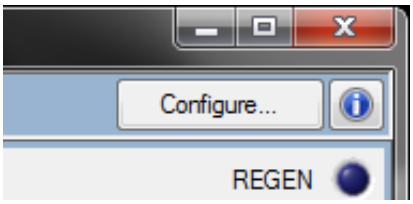
Ensure all instruments are in the “OFF” state by looking at the ON/OFF Indicator and status text in the upper left side of each instrument panel. Turn off any instrument which is currently active.

Wiring and Configuration should always be done in an OFF state with no external UUT power applied.

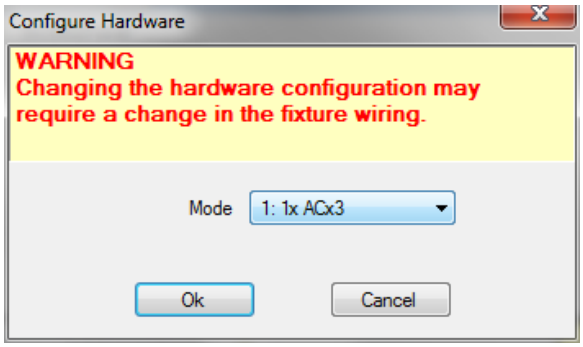
Changing the Hardware Operating Modes (Cont'd)

Next, select the Configure button in the upper right to change the hardware configuration.

This will cause a configuration screen to open allowing you to select a new operating mode.

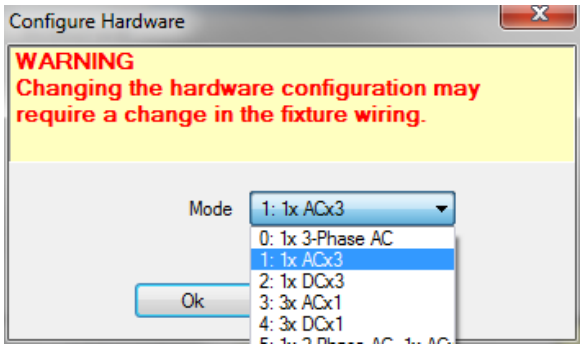


After selecting the Configure button the Configure Hardware dialog will be displayed.



Select the desired operating mode from the list:

Each model supports multiple operating modes which is series and output channel count dependant. If you are unsure of the proper operating mode for your application please review the details provided in the Apendix – Series # Hardware operating modes.



Pressing OK will select the new operating mode and apply the changes to hardware.

Changing the operating mode will typically require changes in the output connections to the UUT.

Previously established safety limits will be cleared.

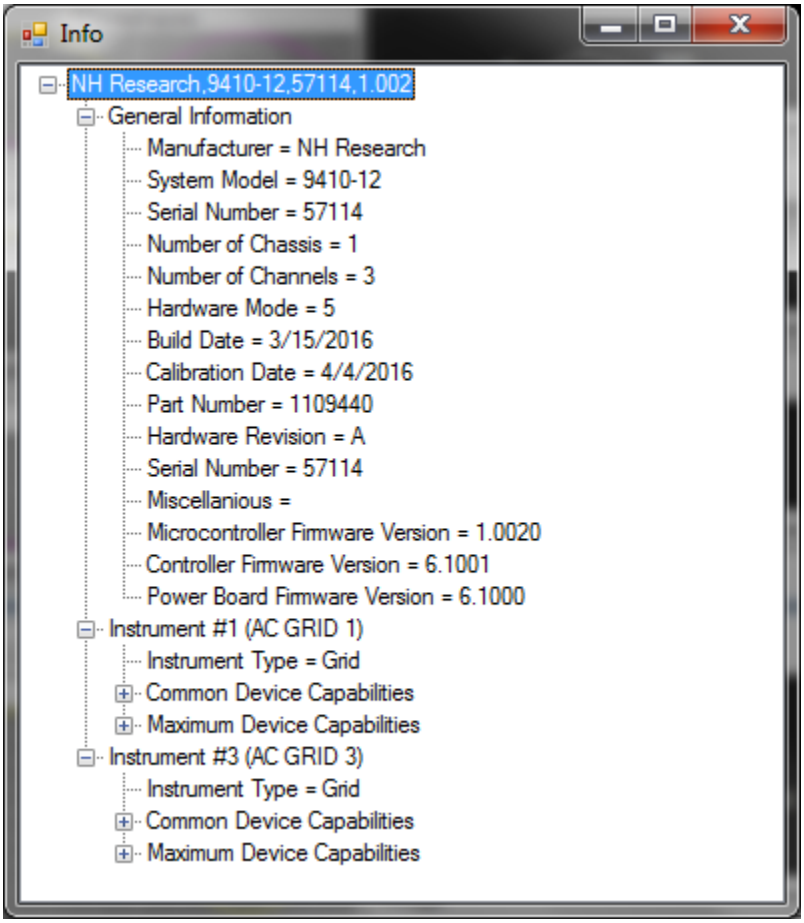
5.3.2 System Information & Capabilities

The system information including build date, last calibration, serial number, etc. is available through the 9400 Panel.

After connecting to the hardware pressing the information button  will display the system information. This button is next to the configure button to the upper right.

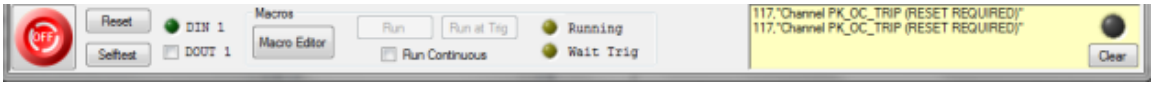
The information displayed provides details about the system including the model number, serial number, revision, and firmware versions.

Device capabilities are dependent on the hardware configuration selected.



5.3.3 System Level Controls

The system information including build date, last calibration, serial number, etc. is available through the 9400 Panel.
After c



Controls from left to right

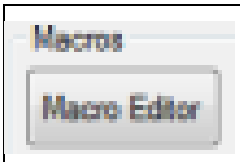
The OFF button provides a quick turn off feature for all output channels. This is different from an e-Stop output as any channel may be turned on again without requiring an reset command to be issued.

The Reset button sends a hardware reset to the system. All channels will return to default settings.

The Self-test button instructs the system to perform a hardware self-diagnostic. Feature is used for troubleshooting issues by NHR Customer support.

Digital Input Indicator

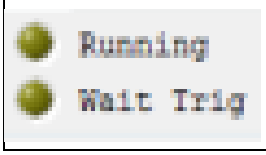
Digital Output Control



Macros are predefined sequences which are loaded to the hardware and executed locally. This ensures rapid fire timing and accurate cycle counting when needed.

More about macros can be found in the programming with macro's section below.

The "Run" and similar buttons shown are used with macros.

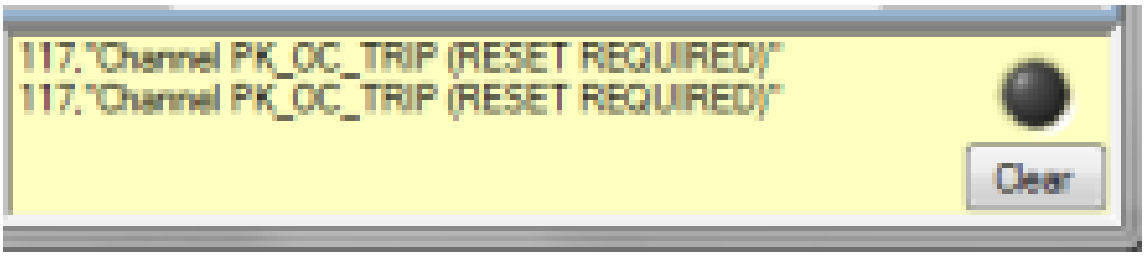


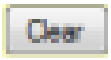
These status indications are associated with Macro's operating state.

5.3.4 Error Message Queue

The lower right corner provides an Error Message Queue. This area under normal operation should be blank. When an error is observed, the associated error message (along with additional instructions as needed) are added to this display window.

When there is an Error, the indicator above the "Clear" button will flash read.

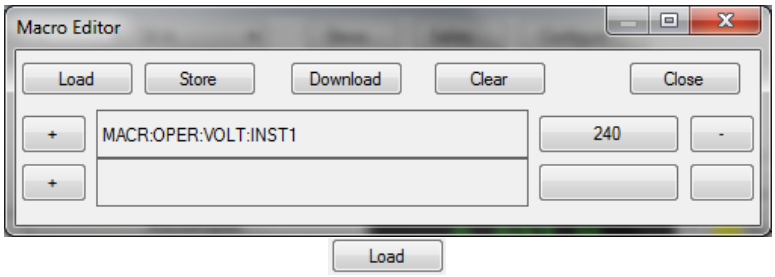


Pressing Clear  will clear most but not all error messages.

Safety trips as well as internal fault detections require additional user intervention such as providing a reset after the issue has been resolved.

5.3.5 Macro Editor

Macros are pre-programed sequences which are downloaded and executed locally on the hardware in order to provide direct cycle and sub-cycle control. Marcro's provide deterministic cycle-based and time-based changes to settings across all instrument channels, to any phase, to wave-shape selection, and any other programmable setting.



Button Options below are described from left to right

Load	Retrieves a previously generated and stored macro file
Store	Saves the current macro file for later use
Download	Downloads the current macro file to the hardware
Clear	Clears the macro editor screen (and macro loaded in hardware_
Close	Closes the editor macro editor window
+	Inserts a new macro step before current selected step
	Editable value entry field
-	Deletes the selected macro step

More information and usage examples can be found in the "MARCOS & USAGE EXAMPLES" section below

Macro's are entered in a similar manor on the touch panel. Please ensure you read the following sections about instrument level control options before attempting to program a macro.

5.4 NHR 9400 Panel – Instrument Level Controls

The main panel automatically detects the current hardware operating mode and adjusts the main screen automatically. It is possible to change the hardware configuration through this software utility which will be discussed in a later section.

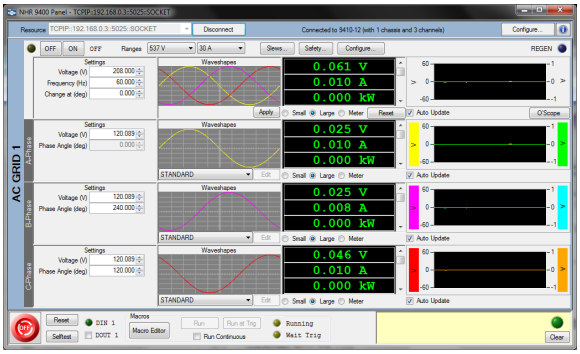


Figure 1 - Three Phase View (with per phase)

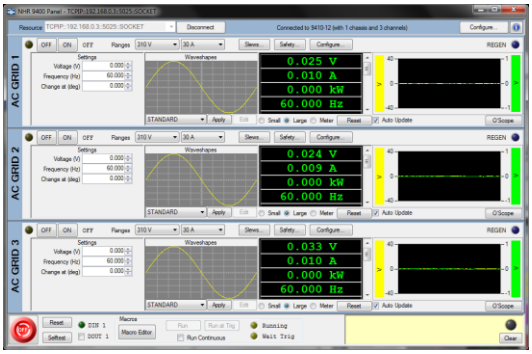


Figure 2 - Three 1 Phase Channels

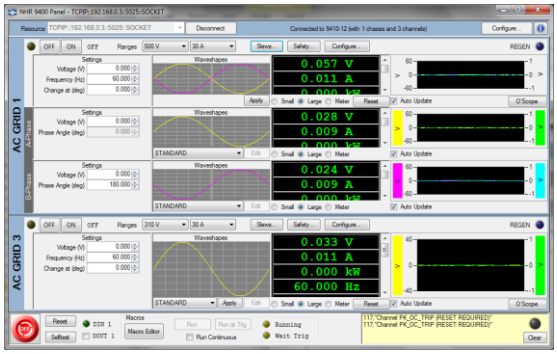


Figure 3 - One Split Phase Channel + One AC Channel

5.4.1 The Instrument & Phase Labels

Some hardware operating modes logically groups multiple outputs into a single instrument. For example, 3-ϕ uses all three phases to create a single three phase instrument whereas split-ϕ logically groups two outputs into one instrument and allows the remaining channel to be configured as a separate AC or DC output.

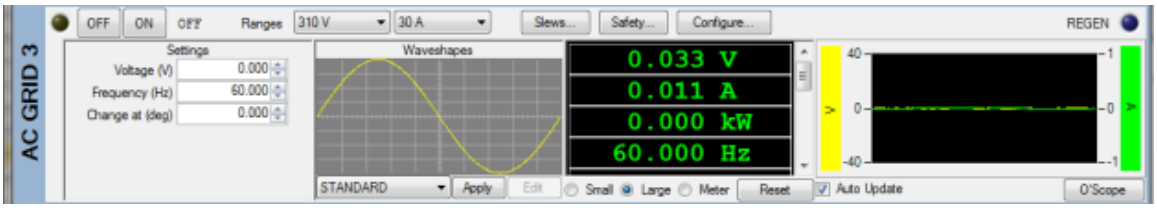
The left most labels provide the logical instrument name(s)

When configured in split-phase + one AC channel the 9410 shows the instrument names as “AC GRID 1” and “AC GRID 3” as shown to the left.

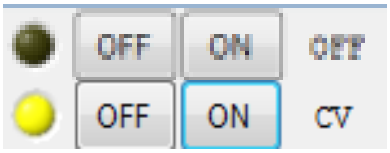
When a channel contains multiple separate phases (such as split-ϕ or 3-ϕ) a phase label is also shown indicating the separate phases within the multi-phase operating mode.

5.4.2 Instrument Output Controls

Each instrument provides multiple control features including safety, turn on/off, command phase angle triggers, slew rates, ranges, etc.



Controls from left to right



On and Off will activate or deactivate the output.

The output state is shown with both in indicator form and current output regulation mode (i.e. CV or OFF)

Voltage ranges are automatically scaled for Line-Line or Line-Neutral depending on the selected hardware mode

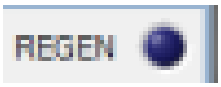
Current ranges are automatically scaled based on system size and the selected hardware mode

The Slews button provides access to the programmable slew rates. More details in the following sections.

The Safety button provides access to the programmable safety limits. More details in the following sections.

The Configure button provides access to additional options like phase angle trigger behavior.

Busy Icon when present indicates an operation is pending



The REGEN indication shows power is being absorbed by the UUT and transferred back to the facility

5.4.3 Establishing Per Phase & Multi-Phase Regulation Limits

When an instrument is multi-phase (either split-ϕ or 3-ϕ), the outputs may be simultaneously programmed using line-line values. Line-neutral values are used when an instrument is single phase, DC, or an individual phase is being programmed.

Note in the example below that a 9410 can be configured for split-ϕ (AC GRID 1) with a $240VAC_{rms(L-L)}$/60Hz (line-line) output where each phase is automatically set to $120VAC_{rms(L-N)}$ and the B-phase has a phase angle of 180^{o}. Any of these settings may be adjusted. In addition, the same system has a second instrument "AC GRID 3" which is programmed as a 1- phase $100VAC_{rms(L-N)}$/50Hz output

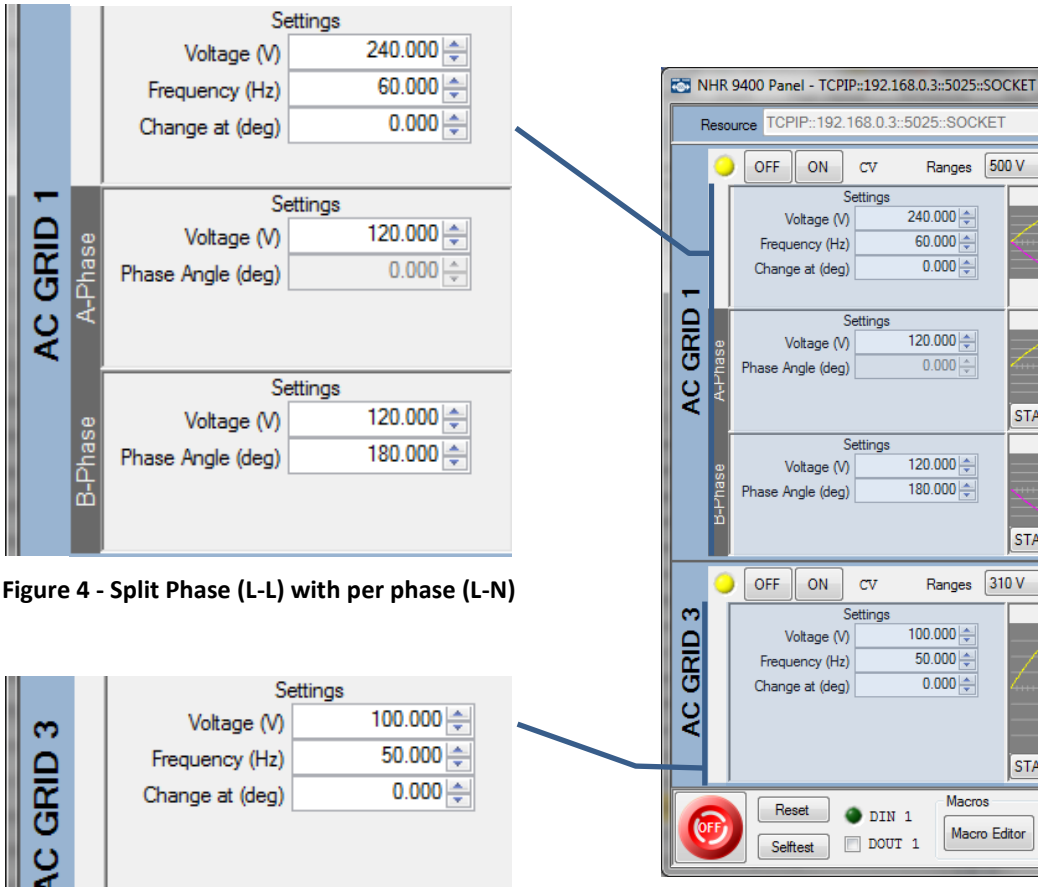


Figure 4 - Split Phase (L-L) with per phase (L-N)

Figure 5 - Single Phase (L-N)

The panel automatically provides the programmable featured based on the supplied model and hardware operating modes selected.

Change at (deg) is used as the trigger angle when operating in a phase angle trigger mode. For more information see the Adjusting phase angle trigger section below.

5.4.4 Selecting Output Wave shapes

The 9400 provides a standard (sine) and three (3) user programmable wave shapes per channel. These are typically used for harmonics and non-pure sinusoidal output controls. The wave shapes are scaled and slewed using the regulation limits provided in the earlier section. For multi-phase operation, the relative phase angle is also taken into account when using user defined wave shapes.

A thumbnail representation of the wave shape is shown allowing the user to confirm the selection before pressing "Apply"

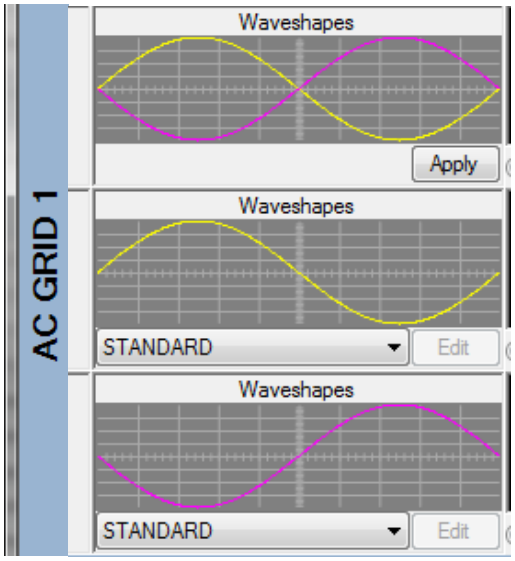


Figure 6 – Wave shape Controls

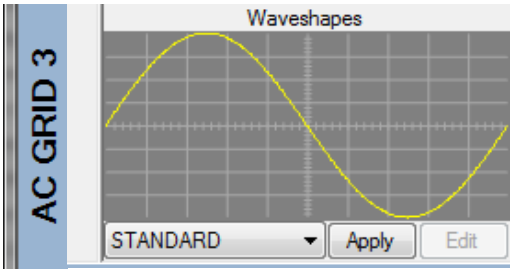
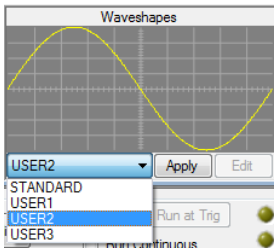


Figure 7 - Single Phase Wave Shape Controls

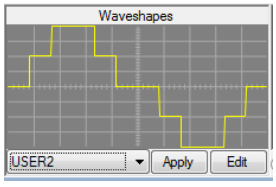
Selecting a wave shape

To select an alternative output wave shape click on the selection tab below the desired phase and select Standard (sine) or one of the three (3) user definable wave shapes.



At power-up, the following wave-shapes are pre-loaded for use:

- User 1: Triangle
- User 2: n-Step Sine
- User 3: Clipped Sine



Pressing the apply button 

will change the wave shape of the output to the selected wave shape immediately.

The user wave shapes may be edited by pressing the edit button. 

More information about the wave shape editor can be found in the advanced control options sections.

5.4.5 Measurements

The 9400 provides a number of last cycle measurements. All of the measurements for any given phase are synchronously captured including voltage, current, power, etc.

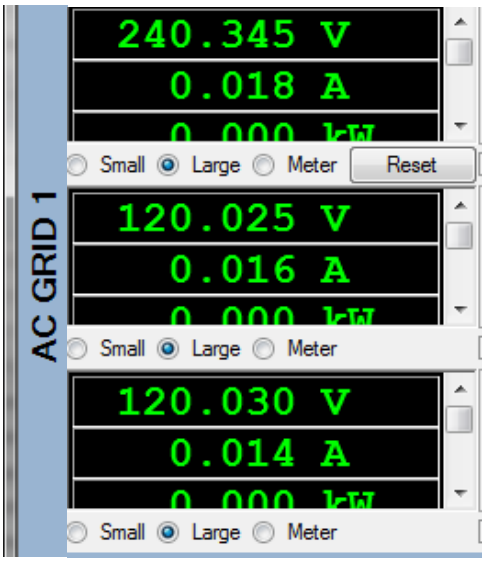


Figure 8 - Split Phase (L-L) with per phase (L-N)

The font size is adjustable and will display as many measurements as the screen size will allow.

Separate font size and meter views are possible on a per phase as well as a multi-phase basis.

Figure 9 - Single Phase (L-N)

5.4.6 Output Thumbnail Waveform Capture

The 9400 soft panel tools use an internal scope capture feature to synchronously capture and display 1-cycle for all voltage & current waveforms per instrument. This provides a real-time view of both the voltage and current behaviors of the UUT.

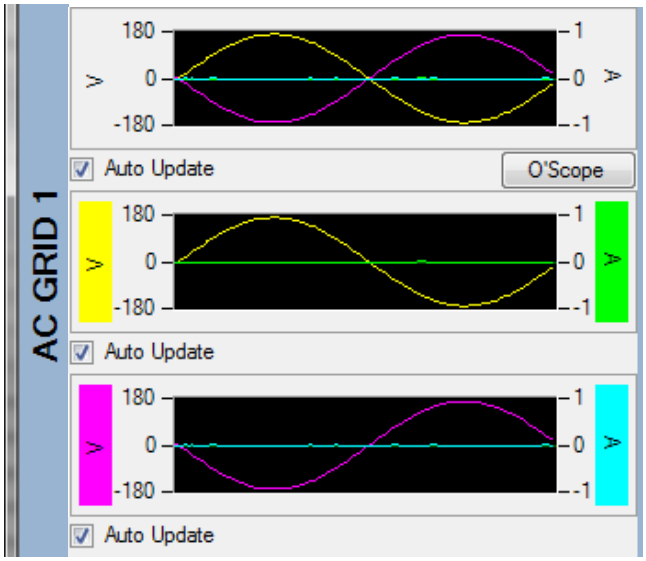


Figure 10 - Split Phase (L-L) with per phase (L-N)

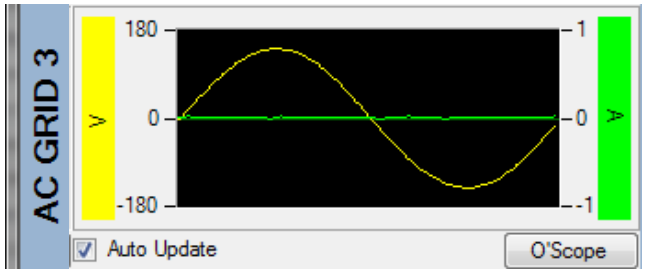
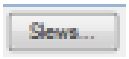
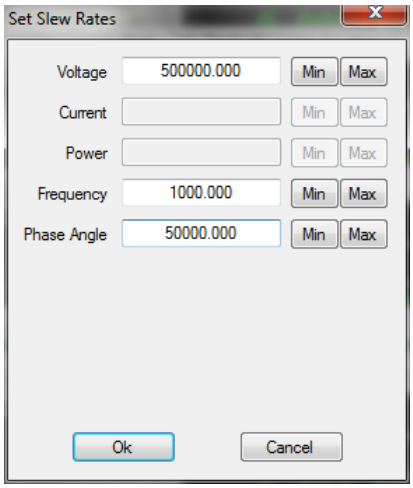


Figure 11 - Single Phase (L-N)

Higher resolution views are possible using the O'Scope panel which is accessed using the O'Scope button. More information about the built in digitizer and O'Scope panel can be found in the following Additional Controls section.

5.4.7 Adjusting Slew Rates

Pressing the "Slews" button  displays the slew rate control panel.



Slew rates provide a ramped linear control between two setting values.

Consider the following example:

> A 9410 Grid Emulator is operating in one-phase mode operating at $120VAC_{rms}$
> The slew rate is set for voltage at 3600 VAC_{rms} /sec.
> The next setting is to apply at 0^{o} phase angle.
>
> If the module is then told to regulate to $60VAC_{rms}$, this represents a 60V change which would take $1/60^{th}$ of a second (1 cycle @ 60Hz)

Result: a 1 cycle linear slew from $120VAC_{rms}$ to $60VAC_{rms}$.

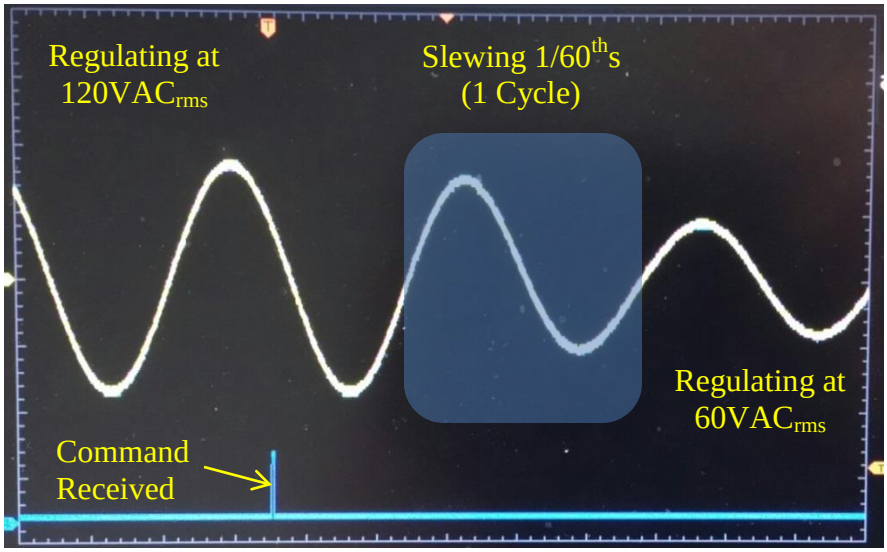
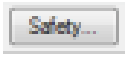
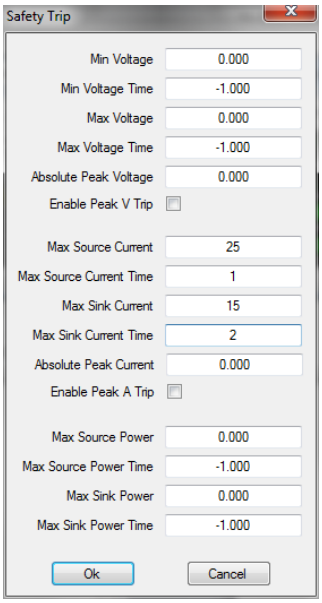


Figure 12 - Scope Capture of 9410 Output showing linear slew

5.4.8 Adjusting Safety

Pressing the "Safety" button 

displays the safety trip settings panel.



Safety limits can be thought of as a programmable breaker which is aware of the power flow direction. When any of the limits are exceeded the system stops flowing power and opens the UUT side contactor isolating the system from the UUT.

Each limit includes a value and a time field. For example, the maximum source current (from 9400 to the UUT) has been set to 25Arms with a time constant of 1s. Like a circuit breaker or fuse, if the current far exceeds 25Arms the time constant is shortened automatically based on the energy being transferred.

There is also a maximum sink current (from UUT to the 9400) allowing a separate limit to be set based on the direction of power flow. In this case, this has been programmed for 15Arms and a time constant of 2s.

There are additional limits based on voltage, power, and peak values for either voltage or current.

Setting a time allowed to -1 disables the safety setting

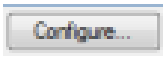
Setting a time allowed to 0 may result in noise causing a safety trip. General recommendations are 0.1 for a fast acting fuse and 0.5 for a slow-blow fuse equivalent.

Safety limits should be set outside of normal operating parameters and are intended to limit UUT damage due to operator error or UUT failure.

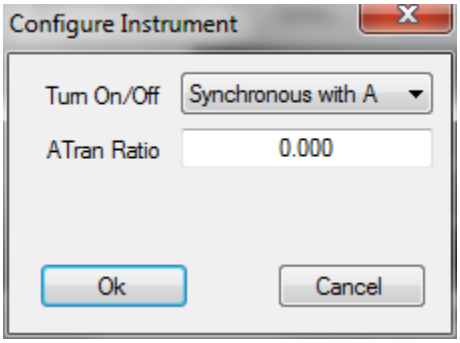
They should be used in the same way that a fuse or circuit breaker would be used in a similar application.

Safety limits do not affect programming capability. It is therefore possible to inject a noise pulse which exceeds the limits as long as it returns to nominal before safety detection time has elapsed.

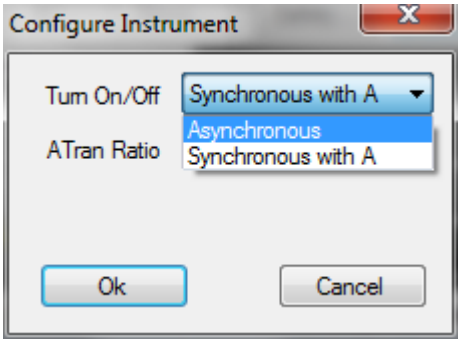
5.4.9 Adjusting Phase Angle Trigger Setting

Pressing the "Configure" button 

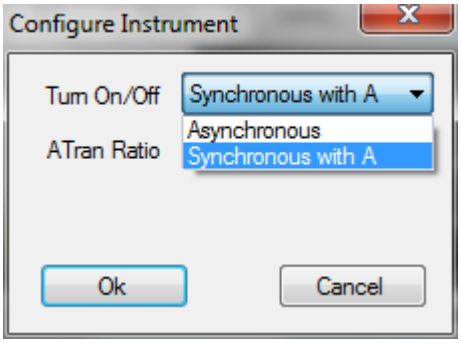
immediately to the right of "Safety" displays the configure instrument panel.



There are two (2) settings in this panel.. The Turn On/Off allows commands to be executed either asynchronously (applied immediately when they are received) or synchronous to the A Phase angle based on the Change at (deg) setting.



Command will be applied immediately



Command will be applied at phase angle

The examples on the following page will demonstrate the differences which can be observed between Asynchronous and Synchronous mode.

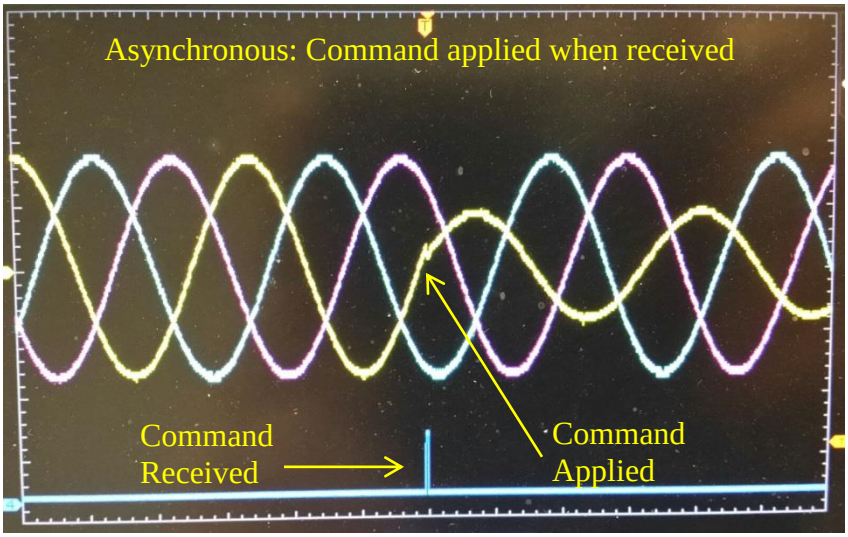
Synchronous with A uses A Phase in either split-ϕ or 3-ϕ mode as the angle reference.

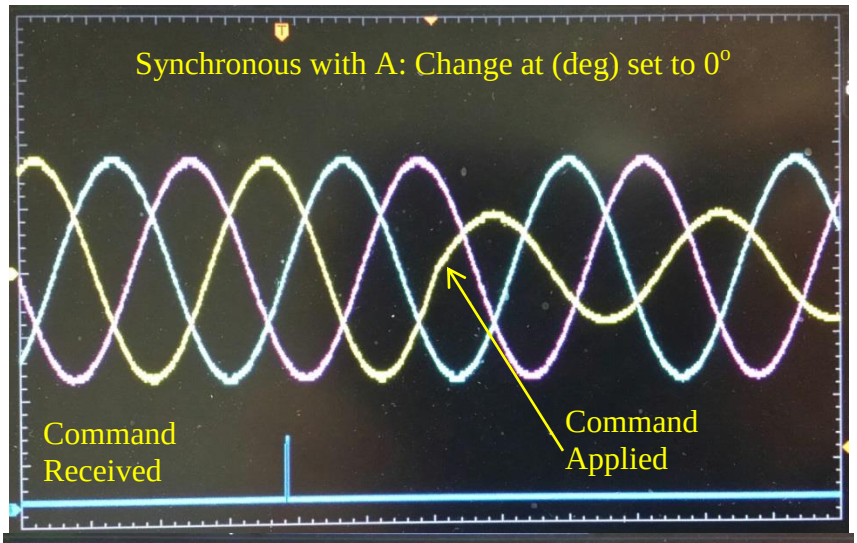
In 1-ϕ mode, The angle reference is the self-phase angle.

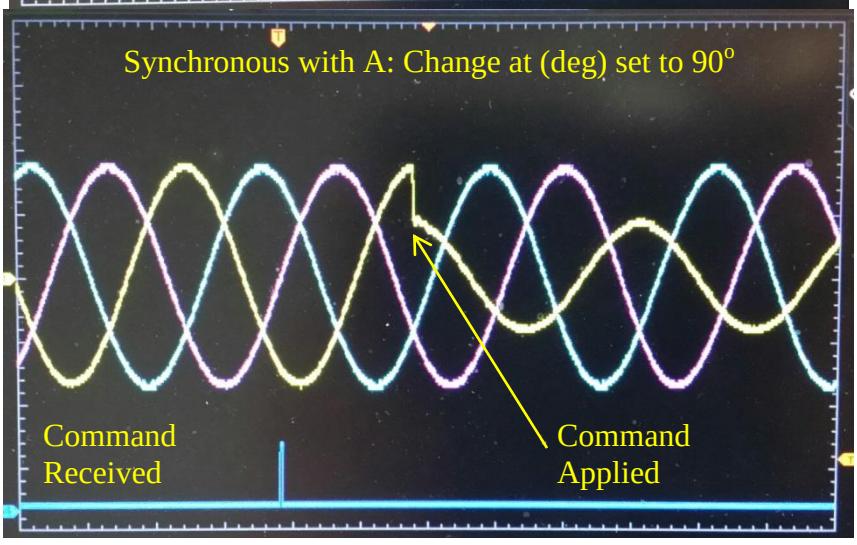
Do not adjust the ATran Radio unless an auto-transformer has been installed. See the installation section for more information about using an external Auto-transformer.

Asynchronous & Synchronous Examples:

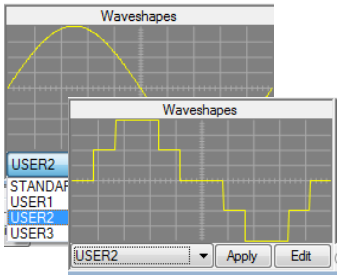
All examples show a transition from 120VAC$_{rms}$ to 60VAC$_{rms}$.







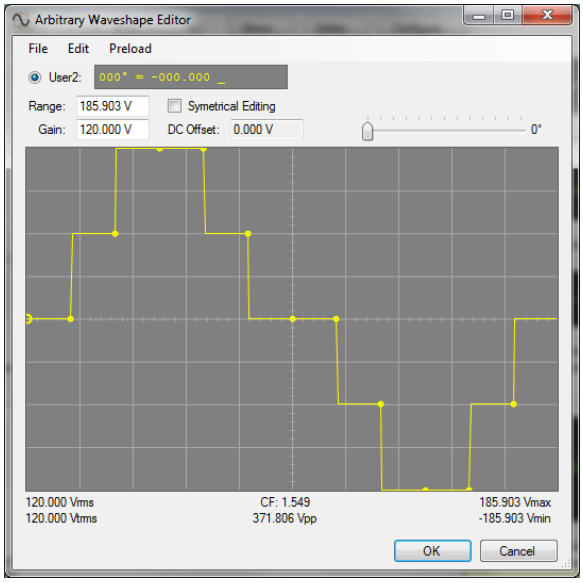
5.4.10 Editing an output wave shape



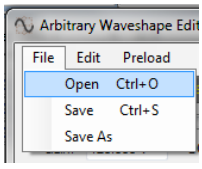
The NHR 9400 Series provides three (3) user definable wave shapes in addition to the standard (sine) output wave shape.

Select the user wave shape to be edited and press the edit button.

This will cause the wave shape editing tool to be displayed.

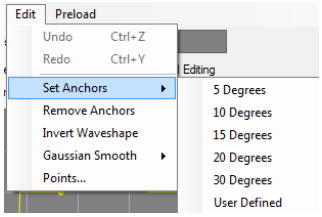


Menu Options

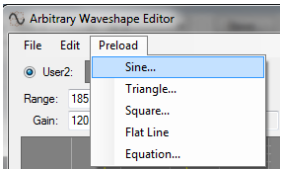


The File Menu – Allows a wave shape to be saved or recalled.

This allows the user to save their wave shapes and recall them or to copy the wave shape to other phases.



The Edit Menu – allows the wave shape to be edited on a point by point basis using anchors for a graphical approach or by points for direct value settings.



The Preload Menu – Preloads a pre-defined wave shape, use an equation, or generate a wave shape with harmonics.

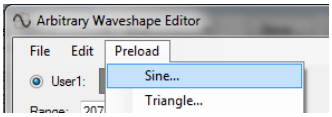
5.4.10.1 Wave shape example – line slap:

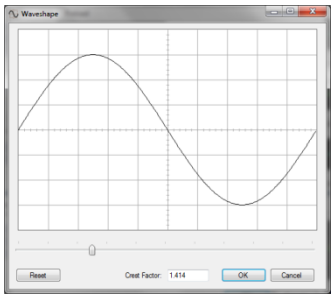
A line slap is an AC disturbance when two power lines are momentarily shorted together. This is represented by a narrow pulse which may transition across the 0V reference.

This type of wave shape is able to be generated using the NHR 9400 Panel.

Select User 1 and click Edit to edit the user wave-shape. Then load a sine shape to be modified by selecting

Preload → Sine…



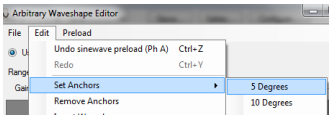


A dialog will appear with a sine wave shape. The dialog allows other modifiers to be applied such as adjusting the crest factor for the wave shape.

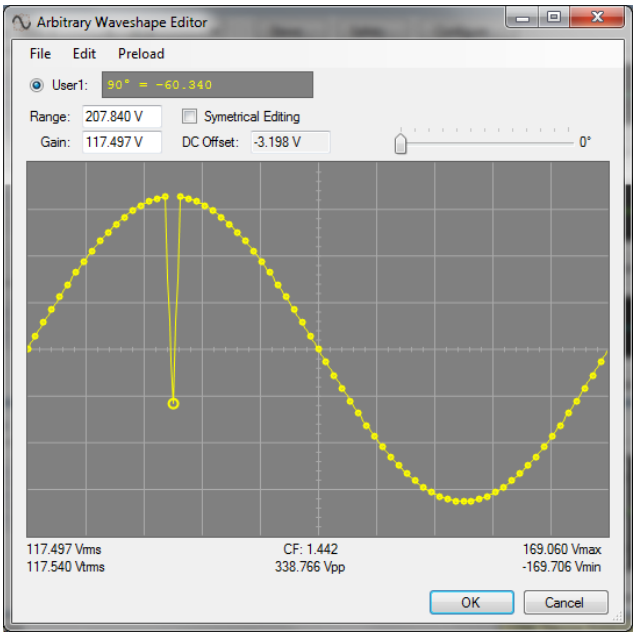
This example uses a standard sine as the starting point.

Click OK to close this dialog.

From the Edit Menu, click set anchors then select 5 degrees. This will place anchors on the wave shape allowing them to be graphically adjusted.



Grab the 90^{o} anchor and drag it down to the desired level



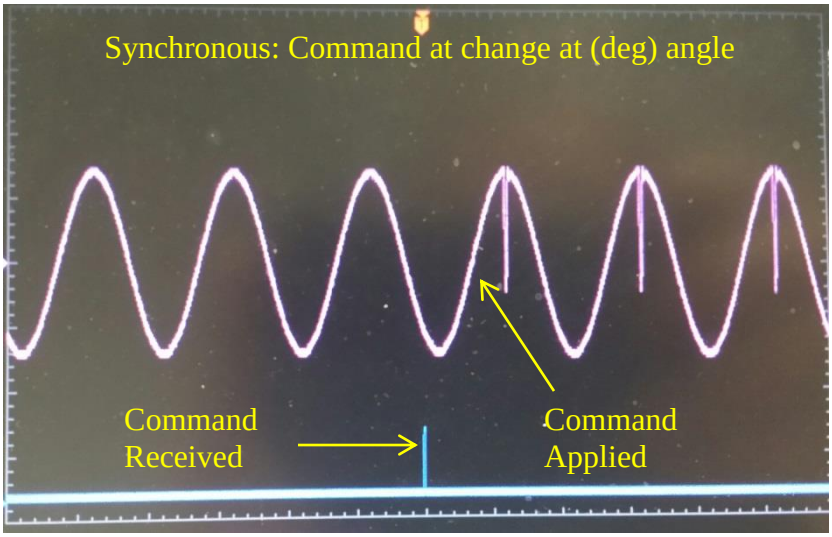
Note: The angle and amplitude are shown in text as well as graphically

Press OK to load the wave shape into User 1

Wave shape example – Generating a line slap simulation (Con'd)

The wave shape has been loaded into user one and is now selectable.
To set the output to follow this new wave shape, click the Apply button. 

The 9400 Series module will use this new wave shape for every new cycle.



Any arbitrary wave shape can be created, downloaded to, & selected for any output.

Macro's are able to select wave shapes and adjust regulation limits providing single cycle-based or timed output control.

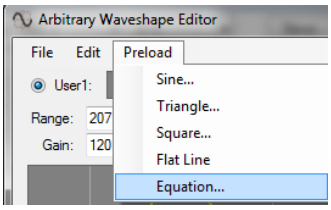
This example for timed or cycle-based transitions is provided in the Macro switching wave shapes section below as well

5.4.10.2 Wave shape example – Formula Based:

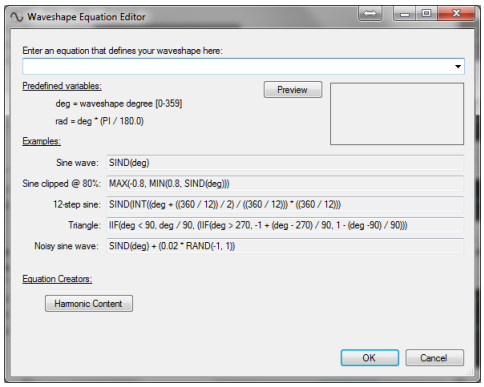
The NHR 9400 panel permits direct manipulation of a wave-shape formula. This permits the user to specify the exact paramaters mathematically. The next section provides a simple harmonic table approach which will automatically generate the mathematical formula needed.

Select User 1 and click Edit to edit the user wave-shape. Then load a sine shape to be modified by selecting

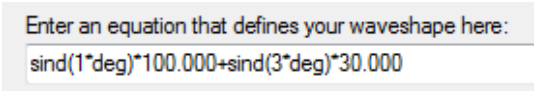
Preload → Equation…



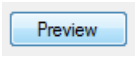
A dialog box will be presented allowing the user to specify a wave-shape formula along with a number of example formulas.



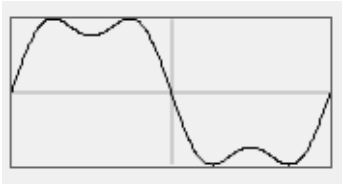
Enter the formula



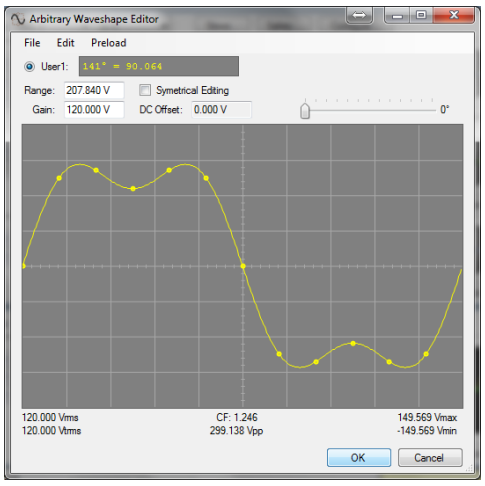
The above formula is equivalent to $A \cdot \sin(\omega) + 0.3 \cdot A \cdot \sin(3w)$

Click the "Preview" button 

to see a graphical representation of the newly generated wave-shape



Press "OK" to close the formula editor,
The pre-loaded wave-shape is displayed on the wave shape editor allowing further modification such as was described in the line-slap example.



If no further modification is desired,

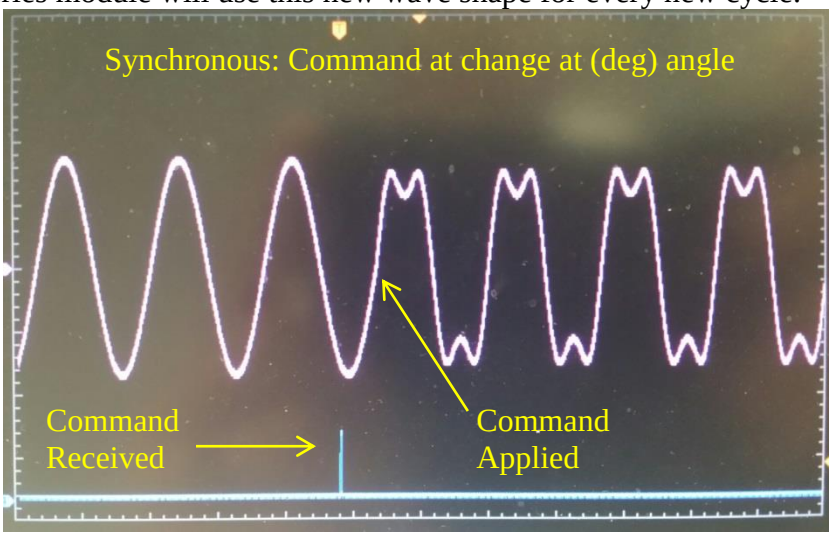
- Save the wave-shape for later use
  (File → Save)
- Click "OK" to load this wave-shape to User 1

Wave-shapes are shapes which are automatically scaled for voltage as well as frequency using normal setting controls

Wave shape example – Formula Based (Con'd)

The wave shape has been loaded into user one and is now selectable.
To set the output to follow this new wave shape, click the Apply button. 

The 9400 Series module will use this new wave shape for every new cycle.



Any arbitrary wave shape can be created, downloaded to, & selected for any output..

Wave-shapes are normalized and downloaded to the module. The 9400 then uses the RMS of the wave shape compared with the programmed RMS to properly scale the output voltage.

This allows the wave shape to follow the output frequency and reach the desired RMS level as well as permitting slew rate control.

A list of supported formula options is included on the next two (2) pages.

Wave shape example – Formula Based (Con'd)

The NHR 9400 Panel supports a wide range of mathematical operations which may be used to generate a formula-based wave shape. All operators and functions are case insensitive.

Simple operations

Symbol	Description	Example	Result
+	Add	1 + 1	2
-	Subtract	9 - 5	4
-	Unary negation	-(5 + 4)	-9
*	Multiply	3 * 6	18
/	Divide	9 / 2	4.5
\	Integer divide	9 \ 2	4
Sqr	Square root	sqr(64)	8
Mod	Modulo (remainder)	7 mod 4	3
^	Raise to power of	4 ^ 5	1024
!	Factorial	5!	120
Sin	Sine (angle in radians)	sin(pi/2)	1
Sind	Sine (angle in degrees)	sind(90)	1
Cos	Cosine (angle in radians)	cos(pi)	-1
Cosd	Cosine (angle in degrees)	cosd(180)	-1
Tan	Tangent (angle in radians)	tan(pi/4)	1
Tand	Tangent (angle in degrees)	tand(45)	1
Atan	Arc tangent (result in radians)	atan(1)	0.7853…
Atand	Arc tangent (result in degrees)	atand(1)	45
Abs	Absolute value	abs(-8)	8
Exp	e to the power of	exp(3)	20.08…
Log	Common log (base-10)	log(100)	2
Ln	Natural log	ln(100)	4.6051…
Ceil	Round up	ceil(6.2)	7
Int	Truncate to integer	int(6.8)	6
Frac	Fractional part	frac(3.125)	0.125
Sgn	Sign (returns -1, 0 or 1)	sgn(-9)	-1
Min	Minimum value	min(10, 3)	3
Max	Maximum value	max(1, 9, 2)	9
And	Bitwise AND	13 and 6	4
Or	Bitwise OR	13 or 6	15
Pi	The ratio of the circumference of a circle to its diameter	Pi	3.14159…

Wave shape example – Formula Based (Con'd)

The NHR 9400 Panel supports comparisons as well as random number generation.

Comparisons

Symbol	Description	Example	Result
>	Greater than	`9 > 2`	`-1`
<	Less than	`7 < 4`	`0`
==	Equal	`(5 * 4) == (4 * 5)`	`-1`
>=	Greater than or equal	`3 >= 3`	`-1`
<=	Less than or equal	`10 <= 9`	`0`
<>	Not equal	`(9 / 2) <> (9 \ 2)`	`-1`

Additional Functions

operand1 **AndAlso** *operand2*

Returns true (-1) if *operand1* is non-zero and so is *operand2*. This is important in situations where *operand2* might evaluate something like a division by zero.

Inline If

Syntax: IIF(expr, truepart, falsepart)

- *expr* is the expression that is to be evaluated
- *truepart* is returned if the expr evaluates as true
- *falsepart* is returned if the expr evaluates as false

Example: `iif(1 + 1 == 2, 4, 5)` returns `4`

operand1 **OrElse** *operand2*

Returns true (-1) if either *operand1* or *operand2* is non-zero. **OrElse** uses short-circuit evaluation, which means that if *operand1* is a non-zero value, then OrElse will return a result without proceeding to evaluate *operand2*.

Rand([*x*]**)**
Rand(*a*, *b***)**

Example:

`rand()` No parameters

Returns a floating point random number between 0 and 1.

`rand(x)` where x > 0

Returns a floating point random number between 0 and 1, using x as seed. The number chosen is the next in a random sequence.

`rand(x)` where x < 0

Returns the same random number each time, using the parameter as seed.

`rand(0)`

Returns the same random number as the one previously generated.

`rand(a, b)`

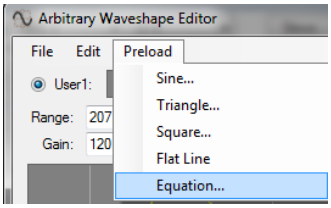
Returns an integer random number between values *a* and *b*.

5.4.10.3 Wave shape example – Harmonics Entry:

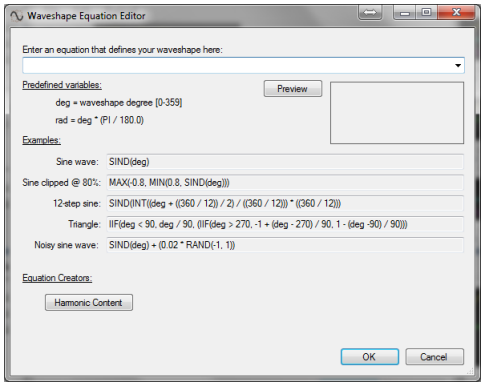
The NHR 9400 panel permits direct entry of the value as well as phase angle for individual harmonics. The result is a pre-built wave-shape formula which may be further edited as described in the previous two sections.

Select User 1 and click Edit to edit the user wave-shape. Then load a sine shape to be modified by selecting

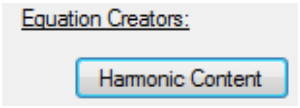
Preload → Equation…



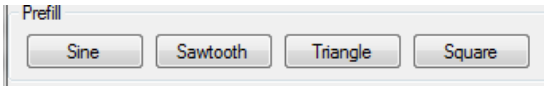
A dialog box will be presented allowing the user to specify a wave-shape formula along with a number of example formulas.

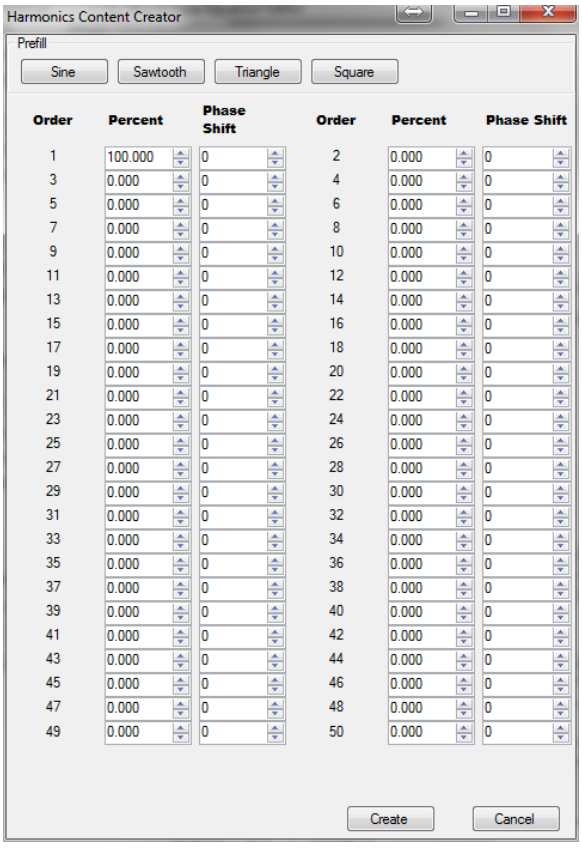


Select the harmonic content button

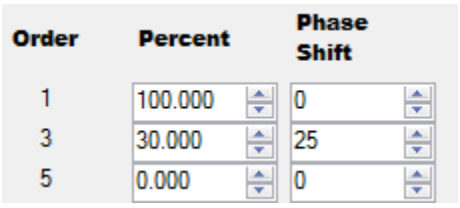


The Harmonics table may be pre-filled using standard shapes or individual harmonics may be provided.





For this example set the 1st order harmonic to 100 with a 0° phase angle and the 3rd harmonic to 30 with a 25° phase angle by entering these values in the appropriate fields.

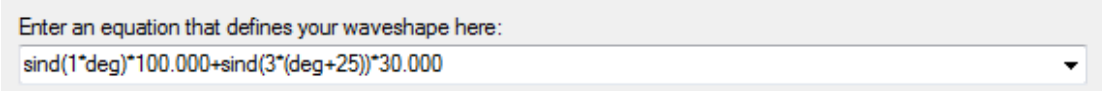


Finally click Create

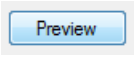
Wave shape example – Harmonics Entry (Con'd)

Note: The input field "Percent" may use percent or actual values from a power meter. The wave-shape is normalized allowing the 9400 to automatically scale the output based on the wave-shape equivalent RMS and the programmed RMS level.

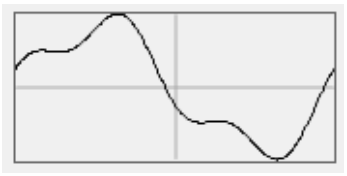
The harmonics equation is displayed in the equation field allowing it to be further edited.



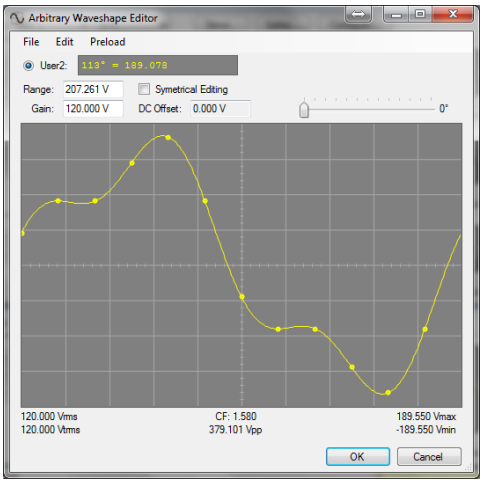
The above formula is equivalent to $A \cdot \sin(\omega) + 0.3 \cdot A \cdot \sin(3w + 25^0)$

Click the "Preview" button 

to see a graphical representation of the newly generated wave-shape



Press "OK" to close the formula editor,
The pre-loaded wave-shape is displayed on the wave shape editor allowing further modification such as was described in the line-slap example.



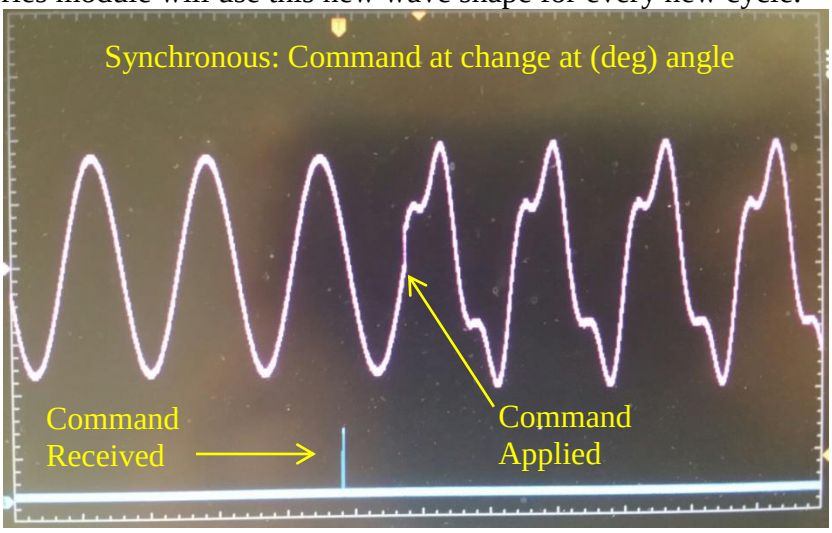
If no further modification is desired,

- Save the wave-shape for later use (File → Save)
- Click "OK" to load this wave-shape to User 1

Wave shape example – Formula Based (Con'd)

The wave shape has been loaded into user one and is now selectable.
To set the output to follow this new wave shape, click the Apply button. Apply

The 9400 Series module will use this new wave shape for every new cycle.



Any arbitrary wave shape can be created, downloaded to, & selected for any output..

Wave-shapes are normalized and downloaded to the module. The 9400 then uses the RMS of the wave shape compared with the programmed RMS to properly scale the output voltage.

This allows the wave shape to follow the output frequency and reach the desired RMS level as well as permitting slew rate control.

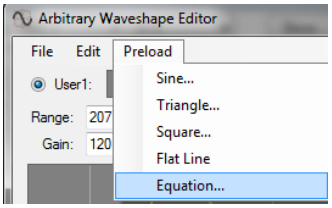
5.4.10.4 Wave shape example – Simulating Phase Jump:

The NHR 9400 is able to support a programmed phase-jump allowing for simulations where the frequency is matched but the relative amplitude or phase angles jump.

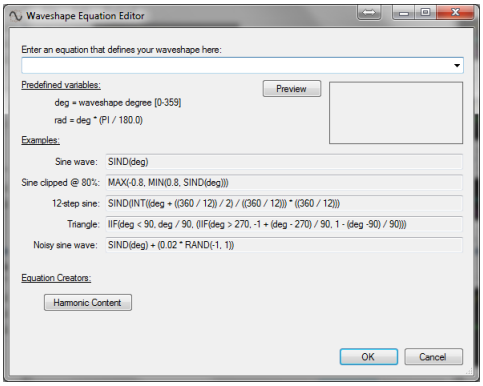
This is programmed in a similar manor as the harmonics section above where the fundamental has been shifted by a specified phase angle.

Select User 1 and click Edit to edit the user wave-shape. Then load a sine shape to be modified by selecting

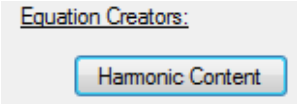
Preload → Equation…



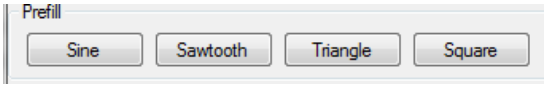
A dialog box will be presented allowing the user to specify a wave-shape formula along with a number of example formulas.



Select the harmonic content button



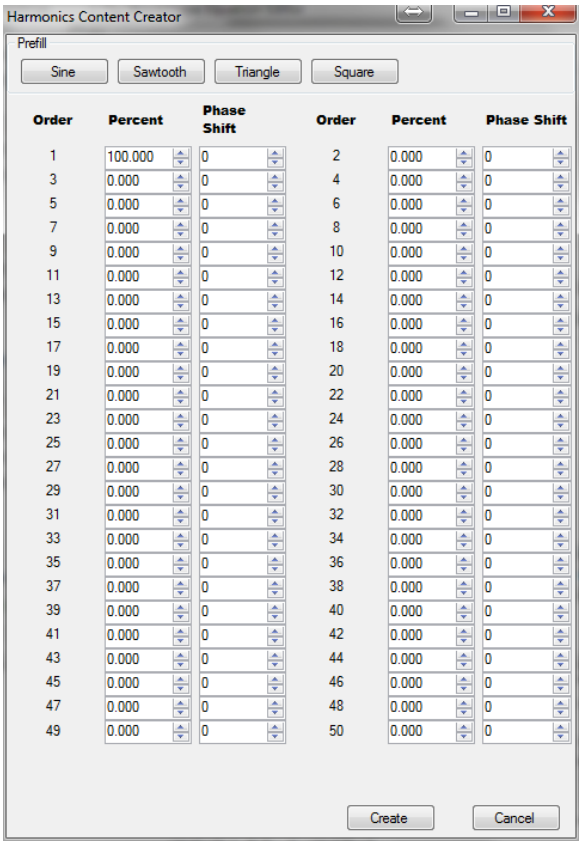
The Harmonics table may be pre-filled using standard shapes or individual harmonics may be provided.



For this example set the 1st order harmonic to 100 with a -55° phase angle all other harmonics set to 0.

Order	Percent	Phase Shift
1	100.000	-55
3	0.000	0
5	0.000	0

This will generate a phase shifted waveshape in User 1

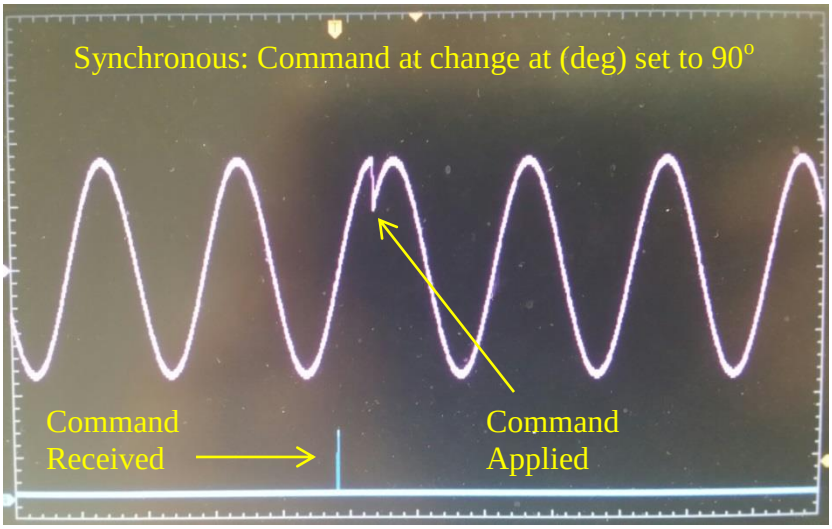


Wave shape example – Simulating Phase Jump (Con'd)

The User 1 now contains a sinusoidal wave-shape which is 55^{o} offset from the standard wave-shape. The main panel may now be used to determine the frequency, amplitude, and the Change at (deg) angle the waveshape will use.

Note: When the system is in synchronous mode, the new wave shape will be applied at the Change at (deg) angle. When the system is operating in immediate mode the wave shape will change based on when the command was received.

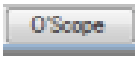
Refer to the Adjusting phase angle trigger section above for more information



Any arbitrary wave shape can be created, downloaded to, & selected for any output.

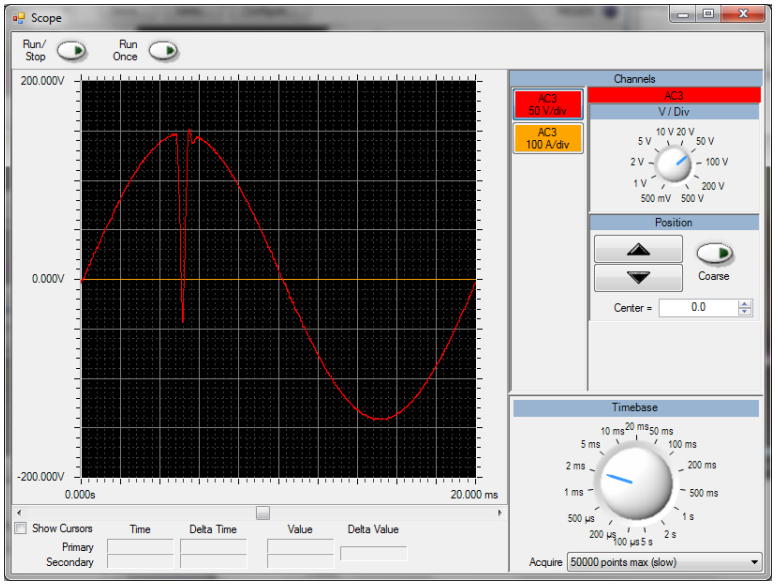
Macro's may be used to simultaneously switch amplitude, frequency, wave-shape, and relative phase angles for multi-phase outputs.

5.4.11 Accessing Oscilloscope View

Pressing the "O'Scope" button 

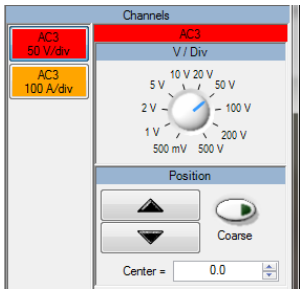
opens an oscilloscope panel.

This utility accesses the internal hardware digitizer and provides many similar functions to an oscilloscope including measurement cursors, horizontal control (time) and vertical control (V/Div & A/Div) as well as cursor measurements.



All captures start at the 0^{o} reference phase angle for self-phase (in single phase operation) or the 0^{o} reference phase angle for A-Phase (in multi-phase operation)

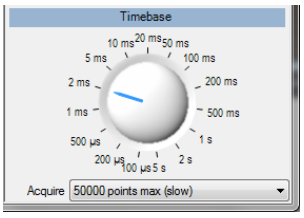
5.4.11.1 Adjusting vertical scale and position



The Oscilloscope allows separate scales per measurement channel as well as vertical positioning of each channel.

These are adjusted by first selecting the channel and then adjusting the knob and position as shown to the left

5.4.11.2 Adjusting the time-base & number of samples



The Oscilloscope function captures between 100uS and 5s per division (1mS up to 50s). It is also possible to specify the maximum number of points between 500 & 50k points which are uniformly distributed across the entire capture time.

Adjusting the time base after a capture provides a waveform "Zoom" feature along with a scroll bar below the displayed waveform to adjust the horizontal view

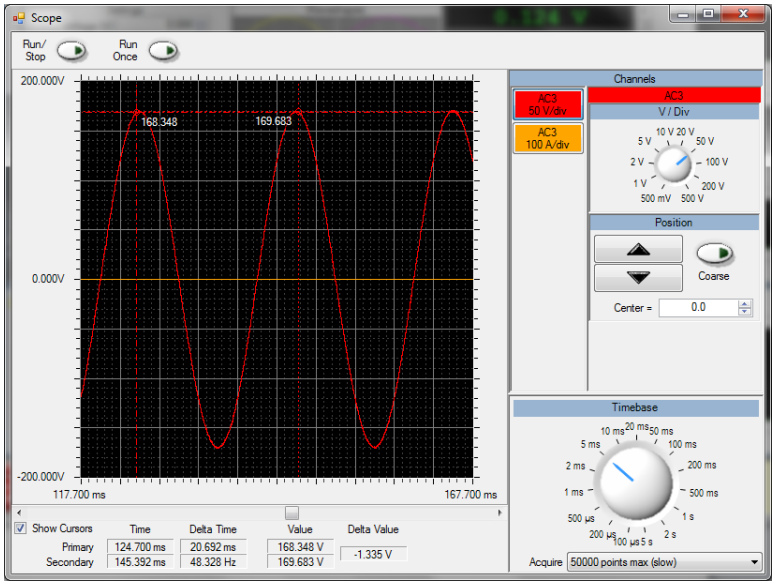
5.4.11.3 Capturing the output

The Run/Stop works similar to an oscilloscope's "normal mode" which arms, triggers at the 0^o reference, downloads the waveform data, and re-arms to capture the output again.

Run once works similar to an oscilloscope's "single sequence mode" which arms, triggers at the 0^o reference, and downloads the waveform data one time only.

5.4.11.4 Cursors

Cursors are activated by checking on the "Show Cursors" check box in the lower left.



The primary cursor is placed using a left click.
The secondary cursor is placed using a right click.

The time & value of each cursor as well as the delta (in time, frequency, and value) is shown in text in the lower panel. The value of each cursor is also placed near the cursor measurement location on the waveform.

5.4.11.5 Closing the Oscilloscope View

The oscilloscope view is closed by pressing the close window button. 

6. MARCOS & USAGE EXAMPLES

Marcros provide direct cycle and sub-cycle control to apply settings and wave-shape changes in a deterministic way. A number of the macro commands are compressed into a single command to preserve space. The firmware as of this document supports 80 compiled commands allowing up to 80 separate cycle adjustments to occur sequentially.

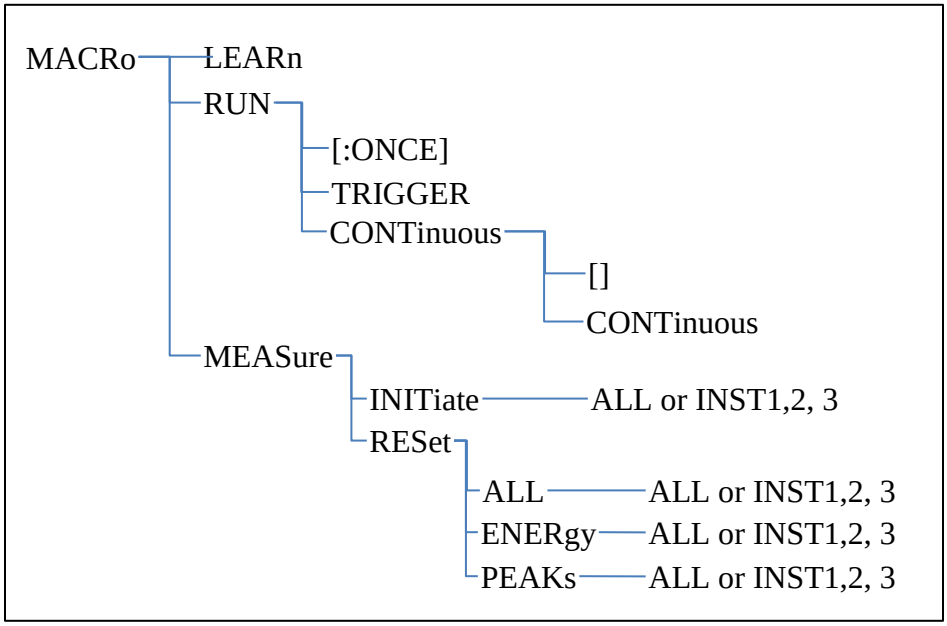
6.1 Macro Organization

Macros are organized in an identical fashion when implemented on the touch panel, NHR 9400 Panel software, or when programmed using SCPI or LABVIEW commands. The NHR 9400 Series Programmer's Reference Manual (09-0335) provides detailed descriptions for of each command and the effect on the system.

6.2 Macro Programming Tree

6.2.1 Commands not commonly used

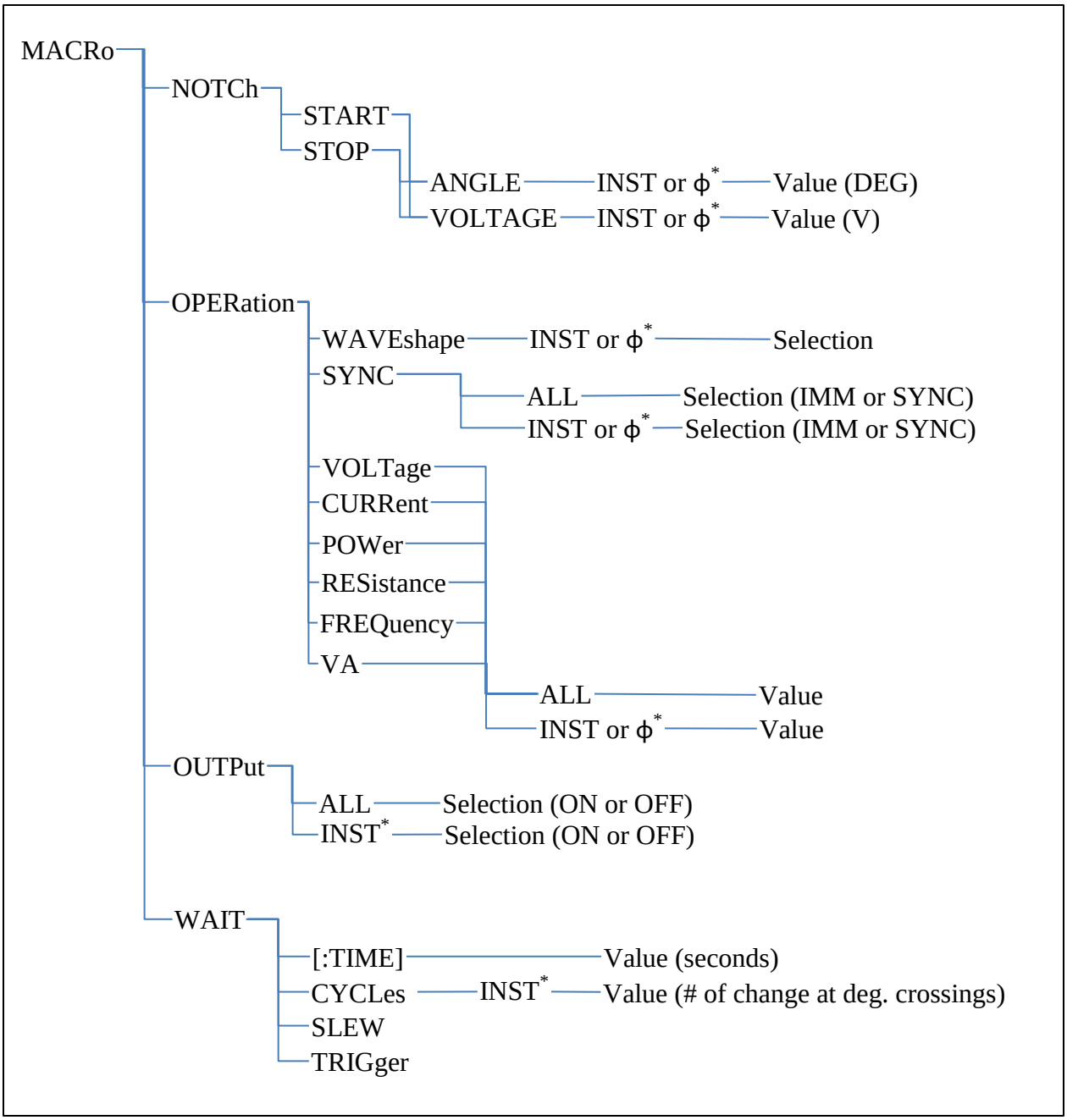
The following macro commands are used to create, clear, or execuite the macro. Waveform measurement capture features are also provided however these are generally only used with an external control program as the touch panel & NHR 9400 Panel do not have a waveform retrieval feature. As such, the following commands are provided for reference only.



Above commands are implemented as buttons & menus or not typically used on the touch panel or NHR 9400 Panel

6.2.2 Common Macro Commands

The following commands are commonly used and have a direct change on the output.



INST or ϕ* denotes if this command is to be applied to an instrument or a specific phase.
INST * denotes which instrument output is affected or # of change at (deg.) crossings.

6.2.2.1 MACRo:NOTCh

Provides a sub-cycle notch with greater precision than can be achieved using a wait time approach. This command requires four (4) parameters including a start angle, stop angle, and the value to execute during the NOTCH as well as a final value.

This command takes into account slew rates. When adjusting between notch values as specified by the NOTCh command.

6.2.2.2 MACRo:OPERation

Sequential MACRo:OPERation commands are merged unless a particular phase has already been adjusted. This optimizes the command as well as allows all settings to be applied at the same time.

For example:

MACRo:OPERation:SYNC:ALL SYNC
MACRo:OPERation:VOLT:APH 120
MACRo:OPERation:VOLT:BPH 60 ---- All of the above commands are compressed into a single command

MACRo:OPERation:VOLT:APH 80 ---- A Phase voltage is adjusted a second time. This results in a new command

Which commands are supported depends on the hardware model as well as the operating mode. Only the commands which are also available on the touch panel are supported.

The following slew section provides more detail about which models support which features.

6.2.2.3 MACRo:OUTPut

The MACRO is capable of turning on and turning off the output contactors.

It is important to note that this operation does require contactor closure and confirmation time. It is generally best to use operation settings for high speed operation changes.

6.2.2.4 WAITs

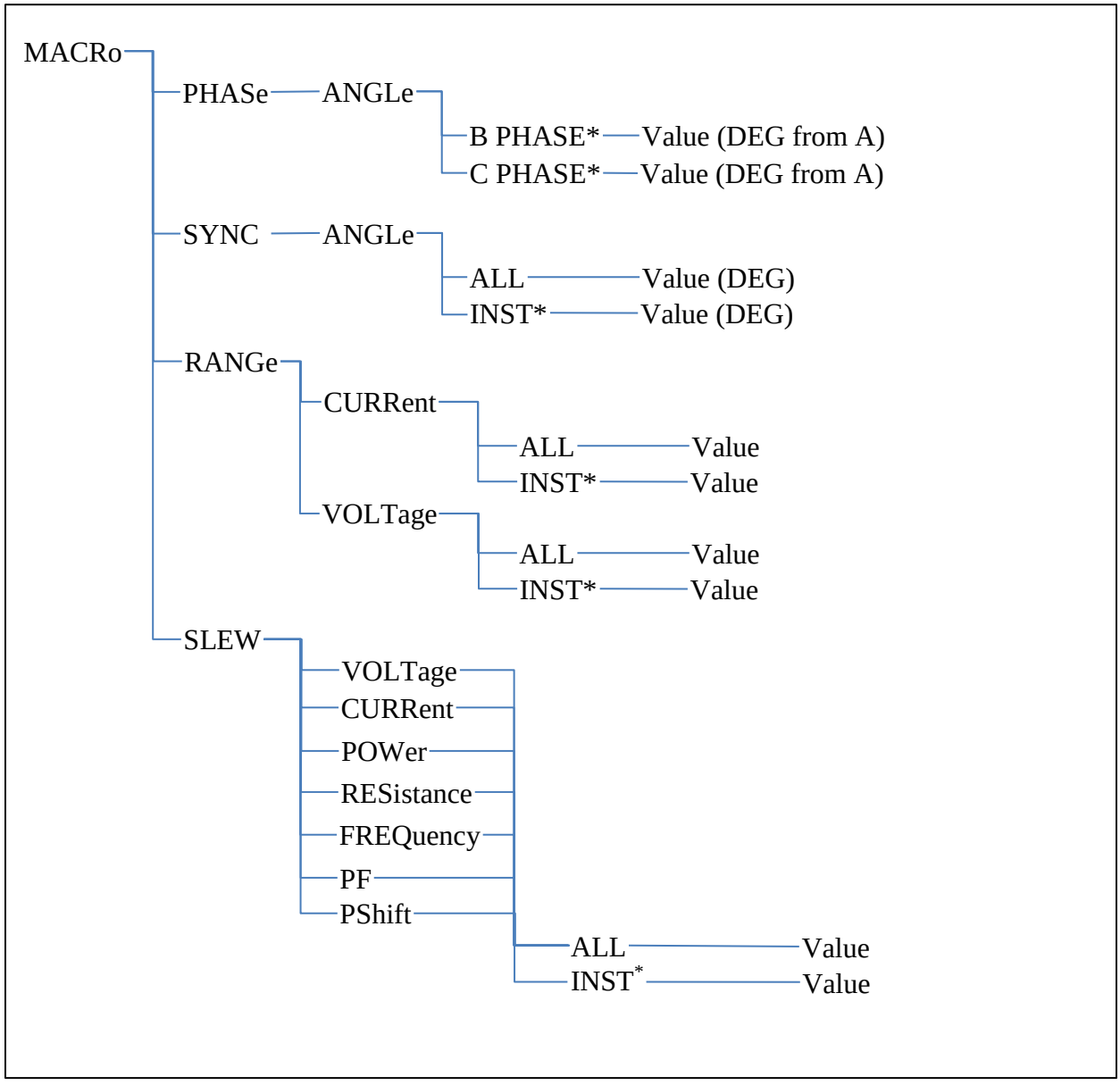
The OPERation:SYNCronuns determine if the command will be processed immediately or SYNChronous with the change at deg. Angle of the A-Phase. As such, a WAIT:TIME may be used to separate a command however the next operation will not occur immediately unless the OPER:SYNC is set to IMMediate.

Similar behavior is found with WAIT:SLEW and WAIT:TRIGger

Cycle counting always occurs based on the Change at (deg.) angle crossings as it assumes that the next operation will likely occur at this angle. This change/counting angle may be adjusted in the macro which is described in the next section.

6.2.3 Additional Macro Commands

The following commands are less commonly used.



B PHASE * applies only in 2-ϕ and 3-ϕ hardware operating modes
C PHASE * applies only in 3-ϕ hardware operating modes
INST * denotes which instrument the setting is applied to is affected

6.2.3.1 MACRo:PHASe

This command allows the Macro to adjust the phase relationship of a multi-phase output. For example, a 2-ϕ output generaly would operate with B-Phase at 180^{o} from A-Phase. This command allows this angle to be adjusted and uses SLEW:PShift to determine the rate of change for this modification

6.2.3.2 MACRo:SYNC:ANGLe

This command adjusts the change at deg. Angle used to apply commands or count cycles. For example: MACRo:SYNC:ANGLe:ALL 90 would change all new commands to be execuited at the 90^{o} phase angle of the main (a-phase)

6.2.3.3 MACRo:RANGe

This command allows the setting range to be ajusted within a macro.

6.2.3.4 MACRo:SLEW

This command adjusts any of the slewable settings. Which commands are supported depends on the hardware model as well as the operating mode.

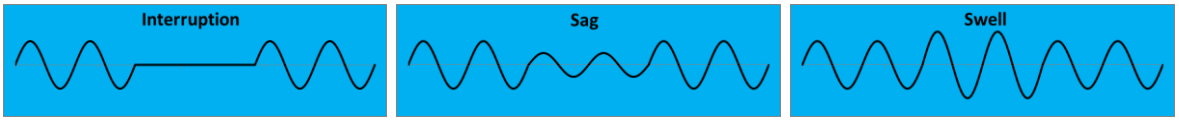
	9410 Grid Emulator			Future 2 Power Supply			Future 3 Electronic Load		
	Voltage Control			Voltage W/ Current Limit			Current Control		
	1-ϕ AC	2/3-ϕ AC	DC	1-ϕ AC	2/3-ϕ AC	DC	1-ϕ AC	2/3-ϕ AC	DC
Voltage	✓	✓	✓	✓	✓	✓	✘	✘	✓
Current	✘	✘	✓	✓	✓	✓	✓	✓	✓
Power (W/VA)	✘	✘	✓	✓	✓	✓	✓	✓	✓
Resistance (Ω)	✘	✘	✓	✘	✘	✓	✓	✓	✓
Frequency (Hz)	✓	✓	#N/A	✓	✓	#N/A	✘	✘	#N/A
Phase Shift	#N/A	✓	#N/A	#N/A	✓	#N/A	✘	✘	#N/A
Power Facor (PF)	✘	✘	#N/A	✘	✘	#N/A	✓	✓	#N/A

Note: When WAIT:SLEW is called, the slew will not be complete until all programmed changes have reached the final set point value. For example, if operating at 10VDC/10ADC and a 1V/s and 1A/s slew is established, The next command requesting 20VDC/30ADC will take 20s (10A to 30A @ 1A/s) to complete even in the case when the output is not in current limit allowing 20V is reached in the first 10s.

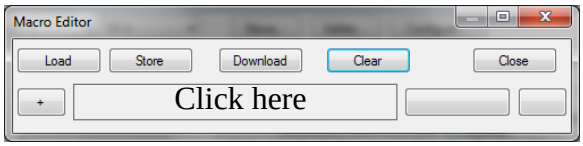
6.3 9410 Macro Usage Examples

6.3.1 Simulating Interruptions, Sags, & Swells

While the causes of interruptions, sags, swells, and even brown-outs may be different, all of the conditions are similar in so far as they represent a change in voltage levels for a period of time.

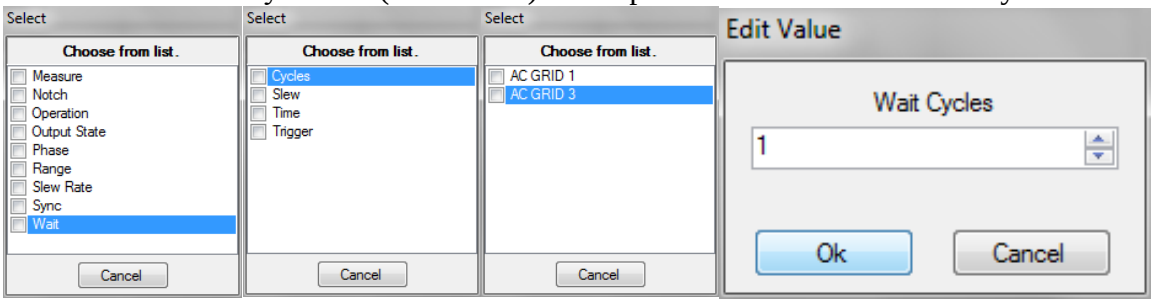


To simulate an interruption, sag, or swell for either an amount of time or cycle(s), open the Macro editor and click on the first empty cell to insert the first step.



The first step commonly selects if the macro will execute commands immediately or synchronously with the A Phase (or self-phase for 1 phase outputs). This setting applies only the following macro commands and does not affect manual operation.

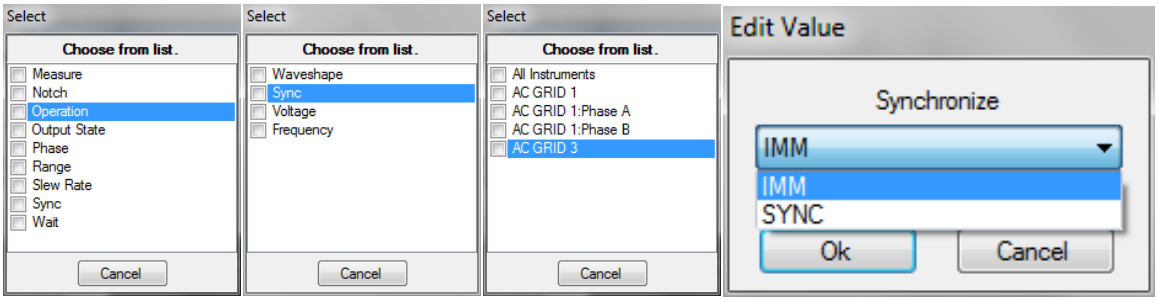
Step 1: Determine the number of cycles that should occur before the disturbance:
Select "Wait" → "Cycle" → (Instrument) → & provide the number of wait cycles.



Wait cycles always counts the number of transitions at the angle specified by Change at (deg).

The above step serves two functions. First it will ensure that some number of cycles occur before making the change. Second, it will align the following changes based on the change at (deg) angle specified. This angle may also be adjusted in the macro before waiting for the pre-disturbance cycles to complete.

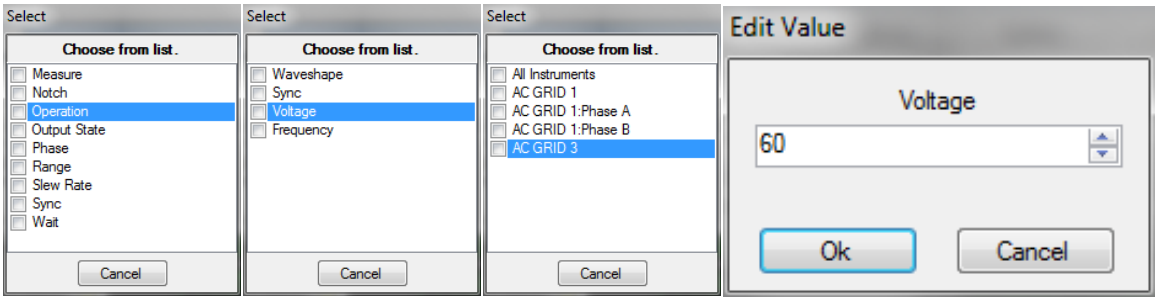
Step 2: Determine if the changes occur immediately or synchronously at the set angle. Select “Operation” → “Sync” → (Instrument) → & Select IMM or SYNC



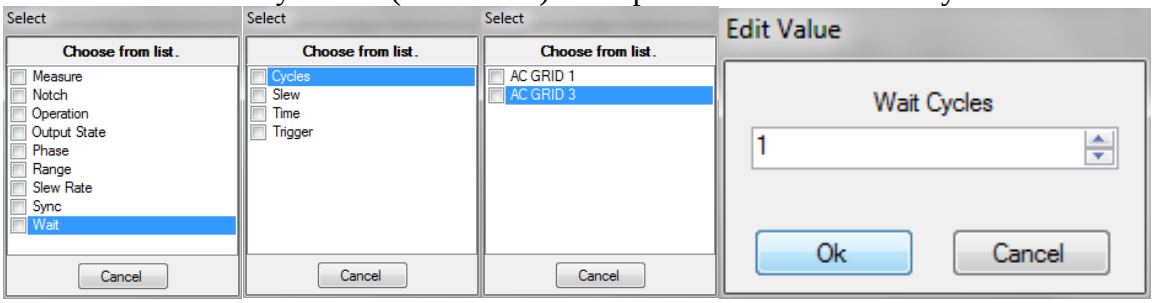
Selecting Immediate (IMM) all the following operation commands are applied immediately after any wait (time or cycles) expires.

Selecting Synchronous (SYNC): The following operation commands are applied at the next changed at (deg) phase after the wait expires. In general, the command is applied on the next cycle.

Step 3: To set the disturbance voltage, click on the next open cell and select: “Operation” → “Voltage” → (Instrument or φ) → & supply the value desired

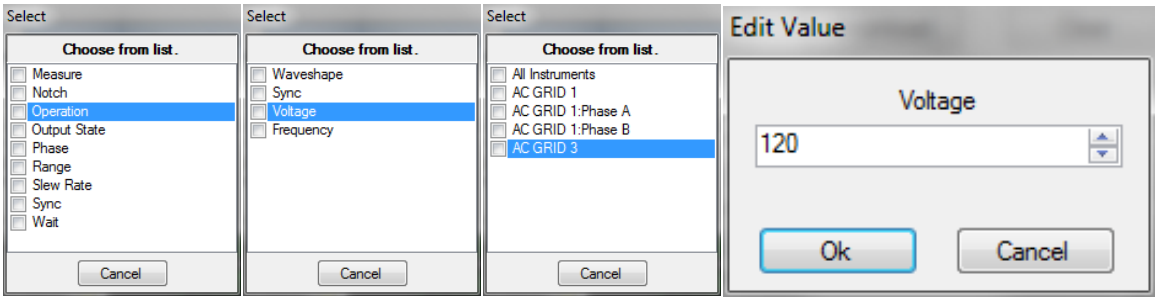


Step 4: Specify the time or cycle(s) the disturbance is to occur, Click the next open cell & select: “Wait” → “Cycle” → (Instrument) → & provide the number of cycles



In IMM Mode: Wait time will use actual time
In SYNC Mode: Wait Time will be rounded up to the next complete cycle

Step 5: Return the output to nominal, select the next open cell then select:
"Operation" → "Voltage" → (Instrument or φ) → & supply the value desired



The macro is now complete

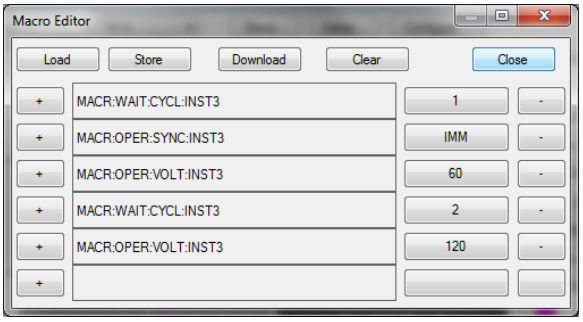


Figure 13 - Immediate Mode

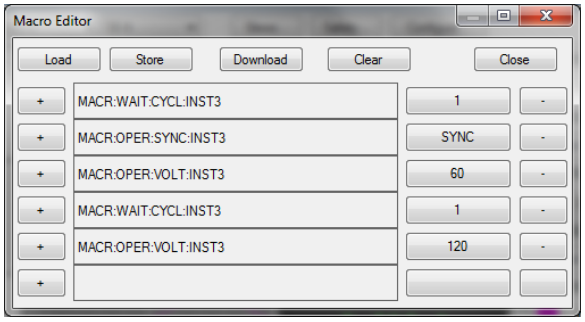
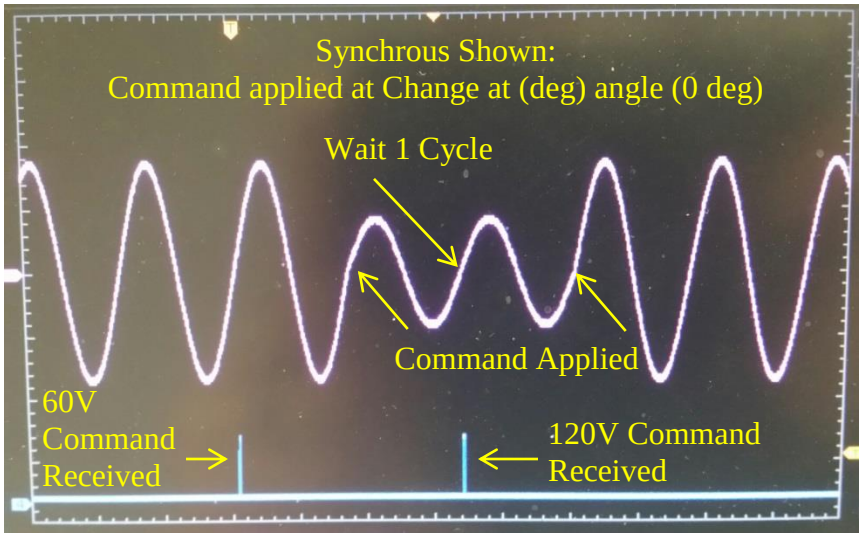


Figure 14 - Synchronous Mode

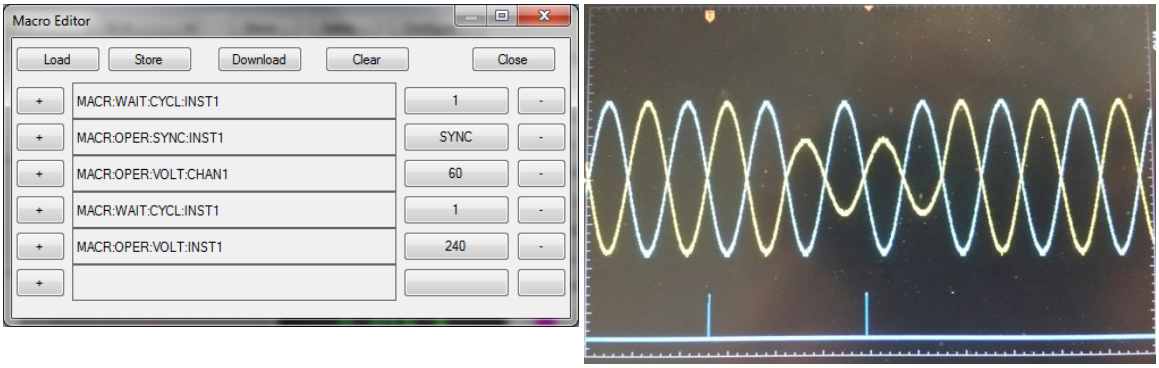
Running the above macro results in the following output



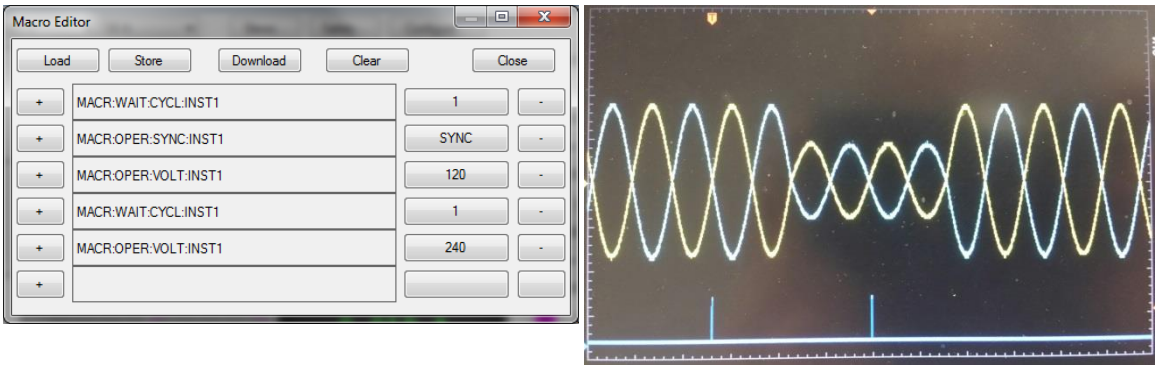
Example shows Sync Mode where the command is applied, Waits for 1 full cycle then releases the next command (120V) which is applied at the next change at (deg) angle.

Multi-Phase output interruptions, sags, & swells

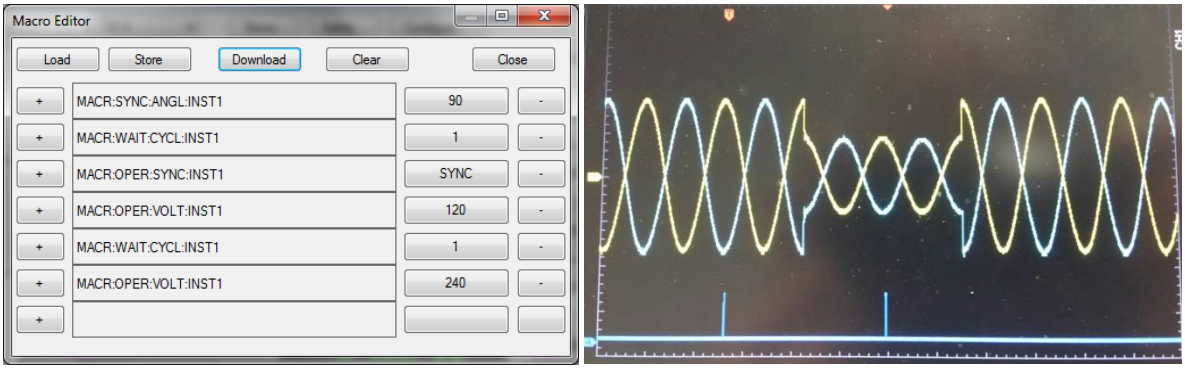
The same process is used to adjust individual phases or all phases of a multi-phase output. Below shows the macro's used to produce a 2-cycle sag on an individual phase, on both phases simultaneously, and on both phases with the sag starting at 90°.



Affecting only one phase (Split Phase Shown)



Affecting both phases (Split Phase Shown)



Affecting both phases with 90° change angle

6.3.2 Simulating Sub-Cycle Changes

This section will describe how to use a macro-notch to provide precise control of the amplitude, phase angle, and slew rate of a sub-cycle disturbance.

There are multiple methods available for simulating sub-cycle changes.
Which method is best depends on the characteristics of the sub-cycle change desired.

Immediate Mode & Wait Time Method

This approach is similar to the previous section and is best suited for programmed disturbances which cross over the 0^o internal reference for the A-Phase in multi-phase operation or the self-phase for single phase operation. To implement this approach use the examples shown in the previous section and replace step 4 with a "WAIT"→"TIME"

Selecting an alternate (user) wave shape

This approach is best suited This approach is similar to the previous section and is best suited for simulating disturbances with quick changes (such as line slap). This approach will be discussed in the next section "Switching Wave Shapes

Macro Notch

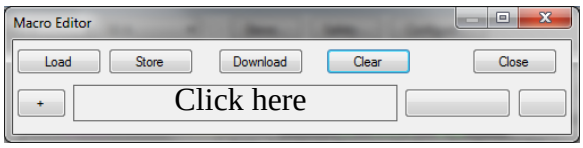
A Notch allows precise and slew-rate controlled sub-cycle changes between the 0^o & 360^o internal reference for the A-Phase in multi-phase operation or the self-phase for single phase operation. Notch may be used along with any wave-shapes resulting in a precise control the amplitude, phase angle, and slew rate of change making up the disturbance.

A notch consists of four (4) programming steps including

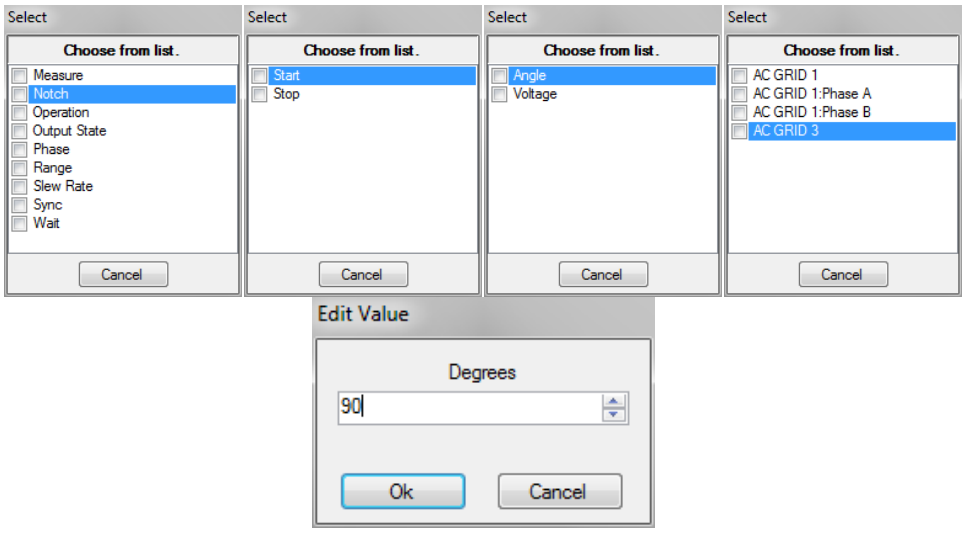
- Start Angle
- Starting Voltage
- End Angle
- Ending Voltage

As mentioned above, slew rate is applied from the pre-notch voltage to the starting voltage as well as from the starting voltage to the ending voltage.

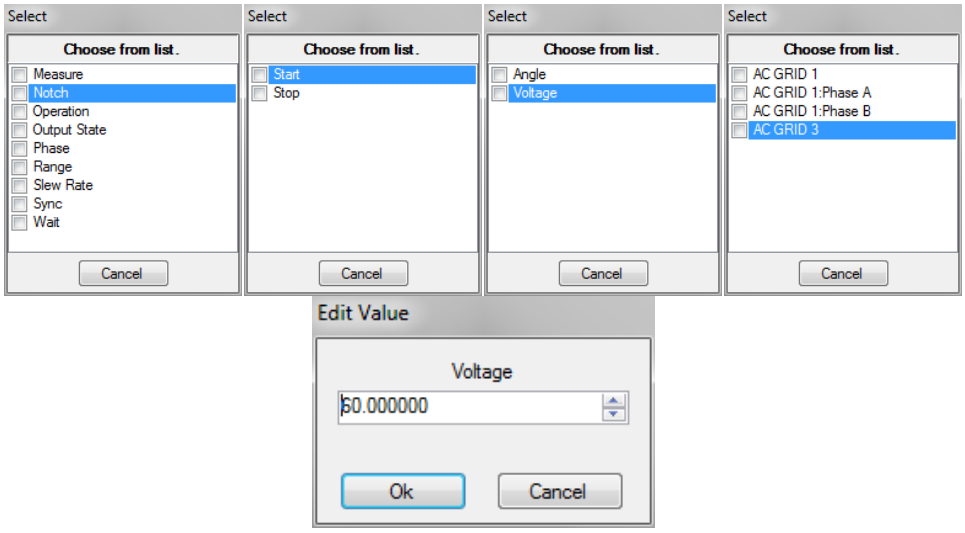
To simulate a notch, open the Macro editor and click on the first empty cell.



Step 1: Speficy the starting angle which will be used to create the notch. Select the first cell then: “Notch” → “Start” → “Angle” → (Instrument or φ) → & the start angle.



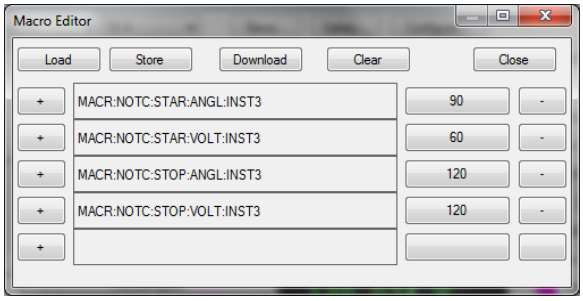
Step 2: Speficy the starting voltage the notch should reach. Select the next cell then: “Notch” → “Start” → “Voltage” → (Instrument or φ) → & the target voltage.



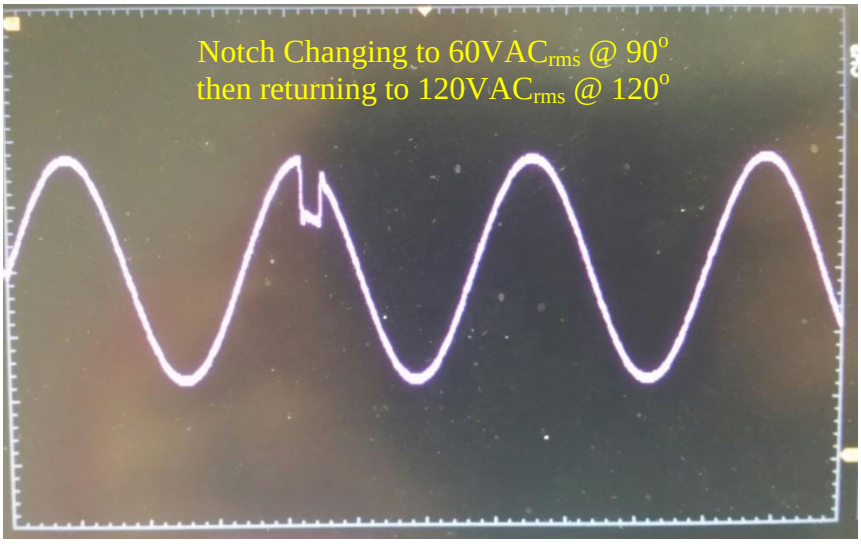
Step 3 & 4: Repeat the above selecting Stop angle and voltage.
For this example: 120^{o} & $120VAC_{rms}$.

Wait cycles always counts the number of transitions at the angle specified by Change at (deg).

The macro is now complete and should look like the one shown below.

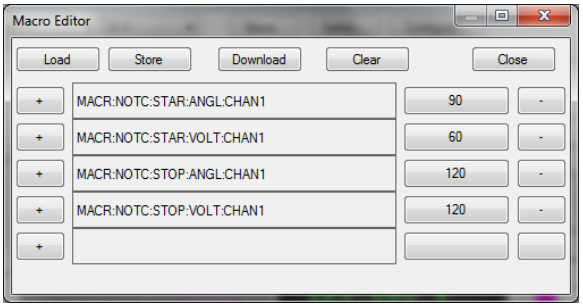


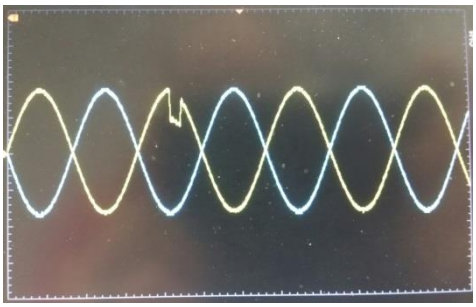
Running the above macro results in the following output



Multi-Phase notches

The same process is used to notch individual phases of a multi-phase output. Below shows a notch applied to A-Phase of a split phase output similar to the example above.





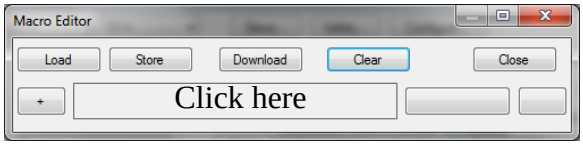
6.3.3 Switching Waves shapes

This section will describe how to use a macro to switch wave shaped either based on cycles or time. Switching wave shapes is commonly used for a line-slap simulation and may also be used to switch in a noisy sin, a harmonics distorted wave shape, or any other wave shape which has been loaded into the module.

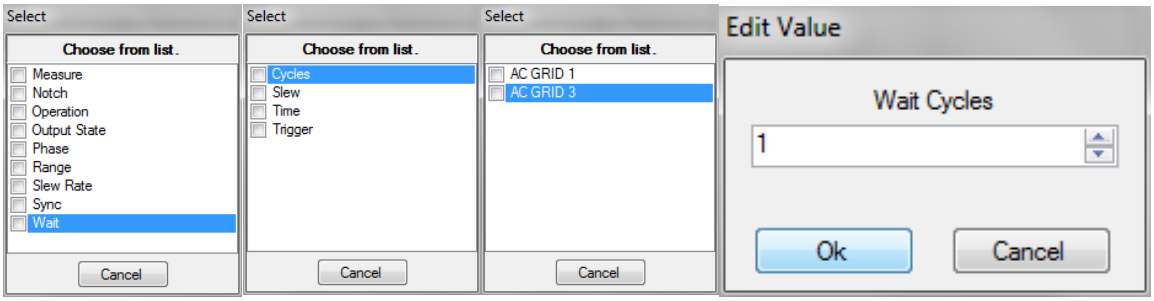
Step 1: Ensure the line-slap wave shape is loaded into USER 1
See the "Editing an output wave shape" for information in creating output wave shapes.

This macro will switch between the standard (sin) and a pre-loaded user wave shape. This technique will allow any of the of the pre-loaded wave shapes to be applied in a similar manor.

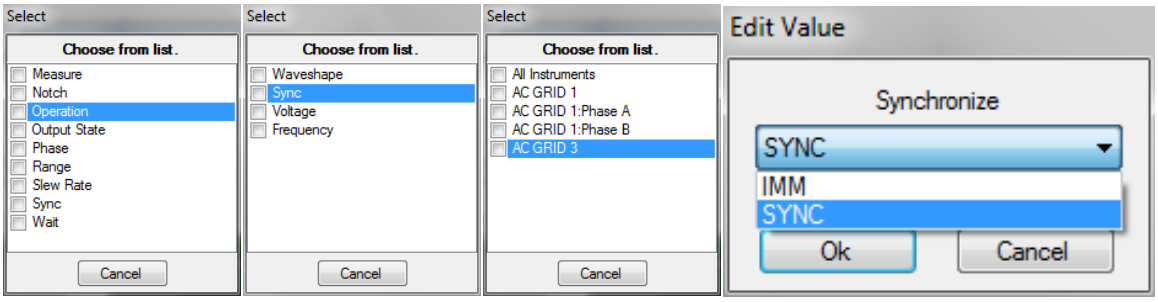
To simulate a notch, open the Macro editor and click on the first empty cell.



Step 2: Determine the number of cycles that should occur before the disturbance:
Select "Wait" → "Cycle" → (Instrument) → & provide the number of wait cycles.



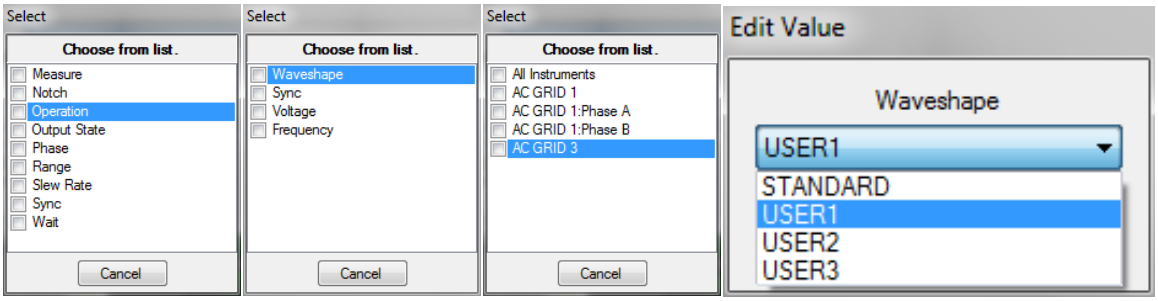
Step 3: Determine if the changes occur immediately or synchronously at the set angle.
Select "Operation" → "Sync" → (Instrument) → & Select IMM or SYNC



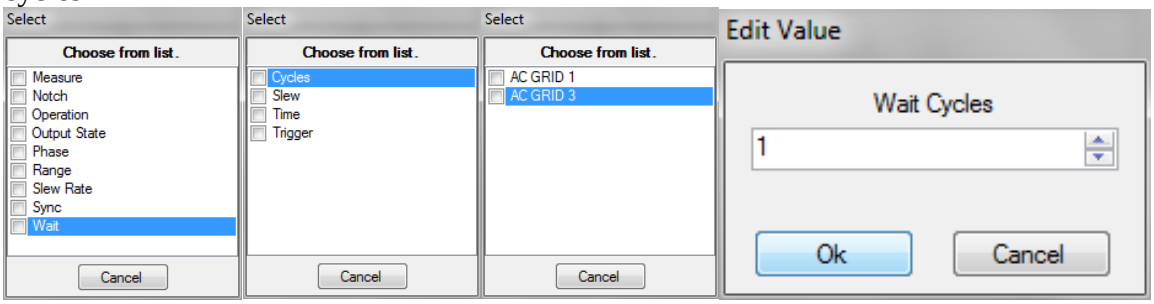
Selecting Immediate (IMM) all the following operation commands are applied immediately after any wait (time or cycles) expires.

Selecting Synchronous (SYNC): The following operation commands are applied at the next changed at (deg) phase after the wait expires. In general, the command is applied on the next cycle.

Step 4: Determine the new output wave shape to be used wave shape
Select "Operation" → "Waveshape" → (Instrument or φ) → select the output shape

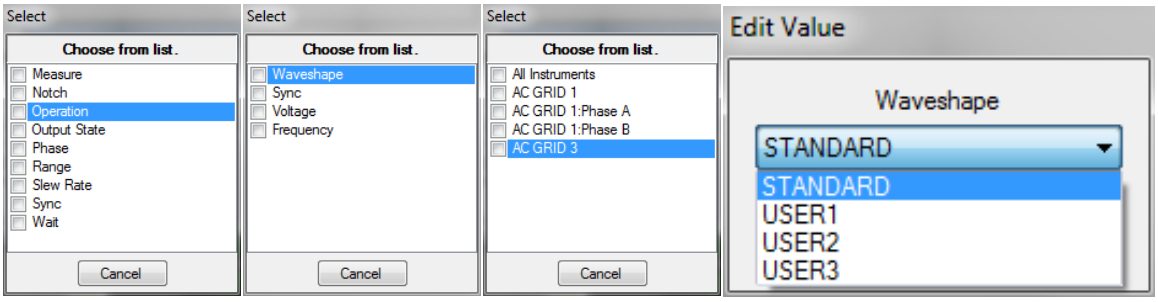


Step 5 (Optional): Specify the time or cycle(s) the disturbance is to occur, Click the next open cell & select: "Wait" → "Cycle" → (Instrument) → & provide the number of cycles

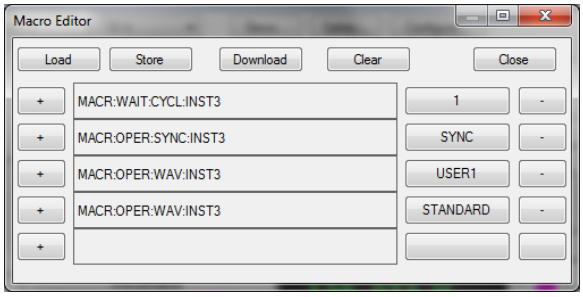


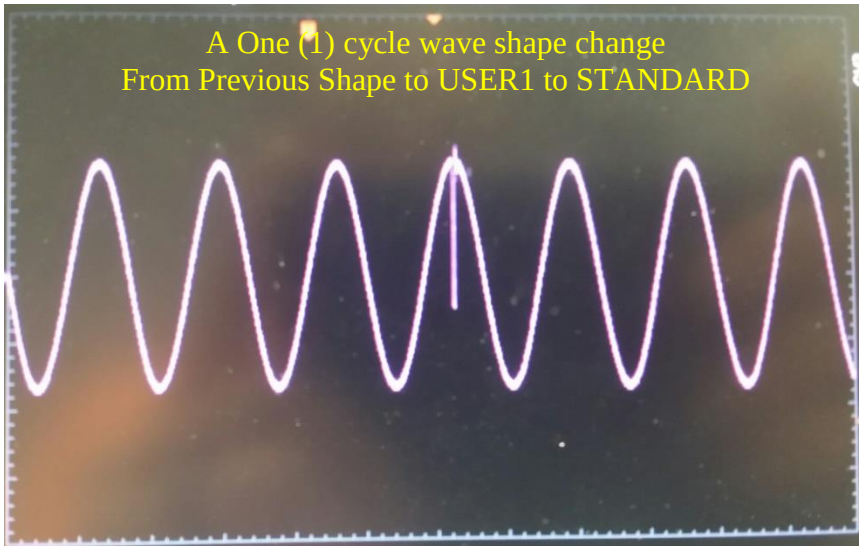
In Synchronous (SYNC) operation: Wave shapes requested for the same phase are applied on sequential cycles and do not need a cycle counter.

Step 6: Determine the next output wave shape to be used wave shape
Select “Operation” → “Waveshape” → (Instrument or φ) → select the output shape



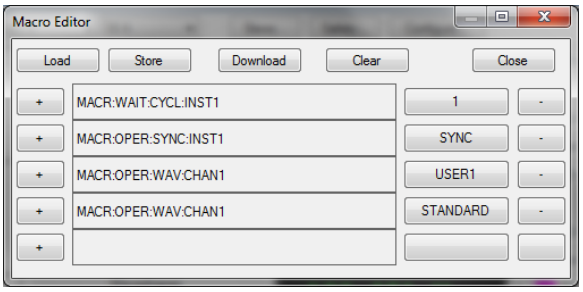
The macro is now complete and provides the output as shown below

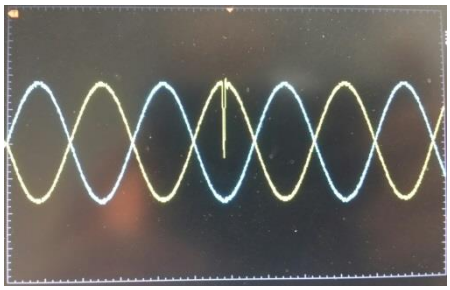




Multi-Phase notches

The same approach may be used on any phase of a multi-phase output as shown



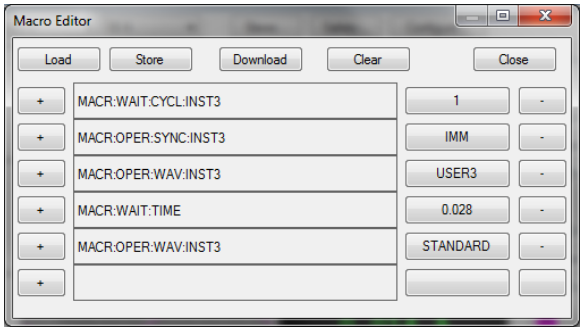


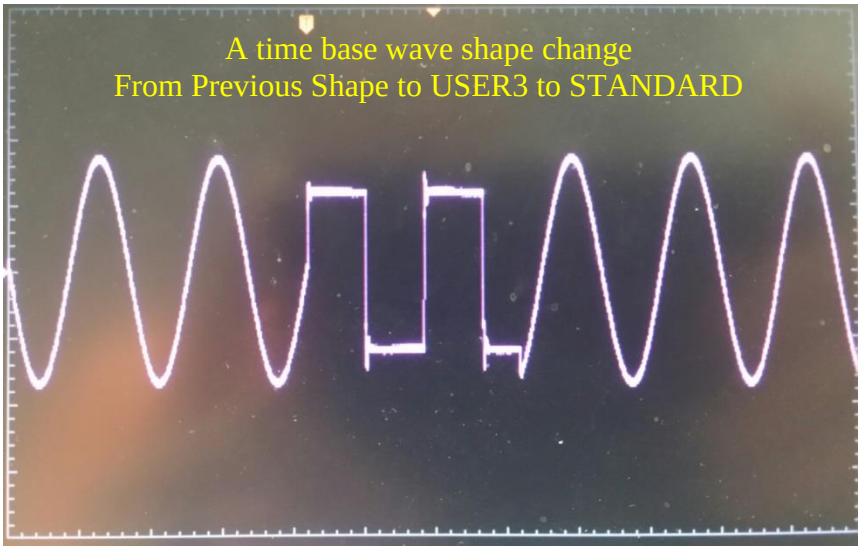
Using Time Based Changes

Waiting for a specific time generally require Immediate (IMM) to be selected in step 3 resulting in an immediate change after the timer expires. By comparison, synchronous (SYNC) operation allows the timer to expire and will apply the next operation command at the next Change at (deg)..

Change step 3 from the above to IMM Mode and change step 5 to WAIT-TIME as shown

Note: For clarity, example uses “USER 3” which has been pre-loaded with a square wave





7. APENDIX – 9410 HARDWARE MODES

The organization of the channels is done by setting a "mode" with the "NHR 9400 Panel" PC tool (see section "Software" below) or through any programming interface (see *Programmer's Reference Manual* 09-0335). Setting the mode will allow you to determine if it is a three output AC source, or a single output DC source, or anything in-between. There are a total of 13 hardware modes available for a three channel 9400 power module, six for a two channel 9400, and two for a one channel 9400. Once set, the mode can be saved as the default so it needn't be set again.

Available hardware modes are dependent on the number of channels installed. Please refer to the appropriate section for details.

The fixture wiring must match the selected hardware operating mode. Failure to ensure may result in damage to the 9400, fixture-wiring, or the UUT.

7.1 Three Channel Power Module

The three channel power module has 13 unique configurations.

Mode	***Available Instruments***	***Channel 1***	***Channel 2***	***Channel 3***
0	One 3-Phase AC	AC1 (Phase A) (Phase Ref)	AC1 (Phase B) (240° from A)	AC1 (Phase C) (120° from A)
1	One AC	AC1 (3x per channel power)		
2	One DC	DC1 (3x per channel power)		
3	Three AC	AC1	AC2	AC3
4	Three DC	DC1	DC2	DC3
5	One 2-Phase AC and One AC	AC1 (Phase A) (Phase Ref)	AC1 (Phase B) (180° from A)	AC3
6	One 2-Phase AC and One DC	AC1 (Phase A) (Phase Ref)	AC1 (Phase B (180° from A)	DC3
7	Two AC	AC1 (2x per channel power)		AC3
8	One AC and One DC	AC1 (2x per channel power)		DC3
9	Two AC and One DC	AC1	AC2	DC3
10	One AC and Two DC	AC1	DC2	DC3
11	One DC and One AC	DC1 (2x per channel power)		AC3
12	Two DC	DC1		DC3

The following sections show NH Researches recommended wiring for each mode.

7.1.1 Mode 0: One 3-Phase AC

Logical Instrument Configuration and UUT Wiring

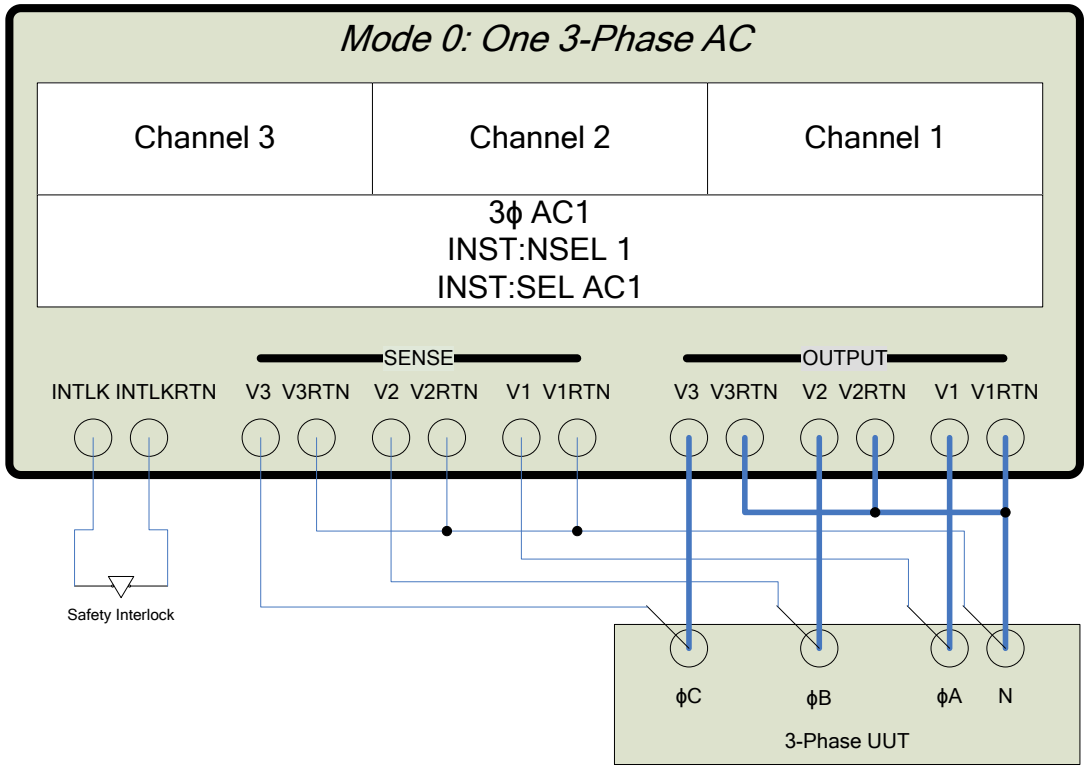


Figure 15 - Mode 0: One 3-Phase AC

Key Maximums for Each Logical Instrument

	Model							
AC1 (3-Phase)	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	12 kW	24 kW	36 kW	48 kW	60 kW	72 kW	84 kW	96 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current / Phase	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current / Phase	3 X Maximum RMS Current							

7.1.2 Mode 1: One AC

Logical Instrument Configuration and UUT Wiring

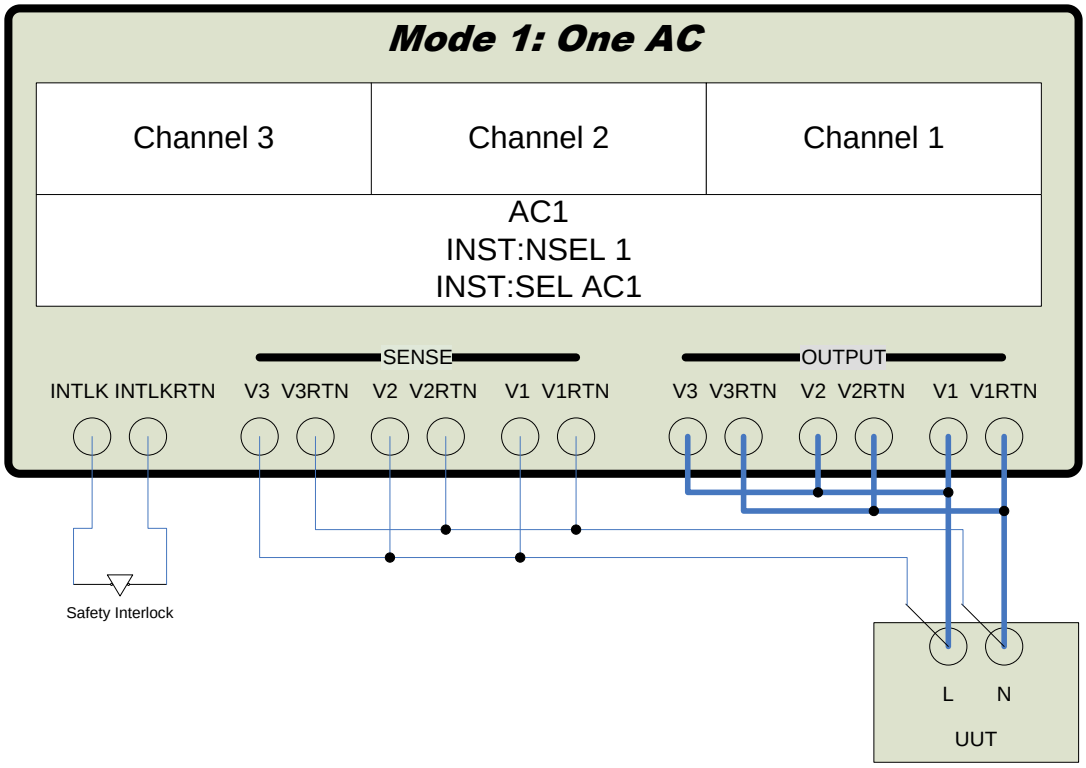


Figure 16 - Mode 1: One AC

Key Maximums for Each Logical Instrument

AC1	Model							
	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	12 kW	24 kW	36 kW	48 kW	60 kW	72 kW	84 kW	96 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	90 Arms	180 Arms	270 Arms	360 Arms	450 Arms	540 Arms	630 Arms	720 Arms
Peak Current	3 X Maximum RMS Current							

7.1.3 Mode 2: One DC

Logical Instrument Configuration and UUT Wiring

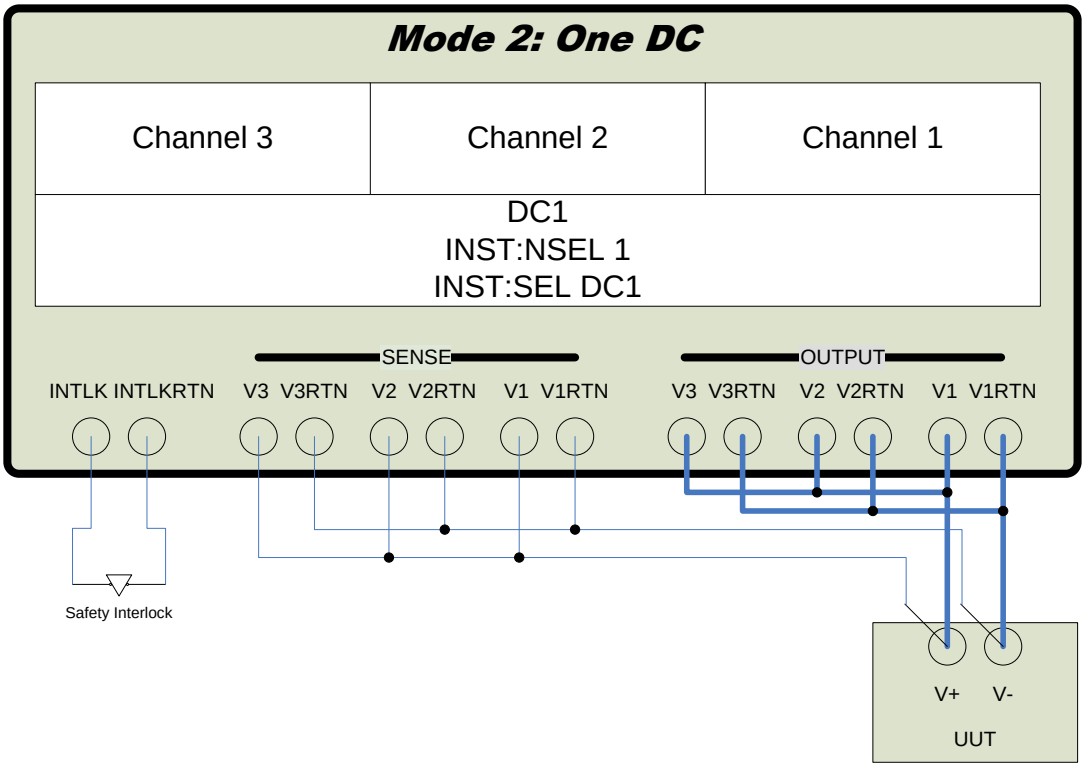


Figure 17 - Mode 2: One DC

Key Maximums for Each Logical Instrument

DC1	Model							
	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	12 kW	24 kW	36 kW	48 kW	60 kW	72 kW	84 kW	96 kW
Max Voltage	400 VDC							
Max Current	90 A	180 A	270 A	360 A	450 A	540 A	630 A	720 A

7.1.4 Mode 3: Three AC

Logical Instrument Configuration and UUT Wiring

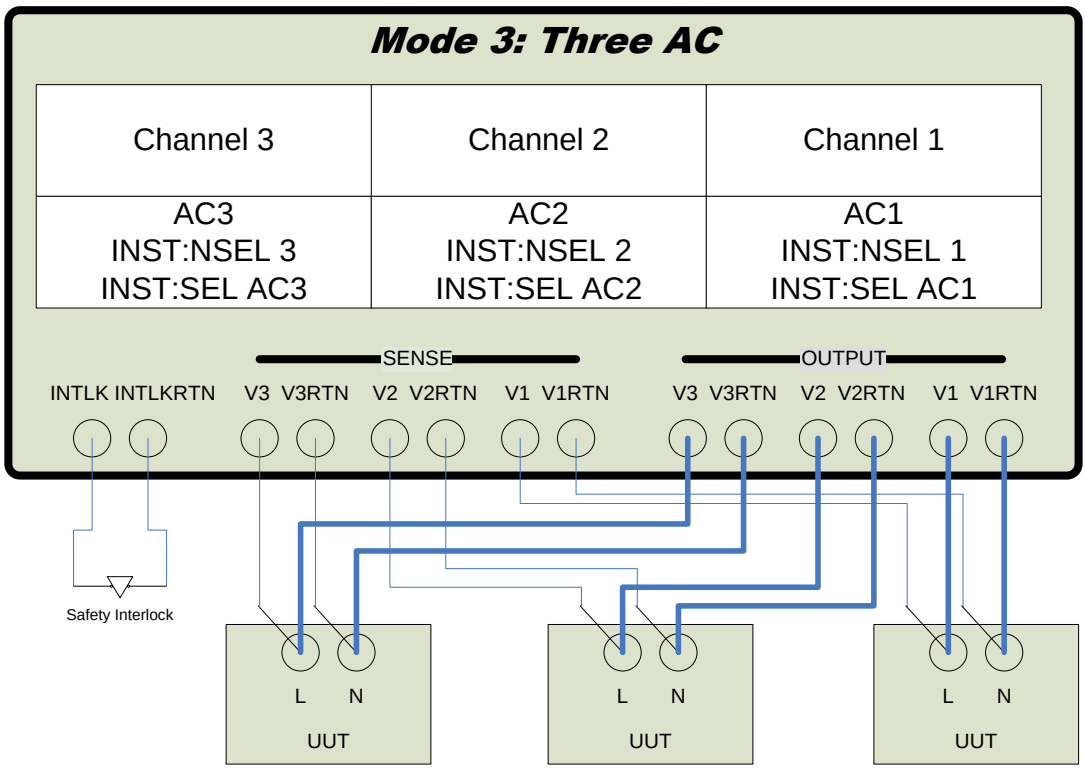


Figure 18 - Mode 3: Three AC

Key Maximums for Each Logical Instrument

	Model							
AC1	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							
AC2								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							
AC3								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							

7.1.5 Mode 4: Three DC

Logical Instrument Configuration and UUT Wiring

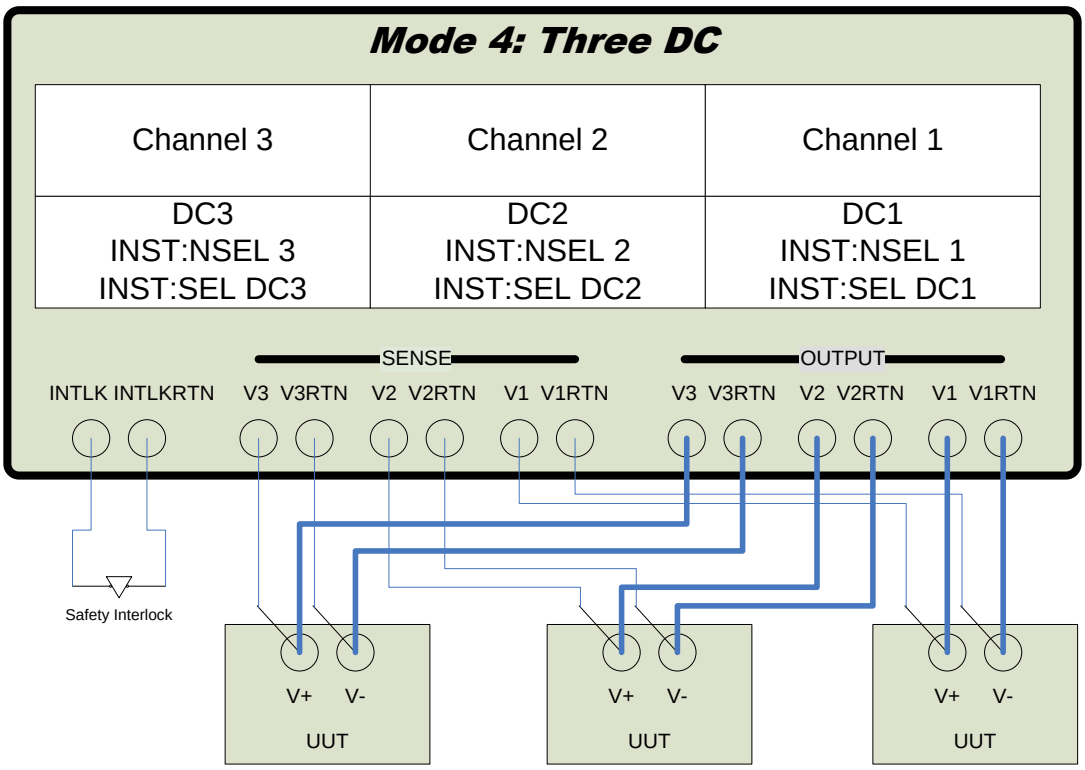


Figure 19 - Mode 4: Three DC

Key Maximums for Each Logical Instrument

	Model							
DC1	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A
DC2								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A
DC3								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A

7.1.6 Mode 5: One 2-Phase AC and One AC

Logical Instrument Configuration and UUT Wiring

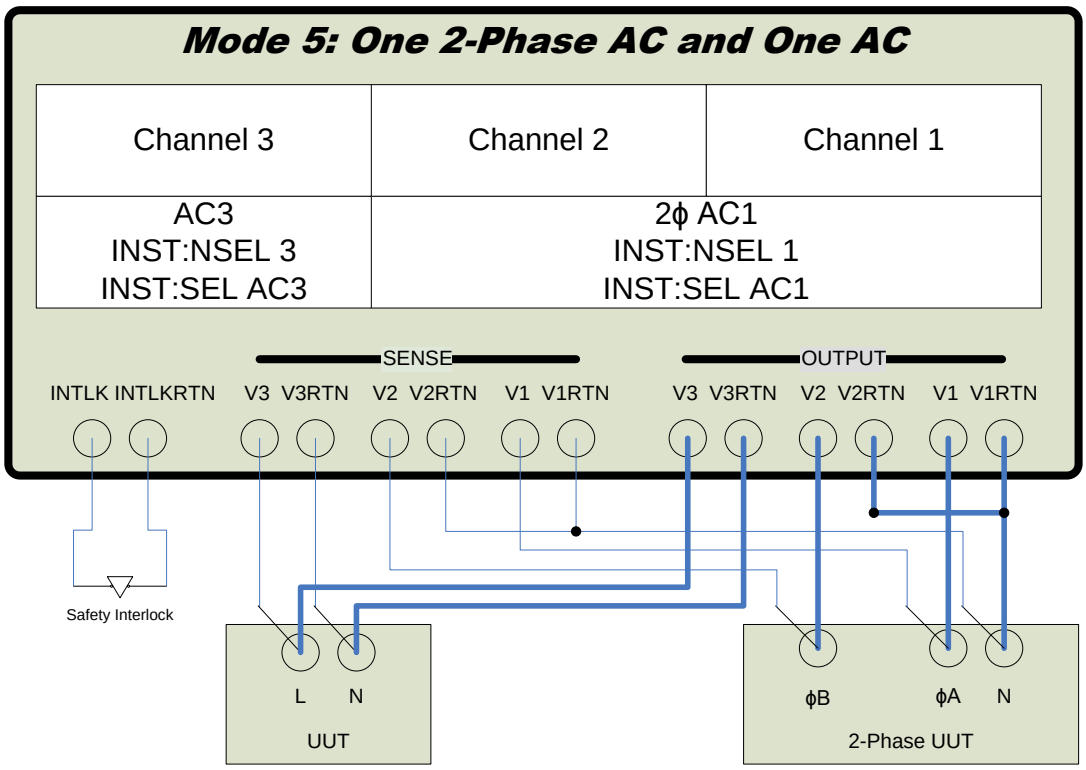


Figure 20 - Mode 5: One 2-Phase AC and One AC

Key Maximums for Each Logical Instrument

	Model							
AC1 (2-Phase)	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	8 kW	16 kW	24 kW	32 kW	40 kW	48 kW	56 kW	64 kW
Max Voltage	500 Vrms Line-Line							
Max Current / Phase	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current / Phase	3 X Maximum RMS Current							
AC3								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							

7.1.7 Mode 6: One 2-Phase AC and One DC

Logical Instrument Configuration and UUT Wiring

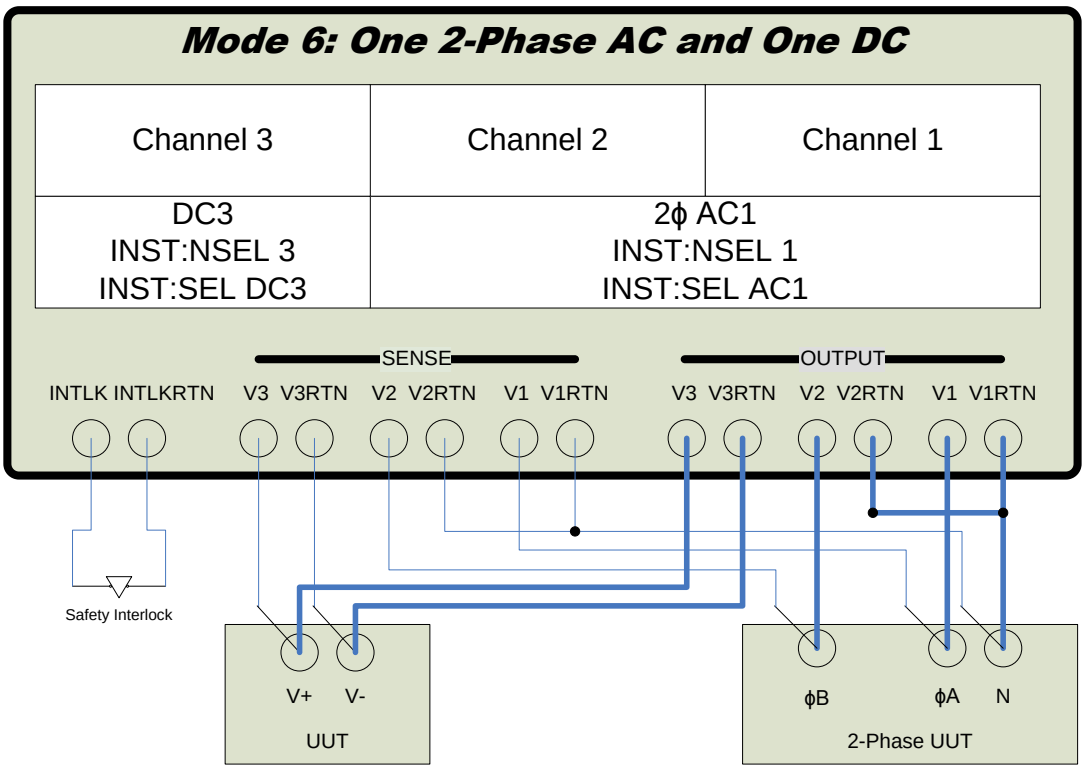


Figure 21 - Mode 6: One 2-Phase AC and One DC

Key Maximums for Each Logical Instrument

	Model							
AC1 (2-Phase)	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	8 kW	16 kW	24 kW	32 kW	40 kW	48 kW	56 kW	64 kW
Max Voltage	500 Vrms Line-Line							
Max Current / Phase	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current / Phase	3 X Maximum RMS Current							
DC3								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A

7.1.8 Mode 7: Two AC

Logical Instrument Configuration and UUT Wiring

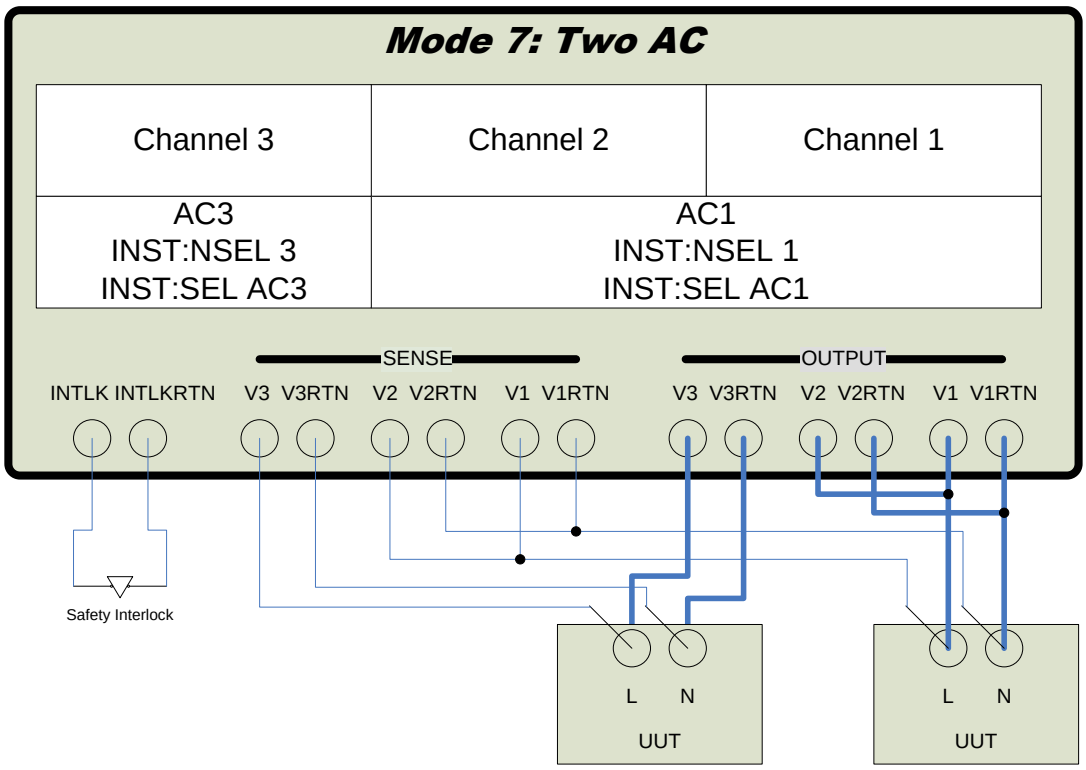


Figure 22 - Mode 7: Two AC

Key Maximums for Each Logical Instrument

	Model							
AC1	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	8 kW	16 kW	24 kW	32 kW	40 kW	48 kW	56 kW	64 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	60 Arms	120 Arms	180 Arms	240 Arms	300 Arms	360 Arms	420 Arms	480 Arms
Peak Current	3 X Maximum RMS Current							
AC3								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							

7.1.9 Mode 8: One AC and One DC

Logical Instrument Configuration and UUT Wiring

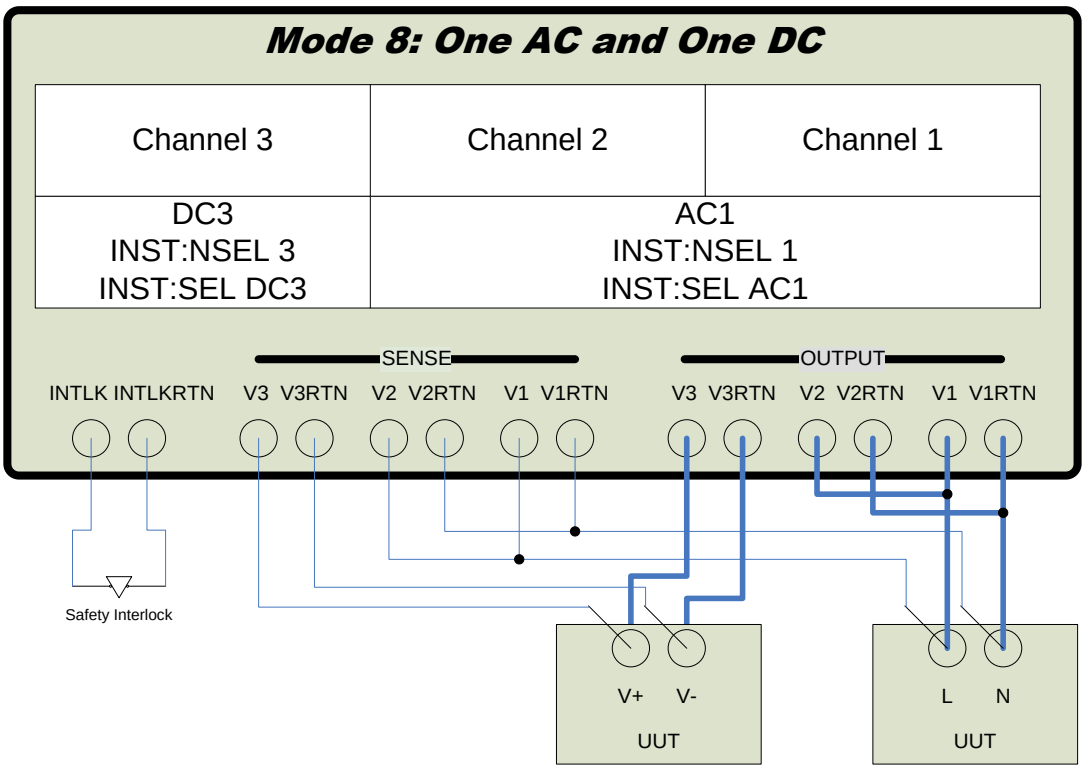


Figure 23 - Mode 8: One AC and One DC

Key Maximums for Each Logical Instrument

	Model							
AC1	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	8 kW	16 kW	24 kW	32 kW	40 kW	48 kW	56 kW	64 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	60 Arms	120 Arms	180 Arms	240 Arms	300 Arms	360 Arms	420 Arms	480 Arms
Peak Current	3 X Maximum RMS Current							
DC3								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A

7.1.10 Mode 9: Two AC and One DC

Logical Instrument Configuration and UUT Wiring

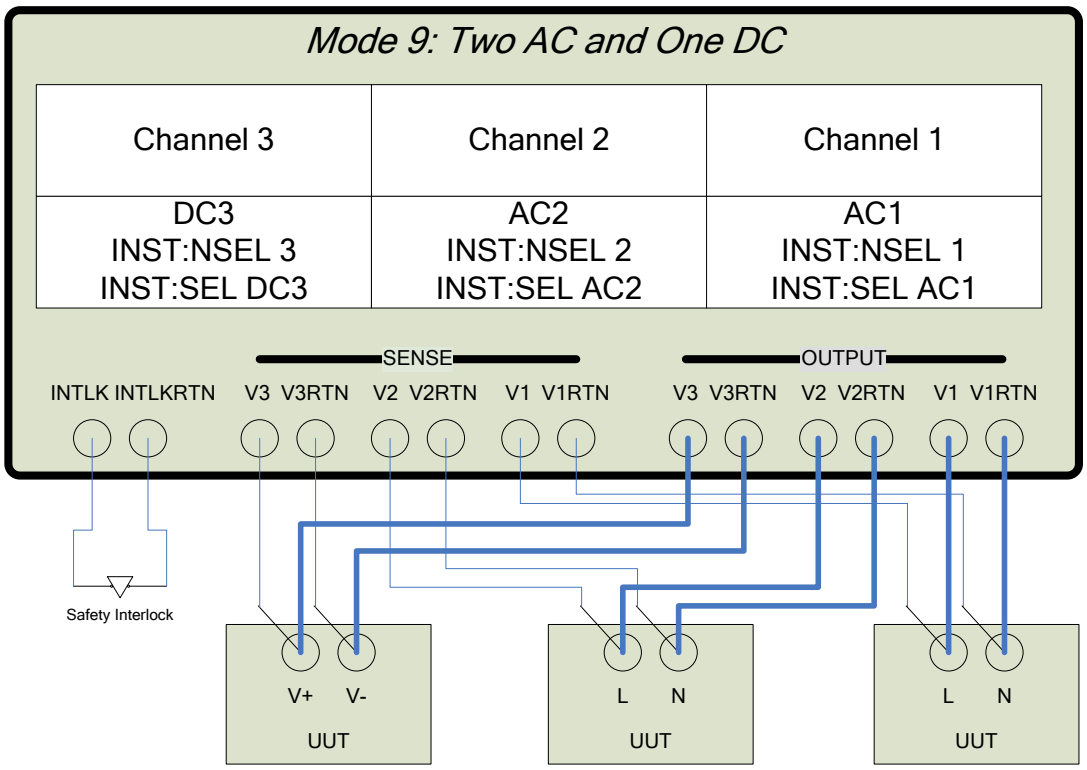


Figure 24 - Mode 9: Two AC and One DC

Key Maximums for Each Logical Instrument

	Model							
AC1	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							
AC2								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							
DC3								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A

7.1.11 Mode 10: One AC and Two DC

Logical Instrument Configuration and UUT Wiring

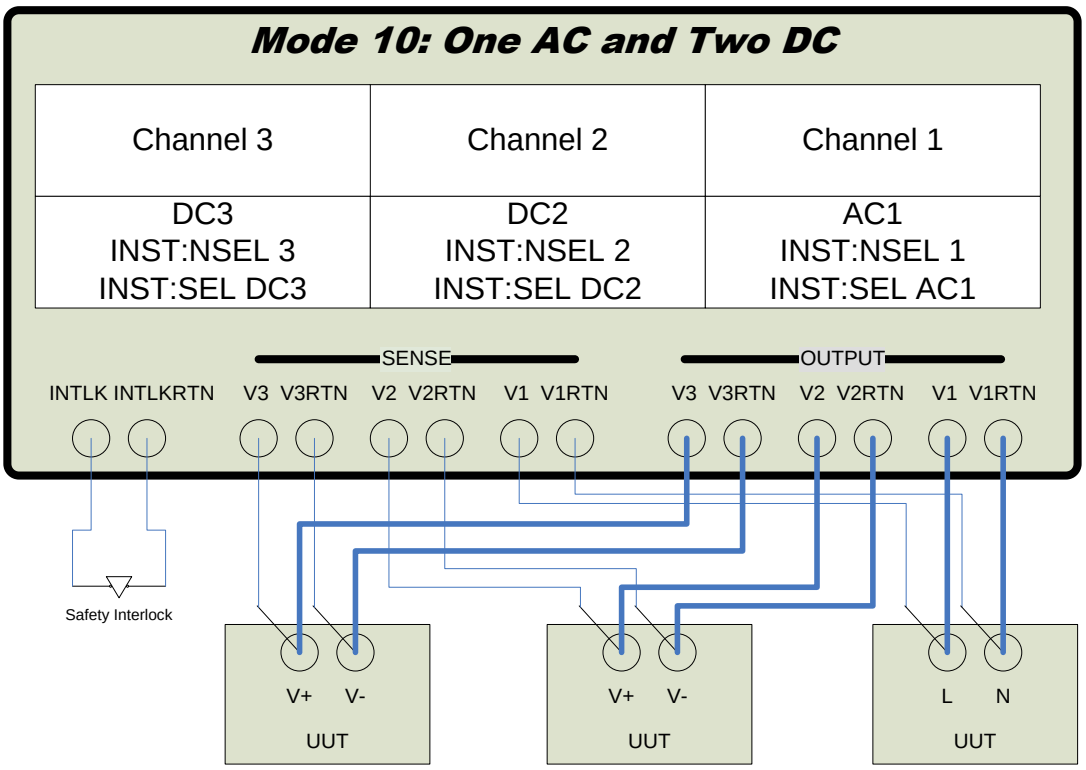


Figure 25 - Mode 10: One AC and Two DC

Key Maximums for Each Logical Instrument

	Model							
AC1	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							
DC2								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A
DC3								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A

7.1.12 Mode 11: One DC and One AC

Logical Instrument Configuration and UUT Wiring

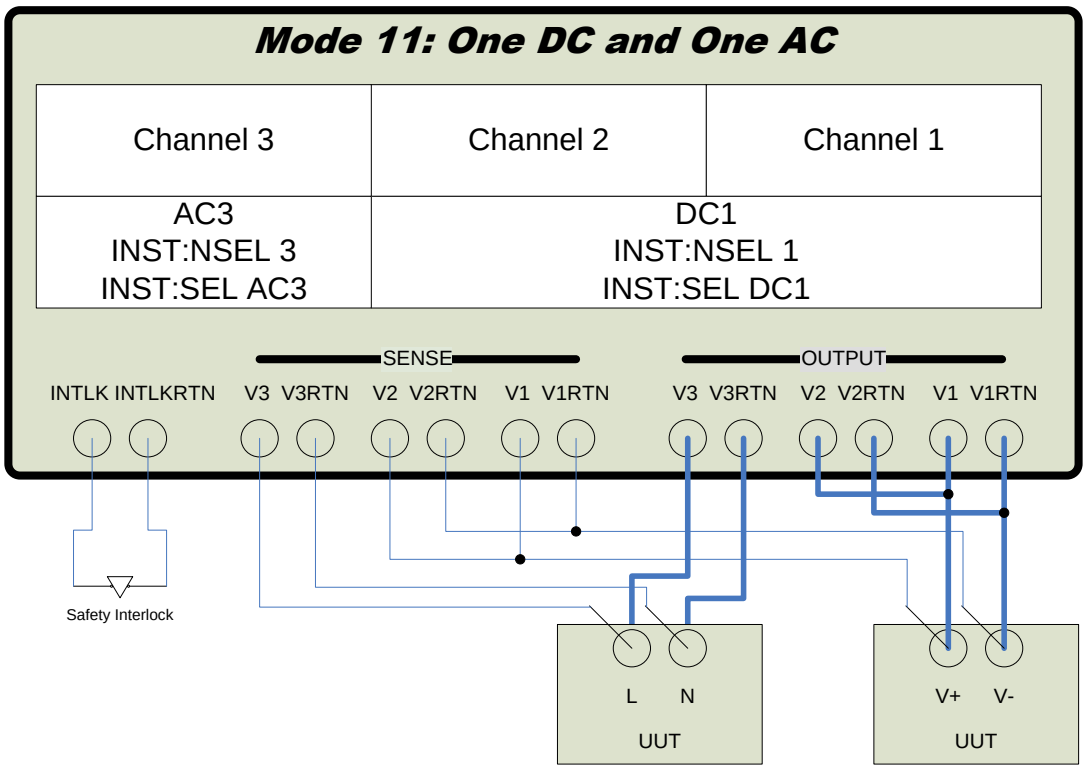


Figure 26 - Mode 11: One DC and One AC

Key Maximums for Each Logical Instrument

	Model							
DC1	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	8 kW	16 kW	24 kW	32 kW	40 kW	48 kW	56 kW	64 kW
Max Voltage	400 VDC							
Max Current	60 A	120 A	180 A	240 A	300 A	360 A	420 A	480 A
AC3								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							

7.1.13 Mode 12: Two DC

Logical Instrument Configuration and UUT Wiring

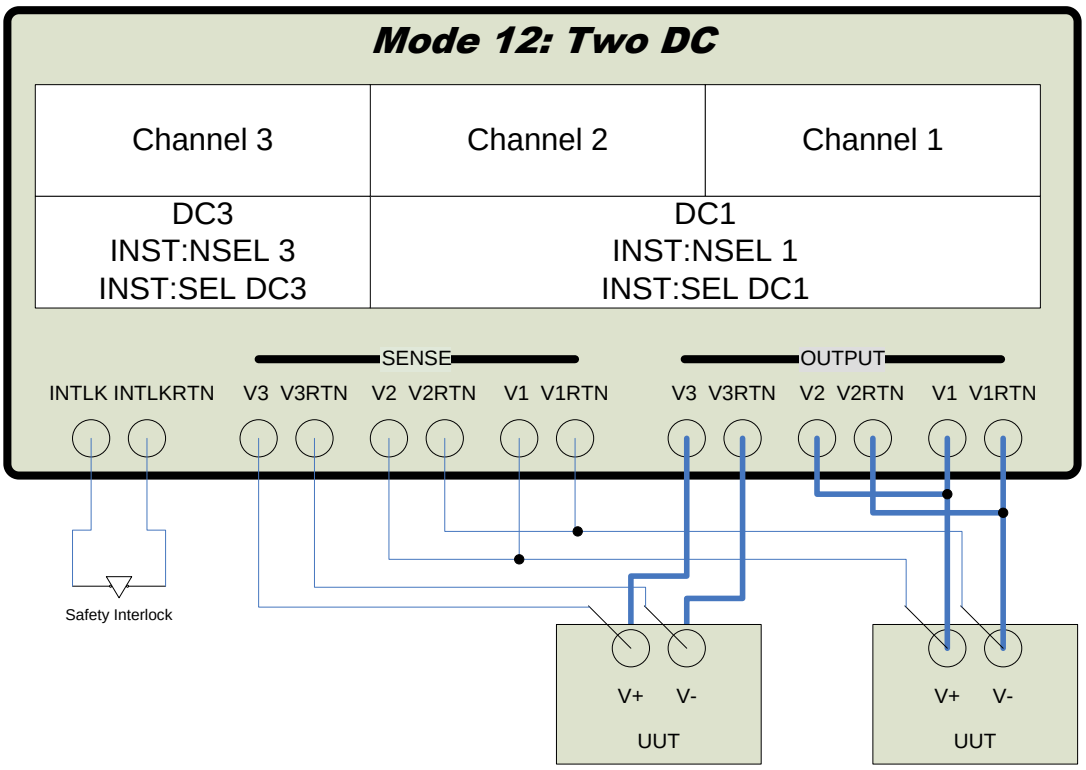


Figure 27 - Mode 12: Two DC

Key Maximums for Each Logical Instrument

	Model							
DC1	9410-12	9410-24	9410-36	9410-48	9410-60	9410-72	9410-84	9410-96
Max Power	8 kW	16 kW	24 kW	32 kW	40 kW	48 kW	56 kW	64 kW
Max Voltage	400 VDC							
Max Current	60 A	120 A	180 A	240 A	300 A	360 A	420 A	480 A
DC3								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A

7.2 Two Channel Power Module

The two channel power module has 6 unique configurations.

Mode	*Available Instruments*	*Channel 1*	*Channel 2*
0	One 2-Phase AC	AC1 (Phase A)	AC1 (Phase B 180°)
1	One AC	AC1	
2	One DC	DC1	
3	Two AC	AC1	AC2
4	Two DC	DC1	DC2
5	One AC and One DC	AC1	DC2

The following figures show the basic wiring for each mode.

7.2.1 Mode 0: One 2-Phase AC

Logical Instrument Configuration and UUT Wiring

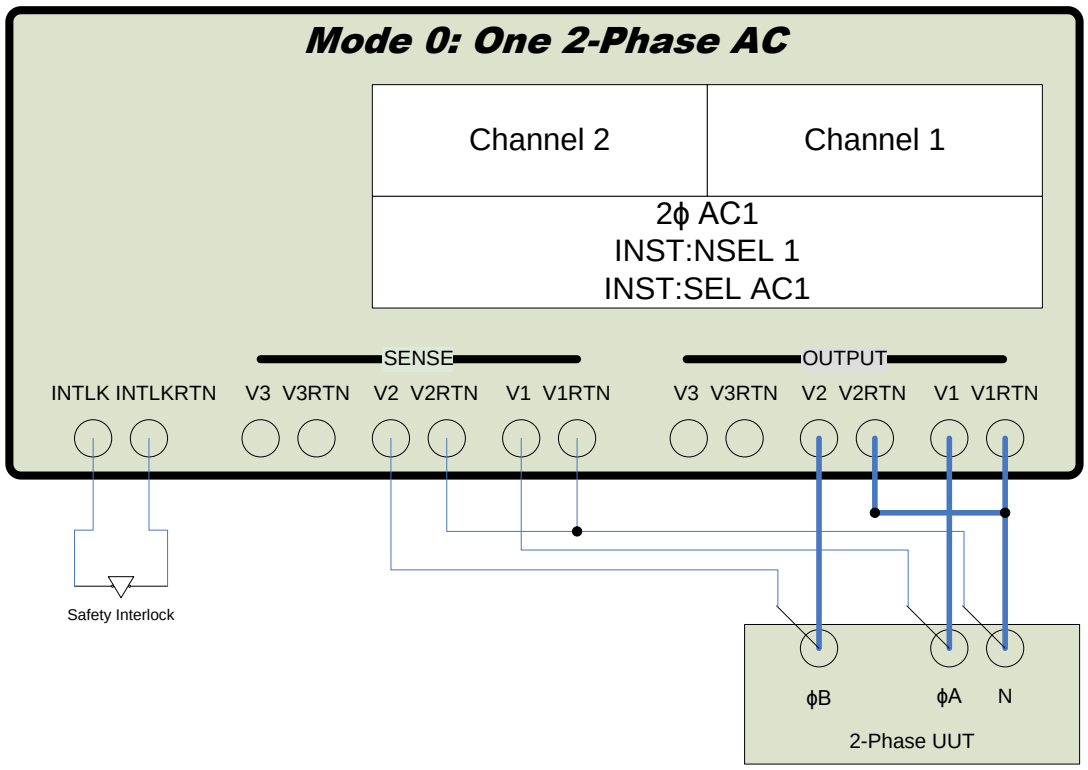


Figure 28 - Mode 0: One 2-Phase AC

Key Maximums for Each Logical Instrument

	Model							
AC1 (2-Phase)								
Max Power	8 kW	16 kW	24 kW	32 kW	40 kW	48 kW	56 kW	64 kW
Max Voltage	500 Vrms Line-Line							
Max Current / Phase	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current / Phase	3 X Maximum RMS Current							

7.2.2 Mode 1: One AC

Logical Instrument Configuration and UUT Wiring

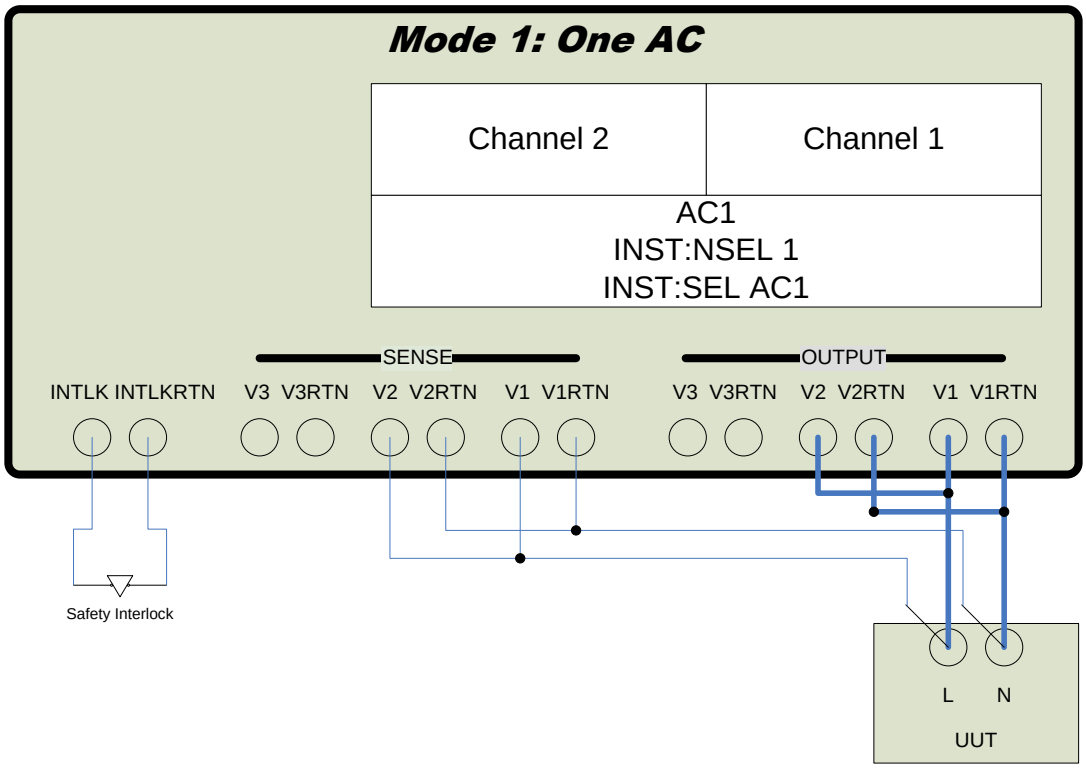


Figure 29 - Mode 1: One AC

Key Maximums for Each Logical Instrument

	Model							
AC1								
Max Power	8 kW	16 kW	24 kW	32 kW	40 kW	48 kW	56 kW	64 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	60 Arms	120 Arms	180 Arms	240 Arms	300 Arms	360 Arms	420 Arms	480 Arms
Peak Current	3 X Maximum RMS Current							

7.2.3 Mode 2: One DC

Logical Instrument Configuration and UUT Wiring

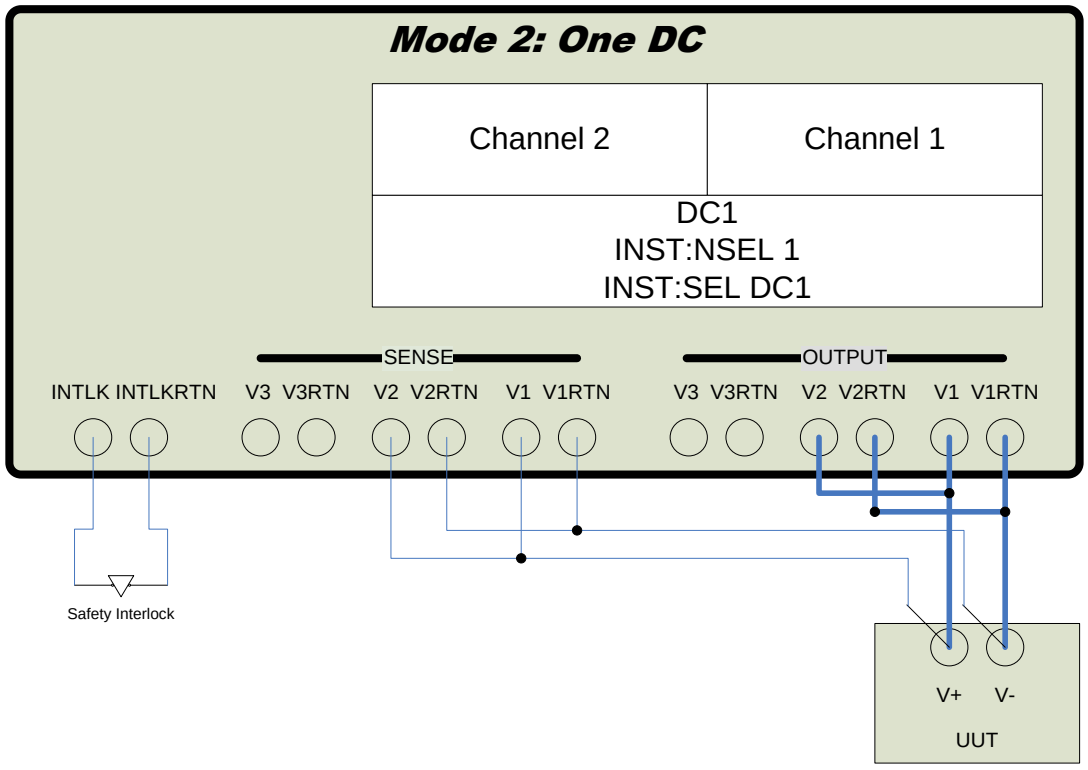


Figure 30 - Mode 2: One DC

Key Maximums for Each Logical Instrument

	Model							
DC1								
Max Power	8 kW	16 kW	24 kW	32 kW	40 kW	48 kW	56 kW	64 kW
Max Voltage	400 VDC							
Max Current	60 A	120 A	180 A	240 A	300 A	360 A	420 A	480 A

7.2.4 Mode 3: Two AC

Logical Instrument Configuration and UUT Wiring

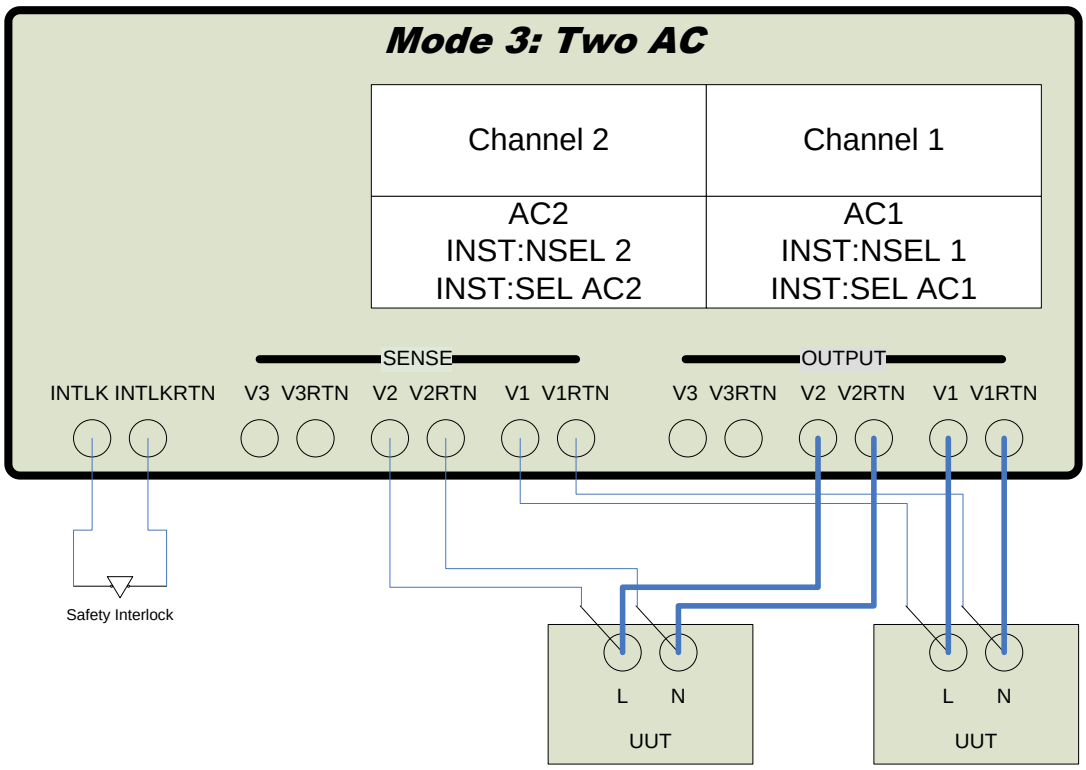


Figure 31 - Mode 3: Two AC

Key Maximums for Each Logical Instrument

	Model							
AC1								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							
AC2								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							

7.2.5 Mode 4: Two DC

Logical Instrument Configuration and UUT Wiring

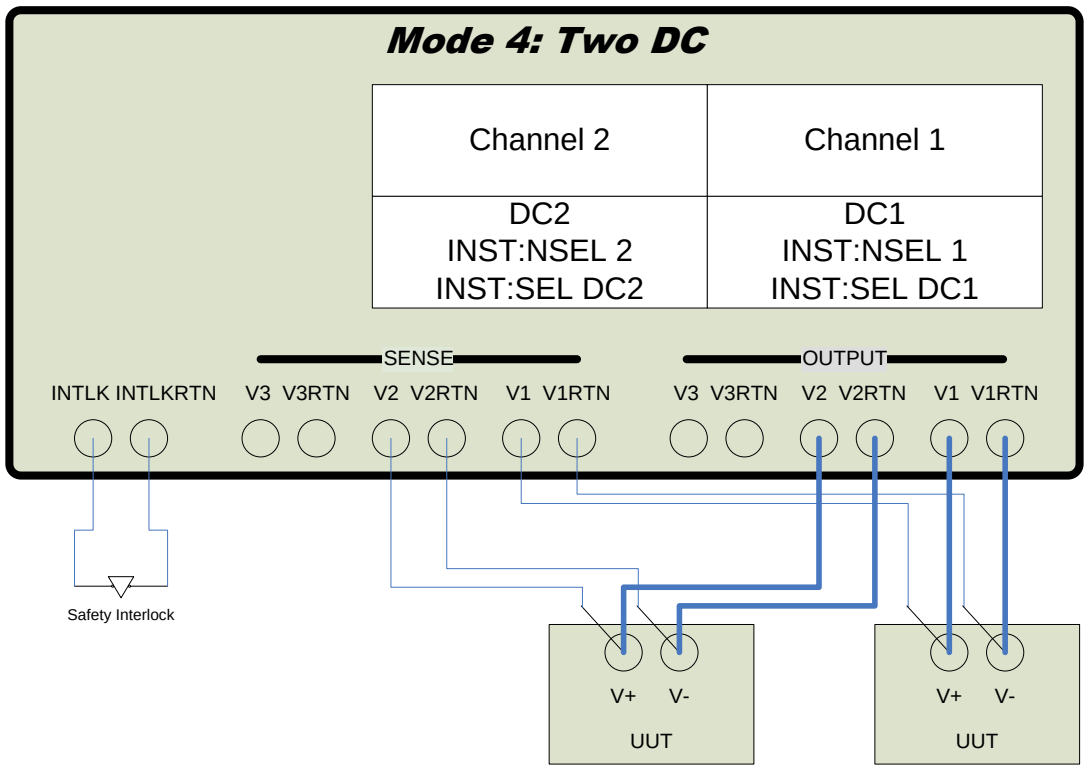


Figure 32 - Mode 4: Two DC

Key Maximums for Each Logical Instrument

	Model							
DC1								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A
DC2								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A

7.2.6 Mode 5: One AC and One DC

Logical Instrument Configuration and UUT Wiring

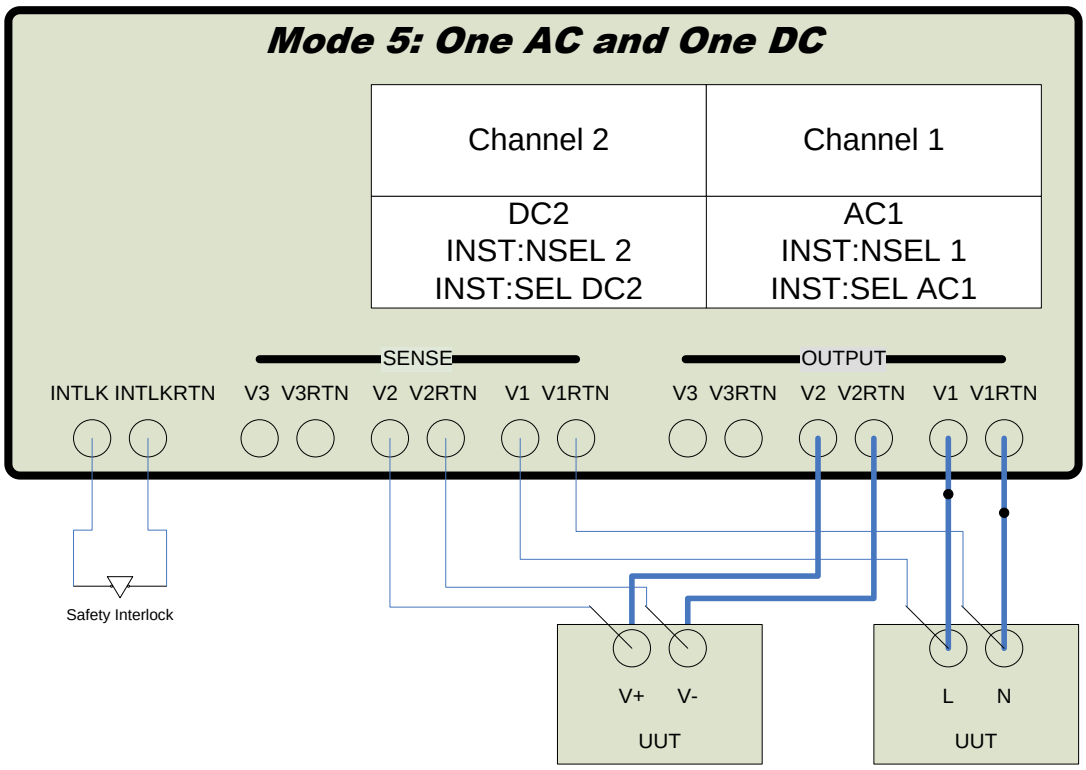


Figure 33 - Mode 5: One AC and One DC

Key Maximums for Each Logical Instrument

	Model							
AC1								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							
DC2								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A

7.3 One Channel Power Module

The one channel power module has 2 unique configurations.

Mode	*Available Instruments*	*Channel 1*
0	One AC	AC1
1	One DC	DC1

The following figures show the basic wiring for each mode.

7.3.1 Mode 0: One AC

Logical Instrument Configuration and UUT Wiring

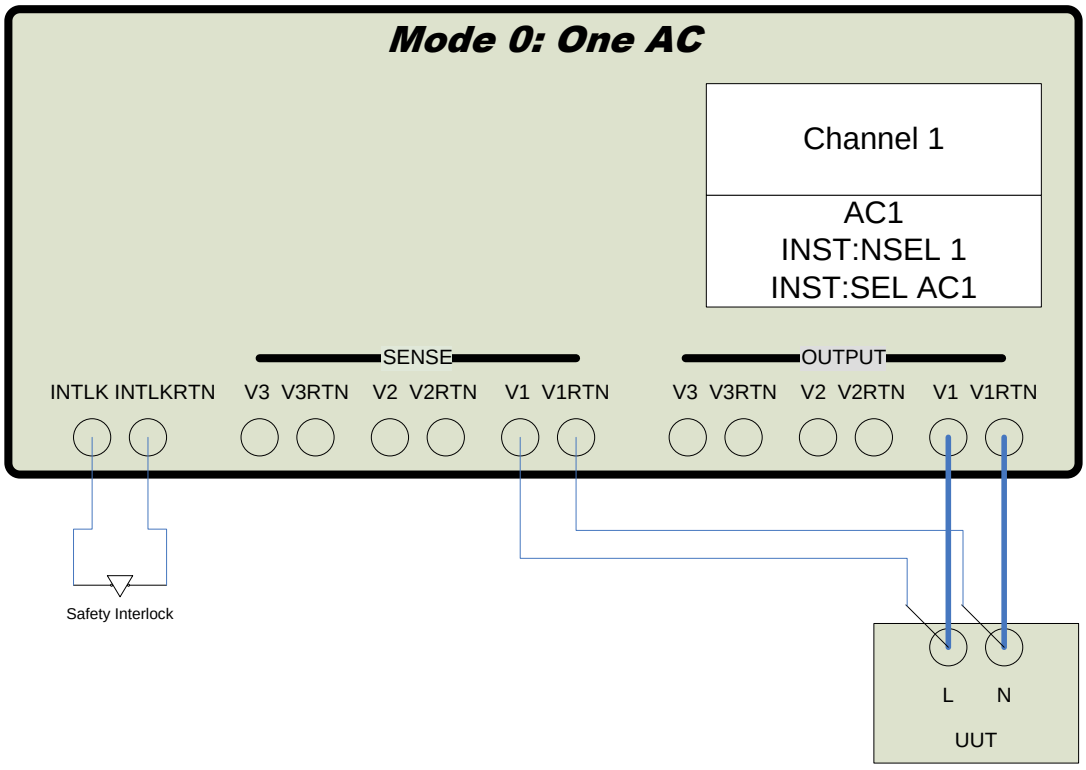


Figure 34 - Mode 0: One AC

Key Maximums for Each Logical Instrument

	Model							
AC1								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	310 Vrms Line-Neutral							
Max Current	30 Arms	60 Arms	90 Arms	120 Arms	150 Arms	180 Arms	210 Arms	240 Arms
Peak Current	3 X Maximum RMS Current							

7.3.2 Mode 1: OneDC

Logical Instrument Configuration and UUT Wiring

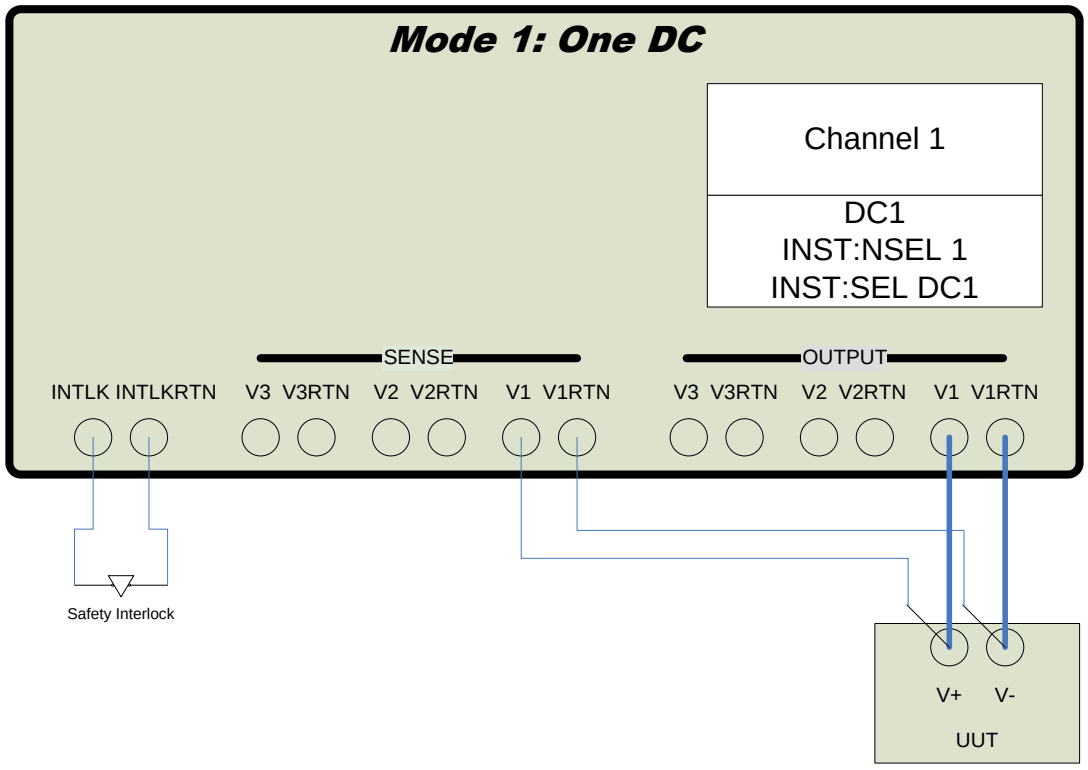


Figure 35 - Mode 1: One DC

Key Maximums for Each Logical Instrument

	Model							
DC1								
Max Power	4 kW	8 kW	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW
Max Voltage	400 VDC							
Max Current	30 A	60 A	90 A	120 A	150 A	180 A	210 A	240 A

8. APENDIX – ADDITIONAL INFORMATION

8.1 Overview

The NHR Model 9400 Series AC/DC Power Module is a family of high efficiency, high power density, power regenerative, rack mountable, and low noise distortion, DC/single/multi-phase power source which provides precise output regulation and advanced measurement.

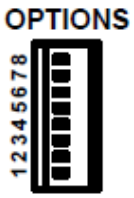
8.1.1 Aux Sys Address Setup

There is an Auxiliary System Address Dipswitch for each 9400 systems. Position 1-4 are used to set system address, position 8 is used to setup firmware download (normally down). If there are multiple 9400 systems in parallel, each system needs to set at different address. This Dipswitch is preset at factory. By default, when only one 9400 system work as an instrument, switch 1-4 will be set at down position (value 0). System will generate a configuration error if the Dipswitch is set wrong.

8.1.2 Emergency-OFF Connector Setup

User need to jumper pin1 and pin2 of the Emergency-Off connector to turn on the system. This connector provides a way to quickly turn off the system with an outside switch at emergency. When pin1 and pin2 are disconnected, all the input relay and output relay will open, and all the semi-conductors will stop switching. System will generate an Emergency Off error and be latched off even if the jumper is back. Recycle power or a reset command can clear the error.

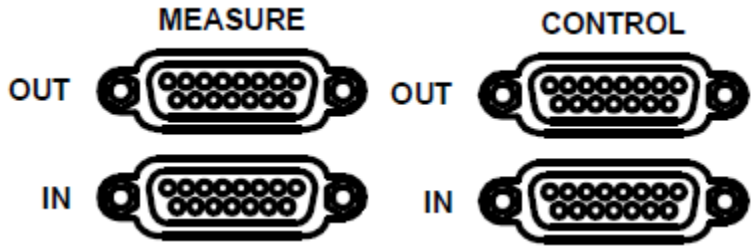
8.1.3 Option Dipswitch Setup



Switch 8	This switch along with switch 8 of the Aux Sys Address setup, determine if user want to update the Controller-Board/Slave-Board firmware or normal operation. Switch Up: Download (update) firmware for Controller Board or

	Slave Boards. Switch Down: Normal Operation This switch has to be set before unit turn on
Switch 7-6	Reserved (default to 0)
Switch 5	Debug/NHR use only
Switch 4-2	Reserved (default to 0)
Switch 1	Set the IP Address This switch has to be set before unit turn on

8.1.4 Parallel Connectors



When there are multiple units in parallel, the measurement parallel connector and the control parallel connector need to be connected in parallel (daisy chained together).

FOR MASTER UNIT, IT IS REQUIRED TO PUT ON THE CAN BUS TERMINATOR ON THE CONTROL IN. THE CAN BUS TERMINATOR IS PROVIDED IN THE INSTALATION KIT.

IT IS REQUIRED TO USE THE NHR PROVIDED CABLE FOR THE PARALLEL.

8.1.5 Key Features

8.1.5.1 High Efficiency and High Power Density

NHR Model 9400 uses the latest SCI MOSFET technology and has very high efficiency (up to 92%) and high Power density (up to 1.92W per cubic inch)

8.2 Configuration

After powering up the unit, the user should verify the desired configuration of the following. These can be set and saved as the power up default with the included PC software tools or through the programming interface. The following should be modified while the output is off:

- Set the hardware configuration mode. This will determine if a channel is in AC or DC mode and whether it is paralleled with other channels.
- Select if you will be using internal or external sense.

- If you are configuring a channel in AC mode and you wish to use an Auto Transformer to boost the output/input voltage set it to use an autotransformer.

9. SERVICE

9.1 NHR 9400 Firmware Updates

There are three (3) separate processors and firmware levels which may periodically require NH Research to issue a firmware update. As such, it is important to understand what firmware is currently loaded on the system and which utility is needed to update the firmware. The following section is only a high level guide intended for NH Research support personnel or customers which have already performed a firmware update.

Discuss the firmware update process with NH Research customer support before attempting to perform an update.

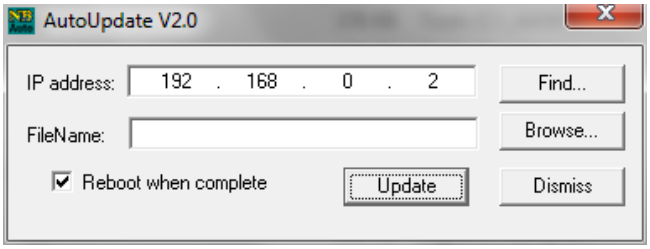
9.1.1 Updating the network processor

The network processor (also known as a netburner) provides the communication between the LAN interface and the internal processors. This processor is responsible for decoding the SCPI commands and converting them to the command interface used within the 9400.

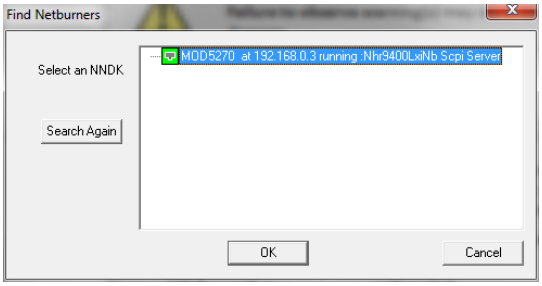
This processor is updated using AutoUpdate.exe which is generally found on the local PC which the 9400 Tools were installed.

Contact NH Research customer support if needed.

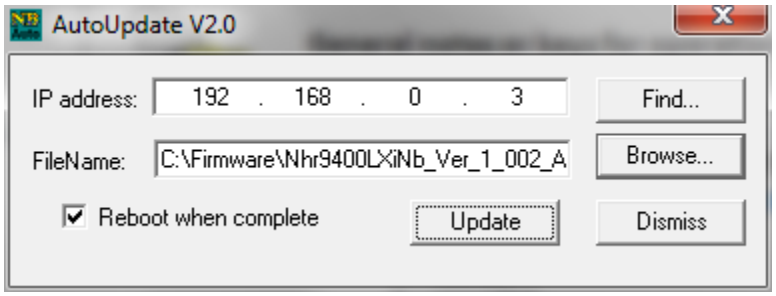
Step 1: Close all external applications and launch AutoUpdate.exe. When launched, AutoUpdate.exe will provide the following window



Either provide the correct IP address or select “Find” to locate net-burner processors. The 9400 will show it is currently running Nhr9400LxiNb Scpi Server

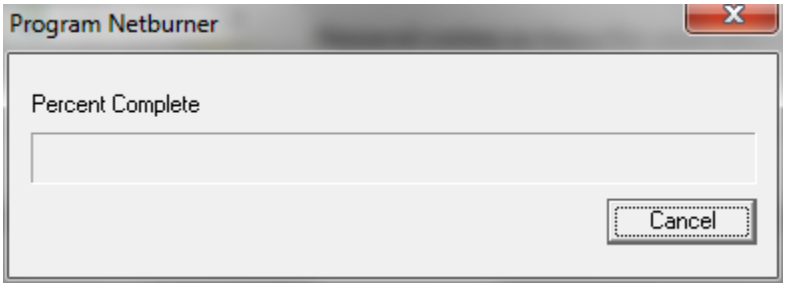


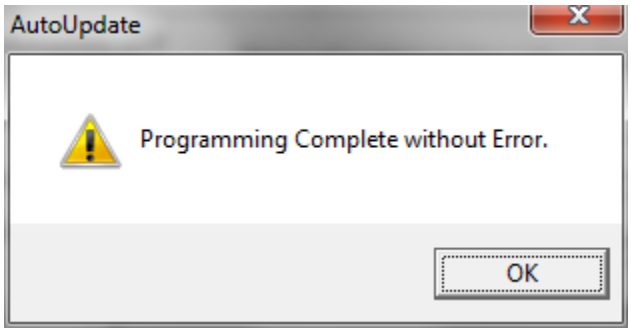
Step 2: Click Browse and locate the firmware file provided by customer support



Step 3: Press Update

The utility will now show a progress bar and a programming complete message





Step 4: Close the update utility and cycle power on the 9400.

9.1.2 Updating the internal processors

The following section is only a high level guide intended for NH Research support personnel or customers which have already performed a firmware update.

Before updating the firmware make sure:

All external control programs are closed (including NHR 9400 Panel)
The system is powered off

The firmware update utility can be found under

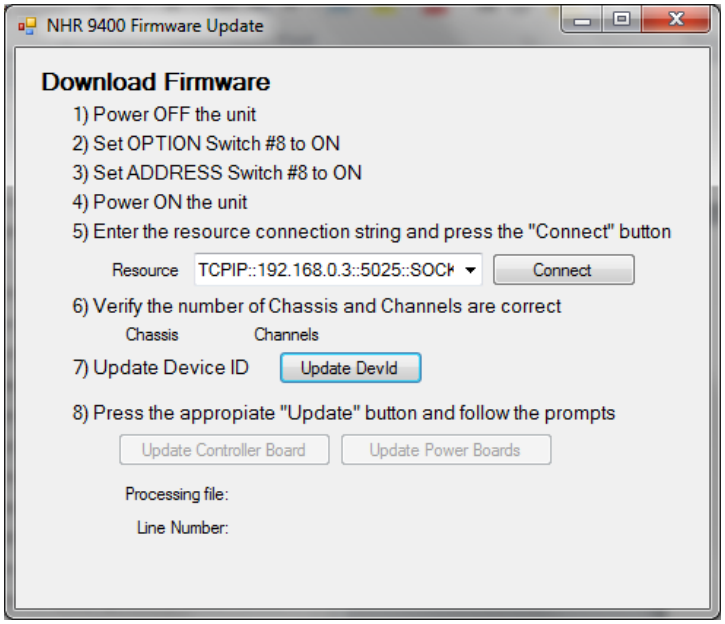
Start → All Programs → NH Research → 9400 Series →
NHR 9400 Firmware Update

Or on the local hard drive under

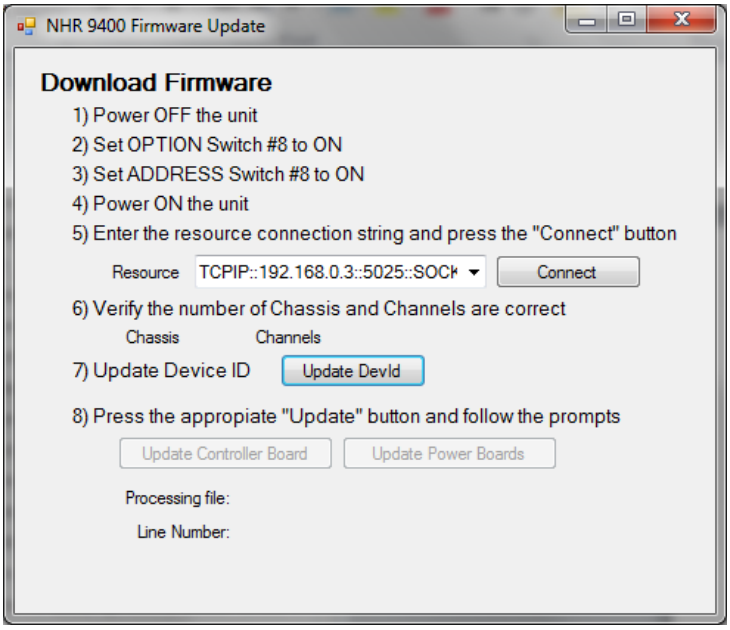
"C:\Program Files (x86)\NH Research\NHR 9400\Utilities\Nhr9400FwUpdate.exe"

When opened the program will instruct the user to take the following actions

1. Power off the unit
2. On the master set OPTIONS switch 8 to ON
3. On the master and all auxiliaries set ADDRESS switch 8 to ON
   (Do not change any of the other switches on the auxiliary modules)
4. Make sure the LAN cable is connected
5. Power on the unit and start the firmware update utility



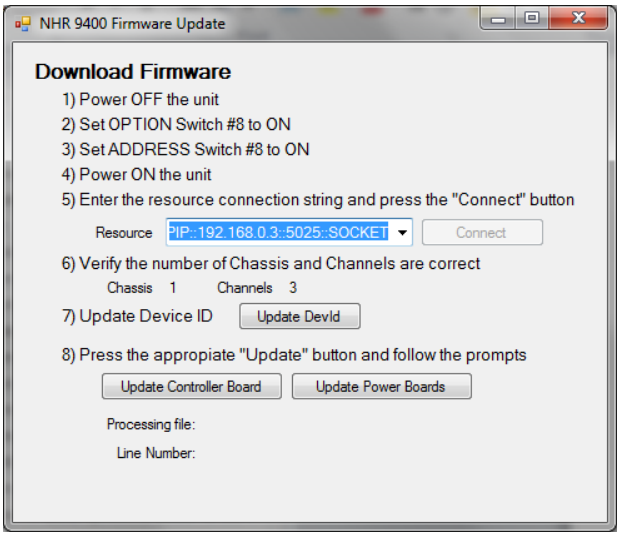
Next, enter the resource connection string in the form of "TCPIP::(ipaddress)::SOCKET" As shown below. The TCPIP address is of the master module which is specified on the back label or was changed using the "Configuring the master modules IP address" section as above.



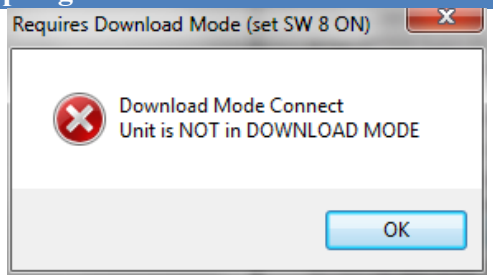
IP ADDRESS 192.168.0.3 used in example
Be sure to use double colons in the resource ID string as shown

Next, Press the connect button. The system will connect or display an error message: If error occurs, close the firmware update utility, correct the error and try again

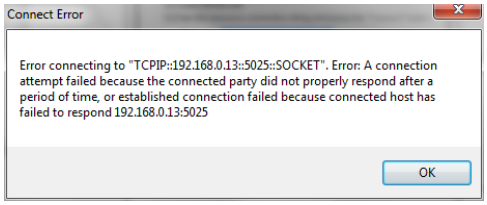
Possible outcomes when attempting to "Connect"



Ready to update firmware



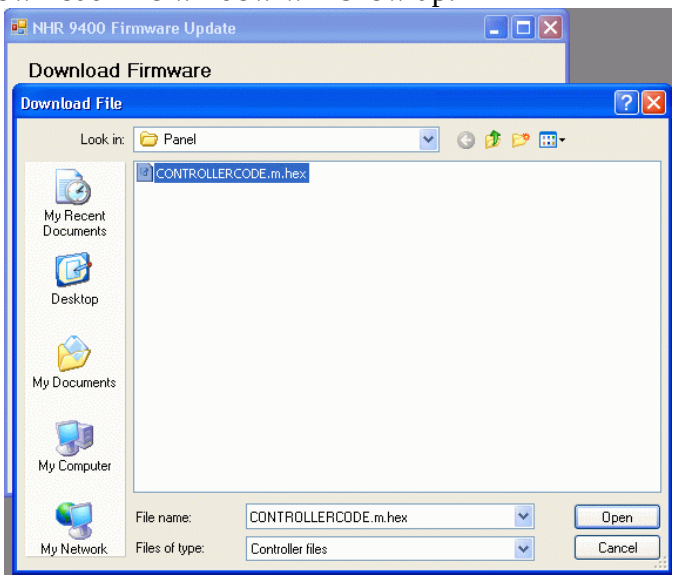
Error: Switches were not set properly



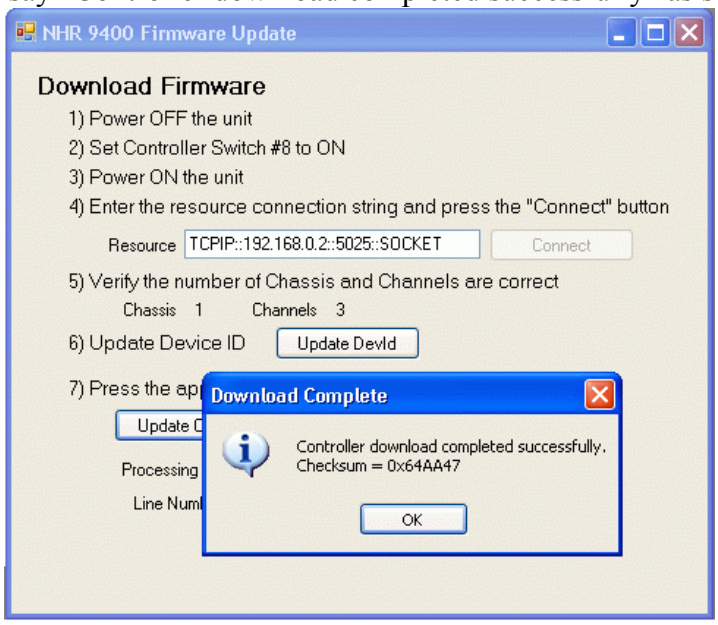
Error: Wrong IP address provided

The Device ID should not be modified. This is used for Factory identification only.

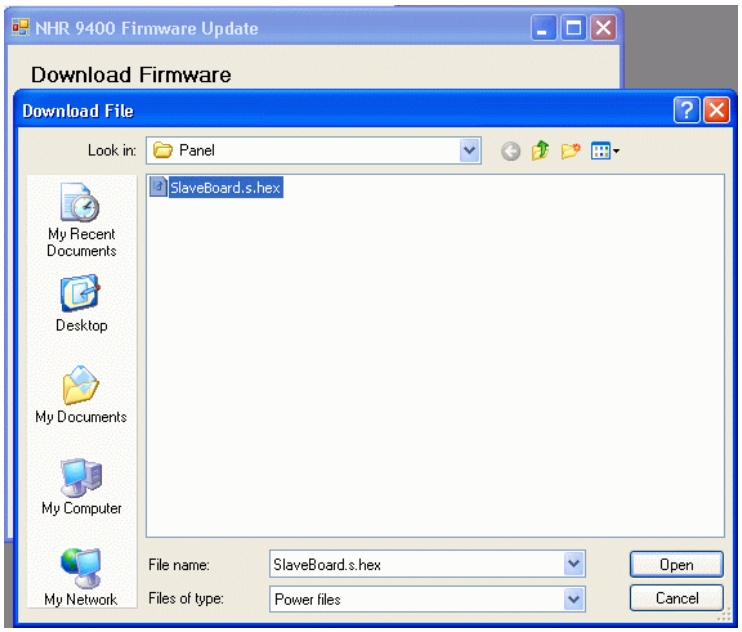
To update the controller board firmware, click the "Update Controller Board" button, the following Download File window will show up:



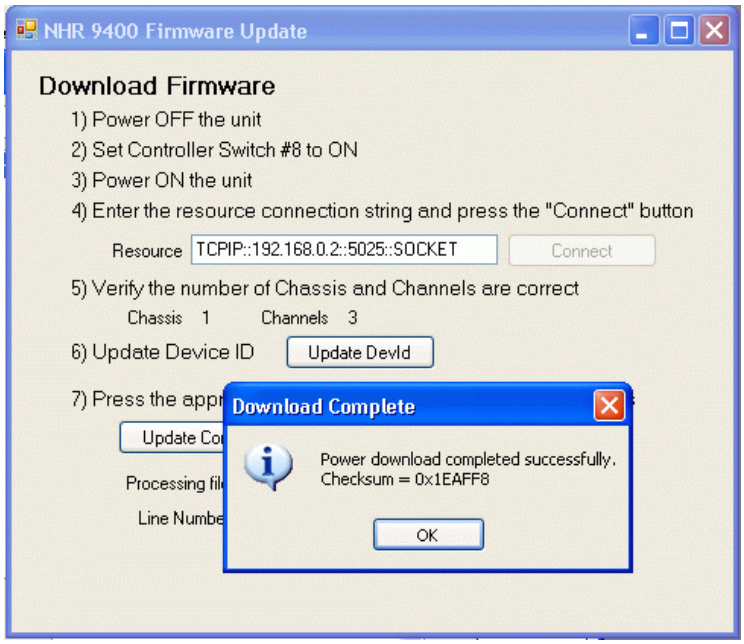
Browse to locate the firmware file provided by NH Research customer support (filename.m.hex) then select "Open". The entire process generally takes 1-2 minutes to download the controller board firmware. When complete, and if it is successful, a pop up window will say "Controller download completed successfully" as shown



To update the controller board firmware, click the “Update Power Board” button, the following Download File window will show up:



Browse to locate the power board firmware file provided by NH Research customer support (filename.m.hex) then select “Open”. The entire process generally takes 1-2 minutes to download the controller board firmware. When complete, and if it is successful, a pop up window will say “Power download completed successfully” as shown



Close the update utility, return all OPTION and ADDRESS switches #8 back to the OFF state and cycle power on the 9400 system. Do not change any other switches

9.2 Periodic Maintenance

The following periodic maintenance schedule is recommended by NH Research and may need to be modified based on the environment or specific customer needs.

Cleaning: Semi-Annual (every 6 Months)

Calibration: Annually

9.2.1 Periodic Cleaning

Always turn off facility power to the 9400 before attempting to inspect or clean the system.

Failure to do so may result in a hazardous condition.

The 9400 should be inspected (externally) for dust buildup in the air intakes (front) and the exaust fans (rear). Cleaning of the 9400 should only be performed with facility power turned off. The exterior of the 9400 may be cleaned with a cloth dampened with a mild detergent. Ensure the cloth is wrung out to prevent excess moisture from being left inside the unit.

Ensure any residual moisture is completely dry before reconnecting facility power or attempting to use the system

Compressed air may be used to remove dust from the front and rear of the unit.
Do not allow the rear fans to spin at high speed when using compressed air.

The touch panel should only be cleaned with laptop or LCD cleaning wipes. Do not attempt to use detergent on the screen as it will damage the touch interface.

Do not open the system to clean internal components.

9.2.2 Periodic Calibration

NH Research recommends an annual calibration cycle. A utility is provided allowing a customer or external calibration laboratory to perform the calibration. Otherwise, contact NH Research customer support to discuss options for NHR personnel to perform the calibration on-site.

The calibration utility can be found under

Start → All Programs → NH Research → 9400 Series → NHR 9400 Calibration

Or on the local hard drive under

"C:\Program Files (x86)\NH Research\NHR 9400\Utilities\Nhr9400Cal.exe"

Require Equipment List:

- NHR Calibration Box (P/N: Xxxxxx)
- HP/Agilent 3458A (or equivalent)

The calibration of the 9400 is fully automatic and supports a manual mode to support non-3458A DMM meters.

Contact NH Research for additional information about Calibration.

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