NHR 9400 Series
AC/DC Power Module

Programmer's Reference Manual

Part No. 09-0335

REVISION S

January 5, 2018

Document History

Rev A		**5/29/2015**	**R. W.**
Rev B	**Add Macro Subsection**	**6/26/2015**	**R.W.**
Rev C	**Add CF (crest factor) and PF (power factor measurements)**	**10/5/2015**	**R.W.**
Rev D	**ECO 17364, Remove INT:SENS references**	**10/15/2015**	**R.W.**
Rev E	**Add absolute peak to SAFety command**	**10/27/2015**	**R.W.**
Rev F	**Include Load Mode**	**11/24/2015**	**R.W.**
Rev G	**Define for separate models**	**12/2/2015**	**R.W.**
Rev H	**ECO 17423, Corrections for separate models and macro ability**	**3/28/2016**	**P.B.**
Rev J	**ECO 17429, Update macro section**	**4/4/2016**	**P.B.**
Rev K	**ECO 17434, Additional details and examples in macro section**	**4/15/2016**	**P.B.**
Rev L	**ECO xxxxx, Load Mode changes & SCPI extensions for emPower**	**11/3/2016**	**P.B.**
Rev M	**ECO xxxxx, add new macro commands**	**4/25/2017**	**R.W.**
Rev N	**Add CAL commands**	**5/19/2017**	**R.W.**
Rev P	**Minor corrections**	**6/5/2017**	**R.W.**
Rev R	**ECO 17650, Add new LOAD specific commands**	**7/27/2017**	**R.W.**
Rev. S	**ECO 17711**	**1/5/2018**	**R.W.**

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SAFETY

WARNING: LIVE CIRCUITS

NO INTERNAL ADJUSTMENT OR COMPONENT REPLACEMENT IS ALLOWED BY NON-NH RESEARCH QUALIFIED PERSONNEL. COMPLETE THE FOLLOWING BEFORE ACCESSING THE INSTRUMENT INTERNALS:

- REMOVE ALL EXTERNAL VOLTAGE SOURCES
- DISCONNECT POWER CORD
- WAIT A MINIMUM OF 1 MINUTE TO DISCHARGE CIRCUITS
- VERIFY CIRCUITS ARE DISCHARGED

Programming Overview

System Overview

All 9400 AC/DC Power Modules consist of one or more power channels with output wave-shaping controls, a pattern generator (**MACRo:**), a digital measurement system, a high speed digitizer (oscilloscope), and triggering features. The control characteristics of the power channels are dependent on the configured output mode (see: **CONFigure:INSTrument:MODE**) as well as the specific model .

DC Output Modes

Model	9410	9420	9430
Channel Type	Grid	Source	Load
Primary Control	Voltage	Voltage	Current
Power Flow	9410 → UUT UUT → 9410	9420 → UUT UUT → 9420[1]	UUT → 9430
Voltage Limit	✓	✓	✓
Current Limit	-	✓	✓
Power Limit (W)	-	✓	✓
Resistance Limit	-	-	✓

[1] Bi-Directional output is an enable feature

AC Output Modes

Model	9410	9420	9430
Channel Type	Grid	Source	Load
Primary Control	Voltage & Frequency	Voltage & Frequency	Current
Power Flow	9410 → UUT UUT → 9410	9420 → UUT	UUT → 9430 9430 → UUT[1,2,3]
Voltage Limit	✓	✓	N/A
Current Limit	-	✓	✓[2,3]
Power Limit (W or VA)	-	✓	✓[2]
Resistance Limit	-	-	✓[3]
Series RL Loading	-	-	✓[4]
User Waveshapes	Voltage	Voltage	Current[2]

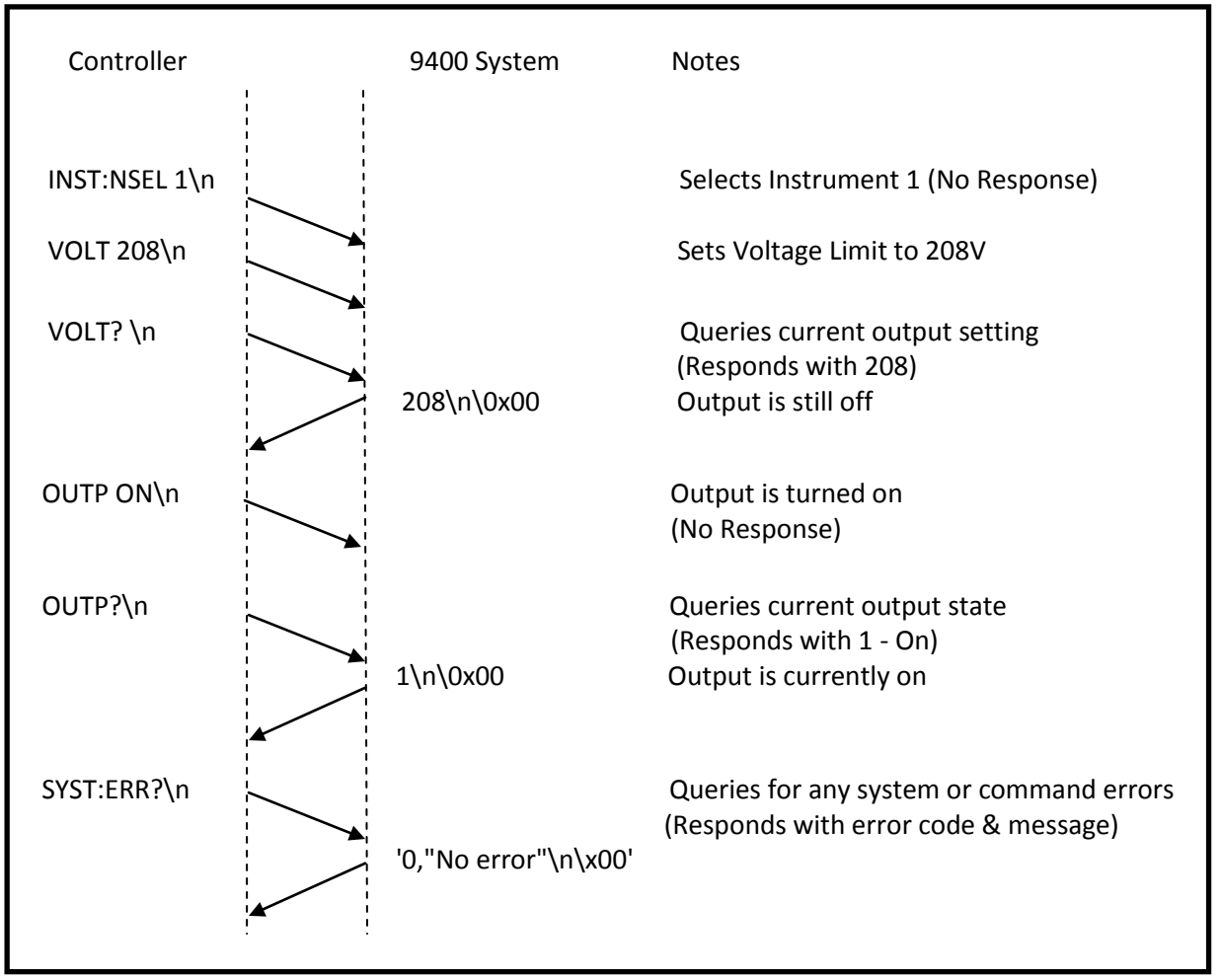
[1] Bi-Directional output is an enable feature
[2] Supported when configured for NORMal loading (see: **CONFigure:INSTrument:LOAD**)
[3] Supported when configured for CR loading (see: **CONFigure:INSTrument:LOAD**)
[4] Supported when configured for RL loading (see: **CONFigure:INSTrument:LOAD**)

Communication Basics

The 9400 series responds to VXI-11 & SCPI (Standard Commands for Programmable Instrument).

In general, SCPI recommends performing a SYSTem:ERRor query after each command to ensure it was processed correctly. This has been removed from the simplified command /query sequence diagram.

Simplified Command / Query sequence (Assuming 9410 or 9420)



The 9400 supports multiple commands in the same sent when they are separated by a semi-colon (;).

For example: "INST:NSEL 1;VOLT 208;VOLT?\n" when received is internally split and processed as if they were received as the first three (3) separate commands shown above.

Important Terminology

(AC or DC) Output: Output is the generic term applied to the connection from the 9400 to the UUT (unit under test). Output should not be construed to imply power flow direction as many of the models and modes are bi-directional. The output characteristics are configured through software commands.

Power Module: Power module is the generic name for the 9400. Depending on the model, the 9400 may act as a AC or DC source, an AC or DC load, or a AC or DC grid emulator.

9410 – Regenerative Grid Simulator (Bi-Directional Voltage & Frequency Control)
9420 – ATE AC/DC Source (Default operation Uni-Directional Voltage & Frequency Control)
9430 – Regenerative AC/DC Load (Default operation Uni-Directional Current Control)

Output Channel: The 9400 has one to three internal power sections per chassis known as channels which can be configured for AC or DC operation. Refer to the product specifications for specific power levels. For example, a 9410-12 supports three (3) channels where each channel is 4 kW/10.5 kVA. The 9410-12 additional support channels 2 & 3 being paralleled with channel 1 allowing for power levels up to 12kW as a single output and many other hardware operating modes

Hardware Mode: The output (AC or DC) & organization of the channels is software selectable (see: **CONFigure:HW:MODE**). Setting the mode will allow you to determine the relationship and operation of the three (3) output channels. For example, the 9410-12 supports 15 unique hardware modes representing various combinations of DC, single-phase, and multi-phase output configurations.

Instrument: Base on the hardware operating mode, a software-configured 9400 will have between one (1), two (2), or three (3) logical instruments. The logical instruments are individually addressable through either an instrument number (see: **INSTrument:NSELect**) or an instrument name (see: **INSTrument:SELect**).

Command: a command is a human readable text string which is sent with a termination character (\n). All commands are processed by the system the appropriate action based on the command is taken. Note: If a command contains a question mark (?) anywhere within the command it is treated as a Query

Query: A query is a command sent with either a trailing '?' (i.e. "*IDN?"") or after the command and before the query paramaters (i.e. FETC:BACK? CH2)

A Query will always respond to a properly formatted command and returns one of the following:

- The query response approperate for the query sent
- <ERROR xxx> where xxx is the error number.
- <NO RESPONSE> if there is nothing to return

Scope of Commands

In addition to selecting AC or DC outputs, the 9400 module is highly configurable allowing more than one logical instrument to be implemented. There are therefore a number of commands which will affect the entire systems operation, effect only the selected logical instrument, or are valid for a specific control connection.

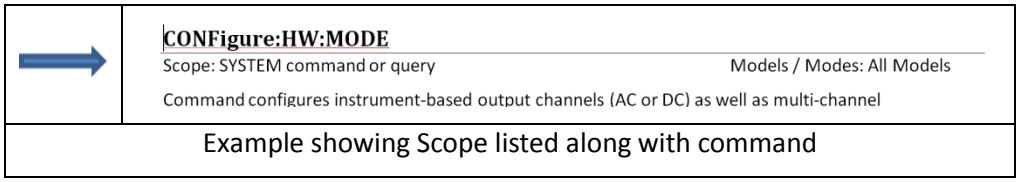
Note: All commands are processed in the order received using a FIFO (first-in / first-out) queue.

Every command or query listed within this reference includes one of the following statements:

- Scope: SYSTEM command (or query, or both).
  - SYSTEM command (or query) act on the entire system without regard to the logical instrument is selected or through which connection the command is issued.

- Scope: INSTRUMENT command (or query, or both).
  - INSTRUMENT command (or query) applies to the currently selected logical instrument (unless otherwise noted) without regard to the connection the command is issued.

- Scope: PER CONNECTION command (or query, or both).
  - PER CONNECTION command (or query) is unique to an individual LAN connection. For example, the 9400 maintains an error queue for each connection such that one connection cannot steal errors from another connection.

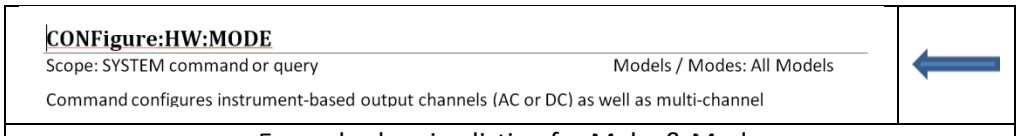


Example showing Scope listed along with command

Model and Mode Specific Commands

There are a number of additional commands which apply or will have a different effect based on the model or operating mode. For example, a 3-ϕ output may allow programming of specific phases whereas a 1-ϕ output does not have specific phases.

These differences in the function of the command are noted within the command description.



Example showing listing for Make & Mode

Units

Unless otherwise stated, units are as follows:

Angles	degrees (°)
Apparent power	Volt-Amperes (VA)
Crest Factor	Unit-less ratio calculated as CF = (instantaneous current / A_{RMS})
Current	Amperes (AC: A_{RMS} / DC: A_{DC})
Energy	Any of the following: Ampere-Hours (Ah) Kilowatt-Hours (kWh) Kilovolt-Ampere-Hours (kVAh)
Frequency	Hertz (Hz)
Power	See True Power
Resistance	Ohms (Ω)
Power Factor	Unit-less ratio calculated as PF = (Apparent Power / True Power)
Time	seconds (s)
True Power	Watts (W)
Voltage	Volts (AC: V_{RMS} / DC: V_{DC}))

Communications

IP Address & Port Numbers

The 9400 uses TCP/IP (Ethernet) and requires a unique IP Address for each system.
Refer to the hardware users-manual for information about setting or changing the IP Address.

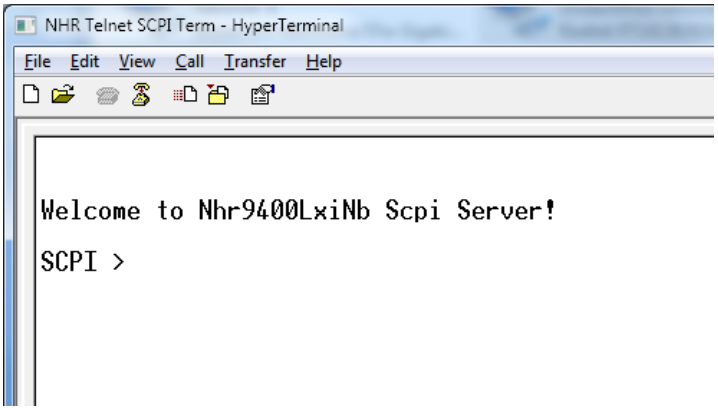
Model 9410 – 9410/9420 Series User's Manual (NHR P/N: 09-0329)
Model 9420 – 9410/9420 Series User's Manual (NHR P/N: 09-0329)
Model 9430 – 9430 Series User's Manual (NHR P/N: 09-0344)

In addition to the IP Address, it is important to supply a port number which indicated the form of communication which will be used.

PORT **5025** is the general program control through an open VXI-II or TCP Socket connection.
This same port will be used for control via:

- NHR 9400 Touch
- SCPI Test
- LabVIEW
- Programs written in any common language (Python, C++, C#, Perl, etc.)

PORT **5024** is a Telnet port and for terminal programs such as HyperTerminal.
This port should NOT be used to general program control.
When using a telnet or terminal emulator, the system will provide a welcome message as shown.
Note: The terminal emulation properties should be set to send line ends with line feeds being sent or received. Refer to your terminal emulator documentation on how to enable this feature.



NHR PC-Based Tools

NH Research supplies a graphical interactive tool (NHR 9400 Panel) and a SCPI Test utility application. These tools are installed from the supplied software CD shipped with each system.

Contact NH Research Customer Support for a copy of this software if required.

NHR 9400 Panel

The NHR 9400 Panel PC Tool, when installed, may be accessed by selecting the panel ICON on the desktop or from the start menu.

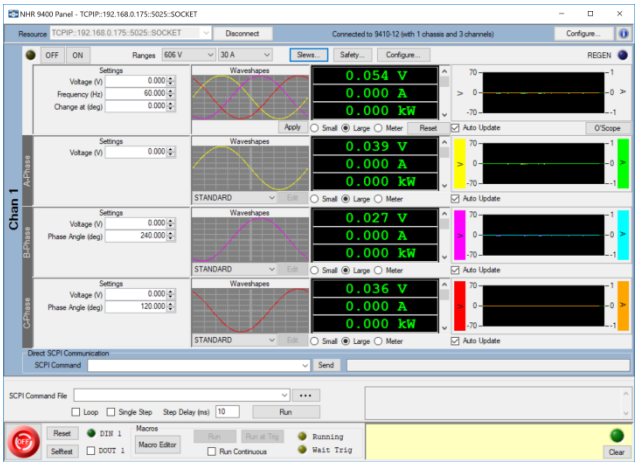
Windows 7: Start→All Programs→NH Research→9400 Series→NHR 9400 Panel
Windows 10: Start→NH Research→NHR 9400 Panel

The NHR 9400 Panel will require the resource (address and port number) of the system to be controlled. This is always in the form of **TCPIP::<ipaddress>::<port>::SOCKET**.

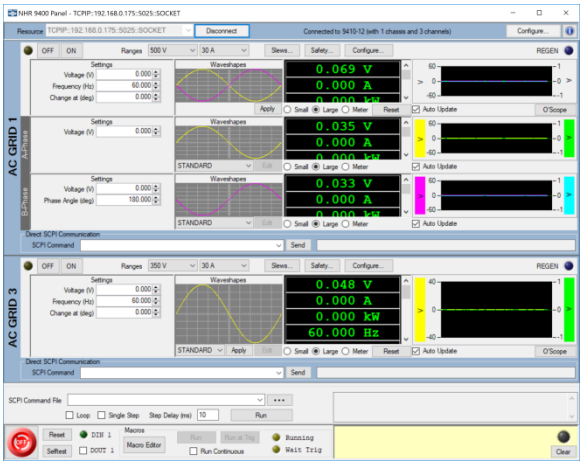
Note the double colons (::) between each of the terms of the resource terms.

Finally, press the connect button.

The Panel will automatically identify the configured hardware mode and display the control panels.

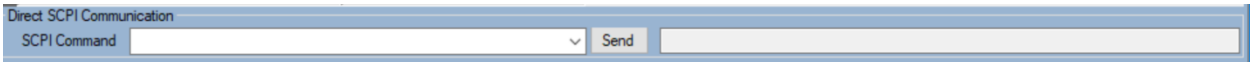


Panel connected to 9410 in 3-ϕ



Panel connected to 9410 in Split-ϕ + 1AC

Below each logical instrument is a Direct SCPI communication feature allowing commands to be tested.



Refer to the hardware users-manual for more details about other features of the NHR 9400 Panel.

SCPI Test Panel

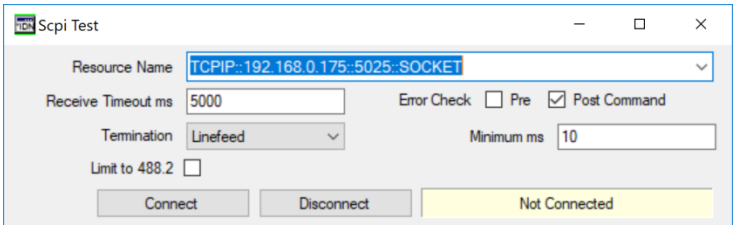
NHR Supplies a SCPI test panel which may also be accessed through the start menu.

Windows 7: Start→All Programs→NH Research→9400 Series→SCPI Test Panel
Windows 10: Start→NH Research→SCPI Test Panel

The SCPI Test Panel will require the resource (address and port number) of the system to be controlled. This is always in the form of **TCPIP::<ipaddress>::<port>::SOCKET**.

Note the double colons (::) between each of the terms of the resource terms.

Finally, press the connect button.



Sample Sequence

***IDN?** Confirm the hardware.

***RST** Reset the hardware.
(Optional)

SYSTem:RWLock
Lock the touch panel

CONFigure:HW:MODE?
Query current mode
(Or adjust using command)

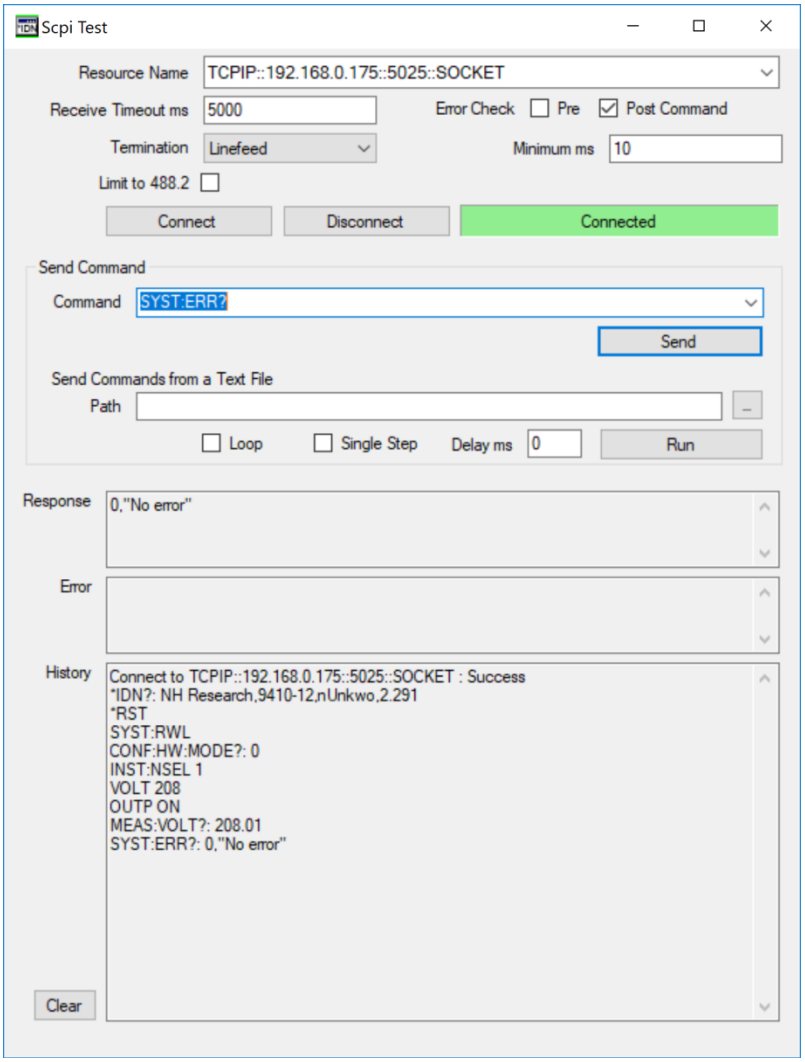
INSTrument:NSELect 1
Select Instrument 1

VOLTage 208
Set output voltage to 208

OUTPut:ON
Turn on the output

MEASure:VOLTage?
Measure the output voltage

SYSTem:ERRor?
Ensure no errors occurred
(SCPI Recommends checking after each command/query)



Programming Examples

Any program, utility, or device which is able to send plain text across a TCP/IP link may be used to communicate with a hardware module. This includes scripting languages such as Python or non-PC controllers such as PLC or PLA devices.

Python Example

Communication is established with Python's native socket function.

More information about programming in Python is available online at http://python.org

While this example is specific to Python, the concepts may be applied to any other programming language including C++, C#, Perl, LUA, ladder-logic, etcetera.

```
# import socket.py
import socket

# establish the socket connection
s = socket.socket(socket.AF_INET,socket.SOCK_STREAM)
s.settimeout(1)
s.connect(("192.168.0.3", 5025))

# Lock out the touch screen
s.send("SYST:RWL\n")

# send the commands as desired
s.send("*IDN?\n")      # Send IDN Query as example

# display the response
print s.recv(1024)

# Return the touch screen to local control
s.send("SYST:LOC\n")

# close the socket
s.close()
```

When the above lines of code are executed, The 9400 will respond with its identification string.

```
NH Research,9410-12,57114,1.003
```

See *IDN for more information about the format of the identification string.

Note: An external program should always send **SYSTem:RWLock** to lock out the touch screen.
The program should also send **SYSTem:LOCal** to unlock the touch screen before closing the connection.

Common SCPI Commands

The 9400 responds to IEEE 488.2 standard-based common interface commands used for reporting, synchronization & internal operating status.

The 9400 series also responds to the optional 488.2 commands which control triggers, power-on conditions, and stored operating parameters.

*CLS (Clear Status)

Scope: SYSTEM command Models / Modes: All Models & Modes

Command clears the error message queue and multiple status registers

Registers cleared: Status Byte, Event Status, and Questionable Status.

Command Parameters None

*ESE (Event Status Enable)

Scope: SYSTEM command and query Models / Modes: All Models & Modes

Command programs the Standard Event Status Enable Register bits.
Query returns the Standard Event Status Enable Register value.

The programming determines which events of the Standard Event Status Event register (see *ESR?) are allowed to set the Event Summary Bit (ESB – bit 5) of the Status Byte register.

The Standard Event Status Enable Register bits have the same bit-level definitions as the Event Status Register (see *ESR).

A "1" in the bit position enables the corresponding event.
All of the enabled events of the Standard Event Status Event Register are logically ORed to cause the Event Summary Bit (ESB) of the Status Byte Register to be set.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

*ESR? (Event Status Register)

Scope: SYSTEM query Models / Modes: All Models & Modes

Query returns the Standard Event Status Register values.

Reading the Standard Event Status Register clears it.
The bit configuration of this register is the same as the Standard Event Status Enable register (see *ESE).

Query Parameters None
Query Returns <NR1> (register value)

Event Status Register

Bit	Status	Description	Hex Value	Dec Value
0	OPC	Operation Complete	0x01	1
1	RQC	Request Control	0x02	2
2	QYE	Query Error	0x04	4
3	DDE	Device Dependent Error	0x08	8
4	EXE	Execution Error	0x10	16
5	CME	Command Error	0x20	32
6	URQ	User Request	0x40	64
7	PON	Power On	0x80	128

*IDN (Identify)

Scope: SYSTEM query Models / Modes: All Models & Modes

Query returns the module identification along with serial number and firmware revision.

Query Parameters None
Query Returns <mfg>,<model>,<sn>,<rev>

Where		
	<mfg>	NH Research
	<model>	94X0-kw (model specific)
	<sn>	serial#
	<rev>	firmware rev of network controller

*OPC (Operation Complete)

Scope: SYSTEM command and query Models / Modes: All Models & Modes

This command causes the interface to set the OPC bit (bit 0) of the Standard Event Status register when the module has completed all pending operations. (See *ESE for the bit configuration of the Standard Event Status registers.) Pending operations are complete when:

- All commands sent before *OPC have been executed. This includes overlapped commands. Most commands are sequential and are completed before the next command is executed. Overlapped commands are executed in parallel with other commands. Commands that affect trigger actions are overlapped with subsequent commands sent to the module. The *OPC command provides notification that all overlapped commands have been completed.
- All triggered actions are completed and the trigger system returns to the idle state. *OPC does not prevent processing of subsequent commands but Bit 0 will not be set until all pending operations are completed. The query causes the interface to place an ASCII "1" in the Output Queue when all pending operations are completed.

Command Parameters None
Query Parameters None
Query Returns <NR1>

*RST (Reset)

Scope: SYSTEM command Models / Modes: All Models & Modes

Command resets the module to initial power on state.

Note: Only **CONFigure:HW:MODE** and **[SOURce:]SAFety** are preserved across reset events.
All remaining CONFigure:<functions> and [SOURce:]<functions> are reset to default states.

Command Parameters None

*SRE (Service Request Enable)

Scope: SYSTEM command and query Models / Modes: All Models & Modes

This command sets the condition of the Service Request Enable Register. This register determines which bits from the Status Byte Register (see *STB for its bit configuration) are allowed to set the Master Status Summary (MSS) bit and the Request for Service (RQS) summary bit. A 1 in any Service Request

Enable Register bit position enables the corresponding Status Byte Register bit and all such enabled bits then are logically ORed to cause Bit 6 of the Status Byte Register to be set.

When the controller conducts a serial poll in response to SRQ, the RQS bit is cleared, but the MSS bit is not. When *SRE is cleared (by programming it with 0), the module cannot generate an SRQ to the controller. The query returns the current state of *SRE.

Command Parameters 0 to 255
Query Parameters None
Query Returns <NR1> (register binary value)

*STB? (Status Byte Register)

Scope: SYSTEM query Models / Modes: All Models & Modes

Query reads the status register.

Reading the Status Byte register does not clear it.
Input summary bits are cleared when the appropriate event registers are read.

(see chapter 3 under "Programming the Status Registers" for more information). A serial poll also returns the value of the Status Byte register, except that bit 6 returns Request for Service (RQS) instead of Master Status Summary (MSS). A serial poll clears RQS, but not MSS. When MSS is set, it indicates that the module has one or more reasons for requesting service.

Query Parameters None
Query Returns <NR1>

Status Byte Register

Bit	Status	Description	Hex Value	Dec Value
0	Busy[1]	Module is busy (NOT able to process additional commands)	0x01	1
1	Remote[1]	Module is in remote mode	0x02	2
2	Error[1]	Error in queue (retrieve with SYSTem:ERRor)	0x04	4
3	QUES	Questionable status summary (See STATus:QUEStionable)	0x08	8
4	MAV	Message available	0x10	16
5	ESP	Event Status byte summary (See *ESR)	0x20	32
6	RQS	Request for service	0x40	64
7	OPER	Operation event summary (See STATus:OPERation)	0x80	128

[1] Bit is not defined in SCPI standard and is implemented as described

*TRG (Trigger)

Scope: SYSTEM command Models / Modes: All Models & Modes

Command generates a system (bus) trigger.

Related command: **TRIGger:SOURce** BUS

This command generates a trigger to any system that has BUS selected as its source.
(See: TRIGger:SOURce for more information about setting up triggers)

Command Parameters None

*TST (Selftest)

Scope: SYSTEM query Models / Modes: All Models & Modes

Query causes the module to reset, run a self-test, and returns the self-test result.

All errors are cleared before running the self-test.
Self-test will generate errors for PROM, Firmware, Configuration and Calibration Errors as required If

Query Parameters None
Query Returns <NR1>

Where		
	0	Self-test passed with no errors
	non-zero	Errors occurred during self-test (see **SYSTem:ERRor**)

*WAI

Scope: SYSTEM command Models / Modes: All Models & Modes

Command instructs the 9400 to pause processing further commands until all operations are completed.

Pending operations are complete when:

- All commands sent before *WAI have been executed. This includes overlapped commands. Most commands are sequential and are completed before the next command is executed. Overlapped commands are executed in parallel with other commands. Commands that affect input voltage or state, relays, and trigger actions are overlapped with subsequent commands sent to the module. The *WAI command prevents subsequent commands from being executed before any overlapped commands have been completed.
- All triggered actions are completed and the trigger system returns to the idle state.

*WAI can be aborted only by sending the module a GPIB DCL (Device Clear) command.

Command Parameters None

STATus:OPERation[:EVENt]?

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the Operation Event register value.

The Operation Event register is a read-only register that holds (latches) all operation status events that pass into it until it has been read. Reading the Operation Event register clears it.

Query Parameters None

Query Returns <NR1>

Operation Event Register (instrument specific)

Bit	Status	Description	Hex Value	Dec Value
0	Ready[1]	Logical Instrument is powered and ready	0x0001	1
1	Execution[1]	Logical Instrument is waiting for phase angle	0x0002	2
2	Ranging	Range change in progress	0x0004	4
3	Sweeping	Slew in progress	0x0008	8
4	Measuring	Measurement in progress	0x0010	16
5	Waiting For Trig	Logical Instrument is waiting for trigger	0x0020	32
6	Trigger Detected[1]	Logical Instrument has received a trigger	0x0040	64
7	Phase Locked[1]	Channel is phase locked to phase A Frequency	0x0080	128
8	Output Enabled[2]	Logical Instrument output relays are closed	0x0100	256
9	Active Mode Bit0[2]	Bit patterns (MSB to LSB): 000 = Off, 001 = CV, 010 = CC, 011 = CP 100 = CS, 101 = CR, 110 = RL, 111 = SB	0x0200	512
10	Active Mode Bit1[2]		0x0400	1024
11	Active Mode Bit2[2]		0x0800	2048
12	Sinking[2]	Logical Instrument is sinking power (Regenerating)	0x1000	4096
13	Macro Ready[1]	Macro loaded and ready to execute	0x2000	8192
14	Program Running	Macro execution in progress	0x0400	16384
15	Reserved	Reserved for future use	0x8000	32768

[1] Bit is defined with a non-standard meaning and is implemented as described
[2] Bit is not defined in SCPI standard and is implemented as described

STATus:OPERation:CONDition?

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the real-time (non-latched) value of the Operation Condition register.

The Operation Condition register has the same bit-level definitions as the Operation Register (see STATus:OPERation).

Query Parameters None
Query Returns <NR1>

STATus:OPERation:ENABle

Scope: INSTRUMENT command and query Models / Modes: All Models & Modes

Command programs the Operation Enable Register bits.
Query returns the Operation Enable Register value.

The Operation Enable register determines which events will set the OPER (bit 7) of the Status Byte Register (see *STB)

The Operation Enable register has the same bit-level definitions as the Operation Register (see STATus:OPERation).

A "1" in the bit position enables the corresponding event.
All of the enabled events of the Operation Condition register are logically ORed to cause the OPER (bit 7) of the Status Byte Register to be set.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

STATus:PRESet

Scope: SYSTEM command Models / Modes: All Models & Modes

Command sets the value of all the enable registers (operation and questionable) to 0 (ALL disabled).

The PRESet command affects only the enable registers, PRESet does not affect either the "status byte" or the "standard event status" as defined by IEEE 488.2. PRESet does not clear any of the event registers or any item from the error/event queue.

The *CLS command is used to clear all event registers and queues in the device status-reporting mechanism. For the SCPI mandatory status data structures, the PRESet command sets the enable registers to 0's.

Command Parameters None

STATus:QUEStionable[:EVENt]?

Scope: SYSTEM query Models / Modes: All Models & Modes

Query returns the Questionable Status register value.

The Questionable Status register is a read-only register that holds (latches) all questionable status events that pass into it until it has been read. Reading the Questionable Event register clears it.

Query Parameters None
Query Returns <NR1>

Questionable Status Register

Bit	Status	Description	Hex Value	Dec Value
0			0x0001	1
1			0x0002	2
2			0x0004	4
3			0x0008	8
4			0x0010	16
5			0x0020	32
6			0x0040	64
7			0x0080	128
8	Calibration	Calibration checksum error	0x0100	256
9	Firmware	Firmware checksum error	0x0200	512
10	Program Exec[1]	Program executing from flash	0x0400	1024
11			0x0800	2048
12			0x1000	4096
13			0x2000	8192
14			0x0400	16384
15	Reserved	Reserved for future use	0x8000	32768

[1] Bit is not defined in SCPI standard and is implemented as described

STATus:QUEStionable:CONDition?

Scope: SYSTEM query Models / Modes: All Models & Modes

Query returns the real-time (non-latched) value of the Questionable Condition register.

The Questionable Condition register has the same bit-level definitions as the Questionable Register (see STATus:QUEStionable).

Query Parameters None
Query Returns <NR1>

STATus:QUEStionable:ENABle

Scope: SYSTEM command and query Models / Modes: All Models & Modes

Command programs the Questionable Enable Register bits.
Query returns the Questionable Enable Register value.

The Operation Enable register determines which events will set the QUES (bit 3) of the Status Byte Register (see *STB)

The Operation Enable register has the same bit-level definitions as the Questionable Register (see STATus: QUEStionable).

A "1" in the bit position enables the corresponding event.
All of the enabled events of the Questionable Condition register are logically ORed to cause the QUES (bit 3) of the Status Byte Register to be set.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

Status Commands

These commands program allow control and monitoring of the status system. The status system consists of a number of registers as well as an error queue.

An application may select the events that shall cause a service request at the mandatory SCPI status data structure level, rather than excluding those that are of no interest to the application. Further, there is no requirement on the application to set up the device-dependent structures for normal device operation. For this concept to be extended to encompass the IEEE 488.2-mandated status data structures, the following sequence of commands is required when initializing the device:

*CLS – Clears all event status registers and queues

*SRE 0 – Clears the IEEE 488.2-mandated service request enable register

*ESE 0 – Clears the IEEE 488.2-mandated standard event status enable register

STATus:PRESet – Presets all other registers and queues

The table below indicates the effects of various commands upon the status data structures in a device.

	SCPI Enable Registers	SCPI Event Registers	SCPI Error/Event Queue Enable	SCPI Error/Event Queue	IEEE 488.2 Registers ESE SRE	IEEE 488.2 Registers SESR STB
*RST	none	none	none	none	none	none
*CLS	none	clear	none	clear	none	clear
power-on	preset#	clear#	preset#	clear#	clear#	clear#
STATus:PRESet	preset	none	preset	none	none	none

Occurs if the power-on state clear flag is true. Effect changes to none if the power-on state clear flag is false.

The following table defines the effect of STATus:PRESet

Register	Filter/enable	PRESet value =
OPERational	ENABle	0's
QUEStionable	ENABle	0's

Requires either PTR, NTR, or both to be set.

SYSTem:ERRor?

PER-CONNECTION query

This query returns the next error number followed by its corresponding error message string from the remote programming error queue. The queue is a FIFO (first-in, first-out) buffer that stores errors as they occur. As it is read, each error is removed from the queue. When all errors have been read, the query returns "0, No Error". If more errors are accumulated than the queue can hold, the last error in the queue is "-350, Too Many Errors".

Query Parameters None
Query Returns <NR1>, <SRD>
Where <NR1> Error Number
<SRD> Error Decription in text

CONFigure and SYSTem Commands

Introduction

The 9400 provides multiple output combinations that are enabled using the CONFigure commands. The output channels may be configured as AC, DC, or in a mixed configuration. Channels may additionally be paralleled for higher power or given a phase relationship allowing for 3-ϕ and split-ϕ output modes. The available programming commands are model dependent and summarized as:

		9410	9420	9430
Control Modes				
	Voltage & Frequency Control	✓	✓	
	Current Control			✓
	4-Quadrent	✓	✓	✓
	Power Flow Direction	9410 → UUT 9410 ← UUT	9420 → UUT	9430 → UUT NOTE 1 9430 ← UUT
Programmable Features - AC or DC unless specifically noted				
	Safety Trip	✓	✓	✓
	AC Waveshape	Voltage	Voltage	Current
	Voltage Limit & Slew	✓	✓	
	Current Limit & Slew	DC Only	✓	✓ NOTE 2 & 3
	Power Limit & Slew	DC Only	✓	✓
	Crest Factor			AC Only NOTE 2
	Power Factor			AC Only NOTE 2
	Resistance Limit & Slew			✓ NOTE 3
	RL Limit & Slew			✓ NOTE 4
Measurement Features				
	Waveform Digitizer	✓	✓	✓
	Energy Star Measurement		✓	

NOTE 1 Bi-Directional is enabled using CONFigure:INSTrument:BIDirectional

NOTE 2 Command available in normal mode CONFigure: INSTrument:LOAD[:MODE] NORMal

NOTE 3 Command available in constant resistance mode CONFigure: INSTrument:LOAD[:MODE] CR
Note: Negative resistance operation requires Bi-Directional power flow to be enabled (note 1)

NOTE 4 Command available in constant RL mode CONFigure: INSTrument:LOAD[:MODE] RL

CONFigure Commands

CONFigure:HW:MODE

Scope: SYSTEM command or query Models / Modes: All Models

Command configures logical instruments including output channels (AC or DC) & channel relationships
Query returns the systems output operating mode

NOTE: This command will reset the hardware and will take a number of seconds to complete.
It is therefore suggested to perform a **SYSTem:ERRor?** query with a minimum of a 5 second timeout in order to detect when the system is ready for operation.

CAUTION: switching modes will likely require fixturing wiring changes.

Command Parameters <NR1>
0 through 16
Query Parameters None
Query Returns <NR1>

For one channel systems including 9410-4, 9420-4, & 9430-4

1 Chan		***Ch A***	
Mode	*Desc*	*Out*	*NSEL*
0	AC1	AC	1
1	DC1	DC	1

For two channel systems including 9410-8, 9420-8, & 9430-8

2 Chan		***Ch A***		***Ch B***				
Mode	*Desc*	*Out*	*NSEL*	*Out*	*Parallel with A*	*Sync with*	*Phase Angle*	*NSEL*
0	AC1, AC1 (2ph)	AC	1	AC	0	A (1)	180	
1	AC1, AC1	AC	1	AC	1	A (1)		
2	DC1, DC1	DC	1	DC	1	A (1)		
3	AC1, AC2	AC	1	AC	0	B (0)	0	2
4	DC1, DC2	DC	1	DC	0	B (0)		2
5	AC1, DC2	AC	1	DC	0	B (0)		2
6	DC1, AC2	DC	1	AC	0	B (0)		2

Note: operating mode will change the scope and values of SOURCe, MACRo, & MEASuments.
Refer to these sections for more details on a per operating mode basis.

Operating in Mode 0: **INSTtument:NSELect 2** is invalid. Channel 2 is slaved to channel 1
The split-ϕ instrument is selected using **INSTtument:NSELect 1.**

Operating in Mode 1-2: **INSTtument:NSELect 2** is invalid. Channel 2 is logically controlled as a parallel channel with channel 1 which is selected by **INSTtument:NSELect 1**

All other operating modes act as separately selectable instruments using **INSTtument:NSELect 1 or 2**

CONFigure:HW:MODE Continued

For three channel systems including 9410, 9420, & 9430 which are ≥ 12kW

3 Chan		***Ch A***		***Ch B***					***Ch C***				
Mode	*Desc*	*Out*	*NSEL*	*Out*	*Parallel with A*	*Sync with*	*Phase Angle*	*NSEL*	*Out*	*Parallel with A*	*Sync with*	*Phase Angle*	*NSEL*
0	AC1, AC1, AC1 (3ph)	AC	1	AC	0	A (0)	240		AC	0	A (0)	120	
1	AC1, AC1, AC1	AC	1	AC	1	A (0)	0		AC	1	A (0)	0	
2	DC1, DC1, DC1	DC	1	DC	1	A (0)	-		DC	1	A (0)	-	
3	AC1, AC2, AC3	AC	1	AC	0	B (0)	0	2	AC	0	C (0)	0	3
4	DC1, DC2, DC3	DC	1	DC	0	B (0)	-	2	DC	0	C (0)		3
5	AC1, AC1, AC3 (2ph)	AC	1	AC	0	A (1)	180		AC	0	C (0)	0	3
6	AC1, AC1, DC3 (2ph)	AC	1	AC	0	A (1)	180		DC	0	C (0)	-	3
7	AC1, AC1, AC3	AC	1	AC	1	A (1)	0		AC	0	C (0)	0	3
8	AC1, AC1, DC3	AC	1	AC	1	A (1)	0		DC	0	C (0)	-	3
9	AC1, AC2, DC3	AC	1	AC	0	B (0)	0	2	DC	0	C (0)	-	3
10	AC1, DC2, DC3	AC	1	DC	0	B (0)	0	2	DC	0	C (0)	-	3
11	DC1, DC1, AC3	DC	1	DC	1	A (1)	-		AC	0	C (0)	0	3
12	DC1, DC1, DC3	DC	1	DC	1	A (1)	-		DC	0	C (0)	-	3
13	AC1, DC2, AC3	AC	1	DC	0	B (0)	0	2	AC	0	C (0)	0	3
14	DC1, AC2, AC3	DC	1	AC	0	B (0)	0	2	AC	0	C (0)	0	3
15	DC1, AC2, DC3	DC	1	AC	0	B (0)	0	2	DC	0	C (0)	-	3

Note operating mode will change the scope and values of SOURCe, MACRo, & MEASuments.
Refer to these sections for more details on a per operating mode basis.

Operating in Mode 0: **INSTtument:NSELect 2 & 3** are invalid. Channel 2 & 3 are slaved to channel 1
The 3-ϕ instrument is selected using **INSTtument:NSELect 1**

Operating in Mode 1-2: **INSTtument:NSELect 2 & 3** are invalid. Channel 2 & 3 are logically controlled as a paralleled AC or DC channel along with channel 1 which is selected by **INSTtument:NSELect 1**

Operating in Mode 5-6: **INSTtument:NSELect 2** is invalid. Channel 2 is slaved to channel 1
The split-ϕ instrument is selected using **INSTtument:NSELect 1**
The remaining channel (AC or DC) is separately selectable using **INSTtument:NSELect 3**

Operating in Mode 7-8: **INSTtument:NSELect 2** is invalid. Channel 2 is logically controlled as a paralleled AC channel along with channel 1 which is selected by **INSTtument:NSELect 1**
The remaining channel (AC or DC) is separately selectable using **INSTtument:NSELect 3**

Operating in Mode 11-12: **INSTtument:NSELect 2** is invalid. Channel 2 is logically controlled as a paralleled DC channel along with channel 1 which is selected by **INSTtument:NSELect 1**
The remaining channel (AC or DC) is separately selectable using **INSTtument:NSELect 3**

All other operating modes act as separately selectable instruments using **INSTtument:NSELect 1, 2, or 3**

CONFigure:HW:MODE:VALid

Scope: SYSTEM query Models / Modes: All Models & Modes

Query returns if a particular configuration is supported by the hardware.

Query Parameters <NR1>
0 through 16
Query Returns <NR1>
0 = Operating mode is not supported
1 = Operating mode is available

CONFigure:INSTrument:SYNChronous

Scope: INSTRUMENT command or query Models / Modes: All Models & Modes

Command configures if [SOURCe:]<Function> commands are immediately or phase-angle controlled
Query returns the synchronous operating mode

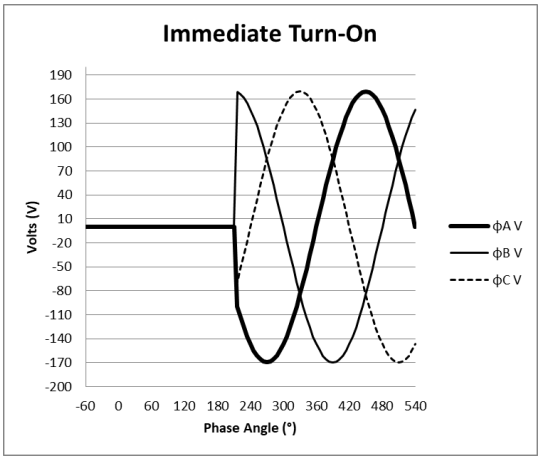
For DC Instruments, This command is accepted and has no operating effect
For AC Instruments, Command sets the angle at which future [SOURCe:]<Function> will be applied
When set to false, new **[SOURCe:]<Function>** commands are processed immediately
When set to true, new **[SOURCe:]<Function>** commands are processed when the primary phase reaches the angle programmed using **[SOURce:]OUTPut:SYNC:ANGLe**

Command Parameters <BOOL>
0 | NO | FALSE | OFF = **[SOURce:]<Function>** applied immediately
1 | YES | TRUE | ON = **[SOURce:]<Function>** applied at ϕ angle
Query Parameters None
Query Returns <NR1>
0 | 1

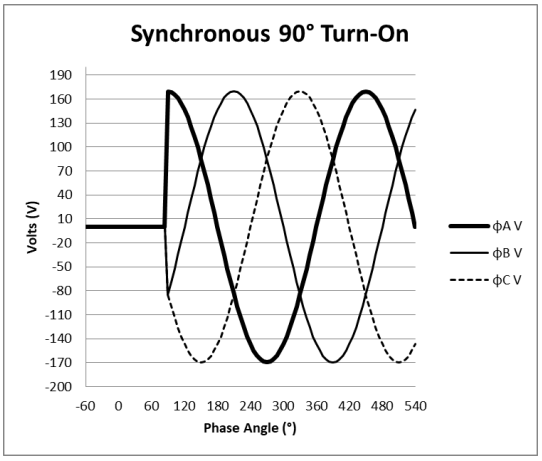
For example, assuming a 9410 (grid simulator) in 3-ϕ mode with an active output of 0V, the following sequence of commands would result in the output turning on either asynchronously (when the command is received) or synchronously (when A Phase reaches 90°) as shown below

CONFure:INSTrument:SYNChronous 0

VOLTage 208



CONFure:INSTrument:SYNCh 1
OUTPut:SYNC:ANGLe 90
VOLTage 208



CONFigure: INSTrument:LOAD[:MODE]

Scope: INSTRUMENT command or query Models / Modes: 9430 only / AC Modes

Command sets the loading features <loading mode> for a 9430 AC output
Query returns the loading features enabled on a 9430

Command is only accepted if the instrument is a 9430, with AC outputs mode, and in an OFF state
Other models & modes: This command is invalid

Command Parameters <loading mode>
NORMal = CC / CP / CVA with modifiers (PF, CF, & $I_{WAVESHAPE}$)
CR = Constant Resistance (with optional CC limit)
RL = Constant series Resistance & Inductance

Query Parameters None

Query Returns <loading mode>

CONFigure:INSTrument:BIDirectional

Scope: INSTRUMENT command or query Models / Modes: See Text

Command enables bi-directional power flow for the 9420 (DC outputs) and 9430 (AC outputs)
Query returns if Bi-directional power flow is permitted.

Command is valid for models / modes listed and is only accepted if the instrument is in an OFF state.
Command has no effect for all other models & modes.

When bi-directional power flow is enabled
9420 DC outputs will regulate DC voltage allowing current in either direction

9430 AC outputs permit additional programming options which are dependent on the <loading mode> selected (see **CONFigure:INSTrument:LOAD**)

<Loading Mode> **NORMal** permits negative power factor values
<Loading Mode> **CR** permits negative resistance values
<Loading Mode> **RL** has no effect as this mode is always uni-directional

Command Parameters <BOOL>
0 | NO | FALSE | OFF = Bi directional mode is disabled
1 | YES | TRUE | ON = Bi directional mode is enabled

Query Parameters None

Query Returns <NR1>
0 | 1

CONFigure: INSTrument:STBY

INSTRUMENT command and query Models / Modes: 9430 only / AC Modes

Command sets the standby detection conditions.
Query returns the configured standby detection conditions for the selected instrument

The 9430 will enter standby if the absolute value of the instantaneous voltage exceeds the programmed <voltage threshold> for the <detect time> in microseconds.

Command Parameters <voltage threshold>,<detect time>
where <voltage threshold> is a positive integer in volts
<detect time> is an integer in microseconds
Query Parameters None
Query Returns <voltage threshold>,<detect time>

Selecting Instrument(s)

The 9400 will contain one (1), two (2), or three (3) logical instruments depending on the **CONFigure:HW:MODE** selected. Unless otherwise noted in a specific command, Any command or queries with an INSTRUMENT scope will be processed by the last instrument selected by either an **INSTrument:NSELect** or an **INSTrument:SELect**.

INSTrument:NSELect

Scope: INSTRUMENT command or query Models / Modes: All Models & Modes

Command selects a logical instrument by its logical instrument number.
Query returns the currently selected logical instrument number

Logical instrument numbers are software configuration dependent based on the **CONFigure:HW:MODE**.

Note: if the logical instrument number is invalid, the selected instrument does not change and an error ***--223, "System Ilegal paramamter value"*** is added to the error queue (see: **SYSTem:ERRor** query)

Command Parameters <NR1> is the logical instrument number (1, 2, or 3)
Query Parameters None
Query Returns <NR1> the logical instrument number

INSTrument:SELect

Scope: INSTRUMENT command or query Models / Modes: All Models & Modes

Command selects an instrument by its alias name created with **INSTrument:DEFine[:NAME]**.
Query returns the current selected logical instrument alias name.

Note: if the instrument alias is invalid, the selected instrument does not change and an error ***-151, "System Invalid string data"*** is added to the error queue (see: **SYSTem:ERRor** query)

Command Parameters <identifier> - is the logical instrument alias in string form
Query Parameters None
Query Returns the current selected logical instrument alias name

Naming the Instrument(s)

Depending on the **CONFigure:HW:MODE** selected, the 9400 will present either one (1), two (2), or three logical instruments. These instruments may be given an alias name in order to improve readability of an end-users software program.

INSTrument:DEFine[:NAME]

Scope: SYSTEM command or query Models / Modes: All Models & Modes

Command assigns an alias name allowing selection of the instrument using **INSTrument:SELect** <name>
Query returns the alias name assigned to a specific output channel.

The logical instrument name <identifier> is associated with a logical instrument number <NR1>.
Only instruments which are able to be selected using **INSTrument:NSELect** may be given an alias name.
Refer to **CONFigure:HW:MODE** for the valid list of instrument numbers for the output mode selected.

Note: This command will replace any previously defined name for the instrument.
Additionally, all whitespaces within the <identifier> are automatically removed.

Command Parameters <identifier>, <NR1>
Query Parameters <NR1>
Query Returns <identifier>

INSTrument:DELete[:NAME]

Scope: SYSTEM command Models / Modes: All Models & Modes

Command disassociates an <identifier> alias from the logical instrument number.

After the command executes, the default identifier is re-associated with the instrument number.

NOTE: The default identifier cannot be deleted.

Command Parameters <identifier> is the logical instrument name in string form

INSTrument:NAME

Scope: SYSTEM query Models / Modes: All Models & Modes

Query returns the <identifier> alias for the requested instrument number.

If no instrument number <NR1> is provided, the <identifier> of the selected instrument is returned.

Query Parameters <NR1>
Where BLANK – Returns identifier of currently selected instrument
1 | 2 | 3 – Returns the identifier of instrument number
Query Returns <identifier>

System Commands

System commands control the system-level functions of the module that are not directly related to input control or measurement functions.

SYSTem:ERRor

Scope: PER-CONNECTION query Models / Modes: All Models & Modes

Query returns a comma separated error number followed by its corresponding error message string.

These errors are queues as a FIFO (first-in / first-out) buffer on a per connection basis.

Note: the error "-350, Too Many Errors" results when too many errors have been received.

Query Parameters None
Query Returns <NR1>, <SRD>

SYSTem:LED

Scope: SYSTEM command and query Model / Modes: All Models & Modes

This command causes the LED on the Module to blink.

Command Parameters 0 | OFF = LAN LED set for normal operation
1 | ON = LAN LED set to blinking state
Query Parameters None
Query Returns 0 | 1

SYSTem:LOCal

Scope: SYSTEM command Model / Modes: All Models & Modes

Command places the touch panel (if present) in local control mode.

All front panel keys are returned to a functional state.

Generally, this command should only be called before closing a remote location to the module.

Related Commands: **SYSTem:REMote** & **SYSTem:RWLock**

Command Parameters None

SYSTem:REMote

Scope: SYSTEM command Model / Modes: All Models & Modes

Command or receipt of an external SCPI command places the touch panel in a non-locked remote mode.

If not the touch panel was not previously in "Remote":
- Touch panel displays the word "REMOTE"
- Touch panel changes display screen to "Monitor" tab

All tabs and settings are still available on the touch screen and may override settings sent from an external program. External programs should issue a **SYSTem:RWLock** command to prevent operator input. This mode is generally used for debug purposes only and can result in two points of control.

Related Commands: **SYSTem:LOCal** & **SYSTem:RWLock**

Command Parameters None

SYSTem:RWLock

Scope: SYSTEM command Model / Modes: All Models & Modes

Command places the 9400 system in remote mode with the touch screen locked.

While in Remote with Lock:
- Touch panel displays the word "REMOTE LOCKOUT"
- Touch panel changes display screen to "Monitor" tab
- Touch panel removes all control and menu tabs
- Touch panel disables the "quick off" button

To the system will not return to local control mode until the external program sends **SYSTem:LOCal**

Related Commands: **SYSTem:LOCal** & **SYSTem:REMote**

Command Parameters None

SYSTem:VERSion

Scope: SYSTEM query Model / Modes: All Models & Modes

Query returns the SCPI version number to which the module complies. The value is of the form YYYY.V, where YYYY is the year and V is the revision number for that year.

Query Parameters None
Query Returns <NR1>

SYSTem:WATChdog:INTerval

Scope: SYSTEM command and query Model / Modes: All Models & Modes

Command specifies the interval (Seconds) in which a command must be received.
Query returns the programmed watchdog interval (Seconds).

When a command is not received within this interval time, the module will 9400 system will automatically enter an OFF state and generate an error. The watchdog timer is automatically reset upon receipt of any command unless **SYSTem:WATCh:ROBust** is also enabled.

Related Commands: **SYSTem:WATCh:ROBust** & **SYSTem:WATChdog:SERVice**

Command Parameters <NR1>
0 = disables the watchdog timer
integer = integer value for interval time in seconds
Query Parameters None
Query Returns <NR1>

SYSTem:WATChdog:ROBust

Scope: SYSTEM command and query Model / Modes: All Models & Modes

Command determines the type communication required to reset the watchdog timer.
Query returns the type of communication required to reset the watchdog timer.

Related Commands: **SYSTem:WATCh:INTerval** & **SYSTem:WATChdog:SERVice**

Command Parameters <BOOL>
0 | NO | FALSE | OFF = Any command resets watchdog
1 | YES | TRUE | ON = Only **SYSTem:WATChdog:SERVice** resets watchdog
Query Parameters None
Query Returns <NR1>
0 | 1

SYSTem:WATChdog:SERVice

Scope: SYSTEM command Model / Modes: All Models & Modes

Command resets watchdog timer

Related Commands: **SYSTem:WATCh:INTerval** & **SYSTem:WATChdog:ROBust**

Command Parameters none

DIGital Subsystem

These commands control the general purpose digital port on the module.

DIGital:INPut

Scope: SYSTEM query Model / Modes: All Models & Modes

Query returns the current state of the general purpose digital input port on the specified module.

Query Parameters None
Query Returns <NR1>
Value to at digital inputs (LSB = Lowest digital input)

DIGital:INPut:COUNt

Scope: SYSTEM query Model / Modes: All Models & Modes

Query returns the number of general purpose digital inputs (expressed as number of bits).

Query Parameters None
Query Returns <NR1>

DIGital:OUTPut

Scope: SYSTEM command and query Model / Modes: All Models & Modes

Command sets the state of the general purpose digital output port on the specified module.
Query returns the last programmed state of the general purpose digital output

Command Parameters <NR1>
Value to write digital outputs (LSB = Lowest digital output)
Query Parameters None
Query Returns <NR1>

DIGital:OUTPut:COUNt

Scope: SYSTEM query Model / Modes: All Models & Modes

Query returns the number of general purpose digital outputs (expressed as number of bits).

Query Parameters None
Query Returns <NR1>

INSTrument CAPabilities

The 9400 is able to be queried for its capabilities allowing the hardware programming capabilities to be automated in the end application.

Many of the instruments valid ranges and values are dependent on the output operating mode selected. Therefore these sections describe each of the available queries to retrieve the hardware capabilities.

System Information Queries

The queries in this section pertain to fixed limits for the connected hardware.

INSTrument:CAPabilities:SYSTem:CHANnels

Scope: SYSTEM Query Models / Modes: All Models & Modes

Query returns the number of output channels detected by the hardware.

There are at most 3 channels.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:SYSTem:CHASsis

Scope: SYSTEM Query Models / Modes: All Models & Modes

Query returns the number of chassis detected (Master + Auxiliaries)

There are at most 8 chassis.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:MACRo:COMMand:MAXimum

Scope: SYSTEM Query Models / Modes: All Models & Modes

Query returns the maximum number of commands which can be stored in a macro.

Refer to the **MACRo** features section for more information on use and programming of macros.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:MACRo:DELay:MAXimum

Scope: SYSTEM Query Models / Modes: All Models & Modes

Query returns the maximum delay time allowed for **MACRo:WAIT[:TIME]** within a single macro step.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:RGAin:NOMinal or MAXimum

Scope: SYSTEM Query Models / Modes: All Models & Modes

Query returns the default or maximum Regulation Gain setting set value used by the hardware.
Refer for **[SOURce:]OUTput:RGAin** for more information about regulation gain.

Note: Adjusting Regulation gain will have an effect on the device output response speed and stability. Contact NH Research customer support before attempting to adjust the regulation gain of the system.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:TRIP:MAXimum

Scope: SYSTEM Query Models / Modes: All Models & Modes

Query returns the maximum trip time (seconds) for a safety limit settings.

Refer to **[SOURce:]SAFety** for more information about setting safety trip limits.

Query Parameters None
Query Returns <NR1>

Measurement Capabilities Queries

INSTrument:CAPabilities:APERture:MAXimum or MINimum

Scope: SYSTEM Query Models / Modes: All Models & Modes

Query returns the absolute maximum (or minimum) measurement aperture setting for the module.

These queries defines the range of values which are valid for **SENSe:SWEep:APERature**.
The selected aperture must be between the minimum (0) and one of the maximum value.
Refer to **SENSe:SWEep:APERature** for more information about setting aperatures.

Aperture time is used by aperture measurement commands and for digitized waveforms.
Refer to the **Measurement Features** section for more information about taking measurements.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:CURRent:MEASurement:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns the absolute peak current measurement capability for instrument selected.

This query is for informational use only and is typically used to set the Y-AXIS for an output graph.

Note: Actual peak current measurement also depends on current set range selected
Refer to **[SOURce:]CURRent:RANGe** for information on how to set & query the current range.

Related commands:
INSTrument:CAPabilities:CURRent:Measurement:RANGe:MAXimum
INSTrument:CAPabilities:CURRent:Measurement:RANGe:MINimum

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:CURRent:MEASurement:ENERgystar:MAXimum

Scope: INSTRUMENT Query Models / Modes: 9420 Only

Query returns the maximum current measurement capability (A_{RMS} or A_{DC}) for the selected instrument and Energy Star range. See **[SOURCE:]CURRent:RANGe:ENERgystar** to select measurement range.

Energy Star measurement is able to measure peak currents with CF > 4

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:CURRent:MEASurement:ENERgystar:LIST

Scope: INSTRUMENT Query Models / Modes: 9420 Only

Query returns a list of Energy Star ranges for the selected operating mode

Query Parameters None

Query Returns <NR1>{,<NR2>}

INSTrument:CAPabilities:CURRent:MEASurement:RANGe:MAXimum
INSTrument:CAPabilities:CURRent:MEASurement:RANGe:MINimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns maximum (minimum) peak current measurement for the selected instrument & range.

This query is for informational use only and is typically used to set the Y-AXIS for an output graph.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:SAMPle:FREQuency:MAXimum or MINimum

Scope: SYSTEM Query Models / Modes: All Models & Modes

Query returns the waveform digitizer's maximum (minimum) sample frequency in Hz.

See **Accessing the Digitizer** in the **Measurement Features** section for more information

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:SAMPle:POINts:MAXimum

Scope: SYSTEM Query Models / Modes: All Models & Modes

Query returns the waveform digitizer's maximum sample memory depth

See **Accessing the Digitizer** in the **Measurement Features** section for more information

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:VOLTage:MEASurement:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns the absolute peak voltage measurement capability for instrument selected.

This query is for informational use only and is typically used to set the Y-AXIS for an output graph.

For AC (1ϕ) & DC outputs: Query response is expressed as line-neutral.

For AC multi-ϕ outputs: Query response is expressed as line-line equivalent value.
For per phase values, refer to:
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:MAXimum
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:MINimum

Note: Actual peak voltage measurement also depends on current set range selected
Refer to **[SOURce:]VOLTage:RANGe** for information on how to set & query the voltage range.

Related commands:
INSTrument:CAPabilities:VOLTage:Measurement:RANGe:MAXimum
INSTrument:CAPabilities:VOLTage:Measurement:RANGe:MINimum

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:MAXimum
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:MINimum

Scope: INSTRUMENT Query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the absolute peak voltage measurement capability for instrument & phase selected.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

For AC multi-ϕ outputs: Query response is expressed as line-neutral equivalent value.

Note: Actual peak voltage measurement also depends on current set range selected
Refer to **[SOURce:]VOLTage:RANGe** for information on how to set & query the voltage range.

Related commands:
INSTrument:CAPabilities:VOLTage:<phase>:Measurement:RANGe:MAXimum
INSTrument:CAPabilities:VOLTage:<phase>:Measurement:RANGe:MINimum

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:VOLTage:MEASurement:RANGe:MAXimum
INSTrument:CAPabilities:VOLTage:MEASurement:RANGe:MINimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns maximum (minimum) peak voltage measurement for the selected instrument & range.

This query is for informational use only and is typically used to set the Y-AXIS for an output graph.

For AC (1ϕ) & DC outputs: Query response is expressed as line-neutral.

For AC multi-ϕ outputs: Query response is expressed as line-line equivalent value.
For per phase values, refer to:
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:RANGe:MAXimum
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:RANGe:MINimum

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:RANGe:MAXimum
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:RANGe:MINimum

Scope: INSTRUMENT Query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns maximum (minimum) peak voltage measurement for instrument, phase & range selected.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

For AC multi-ϕ outputs: Query response is expressed as line-neutral equivalent value.

Query Parameters None
Query Returns <NR1>

Setting Capabilities Queries

INSTrument:CAPabilities:CURRent:MAXimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns the absolute maximum current (A_{RMS} or A_{DC}) output capability for instrument selected.

Note: Actual maximum current (A_{RMS} or A_{DC}) available also depends on current set range selected
Refer to **[SOURce:]CURRent:RANGe** for information on how to set & query the current range.

Related commands:
INSTrument:CAPabilities:CURRent:RANGe:MAXimum
INSTrument:CAPabilities:CURRent:RANGe:LIST[:MAXimum]

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:CURRent:CF:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: 9430 Only / AC NORMal Load

Query returns the minimum and maximum allowable set value for crest factor in NORMal loading mode
Refer to **CONFigure:LOAD:MODE** for information about setting the 9430 in NORmal loading mode.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:CURRent:PF:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: 9430 Only / AC NORMal Load

Query returns the minimum and maximum allowable set value for power factor in NORMal loading.
Refer to **CONFigure:LOAD:MODE** for information about setting the 9430 in NORmal loading mode..

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:CURRent:RANGe:LIST[:MAXimum]
INSTrument:CAPabilities:CURRent:RANGe:LIST:MINimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns a list of maximum or minimum current (A_{RMS} or A_{DC}) ranges for the selected instrument.

This list defines the range of values which are valid for **[SOURce:]CURRent:RANGe**.
The selected current range must be between the minimum (0) and one of the maximum values.
Refer to **[SOURce:]CURRent:RANGe** for more information about selecting ranges.

Related query: **INSTrument:CAPabilities:CURRent:RANGe:MAXimum**

Query Parameters None
Query Returns <NR1>{,<NR1>}

INSTrument:CAPabilities:CURRent:RANGe:MAXimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns the maximum current (A_{RMS} or A_{DC}) set-point value for selected instrument & range.

This maximum value represents the largest value accepted for any of the following commands:
[SOURce:]CURRent (all forms)
MACro:OPERation:CURRent (all forms)
[SOURce:]SAFety

Note: For 9410 (AC Output), this value is only programmable for the safety limit settings.
Refer to **[SOURce:]SAFety** section for more information.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:FREQuency[:RANGe]:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns the maximum (minimum) allowable operating frequency.

For All Models (DC Outputs): This value is informational only.

For 9430 (AC Outputs): This min / max value represent the range of values permitted with:
[SOURce:]LOAD:FREQ

For all other models (AC Outputs): This min / max value represent the range of values permitted with:
[SOURce:]FREQuency
MACRo:OPERation:FREQuency (all forms)

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:POWer[:ALL]:MAXimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns the absolute maximum true power (Watts) setting value for the instrument selected.

The returned value represent the largest total instrument power values permitted with:
[SOURce:]POWer (at instrument level)
MACro:OPERation:POWer (at instrument level)
[SOURce:]SAFety

For 9410 (AC Output), this value is only programmable for the safety limit (**[SOURce:]SAFety**) settings.

For AC multi-ϕ outputs: Per phase limits may be queried using:
INSTrument:CAPabilities:POWer:<phase>: MAXimum

Note: The 9400 will also limit maximum power based on the selected Voltage & Current range.
Refer to **[SOURce:]VOLTage or CURRent:RANGe** for details on setting these ranges.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:POWer:<phase>:MAXimum

Scope: INSTRUMENT Query Models / Modes: All Models / Multi-ϕ AC

Query returns the maximum power (Watts) setting value for the instrument & phase selected.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

For AC multi-ϕ outputs: Query response is the largest per phase / channel power permitted for:
[SOURce:]POWer (at phase level)
MACro:OPERation:POWer (at phase level)

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:RESistance[:POSitive]:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: See Text

These queries will retrieve the minimum (smallest positive) and maximum (largest positive) positive resistance setting for the Module. For example, the minimum = 1.5 and maximum = 1000.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:RESistance:NEGative:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: See Text

These queries will retrieve the minimum (largest negative) and maximum (smallest negative) resistance setting for the Module. For example, the minimum = -1000 and maximum = -5.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:RL:RESistance:MAXimum or MINimum

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC RL Load

Query returns the minimum and maximum resistance that can be set in RL loading mode.
Refer to **CONFigure:LOAD:MODE** for information about setting the 9430 in RL loading mode.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:RL:INDuctance:MAXimum or MINimum

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC RL Load

Query returns the minimum and maximum inductance that can be set in RL loading mode.
Refer to **CONFigure:LOAD:MODE** for information about setting the 9430 in RL loading mode.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:VOLTage[:ALL]:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns the absolute maximum voltage (V_{RMS} or V_{DC}) output capability for instrument selected.

For AC (1ϕ) & DC outputs: Query response is expressed as line-neutral.

For AC multi-ϕ outputs: Query response is expressed as line-line equivalent value.
For per phase values, refer to:
INSTrument:CAPabilities:VOLTage:<phase>:MAXimum or MINimum

Note: Actual maximum voltage (V_{RMS} or V_{DC}) available also depends on voltage set range selected
Refer to **[SOURce:]VOLTage:RANGe** for information on how to set & query the current range.

Related commands:
INSTrument:CAPabilities:VOLTage:RANGe:MAXimum or MINimum
INSTrument:CAPabilities:VOLTage:RANGe:LIST[:MAXimum]
INSTrument:CAPabilities:VOLTage:RANGe:LIST:MINimum

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:VOLTage:<phase>:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns maximum (minimum) voltage (V_{RMS} or V_{DC}) ranges for instrument and phase selected.
This query is informational ONLY and is used by NHR for calibration utilities.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

For AC multi-ϕ outputs: Query response is expressed as line-neutral equivalent value.

Related commands:
INSTrument:CAPabilities:VOLTage:<phase>:RANGe:MAXimum or MINimum
INSTrument:CAPabilities:VOLTage:<phase>:RANGe:LIST[:MAXimum]
INSTrument:CAPabilities:VOLTage:<phase>:RANGe:LIST:MINimum

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:VOLTage[:ALL]:RANGe:LIST[:MAXimum]
INSTrument:CAPabilities:VOLTage[:ALL]:RANGe:LIST:MINimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns a list of maximum or minimum voltage (V_{RMS} or V_{DC}) ranges for the selected instrument.

This list defines the range of values which are valid for **[SOURce:]VOLTage:RANGe**.
The selected current range must be between the minimum (0) and one of the maximum values.
Refer to **[SOURce:]VOLTage:RANGe** for more information about selecting ranges.

For AC (1ϕ) & DC outputs: Query response is expressed as line-neutral.

For AC multi-ϕ outputs: Query response is expressed as line-line equivalent value.
for per phase ranges (for information only), Refer to:
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:RANGe:MAXimum
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement: RANGe:MINimum

Related query: **INSTrument:CAPabilities:VOLTage:RANGe:MAXimum**

Query Parameters None
Query Returns <NR1>{,<NR1>}

INSTrument:CAPabilities:VOLTage:<phase>:RANGe:LIST[:MAXimum]
INSTrument:CAPabilities:VOLTage:<phase>:RANGe:LIST:MINimum

Scope: INSTRUMENT Query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns a list of max or min voltage (V_{RMS} or V_{DC}) ranges for the selected instrument & phase.

The list is for informational purposes only.

For AC (1ϕ) & DC outputs: Query is invalid and and responds with <ERROR -221>.

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

For AC multi-ϕ outputs: Query response is expressed as line-neutral equivalent value.

Related queries include:
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:RANGe:MAXimum
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:RANGe:MINimum

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:VOLTage:RANGe:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns the max / min voltage (V_{RMS} or V_{DC}) value for selected instrument & range.

For all operating modes: This min / max value represent the range of values permitted with:
[SOURce:]VOLTage (at instrument level)
MACro:OPERation:VOLTage (at instrument level)
[SOURce:]SAFety

For AC multi-ϕ outputs: Per phase maximum set-point values are retrieved using:
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement:RANGe:MAXimum
INSTrument:CAPabilities:VOLTage:<phase>:MEASurement: RANGe:MINimum

Note: For 9430 (AC Output), this value is only programmable for the safety limit settings.
Refer to **[SOURce:]SAFety** section for more information.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:VOLTage:<phase>:RANGe:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the max / min voltage (V_{RMS} or V_{DC}) value for selected instrument, phase & range.

For 9430 (AC Output): this value is informational only

For AC (1ϕ) & DC outputs: Query is invalid and and responds with <ERROR -221>.

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

For AC multi-ϕ outputs: Query response is expressed as line-neutral equivalent value.

For all operating modes: This min / max value represent the range of values permitted with:
[SOURce:]VOLTage (per phase)
MACro:OPERation:VOLTage (per phase / channel)

Query Parameters None
Query Returns <NR1>

Slew Rate Capabilities Queries

INSTrument:CAPabilities:CURRent:SLEW:MAXimum or MINimum?

Scope: INSTRUMENT Query Models / Modes: All Models & Modes

Query returns the maximum and minimum current slew rate (A_{rms}/Sec or A_{DC}/Sec) for the instrument.

For 9410 (AC Output): This value is informational only

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:CURRent:PF:SLEW:MAXimum or MINimum?

Scope: INSTRUMENT Query Models / Modes: 9430 Only / AC NORMal Load

Query returns the maximum and minimum power factor slew rate which can be set in normal loading mode. Refer to **CONFigure:LOAD:MODE** for information about setting the 9430 for normal loading.

For 9410 & 9420 (All Outputs), this value is informational only
For 9430 (DC Output), this value is informational only

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:FREQuency:SLEW:MAXimum or MINimum?

Scope: INSTRUMENT Query Models / Modes: 9410 & 9420 / AC Outputs

Query returns the maximum and minimum frequency slew rate which can be set for AC outputs.

For 9410 & 9420 (DC Outputs), this value is informational only
For 9430 (All Outputs), this value is informational only

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:PHASe:SLEW:MAXimum or MINimum

Scope: INSTRUMENT Query Models / Modes: 9410 & 9420 / Multi-ϕ AC

Query returns the maximum and minimum phase angle slew rate which effects the rate of change when adjusting the phase angle relationship of the multi-ϕ outputs.

For All Models (1-ϕ or DC Outputs), this value is informational only
For 9300 (All Outputs), this value is informational only

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:POWer:SLEW:MAXimum or MINimum?

Scope: INSTRUMENT Query Models / Modes: 9410 & 9420 / Multi-ϕ AC

Query returns the maximum and minimum power slew rate (Watts/Sec or VA/Sec) for the instrument.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:RESistance:SLEW:MAXimum or MINimum?

Scope: INSTRUMENT Query Models / Modes: All Models / See Text

For all models with DC outputs or the 9430 in AC/CR Loading Mode,
Query returns the minimum and maximum set resistance slew rate (Ω/Sec) for the selected instrument.

For 9410 & 9420 (AC Mode), this value is informational only
For 9430 (Normal & RL Loading Mode), this value is informational only

Note: For 9430 in CR Mode, when the sign of the resistance is changed, the amount of slew time is calculated based as the absolute value of the delta if the resistance value or ABS(Ω_1 - Ω_2). The 9430 will actually slew to maximum resistance, then change sign, and slew to the set resistance value specified in this amount of time. Refer to **CONFigure:LOAD:MODE** for information about setting the 9430 for CR loading.

Query Parameters None
Query Returns <NR1>

INSTrument:CAPabilities:VOLTage:SLEW:MAXimum or MINimum?

Scope: INSTRUMENT Query Models / Modes: All Models / See Text

Query returns the maximum and minimum voltage slew rate (V_{rms}/Sec or V_{DC}/Sec) for the instrument.

For 9430 (AC Output): This value is informational only

Query Parameters None
Query Returns <NR1>

Output (SOURce:) Commands

Introduction

These commands control the operation and control the operating limits for the logical instruments. In general, these commands have an INSTRUMENT scope and as such will be applied to the currently selected logical instrument.

To select an instrument refer to **INSTrument:NSELect** or **INSTrument:SELect**.

SOURce commands are dependent on hardware model as well as the operating mode selected. It is therefore important to carefully read each command and understand the output effect.

Unless specifically noted in the command description
Single Phase & DC outputs use the command values directly as a Line-Neutral value.

For example, sending the instrument command **[SOURce:]VOLTage 120** to a 9410 configured for either AC Single-ϕ or DC will result with the output being set to $120VAC_{RMS}$ or $120V_{DC}$ respectively.

Hardware Mode	Instrument Control
DC Output **Single Phase (1-φ)**	Voltage $V_{SET(RMS\ or\ DC)}$ as L-N Current $I_{SET(RMS\ or\ DC)}$ as L-N

Multi-phase instruments will assume the same instrument command is to be interpreted as a global setting for all phases. This approach allows all phases to be returned to nominal operating condition quickly with a single command rather than sending individual phase commands. For example, sending the instrument command **[SOURce:]VOLTage 208** to a 9410 configured for 3-ϕ AC output will result in all phases being set to $120V_{RMS}$ whereas sending **[SOURce:]VOLTage 240** to a 9410 configured for 2-ϕ AC output will result in all phases being set to $120V_{RMS}$.

Hardware Mode	Instrument Control
3-φ AC Output	All Phases L-N = $V_{SET(RMS)} / \sqrt{3}$
2-φ AC Output	All Phases L-N = $V_{SET(RMS)} / 2$

It is therefore very important to read each command within this section to determine:

1) What the function of the command is based on model & operating mode
2) How the command is applied based on the model & operating mode

Ranges

As with all measurement devices, the accuracy of any measurement has a dependency on the selected measurement range. For this reason, the 9400 provides independently programmable current and voltage ranges allowing for the most precise accuracy possible for measurement as well as in set.

For a 9410 with an AC output: Current range applies to measurement only
For a 9430 with an AC output: Voltage range applies to measurement only
All other models & operating modes: Current & Voltage Ranges apply to both set & measurements

Changing the range is permitted during operation even while the output is active. All settings remain unless the programmed current or voltage setting is larger than the new range selected. In this case, the setting is automatically adjusted to the maximum value of the new range.

[SOURce:]CURRent or VOLTage:RANGe

Scope: INSTRUMENT Command or Query Models / Modes: All Models & Modes

Command establishes the current (or voltage) range.
Query returns the active hardware range for the selected instrument

Note: the range requested must be between the minimum and maximum allowed values provided by **INSTrument:CAPabilities:CURRent or VOLTage:RANGE:LIST** (min / max). The hardware will always select the next available range which is greater than or equal to (≥) the requested range.

Refer to **INSTument:CAPabilities:CURRent:RANGe:LIST** for a current ranges supported
Refer to **INSTument:CAPabilities:VOLTage:RANGe:LIST** for a voltage ranges supported

IMPORTANT:

Current is always specified as a line current (Line-Neutral) for all models & operating modes.
Voltage (1-ϕ or DC Outputs) is always specified as Line-Neutral V_{RMS} or V_{DC} respectively
Voltage (Multi-ϕ AC) is always specified as Line-Line V_{RMS}

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURCE:]CURRent:RANGe:ENERgystar[:ALL]

Scope: INSTRUMENT Command or Query Models / Modes: 9420 Only / All Modes

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command selects either low or ultra-low current measurement range for Energy Star measurements. Query returns the active measurement range (low or ultra-low)

The ranges are Model Size & output configuration dependent. They are approximately:

Low Range = 1.0A per 4kW channel operating in parallel
Ultra-Low Range = 0.1A per 4kW channel operating in parallel

Refer to **INSTrument:CAPabilities:MEASurement:ENERgystar:LIST** query for the actual values used for low and ultra-low range selection

Energy Star current measurements are further described in Measurement Features section under Energy Star Measurements

Command Parameters <NR1>
Where 0 = Low Range
1 = Ultra-Low Range
Query Parameters None
Query Returns <NR1>

[SOURCE:]CURRent:RANGe:ENERgystar:<phase>

Scope: INSTRUMENT Command or Query Models / Modes: 9420 Only / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command selects either low or ultra-low current measurement range for the selected phase. Query returns the active measurement range (low or ultra-low)

The ranges are Model Size & output configuration dependent. They are approximately:

Low Range = 1.0A per 4kW channel operating in parallel
Ultra-Low Range = 0.1A per 4kW channel operating in parallel

Refer to **INSTrument:CAPabilities:MEASurement:ENERgystar:LIST** query for the actual values used for low and ultra-low range selection

Energy Star current measurements are further described in Measurement Features section under Energy Star Measurements

Command Parameters <NR1>
Where 0 = Low Range
1 = Ultra-Low Range
Query Parameters None
Query Returns <NR1>

Setting Commands

[SOURce:]CURRent[:ALL]

Scope: INSTRUMENT Command or Query Models / Modes: See Text

Command establishes the current limit (A_{RMS} or A_{DC}) as a positive value for the selected instrument.
Query: response depends on the output configuration selected (**CONFigure:HW:MODE**)

For single phase & DC outputs: Query returns the line-neutral programmed current limit

For AC multi-ϕ outputs: A single command parameter establishes the same limit across all phases.
Using the alternate format establishes the limit on a per phases basis.
The query returns the average of all line-neutral per phase current limit
Commanding and querying individual phases is also possible using **[SOURce:]CURRent:<phase>**

Note: Programmable current limit must be between zero (0) and the value returned by **INSTrument:CAPabilities:CURRent:RANGe:MAXimum.**
The rate of change of current is affected by **[SOURce:]CURRent:SLEW**.

How the current limit is achieved depends on the model, output configuration (**CONFigure:HW:MODE**), and the state of the bi-directional enable (**CONFigure:INSTrument:BIDirectional**). The 9430 is also dependent on the loading mode selected using **CONFigure:LOAD:MODE**.

Model	9410		9420		9430			
Primary Control	Voltage		Voltage		Current			
Output (Load Mode)	AC	DC	AC	DC	AC	AC	AC	DC
Load Mode	N/A	N/A	N/A	N/A	NORMal	CR	RL	N/A
A_{LIMIT} Method	N/A	Note 1	Note 2	Note 3	Note 4	Note 4	N/A	Note 5
Initial Reset Value	MAX	MAX	MAX	MAX	0	MAX	MAX	0

Note 1: Output is bi-directional,
the voltage output will decrease voltage to limit current when current is flowing 9400 → UUT
the voltage output will increase voltage to limit current when current is flowing UUT → 9400
Note 2: Output is uni-directional, the voltage output will only ONLY decrease voltage to limit current
Note 3: Output is bi-directional or uni-directional depending on **CONFigure:INSTrument:BIDirectional**
Note 4: Output control is current based and reduces A_{RMS} or A_{DC} for AC & DC outputs respectively
Note 5: Output is uni-directional and current controlled, it will ONLY decrease A_{RMS} or A_{DC} for AC & DC

Related Command: **[SOURce:]CURRent:<phase>**

Command Parameters <NR1>
Alternate Formats <NR1>,<NR2> = Per phase limit for 2-ϕ outputs
<NR1>,<NR2>,<NR3> = Per phase limit for 3-ϕ outputs
Query Parameters None
Query Returns <NR1>

[SOURce:]CURRent:<phase>

Scope: INSTRUMENT Command or Query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command establishes current limit for an individual phase of a multi-phase output.
Query returns the programmed current limit for the selected phase of a multi-phase output.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

For all other models & modes: The value must be between zero (0) and the value returned by **INSTrument:CAPabilities:CURRent:RANGe:MAXimum**

Note: This command has the same limitations as **[SOURce:]CURRent**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]CURRent:PRIOrity

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC NORMal Load

Command sets the current modifying priority for the selected instrument
Query returns the current modifying priority for the selected instruments primary phase

Applies only to 9430 with AC Outputs, **NORMal** loading mode (See: **CONFigure:INSTrument:LOAD**), and when using the **STANDARD** waveshape (See: **[SOURce:]FUNCtion**).

Priority will see all phases to one of the following priority modes:
0 = Unity Power Factor (Implemented as a V_{RMS} (last cycle) dependent resistor)
1 = CF Priority (Maintaining Crest Factor has priority and is reset Default)
2 = PF Priority (Maintaining Power Factor has priority)

For AC multi-phase: This command sets all phases to the same priority.
A query will return the priority of APHase only.
To set / query individual phases use **[SOURce:]CURRent:PRIOrity:<phase>**

Command Parameters 0 | 1 | 2
Query Parameters None
Query Returns -1 | 0 | 1 | 2
Note: -1 is returned ONLY in multiphase mode with the phases having different priority settings.

[SOURce:]CURRent:PRIOrity:<phase>

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC NORMal Load

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command sets the current modifying priority for in individual phase of a multi-phase AC ouput
Query returns the programmed current priority for the selected phase of a multi-phase output.

Applies to 9430 with Multi-ϕ AC output and in NORMal loading only

Note: This command has the same limitations as **[SOURce:]CURRent:PRIOrity**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]CURRent:SHIFt

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC NORMal Load

Command sets the relative current-to-voltage phase shift as either lagging or leading for all phases
Query returns the programmed phase shift direction for the selected instruments primary phase.

Applies only to 9430 with AC Outputs, **NORMal** loading mode (See: **CONFigure:INSTrument:LOAD**), and when using the **STANDARD** waveshape (See: **[SOURce:]FUNCtion**).

For AC multi-phase: This command sets all phases to the same priority.
A query will return the priority of APHase only.
To set / query individual phases use **[SOURce:]CURRent:SHIFt:<phase>**

Note: Changing the **[SOURce:]CURRent:SHIFt** when not at unity power factor (+1 or -1) will result in an immediate change to the new power factor (Voltage to Current phase relationship)

Related Commands: **[SOURce:]CURRent:SHIFt:<phase>** to set individual phase lag/lead

Command Parameters <bool>
0 = Lag
1 = Lead
Query Parameters None
Query Returns <bool>
0 | 1
Note: -1 is returned ONLY in multiphase mode with the phases having different shift settings.

[SOURCE:]CURRent:SHIFt:<phase>

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC NORMal Load

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command sets the current-to-voltage phase shift for an in individual phase of a multi-phase output
Query returns the lag/lead for the selected phase of a multi-phase output.

Applies to 9430 with Multi-ϕ AC output and in NORMal loading only

Note: This command has the same limitations as **[SOURce:]CURRent:SHIFt**.

Command Parameters <bool>
0 = Lag
1 = Lead

Query Parameters None

Query Returns <bool>
0 | 1

[SOURCE:]CURRent:CF

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC NORMal Load

Command adjusts the crest factor (CF = I_{PEAK} / I_{RMS}) for all AC outputs the selected instrument
Query returns the programmed crest factor for the selected instruments primary phase.

Applies only to 9430 with AC Outputs, **NORMal** loading mode (See: **CONFigure:INSTrument:LOAD**), and when using the **STANDARD** waveshape (See: **[SOURce:]FUNCtion**).

For AC multi-phase: This command sets all phases to the same crest factor.
A query will return the crest factor of APHase only.
To set / query individual phases use **[SOURce:]CURRent:CF:<phase>**

Command has no effect on USER waveshapes or other models / modes

To adjust the crest factor on a specific phase refer to **[SOURce:]CURRent:CF:<phase>**

Note: Changing the Crest Factor creates a sinusoidal waveshape with a peak value of CF_{SET} I_{RMS}

Command Parameters <NR2>
Query Parameters None
Query Returns <NR2>
Note: 3.4e+38 is returned ONLY in multiphase mode with the phases having different CF settings.

[SOURce:]CURRent:CF:<phase>

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC NORMal Load

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command adjusts the crest factor (CF = I_{PEAK} / I_{RMS}) for all a single phase of a multi-phase AC output
Query returns the programmed crest factor for the selected phase of a multi-phase output.

Applies to 9430 with Multi-ϕ AC output and in NORMal loading only

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: This command has the same limitations as **[SOURce:]CURRent:CF**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]CURRent:PF

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC NORMal Load

Command adjusts the power factor (voltage to current relationship) for the selected instrument.
Query returns the programmed power factor value for the selected instruments primary phase.

Applies only to 9430 with AC Outputs, **NORMal** loading mode (See: **CONFigure:INSTrument:LOAD**), and when using the **STANDARD** waveshape (See: **[SOURce:]FUNCtion**).

For AC multi-phase: This command sets all phases to the same power factor value.
A query will return the power factor value of APHase only.
To set / query individual phases use **[SOURce:]CURRent:PF:<phase>**

When not enabled for bi-directional mode: Power factor must be in the range from:
0 (lead) → 1 (unity load) → 0 (lag)

When bi-directional is enabled (CONFigure:INSTrument:BIDirectional): Power factors may be
-1 (unity source) → 0 (lead or lag) → 1 (unity load)

In either case, The rate of change of power factor changes is affected by **[SOURce:]CURRent:PF:SLEW**.

Power factor programming is also dependent the waveshape selected (see **[SOURce:]FUNCtion**):
When using the **STANDARD** waveshape:
The angular voltage-to-current relationship is actively adjusted to maintain power factor.

When using the **USER** waveshapes:
The angular voltage-to-current relationship may be adjusted.
In this case, the new angular relationship is defined as:

Angular offset = ARCCOS(PF) for leading
360^{o}-ARCCOS(PF) for lagging

Related Commands: **[SOURce:]CURRent:SHIFt** which establishes leading / lagging.
[SOURce:]CURRent:PRIOrity which establishes current modifier priority
[SOURce:]FUNCtion (all forms) which establishes current loading shape & trim

Command Parameters <NR2>
Query Parameters None
Query Returns <NR2>
Note: 3.4e+38 is returned ONLY in multiphase mode with the phases having different PF settings.

[SOURce:]CURRent:PF:<phase>

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC NORMal Load

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command adjusts the power factor for all a single phase of a multi-phase AC output
Query returns the programmed power factor for the selected phase of a multi-phase output.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: This command has the same limitations as **[SOURce:]CURRent:PF**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]FREQuency

Scope: INSTRUMENT Command or Query Models / Modes: 9410 & 9420 / AC Output Only

Command establishes the operating frequency for the selected instrument.
Query returns the programmed operating frequency for the selected instrument.

For All Models (DC Outputs): This command is accepted and has no effect on operation

For the 9430 (All Modes): This command is accepted and has no effect on operation
Refer to **[SOURce:]LOAD:FREQ** which is used to set the initial frequency detection band.

For 9410 (AC Outputs) & 9420 (AC Outputs): Frequency must be between
INSTrument:CAPabilities:FREQuency min and max.

Note: The instantaneous operating frequency is also affected by **[SOURce:]FREQuency:SLEW**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]FUNCtion[:SHAPE][:ALL]

Scope: INSTRUMENT Command or Query Models / Modes: See Text

Command establishes the output waveshape <alias> for the selected instrument.
Query returns a list of output waveshape aliases active for the selected instrument

For All Models (DC Outputs): This is invalid and generates a system error

For 9410 or 9420 (AC Outputs): The selected waveshape (STANDARD or USERn) will determine the shape of the voltage waveform.

For 9430 (AC Outputs): the selected waveshape (STANDARD or USERn) will determine the shape of the current waveform when operating in **NORMal** loading mode (see **CONFigure:INSTrument:LOAD**). The command / query has no effect when operating in either **CR** or **RL** loading modes.

The new user waveshape will start with an angular offset equal to the previous angular offset. The angular offset may be further manipulated with **[SOURce:]FUNCtion:[:SHAPE]:SHIFt** and **[SOURce:]CURRent:PF**.

Related Commands: **DATA** (all forms)

For AC multi-ϕ outputs: A single command parameter activates the same waveshape alias on all phases. It is important to note that there is a unique waveshape per phase and per alias. Using the alternate format allows different aliases to be selected per phase. Commanding and querying individual phases is also possible using **[SOURce:]FUNCtion:<phase>**

Command Parameters	<alias> = waveshape alias to use across all phases
Alternate Formats	<alias>,<alias2> = Per phase waveshape alias for 2-ϕ outputs
	<alias>,<alias2>,<alias3> = Per phase waveshape alias for 3-ϕ output
Where	<alias> = STANDARD | USER1 | USER2 | USER3
Query Parameters	None
Query Returns	<alias>{,<alias2>{,<alias3>} }

[SOURce:]FUNCtion[:SHAPe]:<phase>

Scope: INSTRUMENT Command or Query Models / Modes: See Text

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command establishes the output waveshape <alias> for an individual phase of a multi-ϕ instrument.
Query returns the waveshape alias for an individual phase of a multi-ϕ instrument

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: This command has the same limitations as **[SOURce:]FUNCtion[:SHAPE][:ALL]**.

Command Parameters	<alias>
Where	<alias> = STANDARD | USER1 | USER2 | USER3
Query Parameters	None
Query Returns	<alias>

[SOURce:]FUNCtion[:SHAPe]:SHIFt

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / See Text

Command allows a <trim> control angular offset of all user-defined waveshapes.
Query returns the current <trim> control value.

On the 9410 & 9420 (All modes): This command (query) is ignored and has no effect

On the 9430 (AC with USER $I_{WAVESHAPE}$ Outputs), The trim value is added to the waveshape offset allowing the waveshape to be adjusted from its initial angle established when the user waveshape was selected. Refer to **[SOURce:]CURRent:PF** (all forms) for an alternate method to shift user waveshapes per phase

Related commands:

[SOURce:]CURRent:PF
[SOURce:]CURRent:PF:<phase>
[SOURce:]FUNCTion[:SHAPE][:ALL]
[SOURce:]FUNCTion[:SHAPE]<phase>

Command Parameters <trim> = 0^{o} to 359.9^{o} additional angular shift applied to all user waveshapes
Query Parameters None
Query Returns <trim>

[SOURce:]LOAD:FREQ

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC NORMal Load

Command establishes the load's initial frequency detection range for the selected instrument.
Query returns the initial detection frequency range.

Applies ONLY to a 9430 configured for AC output (see **CONFigure:HW:MODE**) and for NORMal loading using **CONFigure:LOAD:MODE**.

When the load first detects a voltage, it will only consider it as a valid when the frequency is between <max freq> and <min freq>. After initial detection, the load will track the frequency including outside the range specified by these paramaters.

Allowable values of <min freq> and <max freq> must meet the following requirements:

1) <max freq> / <min freq> ≤ 1.5
2) Both must be within the range of **INSTrument:CAPabilities:FREQuence:MAXimum** and **MINimum**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]OUTPut[:ON]

Scope: INSTRUMENT Command or Query Models / Modes: All Models & Modes

Command controls the output relay state of the selected instrument.
Query returns output relay state of the selected instrument.

Command Parameters <BOOL>
0 | NO | FALSE | OFF = Disable instrument and open output relay
1 | YES | TRUE | ON = Enable instrument and close output relay
Query Parameters None
Query Returns <NR1>
0 | 1

[SOURce:]OUTPut[:ON]:ALL

Scope: SYSTEM Command Models / Modes: All Models & Modes

Command controls the output relay state on all instruments.

Command Parameters <BOOL>
0 | NO | FALSE | OFF = Disable all instruments and open output relays
1 | YES | TRUE | ON = Enable all instruments and close output relays

[SOURce:]OUTPut:ABORt???

Scope: INSTRUMENT Command or Query Models / Modes: All Models & Modes

This command aborts any slewing of voltage, current, power, or frequency.

Command Parameters None

[SOURce:]OUTPut:SYNC:ANGLe[:ALL]
[SOURce:]OUTPut:SYNC:ANGLe:APHase (or BPHase, or CPHase) What is this?

Scope: INSTRUMENT Command or Query Models / Modes: All Models / AC Outputs Only

This command ONLY applies to an instrument in AC mode (see CONFigure:MODE).

Sets the selected logical instrument to apply changes at the set phase angle when operating in CONF:INST:SYNC is 1.

This command establishes the angle used for macro cycle counting (see: **MACRo:WAIT:CYCLes**)

Command Parameters <angle> 0.0 to 359.999 degrees
Query Parameters None
Query Returns <angle>

[SOURce:]PHASe[:ANGLe]

Scope: INSTRUMENT Command or Query Models / Modes: 9410 & 9420 / Multi-Phase AC

Command sets the phase <angle> relationship between the output phases of a multi-phase output
Query returns a list of phase angle relationships of a multi-phase output

For a 9410 & 9420 (AC 3-ϕ Output): Command (query) is valid and establishes the relative phase
The first <angleA_B> is the relative offset of angle A to B.
The second <angleA_C> value is the relative offset of angle A to C.
The rate of change of current is affected by **[SOURce:]PHASe:SLEW**.

For all other models and modes: Command (query) is ignored and has no effect

Command Parameters <angleA_B> = For split-ϕ outputs
Alternate Format <angleA_B>, <angleA_C> = For 3-ϕ outputs
Query Parameters None
Query Returns <angle>{, <angle2>}

[SOURCE:]PHASe[:ANGLe]:BPHase

Scope: INSTRUMENT Command or Query Models / Modes: 9410 & 9420 / Multi-ϕ AC

Command sets the phase <angle> offset between APHase and BPhase for a split-ϕ or 3-ϕ output
Query returns the phase angle relationship between APHase and BPHase.

For 9410 & 9420 (AC Multi-Phase only): Command (query) is valid and establishes the relative phase for the output waveform. The rate of change of current is affected by **[SOURce:]PHASe:SLEW**.

For 9430 (AC Multi-Phase only): Command(query) is invalid and has no effect

For all other models and modes: Query (and command) is invalid and responds with <ERROR -221>

Command Parameters <angle >
Query Parameters None
Query Returns <angle>

[SOURCE:]PHASe[:ANGLe]:CPHase

Scope: INSTRUMENT Command or Query Models / Modes: 9410 & 9420 / Multi-ϕ AC

Command sets the phase <angle> offset between APHase and CPhase for a 3-ϕ output
Query returns the phase angle relationship between APHase and CPHase.

For 9410 & 9420 (3-ϕ AC only): Command (query) is valid and establishes the relative phase for the output waveform. The rate of change of current is affected by **[SOURce:]PHASe:SLEW**.

For 9430 (AC Multi-Phase only): Command(query) is invalid and has no effect

For all other models and modes: Query (and command) is invalid and responds with <ERROR -221>

Command Parameters <angle >
Query Parameters None
Query Returns <angle>

[SOURce:]POWer[:ALL] TEST Multi-phase set and control method]

Scope: INSTRUMENT Command or Query Models / Modes: See Text

Command establishes the True Power limit (W) as a positive value for the selected instrument.
Query returns the programmed total true power limit for the selected instrument.

For AC multi-ϕ outputs: A single command parameter establishes balanced power limit for all phases.
Each phase will be set to W_{SET}/ number of phases.
Using the alternate format establishes the limit on a per phases basis.
The query returns the arithmetic sum of the power limit of all phases.
Commanding and querying individual phases is also possible using **[SOURce:]POWer:<phase>**

Note: The rate of change of current is affected by **[SOURce:]POWer:SLEW**.

How the power limit is achieved depends on the model, output configuration (**CONFigure:HW:MODE**), and the state of the bi-directional enable (**CONFigure:INSTrument:BIDirectional**). The 9430 is also dependent on the loading mode selected using **CONFigure:LOAD:MODE**.

Model	9410		9420		9430			
Priary Control	Voltage		Voltage		Current			
Output (Load Mode)	AC	DC	AC	DC	AC	AC	AC	DC
Load Mode	N/A	N/A	N/A	N/A	NORMal	CR	RL	N/A
W_{LIMIT} Method	N/A	Note 1	Note 2	Note 3	Note 4	Note 4	N/A	Note 5
Initial Reset Value	30	30	30	30	0	30	30	0

Note 1: Output is bi-directional, the voltage output will increase or decrease voltage to limit current
Note 2: Output is uni-directional, the voltage output will only ONLY decrease voltage to limit current
Note 3: Output is bi-directional or uni-directional depending on **CONFigure:INSTrument:BIDirectional**
Note 4: Output control is current and reduces A_{RMS} for AC outputs
Note 5: Output is uni-directional and current controlled, it will ONLY decrease A_{DC} for DC ouputs

Related Command: **[SOURce:]POWer:<phase>**

Command Parameters <NR1> = Total true-power (W) for the selected instrument
Alternate Formats <NR1>,<NR2> = Per phase limit for 2-ϕ outputs
<NR1>,<NR2>,<NR3> = Per phase limit for 3-ϕ outputs
Query Parameters None
Query Returns <NR1>

[SOURce:]POWer:<phase> TEST

Scope: INSTRUMENT Command or Query Models / Modes: See Text

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command establishes true power (W) limit for an individual phase of a multi-phase output.
Query returns the programmed true power (W) limit for the selected phase of a multi-phase output.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: This command has the same limitations as **[SOURce:]POWer[:ALL]** .

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURCE:]RESistance[:ALL] test multi-out command and query resp]

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / See Text

Command adjusts the resistance (Ω) for AC or DC loading outputs the 9430's selected instrument
Query returns the programmed resistance for the selected instruments.

Applies only to 9430 with DC Outputs or a 9430 with AC AC Outputs when configured for, **CR** loading mode (See: **CONFigure:INSTrument:LOAD**)

For 9430 (DC) Mode: Value must be between **INSTrument:CAPabilies:RESistance** MAX/MIN

For 9430 (CR Loading) Mode: Value must be between **INSTrument:CAPabilies:RESistance** MAX/MIN when When bi-directional is not enabled (see **CONFigure:INSTrument:BIDirectional**). When BI-Directional is enabled, the resistance may be programmed with a negative value resulting in current sourcing.

For AC multi-phase: This command sets all phases to the given resistance value
A query will return the average of the resistance across all phases.
To set / query individual phases use **[SOURce:]RESistance:<phase>**

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

Command Parameters <NR1> = Resistance value applied to all outputs
Alternate Formats <NR1>,<NR1> = Per phase limit for 2-ϕ outputs
<NR1>,<NR1>,<NR1> = Per phase limit for 3-ϕ outputs
Query Parameters None
Query Returns <NR1>

[SOURCE:]RESistance:<phase>

Scope: INSTRUMENT Command or Query Models / Modes: See Text

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command establishes the resistance (Ω) limit for an individual phase of a multi-phase output.
Query returns the programmed resistance (Ω) limit for the selected phase of a multi-phase output.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: This command has the same limitations as **[SOURce:]RESistance**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]RL:RESistance[:ALL]

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC RL Load

Command adjusts the series resistance for all AC outputs the selected instrument
Query returns ????? (Test)

Applies only to 9430 with AC Outputs, **RL** loading mode (See: **CONFigure:INSTrument:LOAD**) and must be within the values returned by **INSTrument:CAPabilities:RL:RESistance:MAXimum** and **MINimum**.

Related command: **[SOURce:]RL:INDuctance** – establishes series inductance value

Resistance may be set per phase of a multi-phase AC output using **[SOURce:]RL:RESistance:<phase>**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]RL:RESistance:<phase>

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / RL Multi-ϕ Load

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command adjusts the series resistance for all a single phase of a multi-phase AC output
Query returns the programmed series resistance for the selected phase of a multi-phase output.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: This command has the same limitations as **[SOURce:]RL:RESistance**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]RL:INDuctance[:ALL]

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / RL Multi-ϕ Load

Command adjusts the series inductance for all AC outputs the selected instrument
Query returns ????? (Test)

Applies only to 9430 with AC Outputs, **RL** loading mode (See: **CONFigure:INSTrument:LOAD**) and must be within the values returned by **INSTrument:CAPabilities:RL:INDuctance:MAXimum** and **MINimum**.

Related command: **[SOURce:]RL:RESistance** – establishes series resistance value

Resistance may be set per phase of a multi-phase AC output using **[SOURce:]RL:INDuctance:<phase>**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]RL:INDuctance:<phase>

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / RL Multi-ϕ Load

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command adjusts the series inductance for all a single phase of a multi-phase AC output
Query returns the programmed series inductance for the selected phase of a multi-phase output.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: This command has the same limitations as **[SOURce:]RL:INDuctance**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]OUTPut:RGAin

Scope: INSTRUMENT Command and Query Models / Modes: All Models & Modes

Command adjusts the proportional correction used within the control loop for the selected instrument.
Query returns the setting for the selected instrument.

Value must be between zero (0) and INSTrumnet:CAPabilities:RGAin:MAXimum.

Warning: Contact NH Research customer support before making changes to this setting.
In general, the larger (or smaller) the value programmed will result in larger (or smaller) control loop adjustments. Programming zero (0) inhibits the regulation feedback and will affect system accuracy.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]SAFety (test 9430 for Source direction sense)

Scope: INSTRUMENT Command or Query Models / Modes: All Models & Modes

Command establishes the limits and allowable time which if exceeded will cause a safety trip.
Query returns the safety limits for the selected instrument

Peak Voltage & Currents are instantaneous maximum values and enabled or disabled with a 1 or 0

All other Voltages & Currents are in RMS for AC outputs or DC for DC outputs and include a Time value.
When negative one (-1) the specific safety limit is disabled
When zero (0) the specific safety limit will trigger on any AC single cycle or DC instantaneous
Otherwise, time value must between zero and the **INSTrument:CAPabilities:TRIP:MAXimum** value.

These limits are per direction and specified as either source (9400 → UUT) or sink (UUT → 9400).

Command Parameters <Min $V_{(RMS\ or\ DC)}$>,<Min V Time>,
<Max $V_{(RMS\ or\ DC)}$>,<Max V Time>,
<Max Source $A_{(RMS\ or\ DC)}$>,<Max Source A Time>,
<Max Sink $A_{(RMS\ or\ DC)}$>,<Max Sink A Time>,
<Max Source $W_{(RMS\ or\ DC)}$>,<Max Source W Time>,
<Max Sink $W_{(RMS\ or\ DC)}$>,<Max Sink W Time>,
<Peak $V_{INSTANTANEOUS}$>,<Peak V Enable>,
<Peak $A_{INSTANTANEOUS}$>,<Peak A Enable>

Query Parameters None

Query Returns <Min V>,<Min V Time>,<Max V>,<Max V Time>,<Max Source A>,<Max Source A Time>,<Max Sink A>,<Max Sink A Time>,<Max Source W>,<Max Source W Time>,<Max Sink W>,<Max Sink W Time>,<Peak V>,<Peak V Enable>,<Peak A>,<Peak A Enable>

[SOURce:]VA[:ALL] TEST especially to see if DC = same as POWer

Scope: INSTRUMENT Command or Query Models / Modes: See Text

Command establishes the Apparent Power limit (VA) as a positive value for the selected instrument. Query returns the programmed total apparent power limit for the selected instrument.

For multi-phase outputs, the command value is the total power limit with a balanced power limit per phase (i.e. VA_{SET}/ #ϕ). The query returns the arithmetic sum of the programmed power limits per phase.

Note: The rate of change of current is affected by **[SOURce:]POWer:SLEW**.

How the power limit is achieved depends on the model, output configuration (**CONFigure:HW:MODE**), and the state of the bi-directional enable (**CONFigure:INSTrument:BIDirectional**). The 9430 is also dependent on the loading mode selected using **CONFigure:LOAD:MODE**.

Model	9410		9420		9430			
Priary Control	Voltage		Voltage		Current			
Output (Load Mode)	AC	DC	AC	DC	AC	AC	AC	DC
Load Mode	N/A	N/A	N/A	N/A	NORMal	CR	RL	N/A
W_{LIMIT} Method	N/A	Note 1	Note 2	Note 3	Note 4	Note 4	N/A	Note 5
Initial Reset Value	MAX	MAX	MAX	MAX	MAX	MAX	MAX	MAX

Note 1: Output is bi-directional, the voltage output will increase or decrease voltage to limit current
Note 2: Output is uni-directional, the voltage output will only ONLY decrease voltage to limit current
Note 3: Output is bi-directional or uni-directional depending on **CONFigure:INSTrument:BIDirectional**
Note 4: Output control is current and reduces A_{RMS} or A_{DC} for AC & DC outputs respectively
Note 5: Output is uni-directional and current controlled, it will ONLY decrease A_{RMS} or A_{DC} for AC & DC

Related Command: **[SOURce:]VA:<phase>**

Command Parameters <NR1> = Total apparent-power (VA) for the instrument
Alternate Formats <NR1>,<NR2> = Per phase limit for 2-ϕ outputs
<NR1>,<NR2>,<NR3> = Per phase limit for 3-ϕ outputs
Query Parameters None
Query Returns <NR1>

[SOURce:]VA:<phase> TEST

Scope: INSTRUMENT Command or Query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command establishes apparent power (VA) limit for an individual phase of a multi-phase output. Query returns the programmed apparent power (VA) limit for a single phase of a multi-phase output.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: This command has the same limitations as **[SOURce:]VA[:ALL]**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURCE:]VOLTage[:ALL]

Scope: INSTRUMENT Command or Query Models / Modes: See Text

Command establishes the voltage limit (V_{RMS} or V_{DC}) as a positive value for the selected instrument.
Query: response depends on the output configuration selected (**CONFigure:HW:MODE**)

All single command values must be between either zero (0) or between the values returned by **INSTrument:CAPabilities:VOLTage:RANGe:MAXimum** and **MINimum**.

For single phase & DC outputs: Query returns the line-neutral programmed voltage limit

For all models (AC Multi-ϕ): A query response returns the arithmetic equivalent of line-line value
For 2-ϕ the per phase line-neutral is set to Average(ϕ_V) * 2.
For 3-ϕ the per phase line-neutral is set to Average(ϕ_V) * √3.

For 9410 & 9420 (AC Multi-ϕ): A single command parameter sets an equivalent line-line voltage by programming each phase to an equivalent line-neutral value
For 2-ϕ the per phase line-neutral is set to V_{SET} / 2.
For 3-ϕ this per phase line-neutral is set to V_{SET} / √3.

The alternate format allows a per phase limit to be sent using line-neutral values of either zero (0) or between **INSTrument:CAPabilities:VOLTage:<phase>:RANGe:MAXimum** and **MINimum**

The rate of change of current is affected by **[SOURce:]VOLTage:SLEW**.

Voltage limits have different effects based on the model, output configuration (**CONFigure:HW:MODE**), and the state of the bi-directional enable (**CONFigure:INSTrument:BIDirectional**). The 9430 is also dependent on the loading mode selected using **CONFigure:LOAD:MODE**.

Model	9410		9420		9430	
Primary Control	Voltage		Voltage		Current	
Output (Load Mode)	AC	DC	AC	DC	AC	DC
V_{LIMIT} Method	Note 1	Note 1	Note 2	Note 3	N/A	Note 4
Initial Reset Value	0	0	0	0	MAX	MAX

Note 1: Output is bi-directional, the voltage output will maintained regardless of current direction
Note 2: Output is uni-directional (i.e. net power must flow 9420→UUT)
The voltage output will maintained if not reduced due to either current limit or power
Note 3: Output is bi-directional or uni-directional depending on **CONFigure:INSTrument:BIDirectional**
Note 4: Output uni-directional, current will only be drawn when the terminal voltage ≥ V_{SET}

Related Command: **[SOURce:]VOLTage:<phase>**

Command Parameters <NR1> = L-N limit for AC 1-ϕ & DC / L-L limit for AC multi-ϕ
Alternate Formats <NR1>,<NR2> = Per phase L-N limit for 2-ϕ outputs
<NR1>,<NR2>,<NR3> = Per phase L-N limit for 3-ϕ outputs
Query Parameters None
Query Returns <NR1>

[SOURCE:]VOLTage:<phase>

Scope: INSTRUMENT Command or Query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Command establishes voltage limit for an individual phase as line-neutral (L-N) of a multi-phase output. Query returns the programmed voltage limit for the selected phase of a multi-phase output.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

For all other models & modes: The value must be between the values returned by **INSTrument:CAPabilities:VOLTage:<phase>:RANGe:MAXimum** and **MINimum**

Note: This command has the same limitations as **[SOURce:]VOLTage[:ALL]**.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

Slew Rate Commands

[SOURce:]CURRent:SLEW

Scope: INSTRUMENT Command or Query Models / Modes: All Models & Modes

Command sets rate of change for programmed current (A_{RMS}/Sec or A_{DC}/Sec) changes.
Query returns the programmed rate of change for the selected instrument.

For the 9410 (AC Outputs): Command has no effect

For the 9430 (RL Loading Mode): Command has no effect

For all other Models & Modes: This slew rate programmed must be either zero (0) or between **INSTrument:CAPabilities:CURRent:SLEW:MAXimum** and **MINimum.**
When set to zero (0) the hardware selects the reset default slew rate for the selected instrument

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]CURRent:PF:SLEW

Scope: INSTRUMENT Command or Query Models / Modes: 9430 Only / AC NORMal Load

Command establishes the rate of change (ΔPF/Sec) when a new **SOURce:CURRent:PF** is received.
Query returns the programmed rate of change for the selected instrument.

Applies ONLY to a 9430 configured for AC output (see **CONFigure:HW:MODE**) and for NORMal loading (see: **CONFigure:LOAD:MODE**). This slew rate programmed must be either zero (0) or between **INSTrument:CAPabilities:CURRent:Pf:SLEW:MAXimum** and **MINimum.**
When set to zero (0) the hardware selects the reset default slew rate for the selected instrument

Note: Slew rate is ignored if **[SOURce:]CURRent:SHIFt** is changed (leading & lagging).

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]FREQuency:SLEW

Scope: INSTRUMENT Command or Query Models / Modes: 9410 & 9420 / AC Outputs

Command sets the rate of change (HZ/sec) for a new **SOURce:FREQuency** command is received.
Query returns the programmed rate of change for the selected instrument.

For the 9410 & 9420 (AC Outputs): This slew rate programmed must be either zero (0) or between **INSTrument:CAPabilities:FREQuency:SLEW:MAXimum** and **MINimum.**
When set to zero (0) the hardware selects the reset default slew rate for the selected instrument

For all other Models & Modes: Command has no effect

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]OUTPut:STABility

INSTRUMENT command and query

This command (stability) sets a factor used in the control loop of the instrument . Default is 0 and is normal operation. Larger values allow for stabilizing the control loop when it is showing oscillating or ringing behaviors The value i entered as an integer from 0 to 3.

0 (default) Normal 100% stability factor, 1 – 70%, 2 – 40%, 3 10% (Highest stability)

Command Parameters 0 through 3
Query Parameters None
Query Returns 0 thru 3

[SOURce:]PHASe:SLEW

Scope: INSTRUMENT Command or Query Models / Modes: 9410 & 9420 / Multi-Phase AC

Command sets rate of change in degrees per second when a phase angle relationship is changed
Query returns the programmed rate of change for the selected instrument.

For the 9410 & 9420 (AC Outputs): This slew rate programmed must be either zero (0) or between **INSTrument:CAPabilities:PHASe:SLEW:MAXimum** and **MINimum.**
When set to zero (0) the hardware selects the reset default slew rate for the selected instrument

For all other Models & Modes: Command has no effect

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]POWer:SLEW (test)

Scope: INSTRUMENT Command or Query Models / Modes: All Models / See Text

Command sets rate of change for programmed true (W/sec) or apparent power (VA/sec) changes.
Query returns the programmed rate of change for the selected instrument.

For the 9410 (AC Outputs): Command has no effect

For the 9430 (RL Loading): Command has no effect

For all other models / modes: This slew rate programmed must be either zero (0) or between **INSTrument:CAPabilities:POWer:SLEW:MAXimum** and **MINimum.**
When set to zero (0) the hardware selects the reset default slew rate for the selected instrument

Note: This command is preferred and replaces any value programmed using **[SOURce:]VA:SLEW**

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]RESistance:SLEW

Scope: INSTRUMENT Command or Query Models / Modes: 9430 / See Text

Command sets rate of change in resistance (Ω/sec) for all resistance limit programmed changes.
Query returns the programmed rate of change for the selected instrument.

For the 9410 & 9420: Command has no effect

For the 9430 (NORMal Loading): Command has no effect

For the 9430 (DC, CR, or RL Loading): This slew rate programmed must be either zero (0) or between **INSTrument:CAPabilities:RESistance:SLEW:MAXimum** and **MINimum.**
When set to zero (0) the hardware selects the reset default slew rate for the selected instrument

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

[SOURce:]VA:SLEW

Scope: INSTRUMENT Command or Query Models / Modes: All Models / See Text

NOTE: DEPRECATED COMMAND

Command sets rate of change for programmed true (W/sec) or apparent power (VA/sec) changes.
Query returns the programmed rate of change for the selected instrument.

For the 9410 (AC Outputs): Command has no effect

For the 9430 (RL Loading): Command has no effect

For all other models / modes: This slew rate programmed must be either zero (0) or between **INSTrument:CAPabilities:POWer:SLEW:MAXimum** and **MINimum.**
When set to zero (0) the hardware selects the reset default slew rate for the selected instrument

Note: This command is deprecated and replaces any value programmed using **[SOURce:]POWer:SLEW**

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>
INSTRUMENT command and query

[SOURce:]VOLTage:SLEW

Scope: INSTRUMENT Command or Query Models / Modes: All Models & Modes

Command sets rate of change for programmed voltage (V_{RMS}/Sec or V_{DC}/Sec) changes.
Query returns the programmed rate of change for the selected instrument.

For the 9430 (AC Outputs): Command has no effect

For all other Models & Modes: This slew rate programmed must be either zero (0) or between **INSTrument:CAPabilities:VOLTage:SLEW:MAXimum** and **MINimum.**
When set to zero (0) the hardware selects the reset default slew rate for the selected instrument

Note: For 1-ϕ and DC outputs, this rate of change value is applied as line-neutral
For multi-phase AC outputs, this rate of change value is applied as line-line

Command Parameters <NR1>

Query Parameters None
Query Returns <NR1>

Waveshape Control – DATA Loading

Each output phase of the 9400 supports a three (3) user definable AC arbitrary waveshapes. These waveshapes are in addition to STANDARD (sinusoidal shape) and typically define harmonics, cyclic disturbances, and other transient characteristics. Each user waveshape is comprised of 360 values between -1 and +1 representing a scaled value for each degree.

These values are loaded in groups of 90 values per quadrant.

Q1: 0° to 89° Q3: 180° to 269°
Q2: 90° to 179° Q4: 270° to 359°

Example of loading the DATA buffer:

DATA[:DATA] Q1,<NR1>,<NR2>,<NR3> … ,<NR90> (90 float values) // Load the first 90 points
DATA[:DATA] Q2,<NR1>,<NR2>,<NR3> … ,<NR90> (90 float values) // Load the second 90 points
DATA[:DATA] Q3,<NR1>,<NR2>,<NR3> … ,<NR90> (90 float values) // Load the third 90 points
DATA[:DATA] Q4,<NR1>,<NR2>,<NR3> … ,<NR90> (90 float values) // Load the final 90 points

These data points may then be loaded to an instrument or a specific phase with **DATA:LOAD** (all forms)

For the 9410 & 9420 (AC Modes): The waveshape will be the output voltage waveshape
For the 9430 (AC Outputs Normal Loading): The waveshape will be the output current waveshape

For all other operating modes: The waveshape does not apply.

DATA[:DATA]

Scope: SYSTEM Command and Query Models / Modes: All Models / AC Ouptuts Only

Command loads 90 points waveshape data buffer by quadrant

Query retrieves 90 points from the waveshape data buffer by quadrant

Related Commands: **DATA:LOAD** (all forms) is used to load the buffer into a USER defined waveshape.

For the 9410 & 9420 (AC Modes): The waveshape will be the output voltage waveshape
For the 9430 (AC Outputs Normal Loading): The waveshape will be the output current waveshape

For all other operating modes: The waveshape feature does not apply.

Command Parameters Q1 | Q2 | Q3 | Q4,<NR1>,<NR2>,<NR3> … ,<NR90> (90 float values)
Query Parameters Q1 | Q2 | Q3 | Q4
Query Returns <NR1>,<NR2>,<NR3> … ,<NR90> (90 float values)

DATA:LOAD[:ALL]
DATA:LOAD:APHase, BPHase, or CPHase

Scope: INSTRUMENT Command and Query Models / Modes: All Models / AC Ouptuts Only

Command loads the 360 data points from the DATA buffer into the specified USER waveform.

Query retrieves the 360 data points from the specified USER waveform into the DATA buffer.

Note: The system will not permit loading a new waveshape when the current waveshape is active.
Refer to **[SOURce:]FUNCtion** (all forms) for information about selecting a USER waveshape.

For the 9410 & 9420 (AC Modes): The waveshape will be the output voltage waveshape
For the 9430 (AC Outputs Normal Loading): The waveshape will be the output current waveshape

For all other operating modes: The waveshape feature does not apply.

ata values to the controller for use in defining an arbitrary waveform shape. A query will retrieve the waveform shape from the user memory location for reading with the DATA:DATA query. A return value of 1 indicates success in reading the waveform shape data from the controller and placing it in the DATA:DATA buffer. A return value of 0 indicates waveform shape data was not read from the controller. The query form DATA:LOAD? Returns the base channel for the selected instrument.

Command Parameters USER[1] | USER2 | USER3
Query Parameters USER[1] | USER2 | USER3
Query Returns 0 – Transfer of user waveshape into data buffer failed
1 – Transfer of user waveshape into data buffer succeeded

MACRo Subsection

Introduction

The 9400's MACRO allows for precise control over set operations which cannot be trusted to an external controller. Examples of use include (and are not limited to): Changing the output on a sub-cycle basis, after a specified number of cycles, or after a specified amount of time.

Macros should be carefully constructed as this method has direct access to all output channels.
In general, macro commands with a correct syntax will be accepted even when they are in conflict with the selected hardware mode. It is therefore important to review the similar [SOURce:]<function> command to ensure the operating mode is valid.

The commands in the following section will denote where the command can be targeted>

<inst> - Command may be targeted at the instrument or all instruments
<target> - Command may be targeted to an instrument, all instruments, or a specific channel.

Important Note: When targeting to ALL, all instruments will receive the same programmed value. This can generate an error or unexpected operation especially when the output is not configured for this mode of operation.

Important Note: Targeting a channel will affect the specific output channel directly without regard to the instrument or operating mode.

The typical macro sequence is constructed as shown:

```
MACRo:LEARn 1                          - Start Learning Process
MACRo:OPERation:VOLTage:INST1 200  - Set Instrument 1 to 200V
MACRo:WAIT:TIME 1                      - Wait one second
MACRo:OPERation:VOLTage:INST1 200  - Set Instrument 1 to 240V
(other macro commands)
MACRo:LEARn 0                          - End of Learning Process
```

The macro sequence is not learned by the module and may be executed using a **MACRo:RUN** (all forms).

MACRo:LEARn

Scope: SYSTEM command and query Models / Modes: All Models & Modes

Command controls the macro learning mode for the entire 9400 module.
Query returns the current macro learning mode state

When MACRo:LEARn is true, the 9400 records MACRo:<function> command in a buffer.

When MACRo:LEARn is false, the 9400 is in normal operation and ready for a **MACRo:RUN** (all forms)

Related Commands:

MACRo:RUN (all forms) = starts execution of the pre-loaded sequence
ABORt[:ALL] = stops the execution of a running macro
ABORt:MACRo = stops the execution of a running macro

Command Parameters <bool>
0 | FALSE | OFF = Stop the MACRo learning process
1 | TRUE | ON = Stop the MACRo learning process
Query Parameters None
Query Returns <bool>
0 | 1

MACRo:RUN[:ONCE]

Scope: SYSTEM command Models / Modes: All Models & Modes

Command starts the macro sequence recorded between MACRo:LEARn TRUE and MACRo:LEARn FALSE

The macro will execute one time and leave the hardware in the last operating condition contained within the macro

Command Parameters None

MACRo:RUN[:ONCE]:TRIGger

Scope: SYSTEM command Models / Modes: All Models & Modes

Command enables a macro sequence to run after receiving a trigger

When triggered, the macro will execute one time and leave the hardware in the last operating condition contained within the macro

Command Parameters None

MACRo:RUN:CONTinuous

Scope: SYSTEM command Models / Modes: All Models & Modes

Command starts the macro sequence recorded between MACRo:LEARn TRUE and MACRo:LEARn FALSE

Trigger source is selected before executing the macro using **TRIGger:SOURce**

The macro will execute in a loop continuously until a ***RST**, **ABORt[:ALL]**, or **ABORt:MACRo** is received.

Command Parameters None

MACRo:RUN:CONTinuous:TRIGger

Scope: SYSTEM command Models / Modes: All Models & Modes

Command enables a macro sequence to run after receiving a trigger

Trigger source is selected before executing the macro using **TRIGger:SOURce**

When triggered, the macro will execute in a loop continuously without requiring an additional trigger. This sequence continues until a ***RST**, **ABORt[:ALL]**, or **ABORt:MACRo** is received.

Command Parameters None

MACRo:MEASure:

A Macro is able to start a measurement at a precise location within the macro sequence.
Retreiving (or **FETCh:<measurement>**) is the responsibility for an external control program.

All **MACRo:MEASurement:<function>** commands are recorded and NOT executed until the macro is run.

Command within this section is counted as one (1) command toward the maximum number of command defined by **INSTrument:CAPabilities:MACRo:COMMand:MAXimum**.

MACRo:MEASure:INITiate:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, or **INST3**.

Command starts an aperture capture similar to **INITiate[:IMMediate]**

When <inst> is ALL: The 9400 will start an aperture measurement for all instruments
When <inst> is INSTn: The 9400 will start an aperture measurement for only Instrument "n".

Command Parameters None

MACRo:MEASure:TRIG:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, or **INST3**.

Command starts an triggered aperture capture similar to **INITiate:TRIGger[:IMMediate]**

When <inst> is ALL: The 9400 will start a triggered measurement for all instruments
When <inst> is INSTn: The 9400 starts a triggered measurement for only Instrument "n".

Command Parameters None

MACRo:MEASure:ENERgystar:<inst>

Scope: SYSTEM command Models / Modes: 9420 Only

<inst> must be **ALL**, **INST1**, **INST2**, or **INST3**.

Command starts an energy star measurement similar to sending
[SOURce:]CURRent:RANGe:ENERgystar followed by **INITiate[:IMMediate]:ENERgystar**

When <inst> is ALL: The 9400 will start a Energystar measurement for all instruments
When <inst> is INSTn: The 9400 starts a Energystar measurement for only Instrument "n".

Command Parameters <range>
Where LOW = LOW Energy Star measurement range
XLOW = Ultra-Low Energy Star measurement range

MACRo:MEASure:RESet:ALL:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, or **INST3**.

Command resets measurements similar to **MEASure:RESet[:ALL]**

When <inst> is ALL: The 9400 resets measurements for all instruments
When <inst> is INSTn: The 9400 resets measurements for only Instrument "n".

Command Parameters None

MACRo:MEASure:RESet:ENERgy:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, or **INST3**.

Command resets energy measurements similar to **MEASure:RESet:ENERgy**

When <inst> is ALL: The 9400 resets energy measurements for all instruments
When <inst> is INSTn: The 9400 resets energy measurements for only Instrument "n".

Command Parameters None

MACRo:MEASure:RESet:PEAKs:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, or **INST3**.

Command resets peak measurements similar to **MEASure:RESet:PEAKs**

When <inst> is ALL: The 9400 resets peak measurements for all instruments
When <inst> is INSTn: The 9400 resets peak measurements for only Instrument "n".

Command Parameters None

MACRo:NOTCh Commands

MACRo:NOTCh allows a simple way to produce a sub-cycle notching of the output voltage waveform

These commands are accepted by all modules in all modes however they can only affect the output of a 9410 or 9420 when operating with an AC output.

A NOTCh is comprised of for commands:

STARt:ANGLe = The angle of the cycle where the notch is to begin
STARt:VOLTage = The target voltage to slew to after reaching the start angle
STOP:ANGLe = The andle of the cycle where the notch is to end
STOP:VOLTage = The target voltage to slew to after reaching the stop angle

All four commands are required and are locally compiled by the 9400 into a single hardware command. Therefore the entire command sequence is counted as one (1) command toward the maximum number of command defined by **INSTrument:CAPabilities:MACRo:COMMand:MAXimum**.

MACRo:NOTCh:STARt or STOP:ANGLe:<target>

Scope: SYSTEM command Models / Modes: All Models & Modes

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes start (or stop) <angle> for a sub-cycle notch

When <target> is ALL: The 9400 apply the <angle> value to all instruments
When <target> is INSTn: The 9400 will apply the <angle> value to Instrument "n".
When <target> is CHANn: The 9400 will apply <angle> value to output channel "n".

Command Parameters <angle>

MACRo:NOTCh:STARt or STOP:VOLTage:<target>

Scope: SYSTEM command Models / Modes: All Models & Modes

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes start (or stop) <voltage> for a sub-cycle notch

When <target> is ALL: The 9400 apply the <voltage> value to all instruments
When <target> is INSTn: The 9400 will apply the <voltage> value to Instrument "n".
When <target> is CHANn: The 9400 will apply <voltage> value to output channel "n".

Command Parameters <voltage>

MACRo:OPERation Commands

MACRo operation commands are similar to [SOURce:]<function> allowing a precision sequence of commands to be issued in the order specified within the macro sequence.

Important Note: For <target> within this section: (ALL, INSTn, or CHANn):

ALL applies the same value to all instruments even when if invalid for one or more of the instruments
INSTn always sends the value to the selected instrument similar to INSTrumnet:NSELect n
CHANn always sends the value to the hardware channel regardless of CONFigure:HW:MODE setting.

When <target> is	For a 9410 (Mode 0: 3-ϕ)	For a 9410 (Mode 5: split-ϕ + AC)
ALL	INST 1	INST 1 & INST 3
INST1	INST1	INST 1
INST2	No Effect	No Effect
INST3	No Effect	INST 3
CHAN1	INST 1:APHase	INST 1:APHase
CHAN2	INST 1:BPHase	INST 1:BPHase
CHAN3	INST 1:CPHase	INST 3

MACRo:OPERarion commands are compiled into a single hardware macro command allowing multiple changes to occur simultaneously. This process continues until one of the following is received.

A command other than MACRo:OPERation is received
A command that affects the same physical output is received

The complied command from above is counted as one (1) command toward the maximum number of command defined by **INSTrument:CAPabilities:MACRo:COMMand:MAXimum**.

Important Note and example:

The sequence MACRO:OPERation:VOLT:INST1 208 followed by MACRo:OPERation:VOLT:CHAN3 100 will be either two commands or one command depending on the hardware mode selected.

Examples:

For a 9410 (Mode 0: 3-ϕ) The first command affects all three phases (208 line-line) and the second command affects Phase C (100V line-neutral). As this second command affects a previously programmed output, it is treated as a new hardware

For a 9410 (Mode 5: split-ϕ + AC) The first command affects the split phase instrument (208 line-line) and the second command affects the separate AC channel (100 line-neutral). As one one change occurs per output channel, both commands are compliled into the same command.

MACRo:OPERation:CURRent:<target>

Scope: SYSTEM command Models / Modes: All Models & Modes

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes the voltage limit similar to **[SOURce:]CURRent**

When <target> is ALL: The 9400 apply the current limit to all instruments
When <target> is INSTn: The 9400 will apply the current limit to Instrument "n".
When <target> is CHANn: The 9400 will apply the current limit to output channel "n".

IMPORTANT: Voltage is implemented the same way as **[SOURce:]CURRent**
For Multi-ϕ instrument: An INSTn target will be interpreted as a line-neutral current for all phases
A CHANn target operates similar to **[SOURce:]CURRent:<phase>**

For Single-ϕ or DC instruments: Always interpreted as a the line-neutral current

Command Parameters <NR1>

MACRo:OPERation:CF:<target>

Scope: SYSTEM command Models / Modes: All Models & Modes

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes the crest factor similar to **[SOURce:]CURRent:CF**

When <target> is ALL: The 9400 apply the crest factor to all instruments
When <target> is INSTn: The 9400 will apply the crest factor to Instrument "n".
When <target> is CHANn: The 9400 will apply the crest factor to output channel "n".

IMPORTANT: Operation is supported on a 9430 load configured for NORMal loading
For Multi-ϕ instrument: An INSTn target is interpreted similar to **[SOURce:]CURRent:CF**
A CHANn target is interpreted similar to **[SOURce:]CURRent:CF:<phase>**

For Single-ϕ or DC instruments: Always interpreted similar to **[SOURce:]CURRent:CF**

Command Parameters <NR1>

MACRo:OPERation:FREQuency:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command establishes the operating frequency similar to **[SOURce:]FREQuency**

When <inst> is ALL: The 9400 will apply the frequency limit to all instruments
When <inst> is INSTn: The 9400 will apply the frequency limit to Instrument "n".

Command Parameters <NR1>

MACRo:OPERation:PF:<target>

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes the power factor similar to **[SOURce:]CURRent:PF**

When <target> is ALL: The 9400 apply the power factor to all instruments
When <target> is INSTn: The 9400 will apply the power factor to Instrument "n".
When <target> is CHANn: The 9400 will apply the power factor to output channel "n".

IMPORTANT: Operation is supported on a 9430 load configured for NORMal loading
For Multi-ϕ instrument: An INSTn target is interpreted similar to **[SOURce:]CURRent:PF**
A CHANn target is interpreted similar to **[SOURce:]CURRent:PF:<phase>**

For Single-ϕ or DC instruments: Always interpreted similar to **[SOURce:]CURRent:PF**

Command Parameters <NR1>

MACRo:OPERation:POWer:<target>

Scope: SYSTEM command Models / Modes: All Models & Modes

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes the voltage limit similar to **[SOURce:]POWer**

When <target> is ALL: The 9400 apply the total true power limit for each instrument
When <target> is INSTn: The 9400 will apply the total true power limit to Instrument "n".
When <target> is CHANn: The 9400 will apply the true power limit to output channel "n".

IMPORTANT: Voltage is implemented the same way as **[SOURce:]POWer**
For Multi-ϕ instrument: An INSTn target will be interpreted as the total true power
A CHANn target operates similar to **[SOURce:]POWer:<phase>**

For Single-ϕ or DC instruments: Always interpreted as a the total true power

Command Parameters <NR1>

MACRo:OPERation:RESistance:<target>

Scope: SYSTEM command Models / Modes: All Models & Modes

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes the voltage limit similar to **[SOURce:]RESistance**

When <target> is ALL: The 9400 apply the resistance limit to each instrument
When <target> is INSTn: The 9400 will apply the resistance limit to Instrument "n".
When <target> is CHANn: The 9400 will apply the resistance limit to output channel "n".

IMPORTANT: Voltage is implemented the same way as **[SOURce:]RESistance**
For Multi-ϕ instrument: An INSTn target will be interpreted line-neutral resistance for all phases
A CHANn target operates similar to **[SOURce:]RESistance:<phase>**

For Single-ϕ or DC instruments: Always interpreted as resistance value line-neutral

Command Parameters <NR1>

MACRo:OPERation:RLIductance:<target>

Scope: SYSTEM command Models / Modes: All Models & Modes

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes the series inductance limit **[SOURce:]RL:INDuctance**

When <target> is ALL: The 9400 apply the series inductance limit to all instruments
When <target> is INSTn: The 9400 will apply the series inductance limit to Instrument "n".
When <target> is CHANn: The 9400 will apply the series inductance limit to output channel "n".

IMPORTANT: RL is a special loading mode supported by a properly configured 9430 only.
For Multi-ϕ instrument: An INSTn target is interpreted similar to **[SOURce:]RL:INDuctance**
A CHANn target is interpreted similar to **[SOURce:]RL:INDuctance:<phase>**

For Single-ϕ or DC instruments: Always interpreted similar to **[SOURce:]RL:INDuctance**

Command Parameters <NR1>

MACRo:OPERation:RLResistance:<target>

Scope: SYSTEM command Models / Modes: All Models & Modes

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes the series resistance limit **[SOURce:]RL:RESistance**

When <target> is ALL: The 9400 apply the series resistance limit to all instruments
When <target> is INSTn: The 9400 will apply the series resistance limit to Instrument "n".
When <target> is CHANn: The 9400 will apply the series resistance limit to output channel "n".

IMPORTANT: RL is a special loading mode supported by a properly configured 9430 only.
For Multi-ϕ instrument: An INSTn target is interpreted similar to **[SOURce:]RL:RESistance**
A CHANn target is interpreted similar to **[SOURce:]RL:RESistance:<phase>**

For Single-ϕ or DC instruments: Always interpreted similar to **[SOURce:]RL:RESistance**

Command Parameters <NR1>

MACRo:OPERation:SYNC:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command configures if following MACRo:OPERation:<Function> & [SOURCe:]<Function> commands are immediately or phase-angle controlled similar to **CONFigure:INSTrument:SYNchronous**

When <inst> is ALL: The 9400 will start a triggered measurement for all instruments
When <inst> is INSTn: The 9400 starts a triggered measurement for only Instrument "n".

This command also has an effect on the operation of **MACRo:WAIT:CYCLes:INST1, INST2, or INST3**

Related Command: **MACRo:SYNC:ANGLe:<inst>**

Command Parameters <BOOL>
0 | NO | FALSE | OFF = **MACRo:OPERation:<Function>** is immediate
1 | YES | TRUE | ON = **MACRo:OPERation:<Function>** at ϕ angle

MACRo:OPERation:VA:<target>

Scope: SYSTEM command Models / Modes: All Models & Modes

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes the voltage limit similar to **[SOURce:]POWer**

When <target> is ALL: The 9400 apply the total apparent power limit for each instrument
When <target> is INSTn: The 9400 will apply the total apparent power limit to Instrument "n".
When <target> is CHANn: The 9400 will apply the apparent power limit to output channel "n".

IMPORTANT: Voltage is implemented the same way as **[SOURce:]VA**

For Multi-ϕ instrument: An INSTn target will be interpreted as the total apparent power
A CHANn target operates similar to **[SOURce:]VA:<phase>**

For Single-ϕ or DC instruments: Always interpreted as a the total apparent power

Command Parameters <NR1>

MACRo:OPERation:VOLTage:<target>

Scope: SYSTEM command Models / Modes: All Models & Modes

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes the voltage limit similar to **[SOURce:]VOLTage**

When <target> is ALL: The 9400 apply the voltage limit to all instruments
When <target> is INSTn: The 9400 will apply the voltage limit to Instrument "n".
When <target> is CHANn: The 9400 will apply the voltage limit to output channel "n".

IMPORTANT: Voltage is implemented the same way as **[SOURce:]VOLTage**
For Multi-ϕ instrument: An INSTn target will be interpreted as line-line setting
A CHANn target operates similar to **[SOURce:]VOLTage:<phase>** (line-neutral)

For Single-ϕ or DC instruments: Always interpreted as a line-neutral setting

Command Parameters <NR1>

MACRo:OPERation:WAVeshape:<target>

Scope: SYSTEM command Models / Modes: All Models & Modes

<target> must be **ALL**, **INST1**, **INST2**, **INST3, CHAN1, CHAN2, or CHAN3**.

Command establishes the output waveshape <alias> similar to **[SOURce:]FUNCtion[:SHAPE]**

When <target> is ALL: The 9400 apply the waveshape <alias> to all instruments
When <target> is INSTn: The 9400 will apply the waveshape <alias> to Instrument "n".
When <target> is CHANn: The 9400 will apply the waveshape <alias> to output channel "n".

Command Parameters <alias> = waveshape alias
Where <alias> = STANDARD | USER1 | USER2 | USER3

MACRo:OUTPut Commands

MACRo:OUTPut:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command establishes the output state similar to **[SOURce:]OUTPut**

When <inst> is ALL: The output of all instruments will be turned either ON or OFF
When <inst> is INSTn: The output of Instrument "n" will be turned either ON or OFF

Command Parameters <BOOL>
0 | NO | FALSE | OFF = Disable instrument(s) and open output relay
1 | YES | TRUE | ON = Enable instrument(s) and close output relay

MACRo:PHASe Commands

MACRo:PHASe:ANGLe:BPHase

Scope: SYSTEM command Models / Modes: All Models & Modes

Command adjusts sets the <angle> of phase ϕ_B relative to ϕ_A similar to **[SOURce:]PHASe:ANGle:BPHase**

This command only applies to a 9410 or 9420 when operating with multi-ϕ (2-ϕ or 3-ϕ) outputs

Command Parameters <angle> = 0.0 to 359.999 degrees

MACRo:PHASe:ANGLe:CPHase

Scope: SYSTEM command Models / Modes: All Models & Modes

Command adjusts sets the <angle> of phase ϕ_C relative to ϕ_A similar to **[SOURce:]PHASe:ANGle:CPHase**

This command only applies to a 9410 or 9420 when operating with multi-ϕ (3-ϕ) outputs

Command Parameters <angle> = 0.0 to 359.999 degrees

MACRo:SYNC Commands

MACRo:SYNC:ANGLe:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command configures if synchronization <angle> in degrees similar to **[SOURce:]OUTPut:SYNC:ANGLe**

When <inst> is ALL: The 9400 the sync angle value is applied to all instruments
When <inst> is INSTn: The 9400 the sync angle value is applied to only Instrument "n".

Note: SYNC:ANGLe is also dependant on the initial state of **CONFigure:INSTumnet:SYNChronous** which or the current state if **MACRo:OPERation:SYNC** was processed during macro execution.

This command establishes the angle used for cycle counting (see: **MACRo:WAIT:CYCLes**)

Command Parameters <angle> = 0.0 to 359.999 degrees

MACRo:RANGe Commands

MACRo:RANGe:CURRent:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command configures the current <range> to either the lowest or highest range

LOW selects the lowest possible whereas HIGH selects the highest possible range returned by
INSTrument:CAPabilities:CURRent:RANGe:LIST:MAXimum

Note: This command differs from **[SOURce:]CURRent:RANGe** as the range is either LOW or HIGH

When <inst> is ALL: The new <range> (LOW | HIGH) is applied to all instruments
When <inst> is INSTn: The new <range> (LOW or HIGH) is applied to only Instrument "n".

Command Parameters <range>
LOW = Selects the lowest set & measurement range
HIGH = Selects the highest set & measurement range

MACRo:RANGe:VOLTage:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command configures the voltage <range> to either the lowest or highest range

LOW selects the lowest possible whereas HIGH selects the highest possible range returned by
INSTrument:CAPabilities:VOLTage:RANGe:LIST:MAXimum

Note: This command differs from **[SOURce:]VOLTage:RANGe** as the range is either LOW or HIGH

When <inst> is ALL: The new <range> (LOW | HIGH) is applied to all instruments
When <inst> is INSTn: The new <range> (LOW or HIGH) is applied to only Instrument "n".

Command Parameters <range>
LOW = Selects the lowest set & measurement range
HIGH = Selects the highest set & measurement range

MACRo:SLEW Commands

MACRo:SLEW:CURRent:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command configures the current <slew> rate to similar to **[SOURce:]CURRent:SLEW**

When <inst> is ALL: The new <slew> rate is applied to all instruments
When <inst> is INSTn: The new <slew> rate is applied to only Instrument "n".

Acceptable slew rate values must be either zero (the default slew rate) or a value between
INSTument:CAPabilities:CURRent:SLEW:MAXimum and MINmum

Command Parameters <SLEW>

MACRo:SLEW:FREQuency:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command configures the current <slew> rate to similar to **[SOURce:]FREQuency:SLEW**

When <inst> is ALL: The new <slew> rate is applied to all instruments
When <inst> is INSTn: The new <slew> rate is applied to only Instrument "n".

Acceptable slew rate values must be either zero (the default slew rate) or a value between
INSTument:CAPabilities:FREQuency:SLEW:MAXimum and MINmum

Command Parameters <SLEW>

MACRo:SLEW:POWer:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command configures the current <slew> rate to similar to **[SOURce:]POWer:SLEW**

When <inst> is ALL: The new <slew> rate is applied to all instruments
When <inst> is INSTn: The new <slew> rate is applied to only Instrument "n".

Acceptable slew rate values must be either zero (the default slew rate) or a value between
INSTument:CAPabilities:POWer:SLEW:MAXimum and MINmum

Command Parameters <SLEW>

MACRo:SLEW:RESistance:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command configures the current <slew> rate to similar to **[SOURce:]RESistance:SLEW**

When <inst> is ALL: The new <slew> rate is applied to all instruments
When <inst> is INSTn: The new <slew> rate is applied to only Instrument "n".

Acceptable slew rate values must be either zero (the default slew rate) or a value between **INSTument:CAPabilities:RESistance:SLEW:MAXimum and MINmum**

Command Parameters <SLEW>

MACRo:SLEW:PF:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command configures the power factor <slew> rate to similar to **[SOURce:]CURRent:PF:SLEW**

When <inst> is ALL: The new <slew> rate is applied to all instruments
When <inst> is INSTn: The new <slew> rate is applied to only Instrument "n".

Acceptable slew rate values must be either zero (the default slew rate) or a value between **INSTument:CAPabilities:CURRent:PF:SLEW:MAXimum and MINmum**

Command Parameters <SLEW>

MACRo:SLEW:PSHift:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command configures the relative phase angle <slew> rate to similar to **[SOURce:]PHASe:SLEW**

When <inst> is ALL: The new <slew> rate is applied to all instruments
When <inst> is INSTn: The new <slew> rate is applied to only Instrument "n".

Acceptable slew rate values must be either zero (the default slew rate) or a value between **INSTument:CAPabilities:PHASe:SLEW:MAXimum and MINmum**

Command Parameters <SLEW>

MACRo:SLEW:VOLTage:<inst>

Scope: SYSTEM command Models / Modes: All Models & Modes

<inst> must be **ALL**, **INST1**, **INST2**, **or INST3**

Command configures the voltage <slew> rate to similar to **[SOURce:]VOLTage:SLEW**

When <inst> is ALL: The new <slew> rate is applied to all instruments
When <inst> is INSTn: The new <slew> rate is applied to only Instrument "n".

Acceptable slew rate values must be either zero (the default slew rate) or a value between
INSTument:CAPabilities:VOLTage:SLEW:MAXimum and MINmum

Command Parameters <SLEW>

MACRo:WAIT Commands

MACRo:WAIT[:TIME]

Scope: SYSTEM command Models / Modes: All Models & Modes

Command sets a time delay in <seconds> before processing the next command

Acceptable slew rate values must be between zero and the value returned by
INSTument:CAPabilities:MACRo:DELay:MAXimum

Command Parameters <seconds>

MACRo:WAIT:CYCLes:INST1, INST2, or INST3

Scope: SYSTEM command Models / Modes: All Models & Modes

Command sets a number <cycles> to delay based on the selected instrument channel

A cycle is always treated as a crossing of the angle specified by **[SOURce:]OUTPut:SYNC:ANGLe** regardless of the state of **CONFigure:INSTrument:SYNCronous**.

Important Note: Consider the following macro example for both synchronous and immediate modes.

```
# Macro assume 9410 operating in 3-phase mode
MACRo:LEARn TRUE
MACRo:OPERation:VOLTage:ALL 208          # Set all 3 phases to 120V_RMS
MACRo:WAIT:CYCLes:INST1 1                # Wait one cycle
MACRo:OPERation:VOLTage:CHAN1 100    # Set APHase to 120V_RMS
MACRo:WAIT:CYCLes:INST1 1                # Wait one cycle
MACRo:LEARn FALSE
MACRo:RUN:CONTinous                  # Starts the macro for continuous playback.
```

When the system is synchrounous, the pattern alternates every two cycles as:
the set operation 208V occurs at cycle N
The wait:cycle waits until the crossing at N+1 and releases the next command
The set operation 100V occurs at cycle N+2
The wait:cycle waits until the crossing at N+3 and releases the next command (Continuous)
the set operation 208 occurs at cycle N+4 (and repeats the remaining steps

When the system is operating with an Immediate mode, the pattern alternates every cycle as:
the set operation 208V occurs at cycle N
The wait:cycle waits until the crossing at N+1 and processes Set Operation 100 (immediate)
The wait:cycle waits until the crossing at N+2 and processes Set Operation 208 (immediate)

Command Parameters <cycles>

MACRo:WAIT:SLEW

Scope: SYSTEM command Models / Modes: All Models & Modes

Command will causes a delay in processing macro command until ALL active slewing is complete.

Command Parameters None

MACRo:WAIT:TRIGger

Scope: SYSTEM command Models / Modes: All Models & Modes

Command will causes a delay in processing macro command until a trigger is received

Trigger source is selected before executing the macro using **TRIGger:SOURce**

Command Parameters None

MEASurement Features

Introduction

The 9400 provides two methods for taking measurements.

1. Aperature measurement
   All possible measurements are started with any of the MEASure or INITiate commands
   Hardware sets the Measurement In Progress bit in STATus:OPERation.
   Internal Digitizer captures for the time specified by SENSe:SWEep:APErature
   Measuring continues until the aperature time is complete (rounded up to the next zero crossing)
   The Measurement In Progress bit in STATus:OPERation is cleared
   Any measurement is now available using FETCh:<function>?

   If a MEASure:<function>? was used,
   the response is returned at the end of the Aperature time.
   MEASure:<function>? is equivalent to an INITiate followed by FETCh:<function>?

   Digitized voltage and current waveforms may be downloaded for further processing including Harmonics analysis, THD, etc. See the Aperature – Digitizer section for more details

2. Background measurement
   Background measurements are updated automatically and provide the last complete cycle values for Voltage, Current, Power, CF, PF, etc. The update rate depends on the instrument power channel configuration:
   AC Power Channels: at zero crossing of each channel
   DC Power Channels: every 3.3mS

   Background measurement also return accumulated values such as instaneous peak values (voltage/current/power) as well as accumulated energy terms (kWh/Ah).

   Note: Background measurements may be taken during an Aperature measurent.
   This measurement is affected by range changes including taking Energy Star Measurements.

Returned measurements will generally be dependent on the hardware operating mode and the measurement selected. See the next section for a description of relationship of returned values.

Returned Measurement Values

The 9400 may be configured in multiple modes some of which return differing measurement values depending on instrument model and the configured mode.

Refer to the CONFigure Subsection for more information about selecting hardware operating modes:

The following table applies to both aperture and background measurements

Hardware Mode	Instrument Measurment
DC Output Single Phase (1-φ)	Voltage reported as L-N Actual line currents A_{RMS}/A_{DC} Power (kW) Energy (Ah) Energy (kWh) Apparent Power (VA)

Hardware Mode	Instrument Measurement	Per Phase Measurement
Three Phase (3-φ)	Voltage reported as $V_{A\varphi\ l\text{-}n} \cdot \sqrt{3}$	Voltage reported as L-N per φ
	Average of line currents A_{RMS}/A_{DC}	Actual line currents A_{RMS}/A_{DC} per φ
Split Phase (2-φ)	Voltage shown as $V_{A\varphi\ l\text{-}n} + V_{B\varphi\ l\text{-}n}$	Voltage Shown as L-N per φ
(Note 1)	Average of line currents A_{RMS}/A_{DC}	Actual line currents A_{RMS}/A_{DC} per φ
Common Multi-φ	Total Power (kW)	Power (kW) per φ
	Total Energy (Ah)	Energy (Ah) per φ
	Total Energy (kWh)	Energy (kWh) per φ
	Total Apparent Power (VA)	Apparent Power (VA) per φ

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

Note 1: Split phase may be created using either a split-phase operating mode or in 3 phase mode by setting phase B to 0 ^{o} and phase C to 180^{o} with respect to phase A. In this case, Phase A & C should be used as the power outputs.

Using The Aperture Measurement Method

Measurements within this section are generally instrument commands and should be proceeded with either INSTrument:NSELect or INSTrument:SELect.

As described above, a new aperture measurement sequence may be started with either a MEASure:<function>? Or an INITiate:<TrigSource/function> command. It is important to note that the hardware measurement process will start each time either of these functions are called and will continue to measure until the time specified by SENSe:SWEep:APERture has elapsed.

When in AC mode, the actual aperture used will be a whole multiple of cycles where the number of cycles = aperture * Hz rounded UP to the next whole number.

After the new acquisition sequence completes, all measurements from the same aperture are available using the FETCh:<function>?.

For example:

INST:NSEL 1	// Selects Instrument 1 for measurement
SENS:SWE:APER 1	// Sets the measurement aperture for 1 second
INIT	// starts a new acquisition sequence
FETC:CF?	// returns the measured crest factor observed during 1 second aperture
MEAS:VOLT?	// starts a new acquisition sequence then returns the measured voltage (1s)
FETC:CURR?	// returns the measured current from the SAME acquisition as **voltage**.
FETC:POW?	// returns the measure true power from the SAME acquisition as **voltage**.
SENS:SWE:APER 0.5	// sets the measurement aperture for 0.5 second
MEAS:PF?	// starts a new acquisition sequence then returns the measured power factor
FETC:POW:APP?	// returns the measured apparent power (VA) from the SAME acquisition as **PF**

Aperture measurements may be aborted using either the ABORt[:ALL] or ABORt:TRIGger commands Refer to the TRIGger Subsystem for more information

Note: Use of INIT allows a measurement to be started and other commands to be executed while the measurement is in progress. The FETCh:<measurement> command should be sent after the measuring bit (bit 4) in the operation register is cleared. This bit is retrieved using the STATus:OPERation? query.

Aperture Measurement Commands

ABORt[:ALL]

SYSTEM command

This command resets the list and measurement trigger systems to the Idle state. Any list or measurement that is in progress is immediately aborted. ABORt also resets the WTG bit in the Operation Condition Status register. ABORt is executed at power turn-on and upon execution of *RCL, RST, or any implied abort command (see List Commands).

Command Parameters None

ABORt [: ALL]

Scope: SYSTEM command Models / Modes: All Models & Modes

See the Trigger

Macro Execution is stopped along clearing the assocated bits in the **STATus:OPERating** register
Measurements are halted as described in **ABORt:TRIGer** (below)

ABORt is executed at power turn-on as well upon execution of ***RCL** & ***RST**

Command Parameters None

ABORt:MACRo

SYSTEM command Models / Modes: All Models & Modes

Command stops any macro playback in progress. See Macro subsection.

Command Parameters None

ABORt:TRIGger

Scope: SYSTEM command Models / Modes: All Models & Modes

Command returns the measurement system to an IDLE state including:
Immediately halts all aperature measurements in progress
Resets Measuring bit (bit 4) in the **STATus:OPERating** register
Resets Waiting for Trig Bit (bit 5) in **STATus:OPERerating:CONditional** register

Command Parameters None

INITiate[:IMMediate][:MEASure]

Scope: INSTRUMENT command Models / Modes: All Models & Modes

Command starts an aperture measurement which will run for the time specified by the last received **SENSe:SWEep:APERture** instrument command

Command Parameters None

INITiate[:IMMediate]:ALL

Scope: SYSTEM command Models / Modes: All Models & Modes

Command starts an aperture measurement on all channels which will run for the time specified by the last received **SENSe:SWEep:APERture** instrument command

Command Parameters None

INITiate[:IMMediate]:ENERgystar[:ALL]

Scope: INSTRUMENT command Models / Modes: 9420 Only

Command starts an energy star measurement aperture measurement based on the range selected

Applies to 9420 ONLY

This initiate method instructs the 9420 to use the Energy Start ranges for current measurement. Measurement results are retrieved using the **FETCh:CURRent** and similar FETCh commands.

Refer to **[SOURce:]CURRent:RANGe:ENERgystar** for information about setting ranges.

Command Parameters None

INITiate:TRIGger[:MEASure]

Scope: INSTRUMENT command Models / Modes: All Models & Modes

Command enables the measurement aperture to wait for trigger event.

Command Parameters None

FETCh:CF

Scope: INSTRUMENT query Models / Modes: All Modesl / 1-ϕ AC

Query returns the crest factor measured during the aperature for the selected phase calculated as: maximum (CurrentPeakMax & CurrentPeakMin) / A_{rms}

CF is calculated per phase as the MAX(CurrentPeakMax & CurrentPeakMin) / A_{rms}

Note: This value is calculated and returned in all modes of operation but is only defined for AC per ϕ.

Refer to **FETCh:CH:<phase>** to query individual phases of a multi-phase output

Query Parameters None
Query Returns <NR1> | 1000000 = 1000000 returned when A_{rms} < 0.001

FETCh:CF:<phase>

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the crest factor measured during the aperature for the selected phase calculated as: maximum (CurrentPeakMax & CurrentPeakMin) / A_{rms}

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: This value is calculated and returned in all modes of operation but is only defined for AC per ϕ.

Query Parameters None
Query Returns <NR1> | 1000000 = 1000000 returned when A_{rms} < 0.001

FETCh:CURRent

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the average current (A_{RMS} or A_{DC}) measured during the aperture.

For DC outputs: Value is A_{dc}

For 1ϕ AC outputs: Value is $A_{rms\ line\text{-}neutral}$

In 2ϕ/3ϕ AC outputs: **FETCh:CURRent** returns the average of all phases in $A_{rms\ line\text{-}neutral}$
Refer to **FETCh:CURRent:<phase>** to query individual phases of a multi-phase output

Note: For AC Outputs, an alternate format, **FETCh:CURRent2** returns the measured DC current

Query Parameters None
Query Returns <NR1>

FETCh:CURRent:<phase>

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the average current (A_{RMS}) measured during the aperture for the specified phase.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: For AC Outputs, an alternate format, **FETCh:CURRent2:<phase>** returns measured DC current

Query Parameters None
Query Returns <NR1>

FETCh:CURRent:PEAK:MAXimum or MINimum

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the maximum or minimum instantaneous current observed during the aperture.

For DC outputs: The absolute maximum / minimum instantaneous current during the aperture

For 1ϕ AC outputs: The maximum current for any single cycle during the aperture

For 2ϕ/3ϕ AC outputs: Not sure what this is
Refer to **FETCh:CURRent:PEAK:MAXimum or MINimum:<phase>** to query individual phases

Query Parameters None
Query Returns <NR1>

FETCh:CURRent:PEAK:MAXimum or MINimum:<phase>

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the maximum or minimum instantaneous current observed for the selected phase.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Query Parameters None
Query Returns <NR1>

FETCh:PF

Scope: INSTRUMENT query Models / Modes: All Models / AC Outputs

Query returns the power factor measured during the aperture

In 2ϕ/3ϕ AC outputs:
Refer to **FETCh:PF:<phase>** to query individual phases of a multi-phase output

Note: This value is calculated as True Power / Apparent Power (W/VA) and only valid for AC outputs.

Query Parameters None
Query Returns <NR1>

FETCh:PF:<phase>

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the power factor measured on a the specified phase during the aperture

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Query Parameters None
Query Returns <NR1>

FETCh:POWer[:TRUE]

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the total true power in watts (W) measured during the aperture.

In 2ϕ/3ϕ AC outputs: Power is arithmetic sum of all phase powers
Refer to **FETCh:POWer[:TRUE]:<phase>** to query individual phases of a multi-phase output

Note: For AC Outputs, an alternate format, **FETCh:POWer2** returns the measured DC power

Query Parameters None
Query Returns <NR1>

FETCh:POWer[:TRUE]:<phase>

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the true power measured in watts (W) for the specified phase during the aperture.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: For AC Outputs, an alternate format, **FETCh:POWer2:<phase>** returns the measured DC power

Query Parameters None

Query Returns <NR1>

FETCh:POWer:POWer:PEAK:MAXimum or MINimum

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the maximum or minimum peak apparent power (VA) observed during the aperture.

For DC outputs: The absolute maximum / minimum instantaneous power during the aperture

For 1ϕ AC outputs: The maximum true power in watts (W) for any cycle during the aperture

In 2ϕ/3ϕ AC outputs: Not sure what this is
Refer to **FETCh:POWer:PEAK:MAXimum or MINimum<phase>** to query individual phases

Note: For AC Outputs, an alternate format, **FETCh:POWer2:APParent** returns the DC power

Query Parameters None
Query Returns <NR1>

FETCh:POWer:POWer:PEAK:MAXimum or MINimum:<phase>

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the maximum / minimum true power in watts (W) for any cycle on the selected phase.
For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Query Parameters None
Query Returns <NR1>

FETCh:POWer:APParent

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the total apparent power (VA) measured during the aperture.

In 2ϕ/3ϕ AC outputs: Power is arithmetic sum of all phase apparent powers
Refer to **FETCh:POWer:APParent:<phase>** to query individual phases of a multi-phase output

Note: For AC Outputs, an alternate format, **FETCh:POWer2:APParent** returns the DC power

Query Parameters None
Query Returns <NR1>

FETCh:POWer:APParent:<phase>

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the apparent power (VA) measured for the specified phase during the aperture.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: For AC Outputs, an alternate format, **FETCh:POWer2:APParent<phase>** returns the DC power

Query Parameters None
Query Returns <NR1>

FETCh:POWer:APParent:PEAK:MAXimum or MINimum

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the maximum or minimum peak apparent power (VA) observed during the aperture.

For DC outputs: The absolute maximum / minimum instantaneous power during the aperture

For 1ϕ AC outputs: The maximum apparent power for any cycle during the aperture

In 2ϕ/3ϕ AC outputs: Not sure what this is
Refer to **FETCh:POWer:APParent:PEAK:MAXimum or MINimum:<phase>** to query individual phases

Note: For AC Outputs, an alternate format, **FETCh:POWer2:APParent** returns the DC power

Query Parameters None
Query Returns <NR1>

FETCh:POWer:APParent:PEAK:MAXimum or MINimum:<phase>

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the maximum / minimum apparent power (VA) for any cycle on the selected phase

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Query Parameters None
Query Returns <NR1>

FETCh:VOLTage?

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the average voltage (V_{RMS} or V_{DC}) measured during the aperture.

For DC outputs: Value is V_{dc}

For 1ϕ AC outputs: Value is $V_{rms\ line\text{-}neutral}$

In 2ϕ AC outputs: **FETCh:VOLtage** returns the line-line voltage (arithmetic sum of both phases)

In 3ϕ AC outputs: **FETCh:VOLtage** returns the line-line equivalent voltage calculated as average of line-neutral voltages x √3

Note: For AC Outputs, an alternate format, **FETCh:VOLTage2** returns the measured DC voltage

Query Parameters None
Query Returns <NR1>

FETCh:VOLTage:<phase>

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the average voltage (V_{RMS}) measured during the aperture for the specified phase.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Note: For AC Outputs, an alternate format, **FETCh:VOLTage2:<phase>** returns measured DC current

Query Parameters None
Query Returns <NR1>

FETCh:VOLTage:PEAK:MAXimum or MINimum

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the maximum or minimum instantaneous voltage observed during the aperture.

For DC outputs: The absolute maximum / minimum instantaneous current during the aperture

For 1ϕ AC outputs: The maximum current for any single cycle during the aperture

For 2ϕ/3ϕ AC outputs: Not sure what this is
Refer to **FETCh:VOLTage:PEAK:MAXimum or MINimum:<phase>** to query individual phases

Query Parameters None
Query Returns <NR1>

FETCh:VOLTage:PEAK:MAXimum or MINimum:<phase>

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns the maximum or minimum instantaneous voltage observed for the selected phase.

For AC (1ϕ) & DC outputs: Query is invalid and responds with <ERROR -221>

For AC (2ϕ): a CPHase Query is invalid and responds with <ERROR -221>

Query Parameters None
Query Returns <NR1>

SENSe:SWEep:APERture

Scope: INSTRUMENT command and query Models / Modes: All Models & Modes

Command specified the measurement window time (aperture) in seconds.
Query returns the programmed measurement window time.

Value must be one of the following
-1 = one cycle
0 = Default aperture time for output mode
x = a value between **INSTrument:CAPabilities:APERture:MAXimum** and **MINimum**

Note: For AC outputs: Aperture time will be automatically rounded up to the next complete cycle

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

SENSe:SWEep:POINts

Scope: INSTRUMENT command and query Models / Modes: All Models & Modes

Command specified the maximum number of samples for the digitizer to save
Query returns the actual number of samples stored by the digitizer

The samples requested must be less than **INSTrument:CAPabilities:SAMPle:POINts:MAXimum**

Note: The number of samples actually captured is generally less than the requested maximum value. This value should be retrieved before downloading sample data using either **FETCh:ARRay:CURRent** (all forms) or **FETch:ARRay:VOLTage** (all forms)

Refer to the **Accessing the Digitizer** section for more information about downloading digitizer data.

Command Parameters <NR1>
Query Parameters None
Query Returns <NR1>

SENSe:SWEep:TINTerval?

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the time interval between samples (1 / sample rate) for the saved digitizer data.

Query Parameters None
Query Returns <NR1>

MEASure:<Measurement>
MEASure:<Measurement>:APHase? (or BPHase, or CPHase)

Scope: INSTRUMENT query Models / Modes: All Models & All Modes

MEASure:<Measurement> commands have the same format as a FETCh:<Measurement> command and is functionally equivalent to sending an INITiate (Type) followed by a FETCh:<Measurement>

MEASurement:<Measurement> Table

Measurement		INSTRUMENT QUERY	Equivalent function is INIT followed by
Crest Factor			
	(single ϕ)	MEASure:CF?	INIT;FETCh:CF?
	(per ϕ)	MEASure:CF:<phase>?	INIT;FETCh:CF:<phase>?
Current (A_{rms} for AC / A_{DC} for DC)			
	average	MEASure:CURRent?	INIT;FETCh:CURRent?
	per ϕ	MEASure:CURRent:<phase>?	INIT;FETCh:CURRent:<phase>?
Alternate Current Measurement – DC on AC and AC on DC (A_{DC} for AC / A_{rms} for DC)			
	average	MEASure:CURRent2?	INIT;FETCh:CURRent2?
	per ϕ	MEASure:CURRent2:<phase>?	INIT;FETCh:CURRent2:<phase>?
Current Peak Maximum / Minimum			
	1 ϕ or DC	MEASure:CURRent:MAXimum? MEASure:CURRent:MINimum?	INIT;FETCh:CURRent:MAXimum? INIT;FETCh:CURRent:MINimum?
	per ϕ	MEASure:CURRent:MAXimum:<phase>? MEASure:CURRent:MINimum:<phase>?	INIT;FETCh:CURRent:MAXimum:<phase>? INIT;FETCh:CURRent:MINimum:<phase>?
Power Factor (True Power / Apparent Power)			
	1 ϕ or DC	MEASure:PF?	INIT;FETCh:PF?
	per ϕ	MEASure:PF:<phase>?	INIT;FETCh:PF:<phase>?

MEASurement:<Measurement> Table Continued

Measurement		INSTRUMENT QUERY	Equivalent function is INIT followed by
True Power (W)			
	Total	MEASure:POWer[:TRUE]?	INIT;FETCh:POWer[:TRUE]?
	per ϕ	MEASure:POWer[:TRUE]:<phase>?	INIT;FETCh:POWer[:TRUE]:<phase>?
Peak Power Maximum / Minimum (peak power of any single cycle for AC / Instantaneous power for DC)			
	total	MEASure:POWer:PEAK:MAXimum? MEASure:POWer:PEAK:MINimum?	INIT;FETCh:POWer:APParent:PEAK:MAXimum? INIT;FETCh:POWer:APParent:PEAK:MINimum?
	per ϕ	MEASure:POWer:PEAK:MAXimum:<phase>? MEASure:POWer:PEAK:MINimum:<phase>?	INIT;FETCh:POWer:PEAK:MAXimum:<phase>? INIT;FETCh:POWer:PEAK:MINimum:<phase>?
Apparent Power (VA)			
	Total	MEASure:POWer:APParent?	INIT;FETCh:POWer:APParent?
	per ϕ	MEASure:POWer:APParent:<phase>?	INIT;FETCh:POWer:APParent:<phase>?
Peak Apparent Power Maximum / Minimum (Any single cycle for AC / Instantaneous power for DC)			
	1 ϕ or DC	MEASure:POWer:APParent:PEAK:MAXimum? MEASure:POWer:APParent:PEAK:MINimum?	INIT;FETCh:POWer:APParent:PEAK:MAXimum? INIT;FETCh:POWer:APParent:PEAK:MINimum?
	per ϕ	MEASure:POWer:APParent:PEAK:MAXimum:<phase>? MEASure:POWer:APParent:PEAK:MINimum:<phase>?	INIT;FETCh:POWer:APParent:PEAK:MAXimum:<phase>? INIT;FETCh:POWer:APParent:PEAK:MINimum:<phase>?

MEASurement:<Measurement> Table Continued

Voltage (Refer to FETCh:VOLTage for a description of the returned values)			
	average	MEASure:VOLTage?	INIT;FETCh:VOLTage?
	per ϕ	MEASure:VOLTage:<phase>?	INIT;FETCh:VOLTage:<phase>?
Alternate Voltage Measurement – DC on AC and AC on DC (A_{DC} for AC / A_{rms} for DC)			
	average	MEASure:VOLTage2?	INIT;FETCh:VOLTage2?
	per ϕ	MEASure:VOLTage2:<phase>?	INIT;FETCh:VOLTage2:<phase>?
Voltage Peak Maximum / Minimum			
	1 ϕ or DC	MEASure:VOLTage:MAXimum? MEASure:VOLTage:MINimum?	INIT;FETCh:VOLTage:MAXimum? INIT;FETCh:VOLTage:MINimum?
	per ϕ	MEASure:VOLTage:MAXimum:<phase>? MEASure:VOLTage:MINimum:<phase>?	INIT;FETCh:VOLTage:MAXimum:<phase>? INIT;FETCh:VOLTage:MINimum:<phase>?

Accessing the Digitizer

The digitized voltage and current waveform is available after first completing an **INITiate** (all forms) or a **MEASure** (all forms) command. Either command will start a new aperture measurement and sets measuring (bit 4) in the **STATus:OPERation** register. The measurement will continue to completion at which time the measuring (bit 4) will be cleared.

After the measurement is complete, the following queries provide useful information:

SENSe:SWEep:TINTerval = The time between sample values
SENSe:SWEep:POINts = The number of data points available

FETCh:ARRay:CURRent or VOLTage[:ALL]?

Scope: INSTRUMENT query Models / Modes: All Models / DC & 1-ϕ AC

Query returns an array containing the digitizer sample data for current or voltage.

Applies to DC and AC single phase modes only.
For multi-phase outputs use **FETch:ARRay:CURRent or VOLTage:<phase>**

An example of download digitizer data is included.

Send an "INITiate\n" command
Wait while (**STATus:OPERation?** & 0x10) is true
Query **SENSe:SWEep:POINts** and initialize a blank array (DLdata)
Loop while (length of (DLdata) < SENSe:SWEep:POINTs):
Query **FETCh:ARRay:VOLTage? <start index>** – where <start index> is lenth of (DLdata) array
Append response data to (DLdata) array.

Repeat the process for FETCh:ARRay:CURRent

NOTE: returns 3.40282347e+38 if data is not available or <start index> is past end of digitizer memory.

Query Parameters [<start index> [,<index increment>]]
<start index> is the zero-based index of the first point to fetch.
Defaults to 0.
<index increment> is determines the next sample returned. Defaults to 1.

Query Returns <sample 1>{... ,<sample n>}

FETCh:ARRay:CURRent or VOLTage:<phase>?

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query returns an array containing the digitizer sample data for current or voltage for a single phase.

Applies to multi-phase modes only.
For DC and AC single outputs use **FETch:ARRay:CURRent or VOLTage**

An example of download digitizer data is included.

Send an "INITiate\n" command
Wait while (**STATus:OPERation?** & 0x10) is true
Query **SENSe:SWEep:POINts** and initialize a blank array (DLdata)
Loop while (length of (DLdata) < SENSe:SWEep:POINTs):
Query **FETCh:ARRay:VOLTage:APHase? <start index>** – where <start index> is lenth of (DLdata) array
Append response data to (DLdata) array.

Repeat the process for FETCh:ARRay:CURRent:APHase or for other phases

NOTE: returns 3.40282347e+38 if data is not available or <start index> is past end of digitizer memory.

Query Parameters [<start index> [,<index increment>]]
<start index> is the zero-based index of the first point to fetch.
Defaults to 0.
<index increment> is determines the next sample returned. Defaults to 1.
Query Returns <sample 1>{... ,<sample n>}

MEASure:ARRay:CURRent or VOLTage[:ALL]?

Scope: INSTRUMENT query Models / Modes: All Models / DC & 1-ϕ AC

Query is functionally equivalent to sending an **INITiate** followed by a
FETch:ARRay:CURRent or VOLTage with a start index of zero (0).

Note: Retreiving the entire buffer may require additional FETCh:ARRay queries. For this reason and as no other operations are possible during this process, the preferred method is to use an **INITiate** / **FETch:ARRay** method described above.

Query Parameters None
Query Returns <sample 1>{... ,<sample n>}
NOTE: returns 3.40282347e+38 if <start index> is past the end of available data.

MEASure:ARRay:CURRent or VOLTage:<phase>?

Scope: INSTRUMENT query Models / Modes: All Models / Multi-ϕ AC

<phase> must be **APHase**, **BPHase**, or **CPHase**.

Query is functionally equivalent to sending an **INITiate** followed by a **FETch:ARRay:CURRent or VOLTage:<phase>** with a start index of zero (0).

Note: Retreiving the entire buffer may require additional FETCh:ARRay queries. For this reason and as no other operations are possible during this process, the preferred method is to use an **INITiate** / **FETch:ARRay** method described above.

Query Parameters None

Query Returns <sample 1>{... ,<sample n>}
NOTE: returns 3.40282347e+38 if <start index> is past the end of available data.

Background Measurements

The 9400 hardware is continuously making and updating measurements in the background. This method provides a quick method to return the latest single cycle readings.

Background measurements are updated and available

AC Power Channels: at zero crossing of each channel

DC Power Channels: every 3.3mS

FETCh:BACKground?

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the most recent measurements made by the hardware.

For DC outputs: These values are based on a 300Hz measurement window

For AC outputs: These values pertain to the full cycle.

An alternate form (FETCh:BACKground2) replaces Voltage (V_{RMS}) and Current (A_{RMS}) with V_{DC} and A_{DC}.

Query Parameters [<instrument number>]

1 | 2 | 3 = Instrument number default is currently selected instrument

Alternate Formats <output channel number>

CH1 | CH2 | CH3 = Physical output channel number regardless of Which instrument it is assigned to

Query Returns <NR1>,<NR1>,... representing:

Voltage, Current, Power, Frequency, Ampere Hour, Kilowatt Hour, Voltage Peak Min, Voltage Peak Max, Current Peak Min, Current Peak Max, True Power Peak Min, True Power Peak Max, Apparent Power

FETCh:BACKground:ALL?

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the most recent measurements made by the hardware.

For DC outputs: These values are based on a 300Hz measurement window

For AC outputs: These values pertain to the full cycle.
An alternate form (FETCh:BACKground2:ALL) replaces Voltage and Current with V_{DC} and A_{DC}.

Query Parameters [<instrument number>]
1 | 2 | 3 = Instrument number default is currently selected instrument
Alternate Formats <output channel number>
CH1 | CH2 | CH3 = Physical output channel number regardless of Which instrument it is assigned to
Query Returns <NR1>,<NR1>,... representing:
Voltage, Current, Power, Frequency, Ampere Hour, Kilowatt Hour, Voltage Peak Min, Voltage Peak Max, Current Peak Min, Current Peak Max, True Power Peak Min, True Power Peak Max, Apparent Power, KiloVolt AmpHour, Voltage AC only RMS Min one cycle, Voltage AC only RMS Max one cycle, Current AC only RMS Min one cycle, Current AC only RMS Max one cycle, True Power Min one cycle, True Power Max one cycle, Apparent Power Min one cycle, Apparent Power Max one cycle, Time Stamp,Power Factor, Crest Factor

FETCh:BACKground:DC?

Scope: INSTRUMENT query Models / Modes: All Models & Modes

Query returns the most recent DC measurements made by the hardware.

Query Parameters [<instrument number>]
1 | 2 | 3 = Instrument number default is currently selected instrument
Alternate Formats <output channel number>
CH1 | CH2 | CH3 = Physical output channel number regardless of Which instrument it is assigned to
Query Returns <NR1>,<NR2>
Where <NR1> = DC Voltage
<NR2> = DC Current

MEASure:RESet[:ALL]

Scope: INSTRUMENT command Models / Modes: All Models & Modes

Command is equivalent to sending both **MEASure:RESet:ENERgy** & **MEASure:RESet:PEAKs**.

Command resets all accumulated measurements for the selected instrument:

Ampere Hour, Kilowatt Hour, Voltage Peak Min, Voltage Peak Max, Current Peak Min, Current Peak Max, True Power Peak Min, True Power Peak Max, KiloVolt AmpHour, Voltage AC only RMS Min one cycle, Voltage AC only RMS Max one cycle, Current AC only RMS Min one cycle, Current AC only RMS Max one cycle, True Power Min one cycle, True Power Max one cycle, Apparent Power Min one cycle, Apparent Power Max one cycle

Command Parameters None

MEASure:RESet:ENERgy

Scope: INSTRUMENT command Models / Modes: All Models & Modes

Command resets all accumulated energy measurements for the selected instrument:

Ampere Hour, Kilowatt Hour, KiloVolt AmpHour

Command Parameters None

MEASure:RESet:PEAKs

Scope: INSTRUMENT command Models / Modes: All Models & Modes

Command resets all accumulated peak measurements for the selected instrument:

Voltage Peak Min, Voltage Peak Max, Current Peak Min, Current Peak Max, True Power Peak Min, True Power Peak Max, Voltage AC only RMS Min one cycle, Voltage AC only RMS Max one cycle, Current AC only RMS Min one cycle, Current AC only RMS Max one cycle, True Power Min one cycle, True Power Max one cycle, Apparent Power Min one cycle, Apparent Power Max one cycle

Command Parameters None

TRIGger & ABORt Controls

Trigger commands controls the triggering of the module. Chapter 3 under "Triggering Changes" provides an explanation of the Trigger System.

NOTE: The list and measurement commands must first be enabled using the INITiate commands or no action due to triggering will occur. This does not apply to transient triggers.

ABORt[:ALL]

Scope: SYSTEM command Models / Modes: All Models & Modes

Command is equivalent to sending both **ABORt:MACRo** & **ABORt:TRIGger**.

ABORt is executed at power turn-on as well upon execution of ***RCL** & ***RST**

Command Parameters None

ABORt:MACRo

Scope: SYSTEM command Models / Modes: All Models & Modes

Command resets the in the Program Running bit (bit 10) in **STATus:OPERerating:CONditional** register

Any executing MACRO is also halted leaving the output in the last active state

Command Parameters None

ABORt:SLEW

Scope: SYSTEM command Models / Modes: All Models & Modes

Command resets the Sweeping bit (bit 3) in the **STATus:OPERerating:CONditional** register

The output slew is halted leaving the output in the last active state

Command Parameters None

ABORt:TRIGger

Scope: SYSTEM command Models / Modes: All Models & Modes

Command returns the measurement system to an IDLE state including:
Immediately halts all aperature measurements in progress
Resets Measuring bit (bit 4) in the **STATus:OPERating** register
Resets Waiting for Trig Bit (bit 5) in **STATus:OPERerating:CONditional** register

Command Parameters None

TRIGger:AGENerate

Scope: SYSTEM command and query Models / Modes: All Models & Modes

Command controls the trigger out generation mode.
Query returns the trigger out generation mode enabled state.

When set the 9400 module will generate a trigger out signal for each programming operating change (i.e. new current, resistance, power, voltage, etc.).

Command Parameters <BOOL>
0 | OFF = Trigger out is NOT generated for each new operating command
1 | ON = Trigger out is pulsed for each new operating command
Query Parameters None
Query Returns <BOOL>
0 | 1

TRIGger:SOURce

Scope: SYSTEM command and query Models / Modes: All Models & Modes

Command selects the <trigger source> for measurement & macro starting triggers
Query returns the <trigger source> for the system.

Related Commands:
INITiate:TRIGger[:MEASure]
MACRo:RUN[:ONCE]:TRIGger

Command Parameters <trigger source>

IMMediate	= No trigger required – Procced immediatly
BUS	= Receipt of *TRG command over communication port
EXTernal	= Trigger input as trigger source
D0Rise | D0Fall	= Digital input 0 as source on rising or falling edge
CH1 | CH2 | CH3	= Zero crossing of selected output channel

Query Parameters None
Query Returns <trigger source>

LabVIEW™ Programming

Getting Started with LabVIEW™

Introduction

The AC/DC Power Module is a highly flexible piece of equipment. It can act as one or more AC sources, one or more DC sources, or nearly any combination. The configuration commands allow you to set up the power module to function as you desire.

Preparing the System

Copy the files

Referencing the Driver

Traverse the menu

Initializing the Driver

Open the I/O resource

Accessing Methods and Properties

View the vi collection

Destroying the Driver Instance

Call close

Programming Example

Reference sample code

IVI Programming

Getting Started with IVI

Introduction

The AC/DC Power Module is a highly flexible piece of equipment. It can act as one or more AC sources, one or more DC sources, or nearly any combination. The configuration commands allow you to set up the power module to function as you desire.

The NHR9400 IVI driver implements the IVI Foundation IviACPwr Class Specification (IVI-4.5, Rev. 1.2), along with extensions for the unique capabilities of the NHR9400 power module.

Types of IVI Drivers

The IVI Foundation defines two fundamental types of IVI drivers – IVI-COM drivers and IVI-C drivers. IVI-COM drivers are implemented using standard COM technology. Specifically, IVI-COM drivers support what are known as *custom* COM interfaces. To ensure compatibility with the broadest possible set of development environments, the IVI specifications restrict data types that can be used in an IVI-COM driver to a special set called *oleautomation* data types (also known simply as *automation* data types. Automation types were originally designed for Visual Basic but have since gained broad acceptance. Consequently, IVI-COM drivers can be used in a wide variety of development environments, namely, those that support custom oleautomation COM interfaces.

IVI-C drivers are simple DLLs that export C-based entry points. They use standard include (.h) files to define function signatures and attribute values.

Getting Help

The NHR IVI driver provides documentation in several formats for numerous integrated development environments (IDEs):

- HTML 1.0 help file (.chm) – This is a standalone help file that is used by nearly all IDEs except for Visual Studio. This file can be located in the IVI Foundation folders, usually located in:

  `C:\Program Files\IVI Foundation\IVI\Drivers\NHR9400`

- Microsoft Help Viewer help file (.cab) – This is a help file that is used by Visual Studio 2010 and later. It integrates with the Visual Studio local help so that driver help content appears alongside Visual Studio's own help content as well as the help content of other products that integrate with Visual Studio.

- IntelliSense – IVI drivers used within .NET programming languages, such as Visual C#, require a specially formatted XML file to present IntelliSense help as end users type code. In addition, type libraries are embedded into every IVI-COM driver. Object browsers and many COM-based environments, such as Visual Basic 6 and Visual C++, rely upon information in the type library for IntelliSense help-based features.

- IVI-C function panel help – IVI-C drivers use function panel files (.fp) and attribute files (.sub) to represent the hierarchy of functions and attributes. They also use these files to store help information for the IVI-C drivers. The help information embedded in .fp and .sub files is used by environments such as National Instruments® LabWindows™/CVI and LabVIEW®.

Getting Started with Visual Studio (.NET)

Introduction

Interop assemblies are used in .NET environments, such as C# and VB.NET, to access COM components. When installing an IVI-COM driver on a computer with the .NET Framework, the IVI specifications require an interop assembly be deployed and properly registered. The full path to the interop assemblies for NHR drivers is usually:

```
C:\Program Files\IVI Foundation\IVI\Bin\Primary Interop Assemblies
```

The actual assembly name is:

```
NHR.NHR9400.Interop.dll
```

The topics in this section provide detailed instructions on how to access and use IVI-COM drivers in C# and VB.NET.

Referencing the Driver

In order to access any of the instrument specific interfaces, a reference to the driver DLL must be created.

1. In the Solution Explorer, right-click on References and select "Add Reference."
2. Click the COM tab.
3. Select the following type library: `IVI NHR9400 1.0 Type Library`
   (Note: the version field may differ from the above example)
4. Press OK.

The selected driver should now appear under the References node in Solution Explorer. There will also be entries named `IviDriverLib` and `IviACPwrLib`.

All data types (interfaces and enumerations) are located under namespaces. Usually the namespace-qualified name must be used, but the "using" statement (C#) or "imports" statement (VB) allows the type name to be used directly.

C#:
```
using NHR.NHR9400.Interop;
```

VB:
```
Imports NHR.NHR9400.Interop
```

It is also quite likely that you will want to add entries for `IviDriverLib` and `IviACPwrLib` as well.

Creating an Instance of the Driver

To create a reference to the driver DLL, declare a variable of the driver type and create a new instance.

C#:
```
NHR9400Class driver = new NHR9400Class();
```

VB:
```
Dim driver as new NHR9400
```

Connecting

Calling "Initialize" will establish a connection to an instrument, or setup the driver to work in simulation mode. The first argument selects the desired instrument by "resource name" (stored in the IVI Configuration Store) or physical resource descriptor (like "TCPIP0::192.168.0.2::inst0::INSTR").

C#: `driver.Initialize("NHR9400", true, true, "QueryInstrStatus=true");`

VB#: `driver.Initialize("NHR9400", True, True, "QueryInstrStatus=true")`

Refer to the help documentation section titled "Initializing the IVI-COM Driver" for more information on the arguments for "Initialize."

Accessing Methods and Properties

Each set of capabilities is defined as a hierarchy of interfaces containing methods and properties.

To call a method:

C#: `driver.Utility.Reset();`

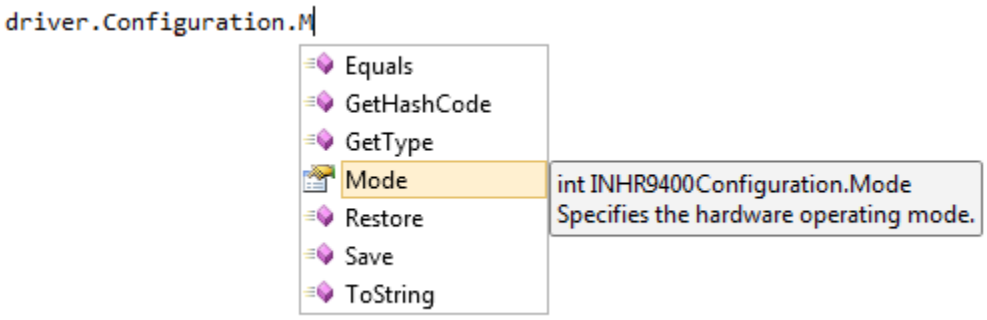
VB: `driver.Utility.Reset()`

To set the value of a property:

C#: `driver.Configuration.Mode = 0;`

VB: `driver.Configuration.Mode = 0`

The IntelliSense system will prompt you for valid selections as you type:



Hardware Mode

The organization of the channels is done by setting a "mode." 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.

There are two ways to specify the operating mode of the power module. The first (and most flexible) is to set the property directly in code using the "Mode" property:

C#: `driver.Configuration.Mode = 6; // Split-phase AC + independent DC`

VB: `driver.Configuration.Mode = 6 ' Split-phase AC + independent DC`

The second method is to specify the desired operation using the "DriverSetup" string in the call to "Initialize." The IVI Foundation IviACPwr section 2.3.4 states that the DriverSetup field can include a

"NumPhases:n" option. When this method is used, the driver automatically selects AC operation in the proper "mode" based on the number of phases requested. To set three-phase operation:

C#:
```
driver.Initialize("NHR9400", true, true, "QueryInstrStatus=true,
DriverSetup=NumPhases:3");
```

VB#:
```
driver.Initialize("NHR9400", True, True, "QueryInstrStatus=true
DriverSetup=NumPhases:3")
```

The following table illustrates the mode selection based on the value of "NumPhases":

"NumPhases"	1-Channel 9400	2-Channel 9400	3-Channel 9400
1	Mode 0	Mode 1	Mode 1
2	N/A	Mode 0	Mode 5*
3	N/A	N/A	Mode 0

Refer to the help documentation section titled "INHR9400Configuration.Mode Property" for descriptions of the various mode settings.

Accessing Instrument Channels

The NHR9400 IVI instrument implements the IVI Foundation IviACPwr instrument class. This class exposes four "output" objects. There is one object per channel, and one final object used to program all channels to the same setting.

The driver stores these objects in an array named "OutputPhases," and they can be accessed individually by name. By convention, the names of the objects are "PhaseA", "PhaseB", "PhaseC" and "AllPhases."

If you configured a 3-phase AC source, you would program the voltage of AC1 as follows:

C#:
```
driver.OutputPhases.Item("PhaseA").Voltage = 120.0; // Line-Neutral
```

VB#:
```
driver.OutputPhases.Item("PhaseA").Voltage = 120.0 ' Line-Neutral
```

Alternately, you could program all phases at the same time:

C#:
```
driver.OutputPhases.Item("AllPhases").Voltage = 208.0; // Line-Line
```

VB#:
```
driver.OutputPhases.Item("AllPhases").Voltage = 208.0 ' Line-Line
```

Note the potentially different behavior of the commands when sent to all channels compared to values sent to individual channels.

If you are using the driver in a DC-only mode (such as Mode 4), the channels are still referred to as "phases," where "PhaseA" is DC1, "PhaseB" is DC2, etc.

Destroying the Driver Instance

When you are finished with the driver, calling "Close" is required; simply releasing the driver object (setting the variable to "null") is not sufficient.

C#:
```
driver.Close();
```

VB:
```
driver.Close()
```

* Channel 3 is unused in this state

Programming Examples

There are five C# programming examples provided with the IVI driver. Each example is written around a different configuration "mode." IVI sample code is normally located in:

`C:\Program Files\IVI Foundation\IVI\Drivers\NHR9400\Examples`

The samples assume you have an entry named "NHR9430" in your IVI Configuration Store (use NI-MAX or other utility to add an entry).

- "1-Ph AC" uses `NumPhases:1` to configure the power module. A multi-channel instrument will have all the channels synchronized together.
- "2-Ph AC" uses `NumPhases:2` to configure the power module. You must have a 2- or 3-channel instrument to run this sample. The instrument will operate in a split-phase mode.
- "3-Ph AC" uses `NumPhases:3` to configure the power module. You must have a 3-channel instrument to run this sample.
- "1-Ch DC" uses `Configuration.Mode` to configure the power module. A multi-channel instrument will have all the channels synchronized together.
- "1-Ph AC + 1-Ch DC" uses `Configuration.Mode` to configure the power module into two logical instruments, one in AC mode and another in DC mode. You must have a 2- or 3-channel instrument to run this sample.

Getting Started with LabWindows™/CVI™

Introduction

The topics in this section provide detailed instructions on how to access and use IVI-C drivers in LabWindows™/CVI™.

Referencing the Driver

In order to access any of the instrument specific interfaces, a reference to the driver DLL must be created.

1. In the Edit menu, select "Add Files to Project", then "Instrument (*.fp)."
2. Browse to find the desired function panel (.fp), usually located in

   `C:\Program Files\IVI Foundation\IVI\Drivers\NHR9400`

   Select `NHR9400.fp`
3. Press "Add", then "OK."

The selected driver should now be added to your Project Tree, and appear under the Instruments folder in the Library Tree.

Initializing the Driver

Expand the NHR9400 node in the Instruments folder and drag an "init" function into the desired area of the source code. Calling "Init" will establish a connection to an instrument, or setup the driver to work in simulation mode. The first argument selects the desired instrument by "resource name" (stored in the IVI Configuration Store) or physical resource descriptor (like "TCPIP0::192.168.0.2::inst0::INSTR").

```
ViSession vi = 0;
ViRsrc resourceName = "NHR9430";
NHR9400_InitWithOptions(resourceName, VI_TRUE, VI_TRUE,
                        "QueryInstrStatus=true", &vi);
```

Refer to the help documentation section titled "Initializing the IVI-C Driver" for more information on the arguments for "Initialize."

After the Init call, the **vi** reference contains the instance of the driver, and is used as the **vi** input parameter of the remaining functions.

Accessing Methods and Properties

Each set of capabilities is defined as a hierarchy of interfaces containing methods and properties.

To call a "method":

```
NHR9400_reset(vi);
```

To set the value of a "property":

```
NHR9400_SetAttributeViBoolean(vi, "AllPhases", NHR9400_ATTR_OUTPUT_ENABLED, VI_TRUE);
```

The IntelliSense system will prompt you for valid selections as you type:

```
NHR9400_SetAttributeViBoolean(,,,);
? ViStatus NHR9400_SetAttributeViBoolean (ViSession Vi, ViConstString RepCapIdentifier, ViAttr AttributeID, ViBoolean AttributeValue)
```

Hardware Mode

The organization of the channels is done by setting a "mode." 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.

There are two ways to specify the operating mode of the power module. The first (and most flexible) is to set the property directly in code using the "Mode" property:

```
// Split-phase AC + independent DC
NHR9400_SetAttributeViInt32(vi, "AllPhases", NHR9400_ATTR_CONFIGURATION_MODE, 6);
```

The second method is to specify the desired operation using the "DriverSetup" string in the call to "Initialize." The IVI Foundation IviACPwr section 2.3.4 states that the DriverSetup field can include a "NumPhases:n" option. When this method is used, the driver automatically selects AC operation in the proper "mode" based on the number of phases requested. To set three-phase operation:

```
NHR9400_InitWithOptions(resourceName, VI_TRUE, VI_TRUE,
                  "QueryInstrStatus=true, DriverSetup=NumPhases:3", &vi);
```

The following table illustrates the mode selection based on the value of "NumPhases":

"NumPhases"	1-Channel 9400	2-Channel 9400	3-Channel 9400
1	Mode 0	Mode 1	Mode 1
2	N/A	Mode 0	Mode 5[†]
3	N/A	N/A	Mode 0

Refer to the help documentation section titled "NHR9400_ATTR_CONFIGURATION_MODE Attribute" for descriptions of the various mode settings.

Accessing Instrument Channels

The NHR9400 IVI instrument implements the IVI Foundation IviACPwr instrument class. This class exposes four "output" objects. There is one object per channel, and one final object used to program all channels to the same setting.

The driver stores these objects in an array named "OutputPhases," and they can be accessed individually by name. By convention, the names of the objects are "PhaseA", "PhaseB", "PhaseC" and "AllPhases."

If you configured a 3-phase AC source, you would program the voltage of AC1 as follows:

```
// Line-Neutral
NHR9400_SetAttributeViReal64(vi, "PhaseA", NHR9400_ATTR_VOLTAGE_LEVEL, 120.0);
```

Alternately, you could program all phases at the same time:

[†] Channel 3 is unused in this state

```
// Line-Line
NHR9400_SetAttributeViReal64(vi, "AllPhases", NHR9400_ATTR_VOLTAGE_LEVEL, 208.0);
```

Note the potentially different behavior of the commands when sent to all channels compared to values sent to individual channels.

If you are using the driver in a DC-only mode (such as Mode 4), the channels are still referred to as "phases," where "PhaseA" is DC1, "PhaseB" is DC2, etc.

Destroying the Driver Instance

When you are finished with the driver, calling "Close" is required; simply releasing the driver object (setting the variable to zero) is not sufficient.

```
/* clean up */
if (vi != 0)
      NHR9400_close(vi);
```

Programming Example

A complete sample of a program written in LabWindows/CVI is available in the examples folder. IVI sample code is normally located in:

```
C:\Program Files\IVI Foundation\IVI\Drivers\NHR9400\Examples
```

The sample assumes you have an entry named "NHR9430" in your IVI Configuration Store (use NI-MAX or other utility to add an entry), and requires a three-channel instrument to run.