Keysight Series N6700C Low-Profile Modular Power System

User's Guide

KEYSIGHT
TECHNOLOGIES

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Do not dispose in domestic household waste.

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WARNING	A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or DEATH. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.
CAUTION	A CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.
	Direct current
	Alternating current
	Frame or chassis terminal
	Standby supply. Unit is not completely disconnected from AC mains when switch is off.
	CAUTION Risk of electric shock
	CAUTION Refer to accompanying documents
	Earth ground terminal
	The CE mark is a registered trademark of the European Community.
	The ETL mark is a registered trademark of Intertek.
	The RCM mark is a registered trademark of the Spectrum Management Agency of Australia.
	South Korean Class A EMC Declaration This equipment has been conformity assessed for use in business environments. In a residential environment this equipment may cause radio interference. This EMC statement applies to the equipment only for use in business environments.

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이 기기는 업무용 환경에서 사용할 목적으로 적합성평가를 받은 기기로서
가정용 환경에서 사용하는 경우 전파간섭의 우려가 있습니다.

※ 사용자 안내문은 "업무용 방송통신기자재"에만 적용한다.

	Contains one or more of the 6 hazardous substances above the maximum concentration value (MCV), 40 Year EPUP.
ISM1-A	This text indicates that the instrument is an Industrial Scientific and Medical Group 1 Class A product (CISPER 11, Clause 4).
ICES/NMB-001	This text indicates product compliance with the Canadian Interference- Causing Equipment Standard (ICES-001).

Safety Notices

The following general safety precautions must be observed during all phases of operation of this instrument. Failure to comply with these precautions or with specific warnings or instructions elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Keysight Technologies assumes no liability of the customer's failure to comply with the requirements.

WARNING   General
Do not use this product in any manner not specified by the manufacturer. The protective features of this product may be impaired if it is used in a manner not specified in the operating instructions.

WARNING   Environmental Conditions
Never use the instrument outside of the specified environmental conditions described in the **Environmental Characteristics** of the specifications.

WARNING   Ground the Instrument
This product is provided with protective earth terminals. To minimize shock hazard, the instrument must be connected to the AC mains through a grounded power cable, with the ground wire firmly connected to an electrical ground (safety ground) at the power outlet. Any interruption of the protective (grounding) conductor or disconnection of the protective earth terminal will cause a potential shock hazard that could result in injury or death.

WARNING   Before Applying Power
Verify that all safety precautions are taken. All connections must be made with the unit turned off, and must be performed by qualified personnel who are aware of the hazards involved. Improper actions can cause fatal injury as well as equipment damage. Note the instrument's external markings described under "Safety Symbols".

WARNING   Some power modules generate voltages exceeding 60 VDC
Ensure that instrument connections, load wiring, and load connections are either insulated or covered so that no accidental contact with lethal output voltages can occur.

WARNING   Do Not Operate in an Explosive Atmosphere
Do not operate the instrument in the presence of flammable gases or fumes.

WARNING   Do Not Remove the Instrument Cover
Only qualified, service-trained personnel who are aware of the hazards involved should remove instrument covers. Disconnect the power cable and any external circuits before removing instrument covers.

WARNING   Do Not Modify the Instrument

Do not install substitute parts or perform any unauthorized modification to the product. Return the product to a Keysight Sales and Service Office for service and repair to ensure that safety features are maintained.

WARNING   Fuses

The instrument contains an internal fuse, which is not customer accessible.

WARNING   Cleaning

To prevent electric shock, always unplug the unit before cleaning. Use a dry cloth or one slightly dampened with water to clean the external case parts. Do not use detergent or chemical solvents. Do not attempt to clean internally.

WARNING   In Case of Damage

Instruments that are not functioning correctly, appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel.

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Legal and Safety Information

Introduction to the Instrument

Front Panel Menu Reference

Command Quick Reference

Models and Options

Specifications and Characteristics

This document includes user, service, and programming information for the Keysight N6700C Series Modular Power System .

Documentation and Firmware Revisions

You can download the latest version of this document at www.keysight.com/find/n6700-doc. The latest version is also available for mobile devices at www.keysight.com/find/n6700-mobilehelp. If you have feedback on this document, please contact Keysight at www.keysight.com/find/n6700-docfeedback.

This document describes firmware revision E.02.01 and up. For the latest firmware revision go to Firmware Updates in the Keysight N6700C Series Operating and Service Guide.

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Introduction to the Instrument

Features at a Glance

The Keysight N6700 Modular Power System is a configurable, one rack- unit (1U) platform that lets you mix and match power modules to create a power system optimized for your test system requirements.

Keysight N6700–N6702 MPS mainframes are available in power levels of 400 W, 600 W, and 1,200 W. Up to four power modules can be installed in each mainframe. Power modules come in power levels of 20 W through 500 W, have various voltage and current combinations, and provide the following performance features:

- **N673xB, N674xB, and N677xA DC Power Modules** provide programmable voltage and current, measurement, and protection features, making these economical models suitable for powering the device-under-test or system resources such as fixture controls.

- **N675xA High-Performance, Autoranging DC Power Modules** provide low noise, high accuracy, fast programming times, and advanced programming and measurement capabilities to speed test throughput.

- **N676xA Precision DC Power Modules** provide precise control and measurements in the milli- and micro-ampere region with the ability to simultaneously digitize voltage and current and capture those measurements into an oscilloscope-like data buffer.

- **N678xA Source/Measure Units (SMU)** have a multiple-quadrant power mesh with separate voltage and current priority source modes. These models are optimized for applications such as battery drain analysis and functional testing.

- **N6783A Application-Specific DC Power Modules** are two-quadrant low-wattage models spe-cifically designed for battery charging/discharging and mobile communications applications.

- **N679xA Electronic Load Modules** are single-quadrant 100 W and 200 W models having constant current, constant voltage, constant power, and constant resistance operating capabilities. They also provide many of the existing measurement and protection features of the other power mod-ules.

The output and system features are described in the following sections. Not all output features are available on every power module. The Model Differences section describes the features that apply only to specific power modules.

Output features

- **Programmable voltage, current, power, or resistance** - Full programming capability is provided for the entire range of output voltage and current for all power modules. Power and resistance pro-graming is available on Keysight N679xA load modules.

- **Low output noise** - Available on Keysight N676xA and N675xA power modules. Output noise is less than 4.5 mV peak-to-peak, which is comparable to linear supplies.

- **Arbitrary waveform generation** - This allows the output to act as a DC bias transient generator or an arbitrary waveform generator.

- **Fast up/down programming** - Available on Keysight N675xA, N676xA, and N678xA SMU power modules. Response time is less than 1.5 millisecond from 10% to 90% of the output rating.

- **Fast transient response** - Available on Keysight N675xA, N676xA, and N678xA SMU power modules. Transient response is less than 100 µs.

- **Output autoranging capability** - Available on Keysight N676xA and N675xA power modules. Autoranging supplies the maximum rated power over a continuous range of voltage and current settings

- **Output On/Off sequencing** - A turn-on/turn-off delay capability for each output allows output on/off sequencing.

- **Remote voltage sensing** - Two remote sensing terminals are provided for each output. When shipped, the remote sense jumpers are included in a separate bag. See Items Supplied.

- **Output protection** - Each output has over-voltage, over-current, and over-temperature protection. Over-voltage and over-current protection are programmable.

- **Multiple-Quadrant operation** - Available on Keysight N678xA SMU and N6783A power modules. 2- quadrant operation provides source and sink output capability. Keysight model N6784A offers 4- quadrant output operation.

- **Electronic Load operation** - Available on Keysight N679xA load modules. 100 W and 200 W input ratings are available.

Measurement features

- **Multiple-output/Single-output meter display** - Switch between a 4-output summary view and a 1-output detailed view of power system information. All power modules display real-time output voltage and current measurements as well as status information.

- **Seamless measurement autoranging** - Available on Keysight N678xA SMU power modules. Output measurements seamlessly autorange between ranges – however, the 10 µA current range must be selected manually.

- **Microampere current measurements** - Available on Keysight N6761A, N6762A, and N678xA SMU power modules. Current measurement can be made as low as 1 μA in the 10 μA range.

- **Fast Digitizing** Available on Keysight N678xA SMU power modules. 5.12 μs/sample for one parameter; 10.24 μs/sample for two parameters.

System features

- **Choice of three interfaces** - GPIB (IEEE-488), LAN, and USB remote programming interfaces are built in.

- **Built-in Web server** - A built-in Web server lets you control the instrument directly from an internet browser on your computer.

- **SCPI language** - The instrument is compatible with the Standard Commands for Programmable Instruments (SCPI).

- **Front panel I/O setup** - Menus let you set up GPIB and LAN parameters from the front panel.

- **Real-time status information** - The front panel indicates the status of each output. It also indicates when a protection shut-down has occurred.

- **Module identification** - Each module has identifying data stored in non-volatile memory. Information includes model number, serial number, and options.

- **Universal AC input** - Mainframes have universal input voltage capability with active power factor correction.

Front Panel at a Glance
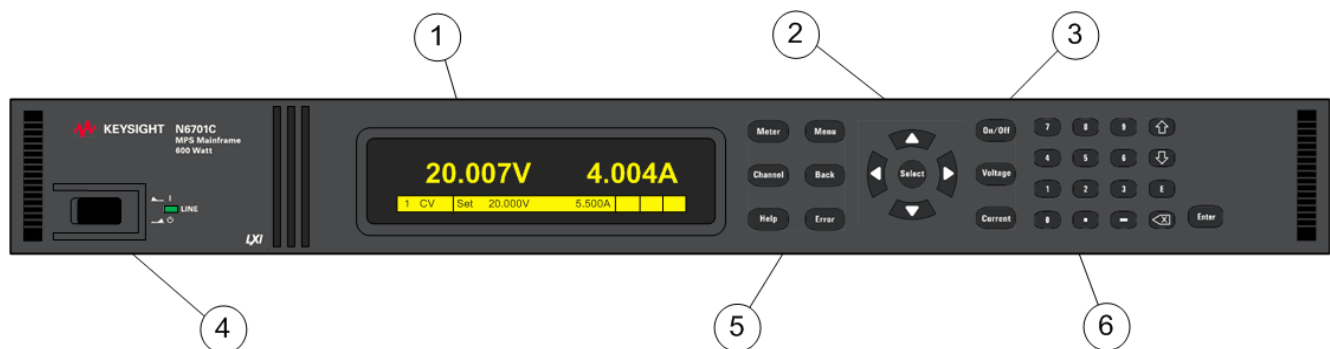
1. **Display** - Turns off after 1 hour of inactivity. Press any key to restore the display.

2. **Navigation keys** - Move the cursor to a menu item. Select the highlighted menu item.

3. **Output keys** - Turn the outputs on or off. Enter voltage or current.

4. **On/Off switch and LED** - LED indicates power is on. Green indicates normal operation. Amber indicates display is in screen-saver mode.

5. **System keys** - Toggle between single-channel and multiple-channel view. Access front panel command menu. Select an output channel to control.

6. **Numeric Entry keys** - Enter values. Arrow keys increment or decrement numeric settings.

Rear Panel at a Glance
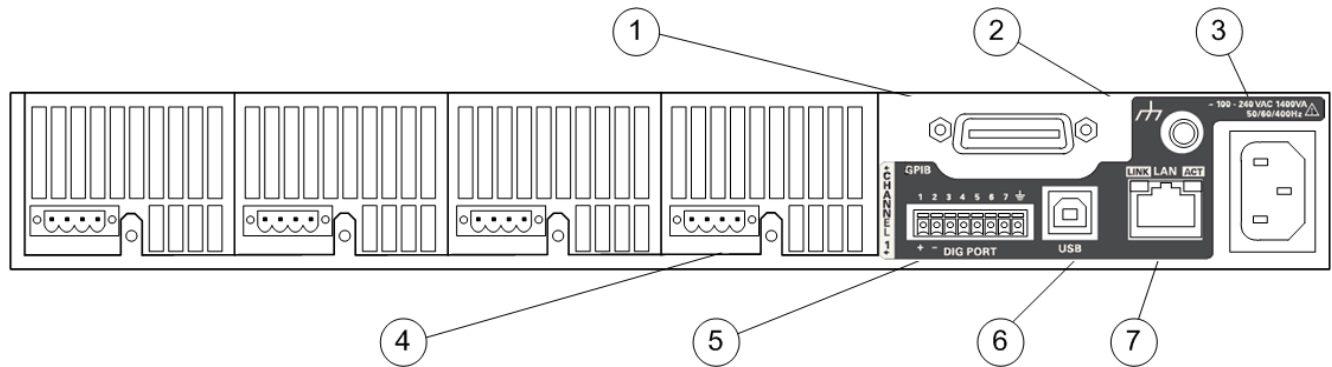
1. **GPIB** - GPIB interface connector.

2. **Ground** - Chassis ground binding post.

3. **IEC 320 connector** - AC input connector. Power cord requires a ground conductor.

4. **Output connector** - Includes +/–output and +/– sense terminals.

5. **Digital connector** - Pin functions are user-configurable.

6. **USB** - USB interface connector.

7. **LAN** - 10/100/1000 Base-T Left LED indicates activity. Right LED indicates link integrity.

> **WARNING** SHOCK HAZARD
> The power cord provides a chassis ground through a third conductor. Be certain that your power outlet is of the three-conductor type with the correct pin connected to earth ground.

Front Panel Display at a Glance

Voltage & Current View	Voltage measurement	Bar indicates output polarity is reversed	Current measurement

Press **Meter** to toggle between views

12.5230V̄   0.1789A

1 CV | Set: 12.523V   2.000A | | | IO

	Operating status (CV = constant voltage)	Voltage and current settings	Interface status (IO = activity on interface)

Voltage, Current, & Power View	Voltage measurement		Current measurement and power measurement

Press **Meter** to toggle between views

**12.5230V̄   0.179A
2.24W**

1 CV | Set: 12.523V   2.000A | | | IO

4-Channel View	Voltage and Current measurements

Press **Meter** to toggle between views

**12.523V̄ | 10.234V | 3.000V | 0.000V
0.179A | 0.341A | 0.200A | 0.000A**

1 CV | 2 CV | 3 CC | 4 OFF

The highlighted channel is the active channel

Grouped-Channel View	Channels 2 through 4 are connected in parallel and have been configured or grouped to act as a single, higher-power channel

Refer to **Output Groups** for more information
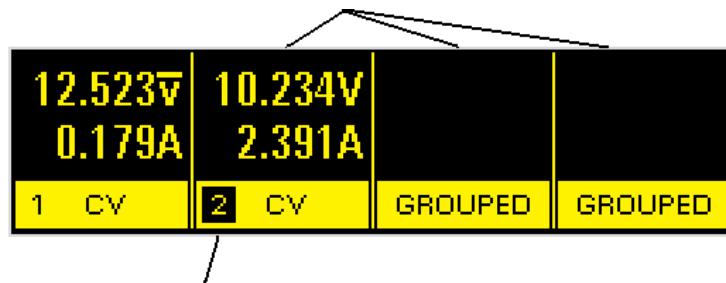
Grouped channels are addressed using the channel number of the lowest channel in the group

Double-Wide View	Channel 2 is a double-wide power module that occupies two channel locations in the mainframe
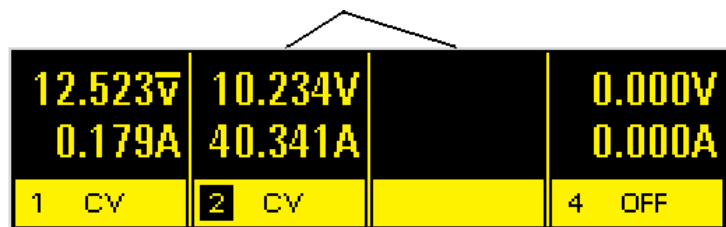
Operating status indicators	OFF = the output is off
	CV = the output is in constant voltage mode
	CC = the output is in constant current mode
	CP+ = the output is limited (or disabled) by the positive power limit
	CP– = the output is limited (or disabled) by the negative power limit
	VL+/– = the output is in positive or negative voltage limit mode
	CL+/– = the output is in positive or negative current limit mode
	OV = the output is disabled by the over-voltage protection
	OV– = the output is disabled by the negative over-voltage protection
	OC = the output is disabled by the over-current protection
	OT = the over-temperature protection has tripped
	PF = the output is disabled by a power-fail condition
	OSC = the output is disabled by the oscillation protection
	INH = the output is disabled by an external inhibit signal
	UNR = the output is unregulated
	PROT = the output is disabled by a condition from a coupled channel
	SH = the load input terminals are shorted (N679xA)
	UVI = an under-voltage inhibit condition occurred (N679xA)

Interface status indicators	Err = an error has occurred (press Error key to display error message)
	Lan = the LAN is connected and has been configured
	IO = there is activity on one of the remote interfaces

Front Panel Keys at a Glance
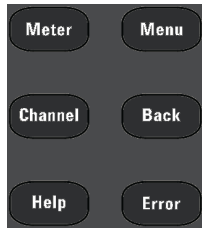
Meter returns the display to metering mode.
Menu accesses the command menu.
Channel selects or highlights a channel to control.
Back backs out of a menu without activating any changes.
Help accesses information about the displayed menu control.
Error displays any error messages in the error queue.
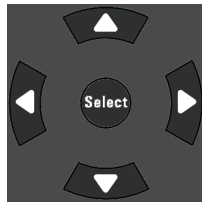
Arrows let you move around in the command menus.
Select lets you make a selection in the command menus. It also lets you enter edit mode for editing the numeric parameters.

On/Off controls the selected output (or all outputs when All is lit). This key is only active in Single- channel or Multiple-channel view.
Voltage lets you change the voltage setting.
Current lets you change the current setting.

The 0 through 9 keys enter numbers.
The (.) key is the decimal point.
The – key is used to enter a minus sign.
The ⬆⬇ arrow keys increment or decrement voltage or current settings. They also select letters in alphabetic entry fields.
The E key enters an exponent. Add the value to the right of the E.
The ⬅ back arrow key deletes digits as it backspaces over them.

The Enter key enters a value. If you exit a field without pressing the Enter key, the value is ignored.

Front Panel Menu Reference

Press the **Menu** key to access the front panel menus. For a brief tutorial, refer to Use the Front Panel Menu. If a menu item is grayed-out, it is not available for the module that is being programmed.

1st Menu Level	2nd Level	3rd & 4th Levels		Description
Output	Settings	Voltage		Programs the voltage setting, limits, and ranges
		Current		Programs the current setting, limits, and ranges
		Power		Programs the power limit on models N679xA loads
		Resistance		Programs the resistance setting on N679xA loads Programs output resistance on N6781A, N6785A
	Mode			Selects voltage, current, resistance, or power priority modes on N678xA SMU, N679xA
	Sequence	Delay		Programs Turn-on /Turn-off delay
		Couple		Couples output channels for output on/off synchronization
	Short			Programs an input short on models N679xA loads
	Advanced	Slew	Current	Programs current slew rate on models N678xA SMU, N679xA
			Voltage	Programs voltage slew rate
			Power	Programs power slew rate on models N679xA loads
			Resistance	Programs resistance slew rate on models N679xA loads
		Pol		Reverses the polarity of the output and sense terminals
		Bandwidth		Programs output bandwidth on N678xA SMU, N679xA
		UVI		Configures under-voltage inhibit on N679xA loads
		Tmode		Programs turn-on/turn-off impedance on N678xA SMU
Measure	Range			Selects voltage and current measurement range
	Sweep			Specifies measurement points, time interval, trigger offset
	Window			Selects measurement window: Rectangular, Hanning
	Input			Selects Auxiliary voltage input on N6781A, N6785A
	Control			Lets you abort a measurement in progress
Transient	Mode			Selects voltage, current, resistance, or power transient modes
	Step			Specifies the triggered step values
	List	Pace		Specifies Dwell or Trigger paced list

1st Menu Level	2nd Level	3rd & 4th Levels		Description
		Repeat		Specifies number of list repetitions or continuous list
		Terminate		Specifies list settings when the list terminates
		Config		Configures voltage, current, resistance, or power list settings
		Reset		Aborts the list and resets all list parameters
	Arb	Repeat		Specifies the number of times the Arb repeats
		Terminate		Specifies the settings when the Arb terminates
		Function		Selects the Arb type and shape
		Config	Step	Specifies the Step level and time
			Ramp	Specifies the Ramp level and time
			Stair	Specifies the Staircase level and time
			Sine	Specifies the Sine parameters
			Pulse	Specifies the Pulse level and time
			Trap	Specifies the Trapezoid level and time
			Exp	Specifies the Exponent parameters
			CD	Specifies the Constant-Dwell parameters
	TrigSource			Specifies the transient and Arb trigger sources
	Control			Initiates, Triggers, or Aborts triggers; displays trigger state
Protect	OVP			Configures over-voltage protection function
	OCP			Configures over-current protection function
	OPP			Configures over-power protection function
	OT			Returns the over-temperature protection margin
	Inh			Configures the external inhibit signal
	Coupling			Disables ALL output channels for a protection fault
	Wdog			Configures the output watchdog timer
	Osc			Enables/disables oscillation protection on N678xA SMU
	Clear			Clears protection conditions and displays output status
States	Reset			Resets all instrument settings to the reset (*RST) state
	SaveRecall			Saves and recalls instrument settings
	PowerOn			Selects the power-on instrument state

1st Menu Level	2nd & 3rd Levels		4th & 5th Levels		Description
System	IO	LAN	Settings		Displays the LAN settings that are presently active
			Modify	IP	Configures the IP addressing of the instrument
				Name	Configures the hostname of the instrument
				DNS	Configures the DNS server
				mDNS	Configures the mDNS service name
				Services	Selects the LAN services to enable or disable
			Apply		Applies the configuration changes and restarts
			Cancel		Cancels the configuration changes
			Reset		Performs an LXI LCI reset of LAN settings and restarts
			Defaults		Resets the network to the as-shipped defaults and restarts
		USB			Displays the USB identification string
		GPIB			Selects the GPIB address
		DigPort	Pins		Programs the digital pin's function and polarity
			Data		Sends/reads data from the digital I/O port
	Groups				Defines output channels that are grouped (paralleled)
	Preferences		Display	Contrast	Configures the display contrast from 0 to 100%
				Saver	Configures the screen saver and wake-on I/O timer
				View	Specifies the channel-view at turn-on
			Keys		Enables/disables key clicks and configures the On/Off key
			Lock		Locks front panel keys using a password
			IDN		Change manufacturer and model for backward compatibility
	Admin		Login/Logout		Enter a password to access the Admin functions
		Cal	Volt	Vprog	Configures High and Low voltage ranges
				Vlim	Calibrates voltage limit High and Low ranges
				Vmeas	Calibrates High, Low, Aux voltage measurement ranges
			Curr	Iprog	Calibrates High and Low current ranges
				Ilim	Calibrates current limit
				Imeas	Calibrates High and Low current measurement ranges
			Misc	CMRR	Calibrates common mode rejection ratio

1st Menu Level	2nd & 3rd Levels	4th & 5th Levels	Description
		Dprog	Calibrates the downprogrammer
		Ipeak	Calibrates I peak
		Resistance	Calibrates output resistance - all ranges
		Count	Returns the calibration count
		Date	Saves the calibration date for each channel
		Save	Saves the calibration data
	IO		Enables/disables the GPIB, USB, and LAN services
	Sanitize		Performs NISPOM secure erase of all user data
	Update		Password protect firmware updates
	Password		Changes the password for the admin functions
	About	Frame	Displays model, output ratings, serial number, firmware
		Module	Displays model, serial number, options, output ratings

Command Quick Reference

Some [optional] commands have been included for clarity. All settings commands have a corresponding query.

ABORt	(ACQuire and ELOG commands only on N676xA, N678xA SMU, Option 054)
:ACQuire (@chanlist)	Cancels any triggered measurements.
:ELOG (@chanlist)	Stops external data logging.
:TRANsient (@chanlist)	Cancels any triggered actions.
CALibrate	
:COUNt?	Returns the number of times the unit has been calibrated.
:CURRent	
[:LEVel] <*value*>, (@channel)	Calibrates the current programming.
:LIMit	
:NEGative <*value*>, (@channel)	Calibrates the negative current limit. (N678xA SMU, N6783A-BAT)
:POSitive <*value*>, (@channel)	Calibrates the positive current limit. (N678xA SMU, N6783A, N679xA)
:MEASure <*value*>, (@channel)	Calibrates the current measurement.
:PEAK (@channel)	Calibrates the peak current limit. N675xA, N676xA)
:DATA <*value*>	Enters the calibration value read by the external meter.
:DATE <*"date"*>, (@channel)	Stores the calibration date in nonvolatile memory.
:DPRog (@channel)	Calibrates the current downprogrammer.
:LEVel P1|P2|P3	Advances to the next level in the calibration.
:PASSword <*value*>	Sets a numeric password to prevent unauthorized calibration.
:RESistance 20|6, (@channel)	Calibrates the output resistance. (N6781A, N6785A)
:SAVE	Saves the calibration constants in non-volatile memory.
:STATe 0|OFF|1|ON	Enables/disables calibration mode.
:VOLTage	
[:LEVel] <*value*>, (@channel)	Calibrates the voltage programming.
:CMRR, (@channel)	Calibrates the voltage common mode rejection ratio. (N675xA, N676xA)
:LIMit	
:POSitive <*value*>, (@channel)	Calibrates the positive current limit. (N678xA SMU)
:MEASure <*value*>, (@channel)	Calibrates the voltage measurement.
:AUXiliary, (@channel)	Calibrates the auxiliary voltage measurement. (N6781A, N6785A)
DISPlay	
[:WINDow]	
[:STATe] 0|OFF|1|ON	Turns the front panel display on or off.
:CHANnel <channel>	Selects the channel in 1-channel view.
:VIEW METER1|METER4|METER_VIP	Selects 1-channel, 4-channel, or 1 channel with power view.

1 Quick Reference

FETCh   (FETCh commands only on N676xA, N678xA SMU, Option 054)

  [:SCALar]

    :CURRent

      [:DC]? (@chanlist)   Returns the averaged measurement.

      :ACDC? (@chanlist)   Returns the RMS measurement (AC + DC).

      :HIGH? (@chanlist)   Returns the High level of a pulse waveform.

      :LOW? (@chanlist)   Returns the Low level of a pulse waveform.

      :MAXimum? (@chanlist)   Returns the maximum value.

      :MINimum? (@chanlist)   Returns the minimum value.

    :POWer

      [:DC]? (@chanlist)   Returns the averaged measurement. (N676xA, N678xA SMU)

      :MAXimum? (@chanlist)   Returns the maximum value.

      :MINimum? (@chanlist)   Returns the minimum value.

    :VOLTage

      [:DC]? (@chanlist)   Returns the averaged measurement.

      :ACDC? (@chanlist)   Returns the RMS measurement (AC + DC).

      :HIGH? (@chanlist)   Returns the High level of a pulse waveform.

      :LOW? (@chanlist)   Returns the Low level of a pulse waveform.

      :MAXimum? (@chanlist)   Returns the maximum value.

      :MINimum? (@chanlist)   Returns the minimum value.

  :ARRay

    :CURRent

      [:DC]? (@chanlist)   Returns an array with the instantaneous measurement.

    :POWer

      [:DC]? (@chanlist)   Returns an array with the instantaneous measurement. (N676xA, N678xA SMU)

    :VOLTage

      [:DC]? (@chanlist)   Returns an array with the instantaneous measurement.

  :ELOG? ‹*value* (@chanlist)   Returns the most recent external datalog records.

FORMat

  [:DATA] ASCII | REAL   Specifies the format of the returned data.

  :BORDer NORMal | SWAPped   Specifies how binary data is transferred.

HCOPy

  :SDUMp

    :DATA?   Returns an image of the front panel display.

    :DATA

      :FORMat BMP|GIF|PNG   Specifies the format for front panel images returned.

IEEE 488.2 Common Commands

*CLS   Clears status.

*ESE ‹*value*›   Sets standard event status enable.

*ESR?	Returns event status register.
*IDN?	Returns instrument identification.
*LRN?	Returns a sequence of SCPI commands.
*OPC	Enables "operation complete" bit in ESR.
*OPC?	Returns a 1 when all pending operations complete.
*OPT?	Returns option number.
*RCL *‹value›*	Recalls a saved instrument state.
*RDT?	Returns output channel descriptions.
*RST	Resets the instrument.
*SAV *‹value›*	Saves an instrument state.
*SRE *‹value›*	Sets service request enable register.
*STB?	Returns the status byte.
*TRG	Generates a trigger.
*TST?	Performs a self-test, then returns results.
*WAI	Pauses command processing until all device commands are done.

INITiate   (ACQuire and ELOG commands only on N676xA, N678xA SMU, Option 054)
   [:IMMediate]
      :ACQuire (@chanlist)   Initiates the measurement trigger system.
      :ELOG (@chanlist)   Initiates external data logging.
      :TRANsient (@chanlist)   Initiates the transient trigger system.
   :CONTinuous
      :TRANsient 0|OFF|1|ON, (@chanlist)   Continuously initiates the transient trigger system.

LXI
   :IDENtify
      [:STATe] 0|OFF|1|ON   Turns the front panel LXI identify indicator on or off.
   :MDNS
      [:STATe] 0|OFF|1|ON   Controls the state of the mDNS server.

MEASure
   [:SCALar]
      :CURRent
         [:DC]? (@chanlist)   Takes a measurement; returns the averaged current.
         :ACDC? (@chanlist)   Takes a measurement; returns the RMS current (AC + DC).
         :HIGH? (@chanlist)   Takes a measurement; returns the High level of a current pulse.
         :LOW? (@chanlist)   Takes a measurement; returns the Low level of a current pulse.
         :MAXimum? (@chanlist)   Takes a measurement; returns the maximum current.
         :MINimum? (@chanlist)   Takes a measurement; returns the minimum current.
      :POWer
         [:DC]? (@chanlist)   Takes a measurement; returns the averaged power. (N676xA, N678xA SMU)
         :MAXimum? (@chanlist)   Takes a measurement; returns the maximum power.
         :MINimum? (@chanlist)   Takes a measurement; returns the minimum power.

:VOLTage

    [:DC]? (@chanlist)   Takes a measurement; returns the averaged voltage.

    :ACDC? (@chanlist)   Takes a measurement; returns the RMS voltage (AC + DC).

    :HIGH? (@chanlist)   Takes a measurement; returns the High level of a voltage pulse.

    :LOW? (@chanlist)   Takes a measurement; returns the Low level of a voltage pulse.

    :MAXimum? (@chanlist)   Takes a measurement; returns the maximum voltage.

    :MINimum? (@chanlist)   Takes a measurement; returns the minimum voltage.

:ARRay   (ARRay commands only on N676xA, N678xA SMU and Option 054)

  :CURRent

    [:DC]? (@chanlist)   Takes a measurement; returns the instantaneous current.

  :POWer

    [:DC]? (@chanlist)   Takes a measurement; returns the instantaneous power. (N676xA, N678xA SMU)

  :VOLTage

    [:DC]? (@chanlist)   Takes a measurement; returns the instantaneous voltage.

OUTPut

  [:STATe] 0|OFF|1|ON [,NORelay], (@chanlist)   Enables/disables the output.

    :COUPle

      [:STATe] 0|OFF|1|ON   Enables/disables output coupling.

      :CHANnel [<*value*>, {<*value*>}]   Selects which channels are coupled.

      :DOFFset <*value*>   Sets a delay offset to synchronize coupled output state changes.

        :MODE AUTO|MANual   Specifies the output delay offset coupling mode.

      :MAX

        :DOFFset?   Returns the delay offset required for this instrument.

    :DELay

      :FALL <*value*>, (@chanlist)   Sets the output turn-off sequence delay.

      :RISE <*value*>, (@chanlist)   Sets the output turn-on sequence delay.

    :PMODE VOLTage|CURRent, (@chanlist)   Sets the mode for turn-on/off transitions. (N6761A, N6762A)

    :TMODE HIGHz|LOWZ, (@chanlist)   Specifies the turn-on/turn-off impedance. (N678xA SMU)

  :INHibit

    :MODE LATChing|LIVE|OFF   Sets the operating mode of the remote inhibit digital pin.

  :PON

    :STATe RST|RCL0   Set the output power-on state.

  :PROTection

    :CLEar (@chanlist)   Resets the latched protection.

    :COUPle0|OFF|1|ON   Enables/disables channel coupling for protection faults.

    :DELay <*value*>, (@chanlist)   Sets the over-current protection programming delay.

    :OSCillation0|OFF|1|ON, (@chanlist)   Enables/disables output oscillation protection. (N678xA SMU)

    :TEMPerature

      :MARGin? (@chanlist)   Returns the margin remaining before the over-temperature trips.

    :WDOG

      [:STATe] 0|OFF|1|ON   Enables/disables the I/O watchdog timer.

      :DELay <*value*>   Sets the watchdog delay time.

:RELay

  :POLarity NORMal|REVerse, (@chanlist)   Sets the polarity of the output relays. (Option 760)

:SHORt

  [:STATe] 0|OFF|1|ON   Simulates a short circuit on the input of the load. (N679xA)

SENSe

  :CURRent

    :CCOMpensate 0|OFF|1|ON, (@chanlist)   Enables/disables the capacitive current compensation. (not on N678xA SMU, N679xA)

    [:DC]

      :RANGe

        [:UPPer] ‹*value*›, (@chanlist)   Selects a DC current measurement range.

        :AUTO 0|OFF|1|ON, (@chanlist)   Enables/disables seamless measurement autoranging. (N678xA SMU)

  :ELOG   (ELOG commands only on N676xA, N678xA SMU, Option 054)

    :CURRent

      [:DC]

        :RANge

          [:UPPer] ‹*value*›, (@chanlist)   Selects the Elog current measurement range.

          :AUTO 0|OFF|1|ON, (@chanlist)   Enables/disables seamless measurement autoranging. (N678xA SMU)

    :FUNCtion

      :CURRent 0|OFF|1|ON, (@chanlist)   Enables/disables current data logging.

        :MINMax 0|OFF|1|ON, (@chanlist)   Enables/disables min/max current data logging.

      :VOLTage 0|OFF|1|ON, (@chanlist)   Enables/disables voltage data logging.

        :MINMax 0|OFF|1|ON, (@chanlist)   Enables/disables min/max voltage data logging.

    :PERiod ‹*value*›, (@chanlist)   Sets the integration time of an Elog measurement.

    :VOLTage

      [:DC]

        :RANge

          [:UPPer] ‹*value*›, (@chanlist)   Selects the Elog voltage measurement range.

          :AUTO 0|OFF|1|ON, (@chanlist)   Enables/disables seamless measurement autoranging. (N678xA SMU)

  :FUNCtion ‹*"function"*›, (@chanlist)   Selects the measurement function (for backward compatibility)

    :CURRent 0|OFF|1|ON, (@chanlist)   Enables/disables current measurements (replaces FUNCtion)

    :VOLTage 0|OFF|1|ON, (@chanlist)   Enables/disables voltage measurements (replaces FUNCtion)

      :INPut MAIN|AUXiliary, (@chanlist)   Selects the voltage measurement input. (N6781A, N6785A)

  :SWEep   (SWEep commands only on N676xA, N678xA SMU, Option 054)

    :OFFSet

      :POINts ‹*value*›, (@chanlist)   Defines the offset in a data sweep for triggered measurements.

    :POINts ‹*value*›, (@chanlist)   Defines the number of points in a measurement.

    :TINTerval ‹*value*›, (@chanlist)   Defines the time period between measurement samples.

      :RESolution RES20|RES40   Sets the measurement resolution.

  :VOLTage

    [:DC]

      :RANGe

        [:UPPer] ‹*value*›, (@chanlist)   Selects a DC voltage measurement range.

:AUTO 0|OFF|1|ON, (@chanlist)	Enables/disables seamless measurement autoranging. (N678xA SMU)
:WINDow	(WINDow command only on N676xA, N678xA SMU, Option 054)
[:TYPE] HANNing|RECTangular, (@chanlist)	Selects the measurement window.

[SOURce:]

ARB	(ARB commands only on N676xA, N678xA SMU, Option 054)
:COUNt?	Sets the ARB repeat count.
:CURRent | :VOLTage | :POWer | :RESISTANCE	Sets the Arb type (POWer and RESISTANCE only on N679xA)
:CDWell	
[:LEVel] *<value>*, {*<value>*}, (@chanlist)	Sets the list of the constant dwell Arb
:DWELl *<value>*, (@chanlist)	Sets the dwell time for the constant dwell Arb
:POINts? (@chanlist)	Returns the number of constant-dwell Arb points
:CONVert (@chanlist)	Converts the selected Arb to a user-defined list
:EXPonential	
:END	
[:LEVel] *<value>*, (@chanlist)	Sets the end level of the exponential Arb
:STARt	
[:LEVel] *<value>*, (@chanlist)	Sets the initial level of the exponential Arb
:TIMe *<value>*, (@chanlist)	Sets the length of the start time or delay
:TCONstant *<value>*, (@chanlist)	Sets the time constant of the exponential Arb
:TIMe *<value>*, (@chanlist)	Sets the time of the exponential Arb
:PULSe	
:END	
:TIMe *<value>*, (@chanlist)	Sets the length of the end time
:STARt	
[:LEVel] *<value>*, (@chanlist)	Sets the initial level of the pulse
:TIMe *<value>*, (@chanlist)	Sets the length of the start time or delay
:TOP	
[:LEVel] *<value>*, (@chanlist)	Sets the top level of the pulse
:TIMe *<value>*, (@chanlist)	Sets the length of the pulse
:RAMP	
:END	
[:LEVel] *<value>*, (@chanlist)	Sets the end level of the ramp
:TIMe *<value>*, (@chanlist)	Sets the length of the end time
:RTIMe *<value>*, (@chanlist)	Sets the rise time of the ramp
:STARt	
[:LEVel] *<value>*, (@chanlist)	Sets the initial level of the ramp
:TIMe *<value>*, (@chanlist)	Sets the length of the start time or delay
:SINusoid	
:AMPLitude *<value>*, (@chanlist)	Sets the amplitude of the sine wave
:FREQuency *<value>*, (@chanlist)	Sets the frequency of the sine wave
:OFFSet *<value>*, (@chanlist)	Sets the DC offset of the sine wave
:STAIRcase	

        :END

           [:LEVel] ‹*value*›, (@chanlist)   Sets the end level of the staircase

           :TIMe ‹*value*›, (@chanlist)   Sets the length of the end time

        :NSTeps ‹*value*›, (@chanlist)   Sets the number of steps in the staircase

        :STARt

           [:LEVel] ‹*value*›, (@chanlist)   Sets the initial level of the staircase

           :TIMe ‹*value*›, (@chanlist)   Sets the length of the start time or delay

        :TIMe ‹*value*›, (@chanlist)   Sets the length of the staircase

      :STEP

        :END

           :TIMe ‹*value*›, (@chanlist)   Sets the end level of the step

        :STARt

           [:LEVel] ‹*value*›, (@chanlist)   Sets the initial level of the step

           :TIMe ‹*value*›, (@chanlist)   Sets the length of the start time or delay

     : TRAPezoid

        :END

           :TIMe ‹*value*›, (@chanlist)   Sets the length of the end time

        :FTIMe ‹*value*›, (@chanlist)   Sets the length of the fall time

        :RTIMe ‹*value*›, (@chanlist)   Sets the length of the rise time

        :STARt

           [:LEVel] ‹*value*›, (@chanlist)   Sets the initial level of the trapezoid

           :TIMe ‹*value*›, (@chanlist)   Sets the length of the start time or delay

        :TOP

           [:LEVel] ‹*value*›, (@chanlist)   Sets the top level of the trapezoid

           :TIMe ‹*value*›, (@chanlist)   Sets the length of the top of the trapezoid

    :UDEFined

        :BOSTep

           [:DATA] ‹*Bool*›{,‹*Bool*›}, (@chanlist)   Generate triggers at the Beginning Of STep

           :POINts? (@chanlist)   Returns the number of BOST points

        :DWELl ‹*value*›, {‹*value*›}, (@chanlist)   Sets the user-defined dwell values

           :POINts? (@chanlist)   Returns the number of dwell points

        :LEVel ‹*value*›, {‹*value*›}, (@chanlist)   Sets the user-defined level values

           :POINts? (@chanlist)   Returns the number of points

:FUNCtion ‹function›, (@chanlist)   Selects the Arb function (for backward compatibility)

   :SHAPe ‹shape›, (@chanlist)   Selects the Arb function (replaces ARB:FUNCtion)

   :TYPE CURRent|VOLTage|RESISTANCE, (@chanlist)   Selects the Arb type (replaces ARB:FUNCtion)

:SEQuence

   :COUNt ‹*value*›|INFinity, (@chanlist)   Sets the number of times the sequence is repeated

   :LENGth? (@chanlist)   Returns the number of steps in the sequence

   :QUALity? (@chanlist)   Returns the quality of the waveforms in the sequence

   :RESet (@chanlist)   Resets the sequence to its power-on default setting

   :STEP

      :COUNt ‹*value*›|INFinity, ‹step#› (@chanlist)   Sets the number of times the sequence step is repeated

      :CURRent ‹function›, ‹step#› (@chanlist)   Programs the steps in a current sequence

:FUNCtion

    :SHAPe \<function\>, \<step#\>, (@chanlist)   Creates a new sequence step

    :PACing DWELl|TRIGger, \<step#\> (@chanlist)   Specifies the type of pacing for the step

    :RESISTANCE \<function\>, \<step#\> (@chanlist)   Programs the steps in a resistance sequence

    :VOLTage \<function\>, \<step#\> (@chanlist)   Programs the steps in a voltage sequence

:TERMinate

    :LAST 0|OFF|1|ON, (@chanlist)   Sets the sequence termination mode

:TERMinate

    :LAST 0|OFF|1|ON, (@chanlist)   Sets the Arb termination mode

[SOURce:]

CURRent

    [:LEVel]

        [:IMMediate]

            [:AMPLitude] \<*value*\>, (@chanlist)   Sets the output current.

        :TRIGgered

            [:AMPLitude] \<*value*\>, (@chanlist)   Sets the triggered output current

    :LIMit

        [:POSitive]

            [:IMMediate]

                [:AMPLitude] \<*value*\>, (@chanlist)   Sets the positive current limit. (N678xA SMU, N6783A, N679xA)

            :COUPle 0|OFF|1|ON, (@chanlist)   Sets the current limit tracking state. (N678xA SMU)

        :NEGative

            [:IMMediate]

                [:AMPLitude] \<*value*\>, (@chanlist)   Sets the negative current limit. (N678xA SMU, N6783A-BAT)

    :MODE FIXed|STEP|LIST|ARB, (@chanlist)   Sets the transient mode.

    :PROTection

        :DELay

            [:TIME] \<*value*\>, (@chanlist)   Sets the over-current protection delay.

            :STARt SCHange|CCTRans, (@chanlist)   Specifies what starts the over-current protection delay timer.

        :STATe 0|OFF|1|ON, (@chanlist)   Enables/disables the over-current protection.

    :RANGe \<*value*\>, (@chanlist)   Sets the output current range.

    :SLEW

        [:POSitive]

            [:IMMediate] \<*value*\>|INFinity, (@chanlist)   Sets the current slew rate. (N678xA SMU, N679xA)

            :MAXimum 0|OFF|1|ON, (@chanlist)   Enables/disables the maximum slew rate override. (N678xA SMU, N679xA)

        :COUPle 0|OFF|1|ON, (@chanlist)   Sets the current slew tracking state. (N679xA)

        :NEGative

            [:IMMediate] \<*value*\>|INFinity, (@chanlist)   Sets the negative current slew rate. (N679xA)

            :MAXimum 0|OFF|1|ON, (@chanlist)   Enables/disables the maximum slew rate override. (N679xA)

[SOURce:]
   DIGital
     :INPut
       :DATA?   Reads the state of the digital control port.
     :OUTPut
       :DATA *‹value›*   Sets the state of the digital control port.
     :PIN‹1-7›
       :FUNCtion *‹function›*   Sets the function of the pins. DIO |DINPut |FAULt |INHibit
                                     |ONCouple |OFFCouple |TOUTput |TINPut
       :POLarity POSitive|NEGative   Sets the polarity of the pins.
     :TOUTput
       :BUS
         [:ENABle] 0|OFF|1|ON   Enables/disables BUS triggers on digital port pins.

[SOURce:]
   FUNCtion CURRent|VOLTage|RESistance|POWer, (@chanlist)   Sets the output priority mode). (N678xA SMU, N679xA)

[SOURce:]
   LIST   (LIST commands only on N676xA, N678xA SMU and Option 054)
     :COUNt *‹value›*|INFinity, (@chanlist)   Sets the list repeat count.
     :CURRent
       [:LEVel] *‹value›*{,*‹value›*}, (@chanlist)   Specifies the setting for each list step.
       :POINts? (@chanlist)   Returns the number of list points (same as steps).
     :DWELl *‹value›*{,*‹value›*}, (@chanlist)   Specifies the dwell time for each list step.
       :POINts? (@chanlist)   Returns the number of list points (same as steps).
     :POWer
       [:LEVel] *‹value›*{,*‹value›*}, (@chanlist)   Specifies the setting for each list step. (N679xA)
       :POINts? (@chanlist)   Returns the number of list points (same as steps).(N679xA)
     :RESistance
       [:LEVel] *‹value›*{,*‹value›*}, (@chanlist)   Specifies the setting for each list step. (N679xA)
       :POINts? (@chanlist)   Returns the number of list points (same as steps).(N679xA)
     :STEP ONCE|AUTO, (@chanlist)   Specifies how the list responds to triggers.
     :TERMinate
       :LAST 0|OFF|1|ON, (@chanlist)   Determines the output value when the list terminates.
     :TOUTput
       :BOSTep
         [:DATA] *‹Bool›*{,*‹Bool›*}, (@chanlist)   Generates a trigger out at the Beginning Of STep
         :POINts? (@chanlist)   Returns the number of list points (same as steps).
       :EOSTep
         [:DATA] *‹Bool›*{,*‹Bool›*}, (@chanlist)   Generates a trigger out at the End Of STep
         :POINts? (@chanlist)   Returns the number of list points (same as steps).
     :VOLTage
       [:LEVel] *‹value›*{,*‹value›*}, (@chanlist)   Specifies the setting for each list step.
       :POINts? (@chanlist)   Returns the number of list points (same as steps).

[SOURce:]

    POWer

        [:LEVel]

            [:IMMediate]

                [:AMPLitude] *<value>*, (@chanlist)   Sets the input power level. (N679xA)

            :TRIGgered

                [:AMPLitude] *<value>*, (@chanlist)   Sets the triggered input power. (N679xA)

        :LIMit *<value>*, (@chanlist)   Sets the power limit on output channels. (not on N678xA)

        :MODE FIXed|STEP|LIST|ARB, (@chanlist)   Sets the power transient mode. (N679xA)

        :PROTection

            :DELay

                [:TIME] *<value>*, (@chanlist)   Sets the power protection delay. (N679xA)

            :STATe 0|OFF|1|ON, (@chanlist)   Enables/disables the power protection. (N679xA)

        :RANGe *<value>*, (@chanlist)   Sets the power range. (N679xA)

        :SLEW

            [:POSitive]

                [:IMMediate] *<value>*|INFinity, (@chanlist)   Sets the power slew rate. (N679xA)

                :MAXimum 0|OFF|1|ON, (@chanlist)   Enables/disables the maximum slew rate override. (N679xA)

            :COUPle 0|OFF|1|ON, (@chanlist)   Sets the power slew tracking state. (N679xA)

            :NEGative

                [:IMMediate] *<value>*|INFinity, (@chanlist)   Sets the negative power slew rate. (N679xA)

                :MAXimum 0|OFF|1|ON, (@chanlist)   Enables/disables the maximum slew rate override. (N679xA)

[SOURce:]

    RESistance

        [:LEVel]

            [:IMMediate]

                [:AMPLitude] *<value>*, (@chanlist)   Sets the output resistance level. (N6781A, N6785A, N679xA)

            :TRIGgered

                [:AMPLitude] *<value>*, (@chanlist)   Sets the triggered resistance. (N679xA)

        :MODE FIXed|STEP|LIST|ARB, (@chanlist)   Sets the resistance transient mode. (N679xA)

        :RANGe *<value>*, (@chanlist)   Sets the resistance range. (N679xA)

        :SLEW

            [:POSitive]

                [:IMMediate] *<value>*|INFinity, (@chanlist)   Sets the resistance slew rate. (N679xA)

                :MAXimum 0|OFF|1|ON, (@chanlist)   Enables/disables the maximum slew rate override. (N679xA)

            :COUPle 0|OFF|1|ON, (@chanlist)   Sets the resistance slew tracking state. (N679xA)

            :NEGative

                [:IMMediate] *<value>*|INFinity, (@chanlist)   Sets the negative resistance slew rate. (N679xA)

                :MAXimum 0|OFF|1|ON, (@chanlist)   Enables/disables the maximum slew rate override. (N679xA)

        :STATe 0|OFF|1|ON, (@chanlist)   Enables/disables output resistance programming. (N6781A, N6785A)

[SOURce:]

    STEP

        :TOUTput 0|OFF|1|ON, (@chanlist)   Specifies whether a trigger is generated when a step occurs.

[SOURce:]

    VOLTage

        [:LEVel]

            [:IMMediate]

                [:AMPLitude] *<value>*, (@chanlist)   Sets the output voltage.

            :TRIGgered

                [:AMPLitude] *<value>*, (@chanlist)   Sets the triggered output voltage.

        :BWIDth

            [:RANGe] LOW|HIGH1|2|3, (@chanlist)   Sets the voltage bandwidth. (N678xA SMU)

            :LEVel LOW|HIGH1|2|3, <frequency>, (@chanlist)   Sets the bandwidth frequency. (N678xA SMU)

        :INHibit

            :VON

                [:LEVel] *<value>*, (@chanlist)   Current will sink if voltage is > voltage-on level. (N679xA)

                :MODE LATChing|LIVE|OFF   Sets the under-voltage inhibit mode. (N679xA)

        :LIMit

            [:POSitive]

                [:IMMediate]

                    [:AMPLitude] *<value>*, (@chanlist)   Sets the positive voltage limit. (N678xA SMU)

            :COUPle 0|OFF|1|ON, (@chanlist)   Sets the voltage limit tracking state. (N6784A)

            :NEGative

                [:IMMediate]

                    [:AMPLitude] *<value>*, (@chanlist)   Sets the negative voltage limit. (N6784A)

        :MODE FIXed|STEP|LIST|ARB, (@chanlist)   Sets the transient mode.

        :PROTection

            [:LOCal]

                [:LEVel] *<value>*, (@chanlist)   Sets the over-voltage protection level.

            :DELay

                [:TIME] *<value>*, (@chanlist)   Sets the over-voltage protection delay. (N678xA SMU, N6783A)

            :REMote

                [:POSitive]

                    [:LEVel] *<value>*, (@chanlist)   Sets the positive remote OV protection. (N678xA SMU, N679xA)

                :NEGative

                    [:LEVel] *<value>*, (@chanlist)   Sets the negative remote OV protection. (N6784A)

            :TRACking

                [:STATe] 0|OFF|1|ON, (@chanlist)   Enables/disables tracking over-voltage protection. (Option J01)

                :OFFSet *<value>*, (@chanlist)   Sets the tracking OVP offset. (Option J01)

        :RANGe *<value>*, (@chanlist)   Sets the output voltage range.

        :RESistance

            [:LEVel]

    [:IMMediate]

        [:AMPLitude] *<value>*, (@chanlist)   Sets the voltage priority resistance level. (N6781A, N6785A)

    :STATe 0|OFF|1|ON, (@chanlist)   Enables/disables the voltage priority resistance. (N6781A, N6785A)

  :SLEW

    [:POSitive]

      [:IMMediate] *<value>*|INFinity, (@chanlist)   Sets the voltage slew rate.

      :MAXimum 0|OFF|1|ON, (@chanlist)   Enables/disables the maximum slew rate override.

    :COUPle 0|OFF|1|ON, (@chanlist)   Sets the current slew tracking state. (N679xA)

    :NEGative

      [:IMMediate] *<value>*|INFinity, (@chanlist)   Sets the negative current slew rate. (N679xA)

      :MAXimum 0|OFF|1|ON, (@chanlist)   Enables/disables the maximum slew rate override. (N679xA)

STATus

:OPERation

  [:EVENt]? (@chanlist)   Queries the operation event register.

  :CONDition? (@chanlist)   Queries the operation condition register.

  :ENABle *<value>*, (@chanlist)   Sets the operation enable register.

  :NTRansiton *<value>*, (@chanlist)   Sets the negative transition filter.

  :PTRansiton *<value>*, (@chanlist)   Sets the positive transition filter.

:PRESet   Presets all Enable, PTR, and NTR registers.

:QUEStionable

  [:EVENt]? (@chanlist)   Queries the questionable event register.

  :CONDition? (@chanlist)   Queries the questionable condition register.

  :ENABle *<value>*, (@chanlist)   Sets the questionable enable register.

  :NTRansiton *<value>*, (@chanlist)   Sets the negative transition filter.

  :PTRansiton *<value>*, (@chanlist)   Sets the positive transition filter.

SYSTem

:CHANnel

  [:COUNt]?   Returns the number of output channels in a mainframe.

  :MODel? (@chanlist)   Returns the model number of the selected channel.

  :OPTion? (@chanlist)   Returns the option installed in the selected channel.

  :SERial? (@chanlist)   Returns the serial number of the selected channel.

:COMMunicate

  :LAN|TCPip:CONTrol?   Returns the initial socket control connection port number.

  :RLSTate LOCal|REMote|RWLock   Configures the remote/local state of the instrument.

:ERRor?   Reads and clears one error from the error queue.

:GROup?   (GROup commands do NOT apply to models N678xA SMU)

  :CATalog?   Returns the groups that have been defined.

  :DEFine <chanlist>   Group multiple channels to create a single channel.

  :DELete <channel>   Remove the specified channel from the group.

    :ALL   Ungroups all channels.

:PASSword

  :FPANel

    :RESet   Resets the front panel lockout password to zero.

:PERSona

  :MANufacturer "<manufacturer>"   Changes the manufacturer identity.

    :DEFault   Sets the manufacturer identity to the factory default.

  :MODel "<model number>"   Changes the model number.

    :DEFault   Sets the model number to the factory default.

:REBoot   Reboots the instrument to its power-on state.

:SECurity

  :IMMediate   Clears all user memory and reboots the instrument.

:VERSion?   Returns the SCPI version that the instrument complies with.

TRIGger   (ACQuire and ELOG commands only on N676xA, N678xA SMU, Option 054)

  :ACQuire

    [:IMMediate] (@chanlist)   Generates an immediate measurement trigger.

    :CURRent

      [:LEVel] *<value>*, (@chanlist)   Sets the triggered level of the output.

      :SLOPe POSitive|NEGative, (@chanlist)   Sets the slope of the signal.

    :SOURce *<source>*, (@chanlist)   Selects the trigger source for the acquisition system: BUS |CURRent<1-4>
                                      |EXTernal |PIN<1-7> |TRANsient<1-4> |VOLTage<1-4>

    :TOUTput

      [:ENABle] 0|OFF|1|ON, (@chanlist)   Enables measurement triggers to be sent to a digital port pin.

    :VOLTage

      [:LEVel] *<value>*, (@chanlist)   Sets the triggered level of the output.

      :SLOPe POSitive|NEGative, (@chanlist)   Sets the slope of the signal.

  :ARB

    :SOURce *<source>*   Selects the trigger source for the arbitrary waveform generator:
                                      BUS |EXTernal |IMMediate

  :ELOG

    [:IMMediate] (@chanlist)   Generates an immediate trigger for external data logging.

    :SOURce *<source>*, (@chanlist)   Selects the trigger source for external data logging:
                                      BUS |EXTernal |IMMediate| PIN<1-7>

  :MEASure

    :TALign

      :CORRection

        [:STATe] 0|OFF|1|ON   Improves the alignment of measurement triggers with measurement data.

  :TRANsient

    [:IMMediate] (@chanlist)   Generates an immediate output transient trigger.

    :SOURce *<source>*, (@chanlist)   Selects the trigger source for the transient system:
                                      BUS |EXTernal IMMediate |PIN<1-7> |TRANsient<1-4>

Models and Options

Model Descriptions

Model Differences

Options

Model Descriptions

Model	Description
N6700C / N6701C / N6702C	400 W / 600 W / 1200W MPS Mainframe - without power modules
N6710B / N6711A / N6712A	Build-to-order Modular Power System – mainframe with installed power modules
N6731B / N6741B	50 W / 100 W 5 V DC Power Module
N6732B / N6742B	50 W / 100 W 8 V DC Power Module
N6733B / N6743B / N6773A	50 W / 100 W / 300 W 20 V DC Power Module
N6734B / N6744B / N6774A	50 W / 100 W / 300 W 35 V DC Power Module
N6735B / N6745B / N6775A	50 W / 100 W / 300 W 60 V DC Power Module
N6736B / N6746B / N6776A, N6777A	50 W / 100 W / 300 W 100 V DC Power Module
N6751A / N6752A	50 W / 100 W High-Performance Autoranging DC Power Module
N6753A, N6754A / N6755A, N6756A	300 W / 500 W High-Performance Autoranging DC Power Module
N6761A / N6762A	50 W / 100 W Precision DC Power Module
N6763A, N6764A / N6765A, N6766A	300 W / 500 W Precision DC Power Module
N6781A, N6782A, N6784A	20 W Source/Measure Unit (SMU)
N6785A, N6786A	80 W Source/Measure Unit (SMU)
N6783A-BAT / N6783A-MFG	18 W / 24 W Application-Specific DC Power Module
N6791A, N6792A	100 W/ 200 W Electronic Load Module

Model Differences

Feature	DC Power	High-Performance	Precision
(● = available)	N673xB, N674xB, N67'7xA	N675xA	N676xA
50 W output rating	N6731B – N6736B	N6751A	N6761A
100 W output rating	N6741B – N6746B	N6752A	N6762A
300 W output rating	N6773A – N6777A	N6753A, N6754A	N6763A, N6764A
500 W output rating		N6755A, N6756A	N6765A, N6766A
Output disconnect relays	Option 761	Option 761	Option 761
Output disconnect/polarity reversal relays [1]	Option 760	Option 760	Option 760
Arbitrary waveform generation	Option 054	Option 054	●
Autoranging output capability		●	●
Voltage or current priority			N6761A, N6762A
Precision voltage and current measurements			●
Low voltage and low current output range			N6761A, N6762A
Low voltage and low current measurement range			●
200 microampere measurement range [2]			Option 2UA
Simultaneous voltage and current measurements			●
SCPI command output list capability [3]	Option 054	Option 054	●
SCPI command array readback [3]	Option 054	Option 054	●
SCPI command programmable sample rate [3]	Option 054	Option 054	●
SCPI command external data logging [3]	Option 054	Option 054	●
Double-wide (occupies 2 channel locations)		N6753A - N6756A	N6763A - N6766A

Note 1 Output current is limited to 10A max. on Models N6742B and N6773A with Option 760.
Option 760 is not available on Models N6741B, N6751A, N6752A, N6761A, and N6762A.
Note 2 Option 2UA.is only available on Models N6761A and N6762A. It includes Option 761.
Note 3 Only available when using the remote interfaces; not from the front panel.

Feature	Source/Measure Units (SMU)					Application-Specific	
(● = available)	N6781A	N6782A	N6784A	N6785A	N6786A	N6783A –BAT	N6783A –MFG
Output rating	20 W	20 W	20 W	80 W	80 W	24 W	18 W
2-quadrant operation	●	●		●	●	●	●
4-quadrant operation			●				
Auxiliary voltage input	●			●			
Output disconnect relays	●	●	●	●	●	Opt. 761	Opt. 761
Arbitrary waveform generation [1]	●	●	●	●	●	●	●
Negative voltage protection	●	●	●	●	●	●	●
Voltage or current priority	●	●	●	●	●		
Programmable resistance	●			●			
Number of voltage output ranges	3	3	3	4	4	1	1
Number of current output ranges	3	3	4	4	4	1	1
Number of voltage measurement ranges	3	3	3	1	1	1	1
Number of current measurement ranges	4	4	4	3	3	2	2
Simultaneous voltage and current measurements	●	●	●	●	●		
Seamless measurement autoranging	●	●	Opt. SMR	●	●		
SCPI output list capability [1, 2]	●	●	●	●	●	●	●
SCPI array readback [2]	●	●	●	●	●	●	●
SCPI programmable sample rate [2]	●	●	●	●	●	●	●
SCPI external data logging [2]	●	●	●	●	●	●	●
Double-wide (occupies two channel locations)				●	●		

Note 1 Arbitrary waveforms and List capability is not available on the negative current output on Model N6783A
Note 2 Only available when using the remote interfaces; not from the front panel.

Feature	Load Modules	
(● = available)	N6791A	N6792A
Input rating [1]	100 W	200 W
Input terminal short capability	●	●
Arbitrary waveform generation	●	●
Under-voltage inhibit	●	●
Voltage, current, resistance, and power priority mode	●	●
Number of resistance input ranges	3	3
Number of current input ranges [2]	2	2
Number of voltage input ranges [2]	1	1
Number of power input ranges	2	2
Simultaneous voltage and current measurements	●	●
SCPI command output list capability [3]	●	●
SCPI command array readback [3]	●	●
SCPI command programmable sample rate [3]	●	●
SCPI command external data logging [3]	●	●
Double-wide (occupies 2 channel locations)		●

Note 1 The load module's input is referred to by the term "Output" throughout this document.
Note 2 The input and measurement ranges re coupled.
Note 3 Only available when using the remote interfaces; not from the front panel.

Options

Mainframe Options	Description
908	Rack Mount Kit. For mounting in a 19-inch EIA rack cabinet. Also available as Model N6709A.
FLR	Filler module. For mainframes with less than four power modules. Also available as Model N6708A.

Power Module Options	Description
054	High-Speed Test Extensions. Includes digitized output measurements and output list capability. Available for Models N673xB,- 4xB,-5xA, -7xA. Included with Models N676xA, N678xA SMU, and N6783A.
760 [1]	Output disconnect/polarity reversal. Disconnects the + and – output and sense terminals. Switches the + and – output and sense polarities. Not available on N6741B, N6751A, N6752A, N676xA, N678xA.SMU, or N679xA.
761 [1]	Output disconnect. Disconnects + and – output and sense terminals. Standard on N678xA SMU. Not available on N679xA.
UK6	Commercial calibration with test results data
1A7	ISO 17025 calibration certificate
2UA	200 microampere measurement range with output disconnect relays. Only on Models N6761A, N6762A.
J01	Tracking overvoltage protection function. Only available on Models N6752A, N6754A, and N6762A when installed in an N6700B, N6701A, or N6702A mainframe.
SMR	Seamless measurement autoranging for Model N6784A. Included with Models N6781A, N6782A, N6785A, and N6786A.

Note 1 A small AC network is always present across the output terminals.

Specifications

Supplemental Characteristics

Dimension Diagrams

This section lists the supplemental characteristics of the Keysight N6700C Modular Power System. Supplemental characteristics are not warranted but are descriptions of performance determined by design or by type testing. All supplemental characteristics are typical unless otherwise noted.

Specifications and characteristics are subject to change without notice.

> **NOTE**   Complete specifications and supplemental characteristics information for all power modules are included in the Keysight N6700 Modular Power System Family Specifications Guide.

Supplemental Characteristics N6700C, N6701C, N6702C

Characteristic	Keysight N6700C, N6701C, N6702C
Maximum Total Power Available for Power Modules:	400 W (for N6700C mainframes) 600 W (for N6701C mainframes) 1200 W (for N6702C mainframes)
Internal Flash memory:	8 Mbytes

Protection Response
  INH Input:
  Fault on coupled output:
	5 μs from receipt of inhibit to start of shutdown
	< 10 μs from receipt of fault to start of shutdown

Command Processing Time:	≤ 1 ms from receipt of command to start of output change
Digital Control Characteristics	
Maximum voltage ratings	+16.5 VDC/-5 VDC between pins (pin 8 is internally connected to chassis ground).
Pins 1 and 2 as FLT output	Maximum low-level output voltage = 0.5 V @ 4 mA Maximum low-level sink current = 4 mA Typical high-level leakage current = 1 mA @ 16.5 VDC
Pins 1 - 7 as digital/trigger outputs (pin 8 = common)	Maximum low-level output voltage = 0.5 V @ 4 mA; 1 V @ 50 mA; 1.75 V @ 100 mA Maximum low-level sink current = 100 mA Typical high-level leakage current = 0.8 mA @ 16.5 VDC
Pins 1 - 7 as digital/trigger inputs and pin 3 as INH input (pin 8 = common)	Maximum low-level input voltage = 0.8 V Minimum high-level input voltage = 2 V Typical low-level current = 2 mA @ 0 V (internal 2.2k pull-up) Typical high-level leakage current = 0.12 mA @ 16.5 VDC

Characteristic	Keysight N6700C, N6701C, N6702C
Interface Capabilities	
LXI Core 2011:	10/100/1000 Base-T Ethernet (Sockets, VXI-11 protocol, Web interface)
USB 2.0 (USB-TMC488):	Requires Keysight IO Library version M.01.01 or 14.0 and up
10/100/1000 LAN:	Requires Keysight IO Library version L.01.01 or 14.0 and up
Web server:	Requires a Web browser
GPIB:	SCPI - 1993, IEEE 488.2 compliant interface
Regulatory Compliance:	
EMC:	Complies with European EMC Directive for test and measurement products: IEC/EN 61326-1; CISPR 11, Group 1, class A; AS/NZS CISPR 11; ICES/NMB-001
	Complies with Australian standard and carries C-Tick mark This ISM device complies with Canadian ICES-001 Cet appareil ISM est conforme à la norme NMB-001 du Canada
Safety:	Complies with European Low Voltage Directive and carries the CE-marking. Conforms to US and Canadian safety regulations.
Environmental	
Operating environment:	Indoor use, installation category II (for AC input), pollution degree 2
Temperature range:	0°C to 55°C (output current is derated 1% per °C above 40°C
Relative humidity:	Up to 95% (non-condensing)
Altitude:	Up to 2000 meters
Storage temperature:	-30°C to 70°C
Acoustic Noise Declaration This statement is provided to comply with the requirements of the German Sound Emission Directive, from 18 January 1991	Sound Pressure Lp <70 dB(A), At Operator Position, Normal Operation, According to EN 27779 (Type Test). Schalldruckpegel Lp <70 dB(A), Am Arbeitsplatz, Normaler Betrieb, Nach EN 27779 (Typ-prüfung).
Output Terminal Isolation:	No output terminal may be more than 240 VDC from any other terminal or chassis ground.
	N6781A/N6785A Note: When using the AUX measurement input terminals on Models N6781A and N6785A, no output or input terminal may be more than ±60 VDC from any other terminal or chassis ground.
AC Input	
Input ratings:	~ 100 VAC – 240 VAC; 50/60/400Hz
Input ranges:	86–264 VAC; 47–63Hz; 380–420 Hz
Power Consumption:	1000 VA (N6700C) 1440 VA (N6701C) 1440 VA (N6702C @ < 180 VAC input) 2200 VA (N6702C @ > 180 VAC input)
Power Factor (Note 1):	0.99 @ nominal input and rated power
Fuse:	Internal fuse - not customer accessible
	N6702C Note: AC mains circuits rated at 100-180 VAC **cannot** supply enough current to power the N6702A mainframe when operated at its full rated power. When connected to a 100-180 VAC mains, internal circuits will limit the power available to modules to 600 W maximum.

Characteristic	Keysight N6700C, N6701C, N6702C
Net Weight	
N6700C with 4 modules:	12.73 kg / 28 lbs.
N6701C with 4 modules:	11.82 kg / 26 lbs.
N6702C with 4 modules:	14.09 kg / 31 lbs.
Single-wide module (typical):	1.23 kg / 2.71 lbs
Dimensions:	Refer to the dimension diagrams in the following section.

Note 1 Under full load at 400 Hz, power factor drops from 0.99 @ 120 VAC to as low as 0.76 @ 265 VAC. Power factor degrades further under no load conditions.

Dimension Diagrams
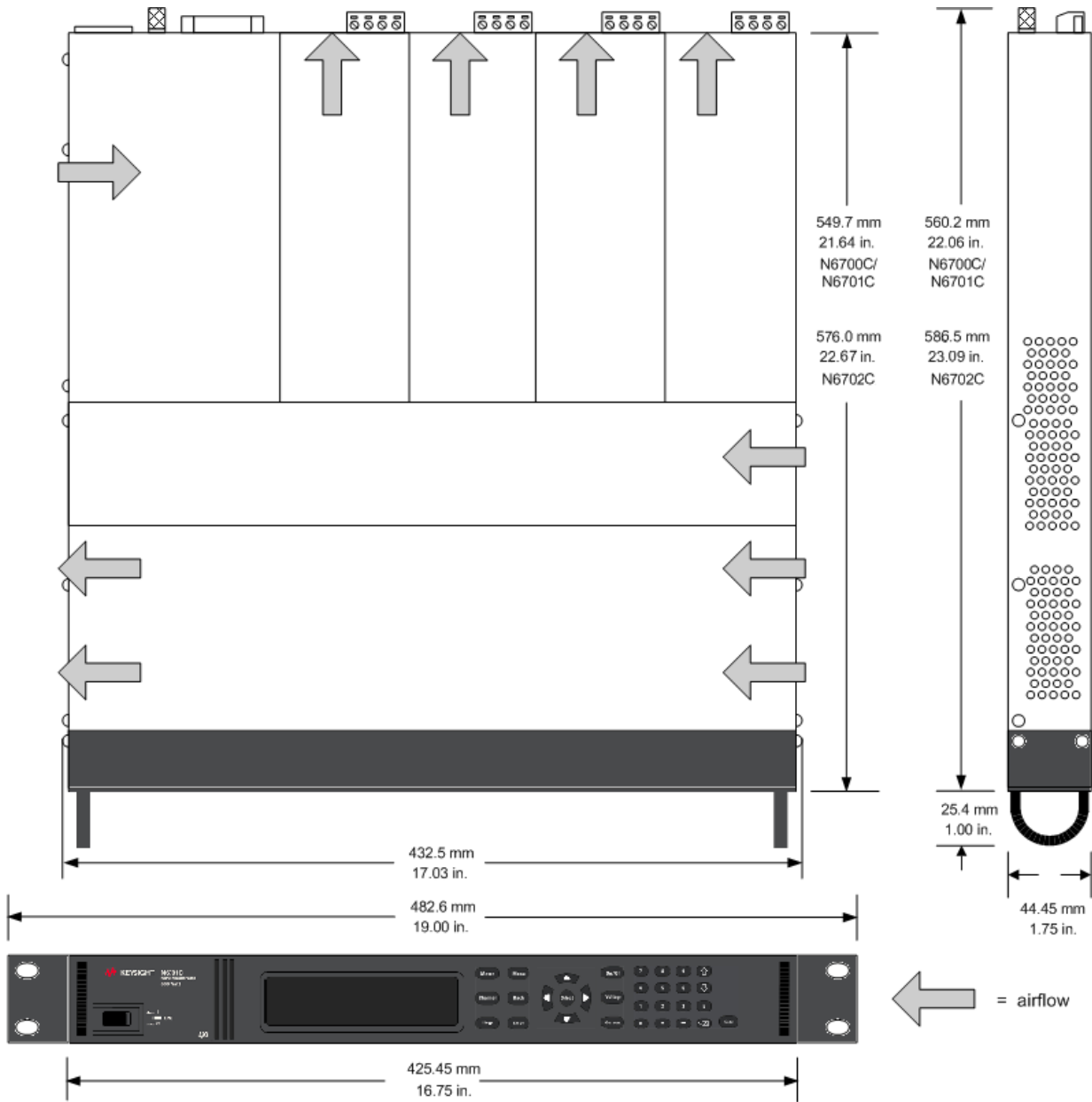
2

Installation

Preliminary Information

Installing the Mainframe

Connecting the Power Cord

Connecting the Outputs

Remote Sense Connections

Parallel and Series Connections

Auxiliary Measurement Connections

Interface Connections

KEYSIGHT
TECHNOLOGIES

Preliminary Information

Check for Items Supplied

Inspect the Unit

Review Safety Information

Observe Environmental Conditions

Check for Items Supplied

Before getting started, check the following list and verify that you have received these items with your unit. If anything is missing, please contact your nearest Keysight Sales and Support Office.

Mainframe Items	Description	Part Number
Power Cord	A power cord suitable for your location.	Call Keysight Sales & Support Office
Ferrite Core for N6700B	Installs on power cord to reduce common mode currents	Keysight 9170-2131
Digital Connector plug	8-pin connector for connecting signal lines to the digital port.	Keysight 1253-6408 Phoenix Contact MC 1,5/8-ST-3,5
Automation-Ready CD	Contains Keysight IO Libraries Suite.	Keysight E2094N
Quick Reference Guide	Contains quick reference information.	Keysight 5969-2950
T-10 Torx tool	Tool for installing or removing power modules.	Keysight 8710-2416
DC Power Module Items	Description	Part Number
8 A Output Connector plug	One 8 A, 8-pin connector plug for connecting power and sense leads. Only used in N678xA SMU.	Keysight 1253-6408 Phoenix Contact MC 1,5/8-ST-3,5
12 A Output Connector plug	One 12 A, 4-pin connector plug for connecting power and sense leads. Used in all except N6731B, N6741B, N6753A-N6756A, N6763A-N6766A, N6773A, N678xA SMU, N6791A, N6792A.	Keysight 1253-5826 Phoenix Contact MSTB 2,5/4-STF
20 A Output Connector plug	One 20 A, 4-pin connector plug for connecting power and sense leads. Only used in N6731B, N6741B, N6754A, N6756A, N6764A, N6766A, N6773A, N6791A.	Keysight 1253-6211 Phoenix Contact PC 4/4-ST-7,62
50 A Output Connector plug	One 50 A, 2-pin connector plug for connecting power leads. Only used in N6753A, N6755A, N6763A, N6765A, N6792A.	Keysight 1253-7187 Molex 39422-0002
AUX Measurement connector plug	A 2-pin connector plug for connecting the auxiliary measurement inputs. Only used in N6781A and N6785A.	Keysight 1253-8485 Phoenix Contact FMC 1,5/2-ST-3,5
Small Sense Jumpers	Two small jumpers for local sensing at the output connector. Used in all except N6731B, N6741B, N6753A-N6756A, N6763A-N6766A, N6773A, N678xA SMU, N6791A, N6792A.	Keysight 8120-8821 Phoenix Contact EPB 2-5(1733169)

DC Power Module Items	Description	Part Number
Large Sense Jumpers	Two large jumpers for local sensing at the output connector. Only used in N6731B, N6741B, N6754A, N6756A, N6764A, N6766A, N6773A, N6791A.	Keysight 0360-2935 Phoenix Contact 3118151
Sense Connector	A 4-pin connector for connecting sense leads. Wires (p/n 5185-8847) are used for local sensing. Only used in N6753A, N6755A, N6763A, N6765A, N6792A.	Keysight 1253-5830 Phoenix Contact MC 1,5/4-ST-3,5
Calibration Certificate	A certificate of calibration referenced to the serial number.	N/A

Inspect the Unit

When you receive your power system, inspect it for any obvious damage that may have occurred during shipment. If there is damage, notify the shipping carrier and nearest Keysight Sales and Support Office immediately. Refer to www.keysight.com/find/assist.

Until you have turned on and checked out the power system, save the shipping carton and packing materials in case the unit has to be returned.

Review Safety Information

This power system is a Safety Class 1 instrument, which means it has a protective earth terminal. That terminal must be connected to earth ground through a power source equipped with a ground receptacle.

Refer to the Safety Summary page at the beginning of this guide for general safety information. Before installation or operation, check the power system and review this guide for safety warnings and instructions. Safety warnings for specific procedures are located at appropriate places throughout this Guide.

WARNING   **Some power modules generate voltages exceeding 60 VDC**
Ensure that instrument connections, load wiring, and load connections are either insulated or covered so that no accidental contact with lethal output voltages can occur.

Observe Environmental Conditions

WARNING   **Do not operate the instrument in the presence of flammable gases or fumes.**

The environmental conditions of the power system are documented under Environmental Characteristics. Basically, the unit should only be operated indoors in a controlled environment.

The dimensions of your instrument as well as an outline diagram are also documented under Specifications. A fan cools the power system by drawing air through the sides and exhausting it out the side and back. The instrument must be installed in a location that allows sufficient space at the sides and back of the unit for adequate air circulation.

Installing the Mainframe

Module Installation

Rack Mounting

Bench Installation

Redundant Ground for 400 Hz Operation

Module Installation

NOTE	The information in this section applies if you have purchased an N6700 mainframe without the modules installed, or if you are adding a module to the mainframe.

CAUTION	**Equipment Damage** Turn the mainframe off and disconnect the power cord before installing or removing modules. Observe all standard electrostatic discharge precautions before handling electronic components.

Modules must be installed next to one another, starting with slot 1. Do not leave any empty slots between modules, otherwise the power system will not operate.

Any remaining unused slots must have a filler module (N6708A) installed to ensure proper cooling. Do not install filler modules between modules.

Tools required: T10 Torx driver; Small flat-blade screwdriver

Step 1. Remove the blower cover.

Remove the screws from the top and sides of the blower cover. Tilt the cover up and slide it out.
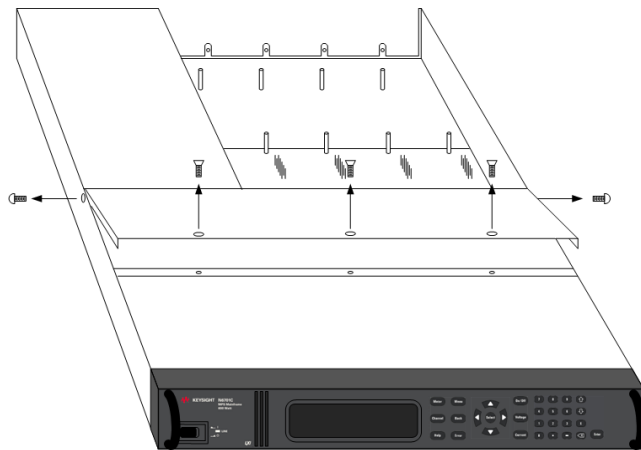
Step 2. Install the power module.

Align the module over the pins and push it down onto the mainframe connector. Install a filler module in any unused slots.
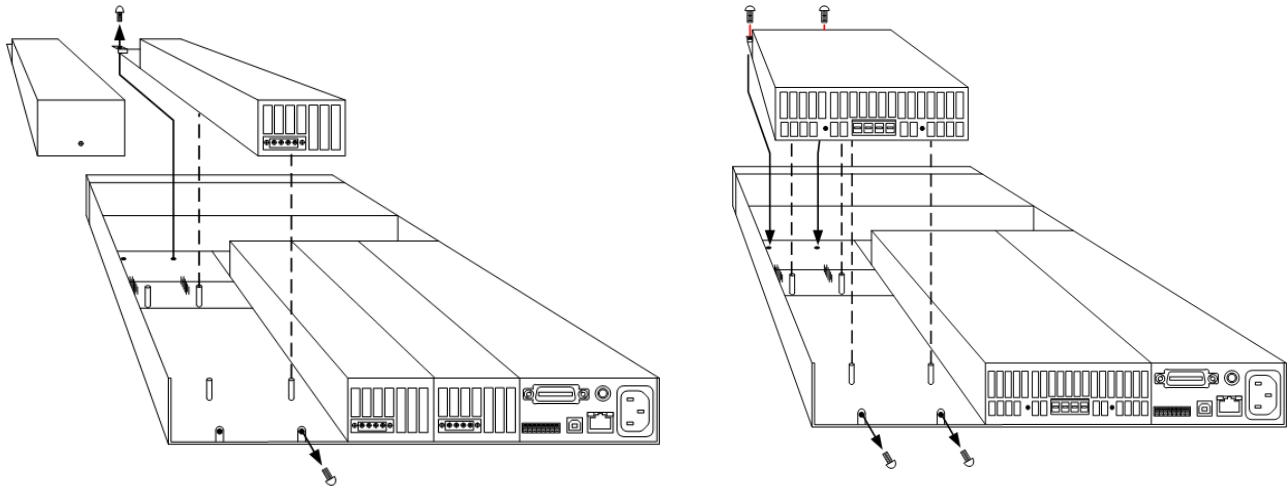
Step 3. Install the screws at each end of the module.

Use a T10 Torx driver to tighten the screws. Because the RFI strips apply upward pressure, continue pushing down on the module until the screws are tight.

Step 4. Replace the blower cover when finished.

Carefully fit the spring clips under the lip of the modules.
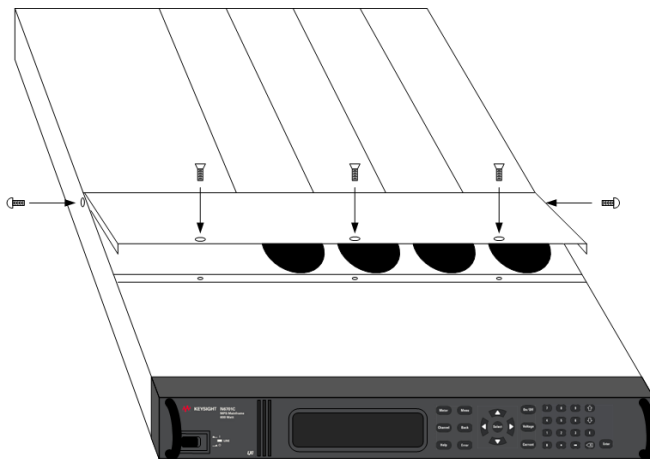
Power Module Channel Assignment

The slot location of a module in the mainframe determines the channel assignment of the module. When viewed from the rear, the module next to the GPIB connector is always output channel one. Numbering continues sequentially to the left, from 1 up to 4.

Double-wide modules are assigned the number of the lowest numbered slot in which is installed. For example, if a double-wide module is installed in slots 3 and 4, it is assigned channel number 3.

Grouped modules, those that are connected in parallel and have been configured or grouped to act as a single higher-power channel, are assigned the channel number of the lowest numbered slot of the group. Refer to Output Groups for more information.

Rack Mounting

CAUTION	You cannot use support rails for rack mounting your instrument.
	Support rails would block the airflow needed for cooling.
	Use Rack Mount kit (Option 908) to rack mount your instrument.
	The Rack Mount Kit is also available by ordering part number N6709A.

Keysight N6700 MPS mainframes can be mounted in a 19-inch EIA rack cabinet. They are designed to fit in one rack-unit (1U) of space. Do not block the air intake and exhaust at the sides of the unit, or the exhaust at the rear of the unit.

Tools required: Phillips driver, T22 Torx driver, T10 Torx driver

Step 1. Install eight clip-nuts on the rack frame (2 in each corner) where your instrument will be located.

The following figure references the installation steps.
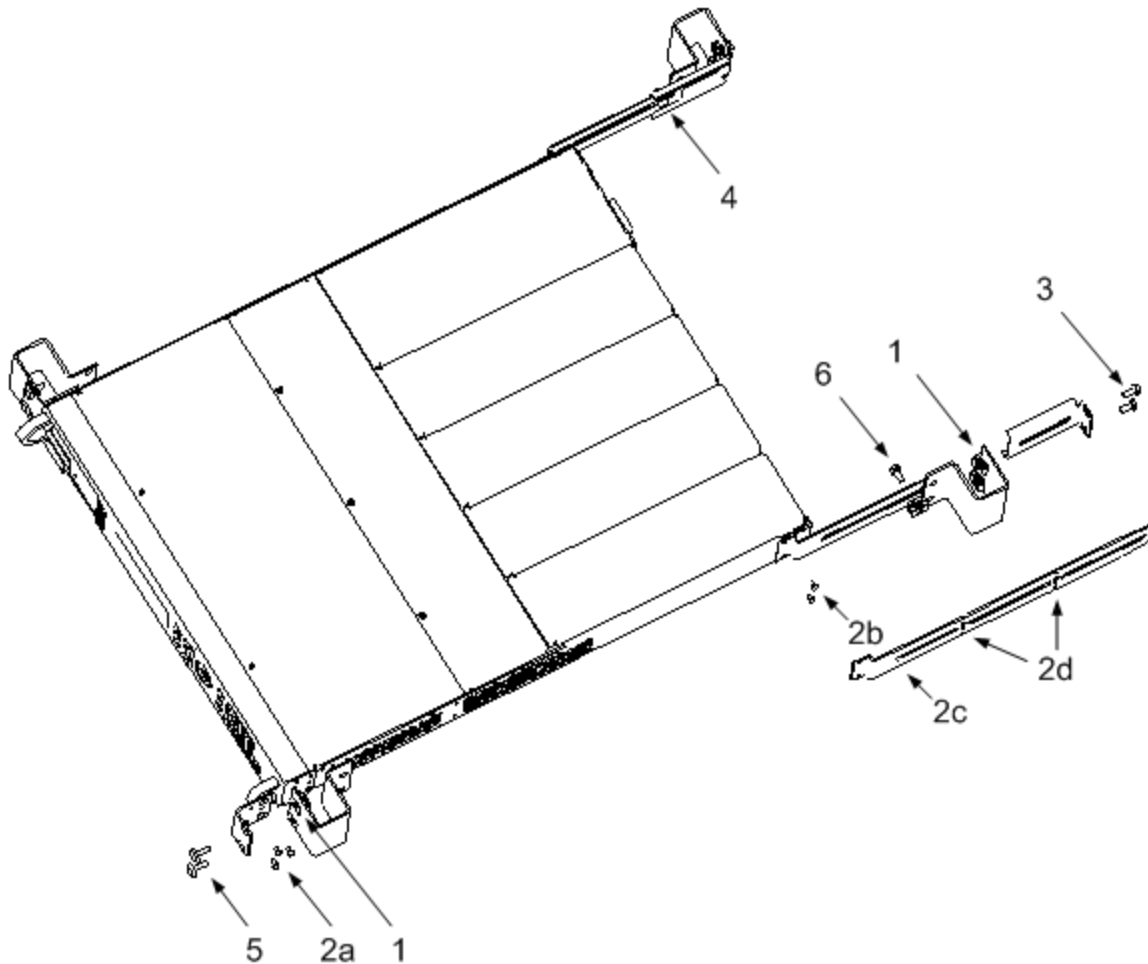
Step 2. Install the two front ears and the two rear extender supports on the instrument as shown in the figure.

Use six M3 x 8mm screws (a) for the front ears and four M3 x 6mm screws (b) for the extender supports. If the standard extender supports are either too short or too long, use the longer supports (c). Cut the supports if required (d).

Step 3. Install the two rear ears on the back of the instrument rack as shown in the figure.

Use four plain 10-32 screws to install the rear ears.

Step 4. Slide the instrument into the rack, making sure that the rear extender supports are aligned inside the rear ears.

Step 5. Attach the front ears to the front of the instrument rack using the four dress 10-32 screws provided.

Step 6. This is optional. Insert a plain 10-32 screw through the slot of the rear ear and extender support and attach it using a clip nut.

This will prevent the unit from being slid out of the front of the rack.

Bench Installation

CAUTION Do not block the air intake and exhaust at the sides, or the exhaust at the rear of the unit. Refer to the dimension diagram in the **Specifications** section.

Minimum clearances for bench operation are 2 inches (51 mm) along the sides and back.

Redundant Ground for 400 Hz Operation

At 400 Hz AC input operation, the leakage current of the unit exceeds 3.5 mA. This requires the installation of a permanent, redundant ground from the instrument chassis to earth ground. This ensures that ground will always be connected and that any leakage current will be diverted to ground.

Refer to the **Specifications** section for power factor statistics at 400 Hz operation.

Refer to Redundant Ground in the Operating and Service Guide document for installation instructions.

Connecting the Power Cord

WARNING   FIRE HAZARD Use only the power cord that was supplied with your instrument. Using other types of power cords may cause overheating of the power cord, resulting in fire.

SHOCK HAZARD The power cord provides a chassis ground through a third conductor. Be certain that your power outlet is of the three-conductor type with the correct pin connected to earth ground.

Connect the power cord to the IEC 320 connector on the rear of the unit. If the wrong power cord was shipped with your unit, contact your nearest Keysight Sales and Support Office.

The AC input on the back of your unit is a universal AC input. It accepts nominal line voltages in the range of 100 VAC to 240 VAC. The frequency can be 50 Hz, 60 Hz, or 400 Hz.

Keysight N6702C Mainframe Note: Standard AC mains circuits rated at nominal 100-120 VAC cannot supply enough current to power the N6702A mainframe when it is operated at its full rated power. Nevertheless, the N6702A can be connected to an AC mains circuit rated at nominal 100-120 VAC. In this case, internal circuits will limit the power available to modules to 600 W. As a result of this power limiting, the current drawn from the AC mains will be < 15 A, so that standard 100-120 VAC mains circuits will not be overloaded.

NOTE   The detachable power cord may be used as an emergency disconnecting device. Removing the power cord will disconnect AC input power to the unit.

Snap-on Ferrite core for N6700C

Installing the supplied ferrite core is only necessary if you are connecting highly sensitive loads to the output of the N6700C. The purpose of the ferrite core is to reduce the possibility of common mode current spikes appearing at the output of the power system when AC power is switched on or off. Note that N6701C and N6702C mainframes have built-in ferrite cores.

Additional measures to protect sensitive loads from common mode currents are discussed under Protecting Sensitive Loads from AC Power Switching Transients.

To install the core:

1. Locate the core anywhere along the cord.
2. Pass the power cord through the core twice.
3. Close the core.
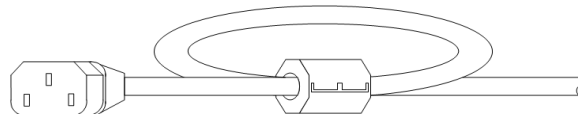
Connecting the Outputs

Output Wiring

Wire Sizing

Keysight N678xA SMU Wiring

Multiple Load Wiring
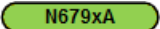
Positive and Negative Voltages

Load Capacitor Response Times

Ferrite Core Installation – for Keysight N6792A only

Protecting Sensitive Loads

| NOTE | Keysight N679xA Load Module input terminals are referred to as "Outputs" throughout this document N679xA . |

Output Wiring

| WARNING | SHOCK HAZARD Turn off AC power before making rear panel connections. All wires and straps must be properly connected with the terminal block screws securely tightened.

Some power modules generate voltages in excess of 60 VDC. Ensure that instrument connections, load wiring, and load connections are either insulated or covered so that no accidental contact with lethal output voltages can occur. |

Disconnect the connector plug to make your wire connections. The 8A connector plug accepts wires sizes from AWG 14 to AWG 30. The 12A connector plug accepts wires sizes from AWG 12 to AWG 30. The 20A connector plug accepts wires sizes from AWG 10 to AWG 24. The 50A connector plug accepts wires sizes from AWG 6 to AWG 20. Wire sizes smaller than AWG 20 are not recommended. Connect the load wires to the + and - terminals. Connect the sense wires to the +s and –s terminals. Sense jumpers are provided for local sensing.

Securely fasten all wires by tightening the screw terminals. Insert the connector plug into the back of the unit. Secure the 12 A and 50 A connector by tightening the locking screws. A chassis ground binding post is located next to the AC input connector for ground connections.

Part number information for all connector plugs is provided under Items Supplied.

| CAUTION | On power modules with the 50A sense connector, the +LS and –LS terminals are ONLY used for local sense connections as illustrated. Do not connect the +LS and –LS terminals in any other way. |
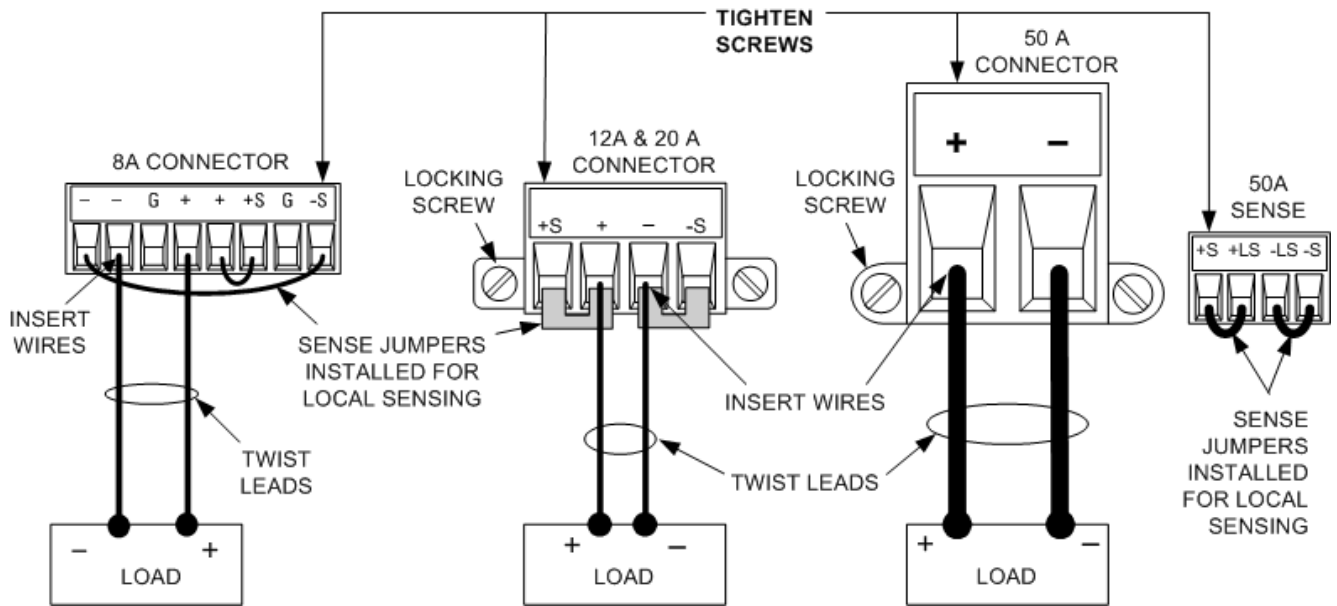
Wire Sizing

> **WARNING** FIRE HAZARD Select a wire size large enough to carry short-circuit current without overheating (refer to the following table). To satisfy safety requirements, load wires must be heavy enough not to overheat while carrying the short-circuit output current of the unit. Keysight Model N678xA SMU wiring requirements are described in the following section.

Along with conductor temperature, you must also consider voltage drop when selecting wire sizes. The following table lists the resistance for various wire sizes and the maximum lengths to limit the voltage drop to 1.0 V per lead for various currents.

Note that the minimum wire size required to prevent overheating may not be large enough to prevent over-voltage tripping or maintain good regulation. Under most conditions, the load wires should also be heavy enough to limit the voltage drop to no more than l.0 V per lead.

To help prevent nuisance tripping of the over-voltage circuit, select a wire size sufficient to handle the FULL output current of the unit no matter what the intended load current or current limit setting

Load lead resistance is also an important factor relating to the CV stability of the instrument when remote sensing capacitive loads. If high capacitance loads are expected, you should not use wire gauges heavier than 12 to 14 AWG for long runs of load lead.

Wire Size	Metric size (Note1)		Resistance	Max length to limit voltage to 1 V/lead			
				for 5 A	for 10 A	for 20 A	for 50 A
AWG	2 wires bundled	4 wires bundled	Ω per foot	Wire length in feext			
20	7.8	6.9	0.0102	20	x	x	x
18	14.5	12.8	0.0064	30	15	x	x
16	18.2	16.1	0.0040	50	25	x	x
14	29.3	25.9	0.0025	80	40	20	x
12	37.6	33.2	0.0016	125	63	30	x
10	51.7	45.7	0.0010	200	100	50	20
8	70.5	62.3	0.0006	320	160	80	32
6	94	83	0.0004	504	252	126	50
Area in mm^2	2 wires bundled	4 wires bundled	Ω per meter	Wire length in meters			
0.5	7.8	6.9	0.0401	5	x	x	x
0.75	9.4	8.3	0.0267	7.4	x	x	x
1	12.7	11.2	0.0200	10	5	x	x
1.5	15.0	13.3	0.0137	14.6	7.2	x	x
2.5	23.5	20.8	0.0082	24.4	12.2	6.1	x
4	30.1	26.6	0.0051	39.2	19.6	9.8	3.9
6	37.6	33.2	0.0034	58	29	14.7	5.9
10	59.2	52.3	0.0020	102	51	25	10.3

Notes:

1. Capacity for AWG wires derived from MIL-W-5088B. Maximum ambient temperature: 55°C. Maximum wire temperature: 105°C.
2. Capacity for metric wires are derived from IE Publication 335-1.
3. Capacity of aluminum wire is approximately 84% of that listed for copper wire.
4. "x" indicates wire is not rated for the maximum output current of the power module.
5. Because of wire inductance considerations, it is also recommended that you keep your load leads twisted, tie wrapped, or bundled together and less than 50 feet (14.7 meters) in length per lead.

Keysight N678xA SMU Wiring

| NOTE | Because of the effect of wire inductance, the wire length information given in the previous table does not apply to Models N678xA SMU. |

To minimize the effect of wire inductance, the following table describes the allowable load lead and wire length for several common output wire types. Using longer (or shorter) wire lengths than those indicated in the table may cause output oscillation.

Cable Type	To module connector	
	Length in feet	Length in meters
Twisted pair (AWG 14 or smaller)	1 to 4.25 feet	0.3 to 1.3 meters
50 ohm coaxial (RG-58)	2 to 10 feet	0.6 to 3 meters
10 ohm coaxial (inductance per cable foot ≤ 32 nH)	8.5 to 33 feet	2 to 10 meters

High Bandwidth Modes with Remote Sensing

The following wiring requirements apply when using Keysight Models N678xA SMU in the High bandwidth modes with remote sensing.

Refer to Output Bandwidth for more information about the bandwidth settings.
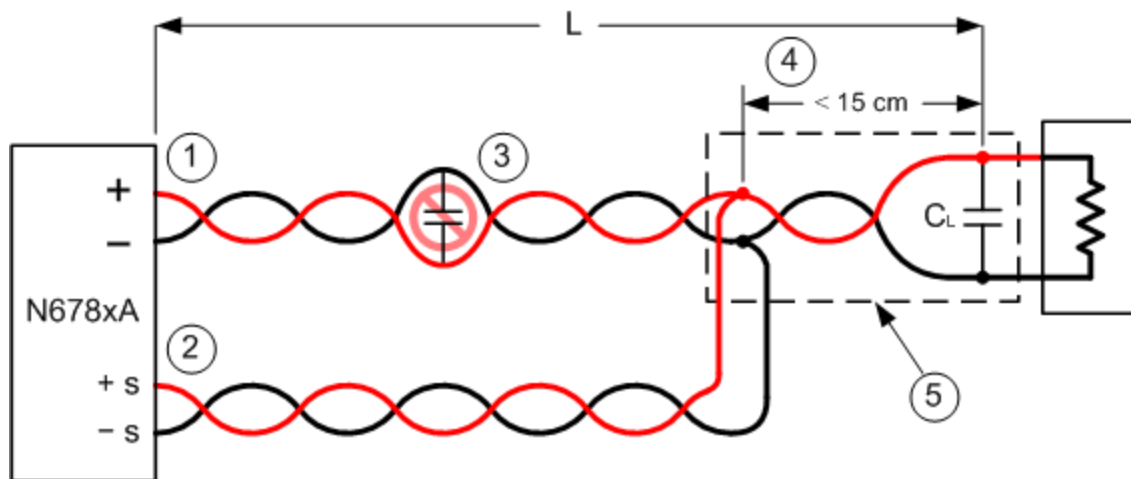
1. Load wires must be twisted-pair or coax and must not be twisted along with the sense wires. Refer to the above table for length (L).

2. Sense wires must be twisted-pair or coax and must not be twisted with the load wires.

3. No capacitors are allowed within the sense-compensated load path.

4. If the load capacitor (CL) is not located at the sense point, the distance from the sense point to the load capacitor cannot exceed 15 cm and must be twisted-pair, coax, or pc traces.

5. If the test fixture consists of pc traces, the positive and negative traces should be directly facing on adjacent layers.

To minimize inductance, the width (w) of the traces should be at least as great as the thickness of the dielectric (h). It is better to make the traces much wider than this minimum requirement in order to minimize the DC resistance.
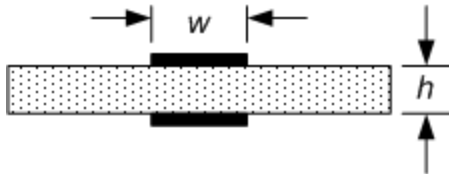
Low Bandwidth Mode with Remote or Local Sensing

All previously stated wiring requirements still apply in Low bandwidth mode except for the following.

The 15 cm maximum limit between the sense point and the load capacitor (see #4) does not apply when using Low bandwidth mode.

Guard Connections

The purpose of a cable guard is to eliminate the effects of leakage current that can exist in the current path of the external test circuit. The cable guard can be used when the test fixture requires guarding and the power system is sourcing or measuring DC currents under 1 μA. Without a guard, leakage currents in the test circuit could affect the accuracy of the micro-amp measurements. Guarding is generally not required when measuring currents 1 μA and greater.

As shown below, cable guards are available at the output connector of Keysight Models N678xA SMU. The guard is typically used to drive the shields of cables and test fixtures. It provides a buffered voltage that is at the same potential as the + output terminals of the module connector. The guard current is limited to about 300 μA.

1. N678xA SMU connector

2. Guard shield (can be the shield of a coaxial cable)
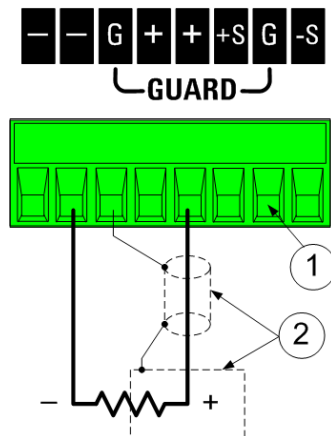
Multiple Load Wiring

If you are using local sensing and are connecting multiple loads to one output, connect each load to the output terminals using separate load wires as shown in the following figure. This minimizes mutual coupling effects and takes full advantage of the power module's low output impedance. Keep each wire-pair as short as possible and twist or bundle the wires to reduce lead inductance and noise pickup. The goal is to always minimize the loop area or physical space between the + and - load wires from the power system to the load.

Note that Keysight Models N678xA SMU have additional wiring restrictions as previously discussed under Keysight N678xA SMU Wiring.
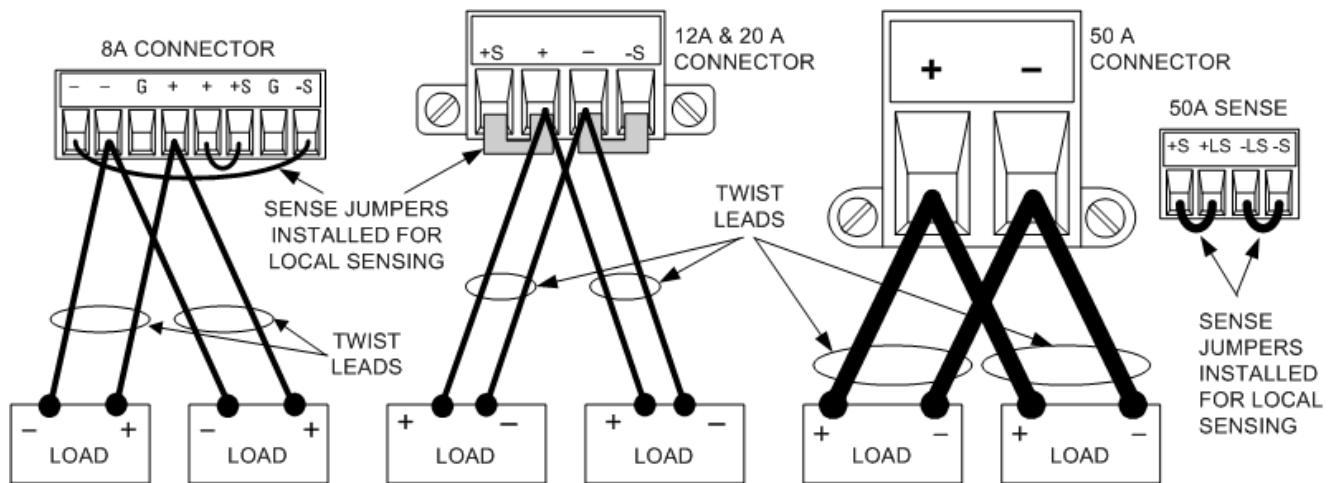
If load considerations require the use of distribution terminals that are located away from the instrument, connect the output terminals to the remote distribution terminals by a pair of twisted or bundled wires. Connect each load to the distribution terminals separately. Remote voltage sensing is recommended under these circumstances. Sense either at the remote distribution terminals or, if one load is more sensitive than the others, directly at the critical load.

Positive and Negative Voltages

Either positive or negative voltages with respect to ground can be obtained from the output by grounding (or "commoning") one of the output terminals. Always use two wires to connect the load to the output regardless of where or how the system is grounded. The instrument can be operated with any output terminal ± 240 VDC including output voltage from ground.

> **NOTE** Keysight Models N678xA SMU are optimized for grounding the negative output terminal. Grounding the positive terminal may result in increased current measurement noise and a reduction in current measurement accuracy.

Load Capacitor Response Times

When programming with an external capacitor, voltage response time may be longer than that for purely resistive loads. Use the following formula to estimate the additional up-programming response time:

$$\text{Response Time} = \frac{(\text{Added Output Capacitor}) \times (\text{Change in Vout})}{(\text{Current Limit Setting}) - (\text{Load Current})}$$

Note that programming into an external output capacitor may cause the power system to briefly enter constant current or constant power operating mode, which adds additional time to the estimation.

Ferrite Core Installation - for Keysight N6792A only

> **NOTE**
>
> Compliance to radio frequency interference (RFI) standards requires a ferrite core to be installed on the load leads of the load module. The core is supplied with the module and does not affect the functionality of the module.

1. Locate the core along the length of the cables and pass the load cables through the core once

2. Clip the ferrite core onto the load cables as close as possible to the output connector. The recommended distance from the connector to the core is 4 cm or less.

3. Attach the tywrap to the load wires to prevent the core from sliding away from the connector.
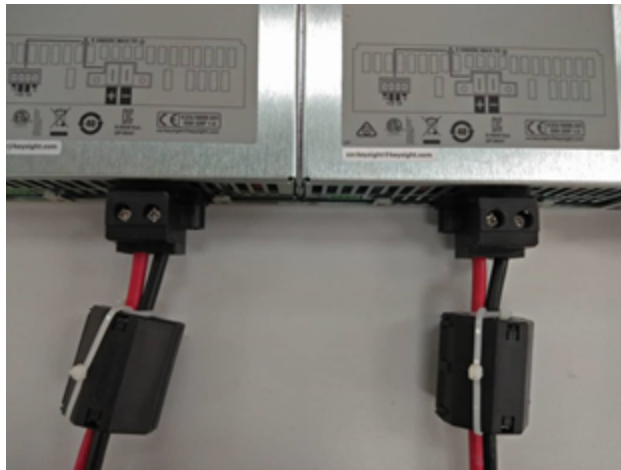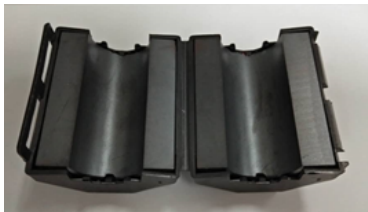
Protecting Sensitive Loads from AC Power Switching Transients

| NOTE | This only applies if you are connecting loads that are highly sensitive to voltage or current transients to the output of the power system. If your load is connected directly to the output of the power system and is not connected to chassis ground in any way, you do not need to worry about AC power switching transients appearing at the output of the power system. |

Operating the AC line switch can inject common mode current spikes into the DC output leads, resulting in voltage spikes that may damage loads that are highly sensitive to voltage or current transients. Note that any electronic device meeting international standards for EMI compliance is likely to generate similar current spikes. This situation arises from the presence of EMI filters at both the AC input and the DC output. These filters typically include common mode capacitors connected to the chassis of the power system. Since the AC input has an earth ground, any load that is also earth-grounded provides a possible return path for common mode currents.

The following figure illustrates a typical situation where a load that might otherwise be floating becomes grounded, thereby providing a return path for any injected currents. In this case, the return path is created by the low side of the scope probe, which is connected to the load circuit common and also to the scope's chassis. For this and similar cases, the following steps by order of preference, will help mitigate common mode current spikes appearing at the output when the power system is turned on or off by the AC line switch:

1. Install a ferrite core (Keysight p/n 9170-2131) on the power cord to insert additional impedance in the current path. This ferrite core is now installed inside N6701C and N6702C mainframes.

2. Install a separate bonding wire from the load's common point, to the ground terminal of the power system. This provides a lower impedance path that helps direct injected currents away from the DC output leads (and the sensitive load).

3. Break the return path through the external equipment. For example, instead of the single-ended scope shown in the figure, you can use a differential scope with a floating input or you can connect an isolated measuring instrument to the load.
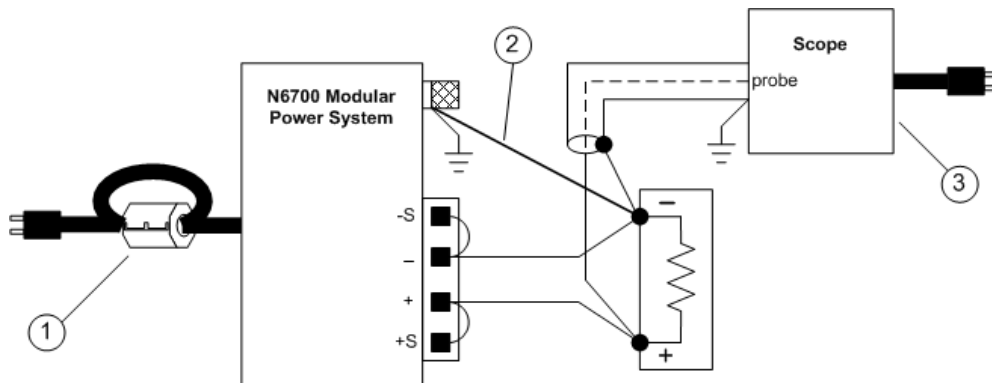
| NOTE | Disconnecting the load from the output before switching the power system on or off will **always** protect the load from common mode currents. |

Remote Sense Connections

Wiring

Open Sense Leads

Over-Voltage Protection Considerations

Output Noise Considerations

Wiring

> **WARNING** SHOCK HAZARD Turn off AC power before making rear panel connections.

Remote sensing improves the voltage regulation at the load by monitoring the voltage there instead of at the output terminals. This allows the power system to automatically compensate for the voltage drop in the load leads. Remote sensing is especially useful for CV operation with load impedances that vary or have significant lead resistance. It has no effect during CC operation. Because sensing is independent of other power system functions, remote sensing can be used regardless of how the power system is programmed.

Connect the unit for remote sensing by first disconnecting the straps between sense and load terminals. Make your connections as shown in the following figure. Connect the load to the output terminals using separate connecting wires. Keep the wire-pair as short as possible and twist or bundle it to reduce lead inductance and noise pickup. Keep load leads under 14.7 meters (50 feet) per lead because of inductance effects.
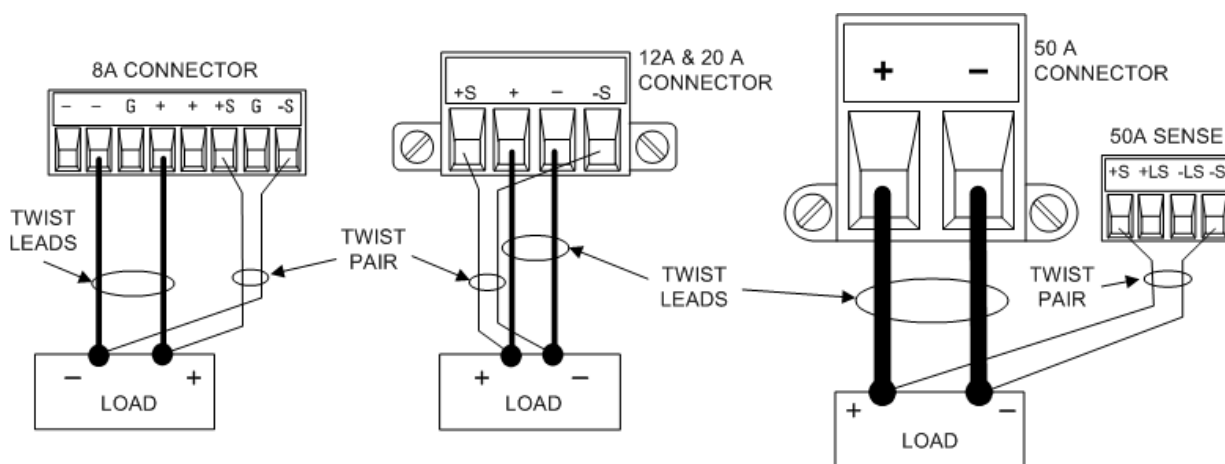
Connect the sense leads as close to the load as possible. Do NOT bundle the sense wire-pair together with the load leads; keep the load wires and sense wires separate. The sense leads carry only a few milliamperes of current and can be a lighter gauge than the load leads. However, note that any voltage drop in the sense leads can degrade the voltage regulation of the instrument. Keep the sense lead resistance less than about 0.5 Ω per lead (this requires 20 AWG or heavier for a 50 foot length).

Note that Keysight Models N678xA SMU require remote sensing when using any of the High output bandwidth modes discussed under Set the Output Bandwidth. Also, these models have additional wiring restrictions as discussed under Keysight N678xA SMU Wiring Requirements.

> **CAUTION** When remote sensing on power modules with the 50 A sense connector, do not connect the +LS and −LS terminals. These are dedicated for local sensing only.

Open Sense Leads

The sense leads are part of the output's feedback path. Connect them in such a way so that they do not inadvertently become open circuited. The power system includes protection resistors that reduce the effect of open sense leads during remote-sensing operation. If the sense leads open during operation, the power system returns to the local sensing mode, with the voltage at the output terminals approximately 1% higher than the programmed value.

Over-Voltage Protection Considerations

You must take into account any voltage drop in the load leads when setting the over-voltage trip point. This is because the OVP circuit senses at the output terminals and not at the sense terminals. Due to the voltage drop in the load leads, the voltage sensed by the OVP circuit could be higher than the voltage being regulated at the load.

OVP for Keysight N678xA SMU (local OVP)

For Keysight Models N678xA SMU only, the OVP circuit senses at the 4-wire sense terminals rather than at the output terminals. This allows for more precise overvoltage monitoring directly at the load. Since incorrect sense terminal wiring could defeat this feature, there is also a local OVP function.

The **Local OVP** function tracks the programmed OVP setting and trips if the voltage at the + and - output terminals rises more than 1.5 V above the programmed OVP setting. The local OVP also trips if the voltage at the output terminals exceeds 7.5 V on the 6 V range and 21.5 V on the 20 V range.

Output Noise Considerations

Any noise picked up on the sense leads will appear at the output terminals and may adversely affect CV load regulation. Twist the sense leads or use a ribbon cable to minimize the pickup of external noise. In extremely noisy environments it may be necessary to shield the sense leads. Ground the shield at the power system end only; do not use the shield as one of the sensing conductors.

The noise specifications documented in the Keysight N6700 Modular Power System Family Specifications Guide apply at the output terminals when using local sensing. However, voltage transients may be produced at the load by noise induced in the leads or by load current transients acting on the inductance and resistance of the load lead. If it is desirable to keep voltage transient levels to a minimum, place an aluminum or tantalum capacitor, with an approximate value of 10 µF per foot (30.5 cm) of load lead, right across the load.

## Parallel and Series Connections

Parallel Connections

Series Connections

Parallel Connections

> **CAUTION** **Equipment Damage** Only connect power supplies that have identical voltage and current ratings in parallel. Keysight Models N678xA SMU may be paralleled, but ONLY when operated in Current Priority mode. Voltage Priority operation is not allowed.

Connecting power supplies in parallel provides a greater current capability than can be obtained from a single unit.

The following figures show how to connect two outputs in parallel. The figure on the left illustrates local sensing. If voltage drop in the load leads is a concern, the figure on the right shows how to connect the sense leads directly at the load. Note that in both cases, the remote sense terminals must be connected.
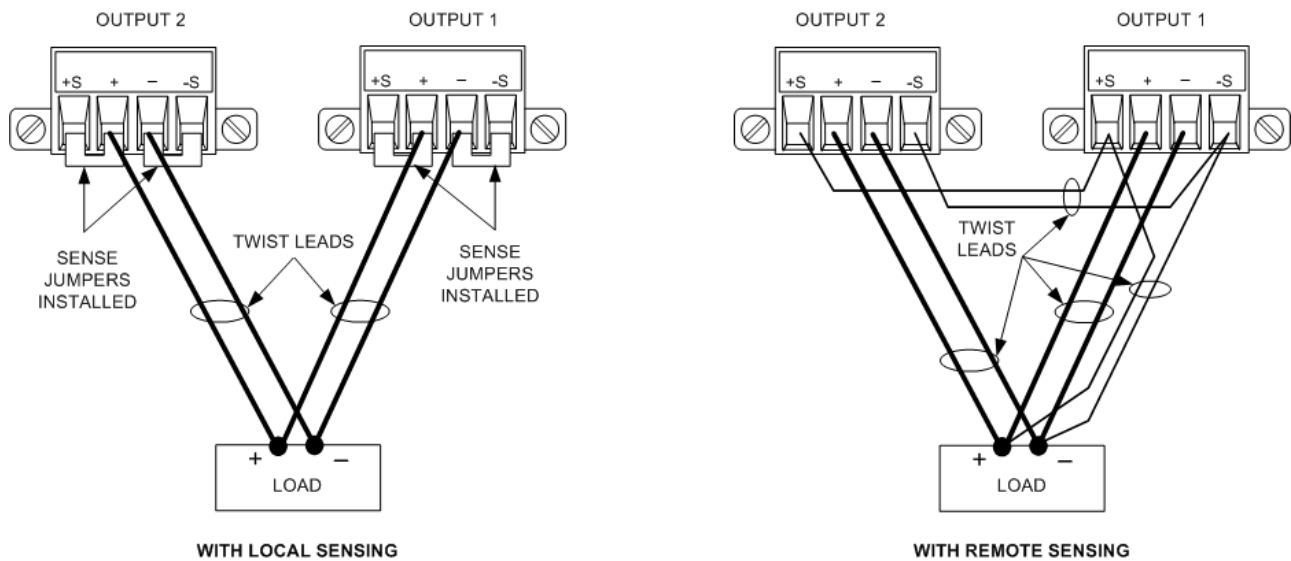
The following figure shows the connections for 50A power modules.

WITH LOCAL SENSING   **WITH REMOTE SENSING**
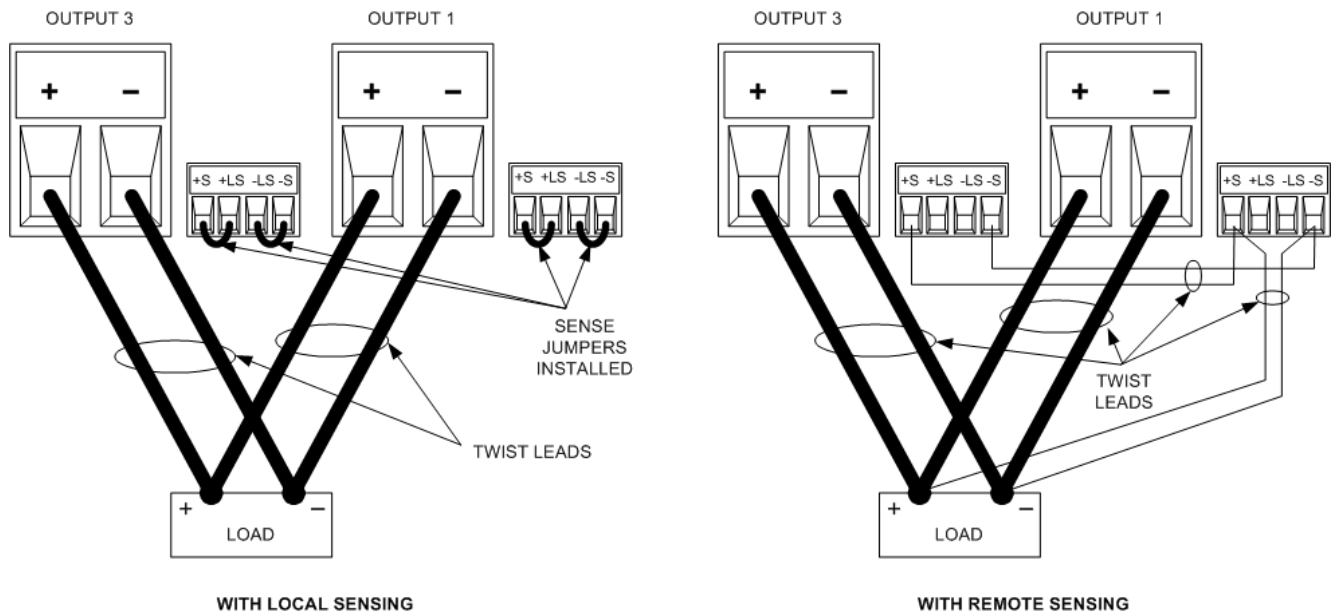
The following figure shows the paralleled connections for N678xA SMU power modules. Note that remote sensing is not normally used in Current Priority mode.
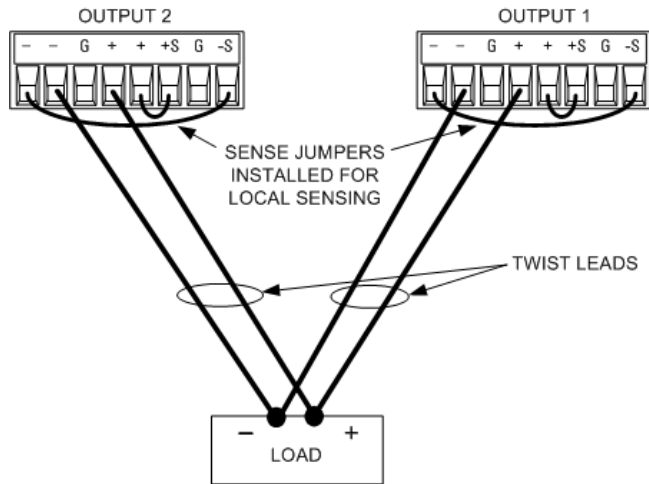
Grouping the Outputs

The output grouping function is not available for N678xA SMU power modules.

Once outputs have been connected in parallel, they can be configured or "grouped" to act as a single, higher-power channel. This applies when programming via the front panel or using SCPI commands. How to group output channels that have been connected in parallel is discussed under Output Groups.

If you are not grouping output channels, first program both outputs to the desired output voltage. Then program the current limit of each output. In Current Priority mode, program the output current of

each output to one half of the total desired output current. Set the voltage limit to a value higher than the expected output voltage.

Effect on Specifications

Specifications for outputs operating in parallel can be obtained from the specifications for single outputs. Most specifications are expressed as a constant or as a percentage (or ppm) plus a constant. For parallel operation, the percentage portion remains unchanged while constant portions or any constants are changed as indicated below. For current readback accuracy and temperature coefficient of current readback, use the minus current specifications:

Current: All parallel specifications referring to current are twice the single output specification except for programming resolution, which is the same for both single output and parallel output operation.

Voltage: All parallel specifications referring to voltage are the same as for a single output except for CV load effect, CV load cross regulation, CV source effect, and CV short term drift. These are all twice the voltage programming accuracy (including the percentage portion) at all operating points.

Load Transient Recovery Time: Load transient specifications are typically twice the single output.

Series Connections

| **WARNING** | SHOCK HAZARD Floating voltages must not exceed 240 VDC. No output terminal may be more than 240 VDC from chassis ground. |

CAUTION	Only connect outputs that have identical voltage and current ratings in series. Keysight Models N678xA SMU and N6783A cannot be connected in series.
	To prevent currents from damaging the power system when the load is connected, always turn series-connected outputs on and off together.
	Do not leave one output on while the other is off.

Connecting outputs in series provides a greater voltage capability than can be obtained from a single output. Because the current is the same through each element in a series circuit, outputs connected in series must have equivalent current ratings.

The following figures show how to connect two outputs in series to a single load. If voltage drop in the load leads is a concern, connect the sense leads of output 1 and output 2 for remote sensing as shown in the figure on the right. Note that the +sense lead of output 1 must remain connected to the –sense terminal of output 2.
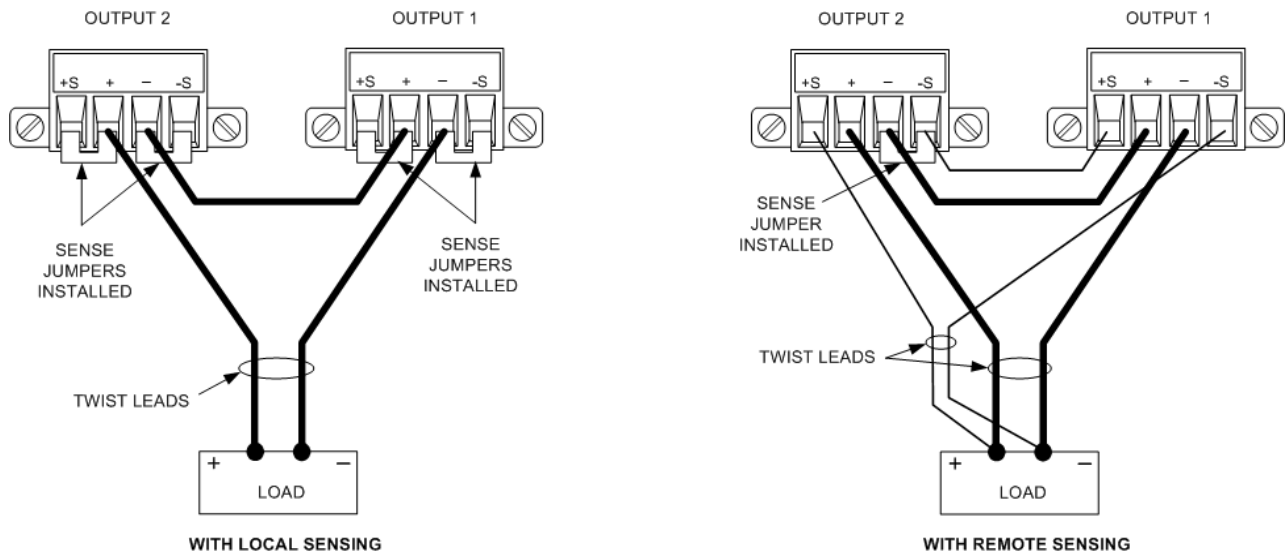
The following figure shows the connections for 50A power modules.
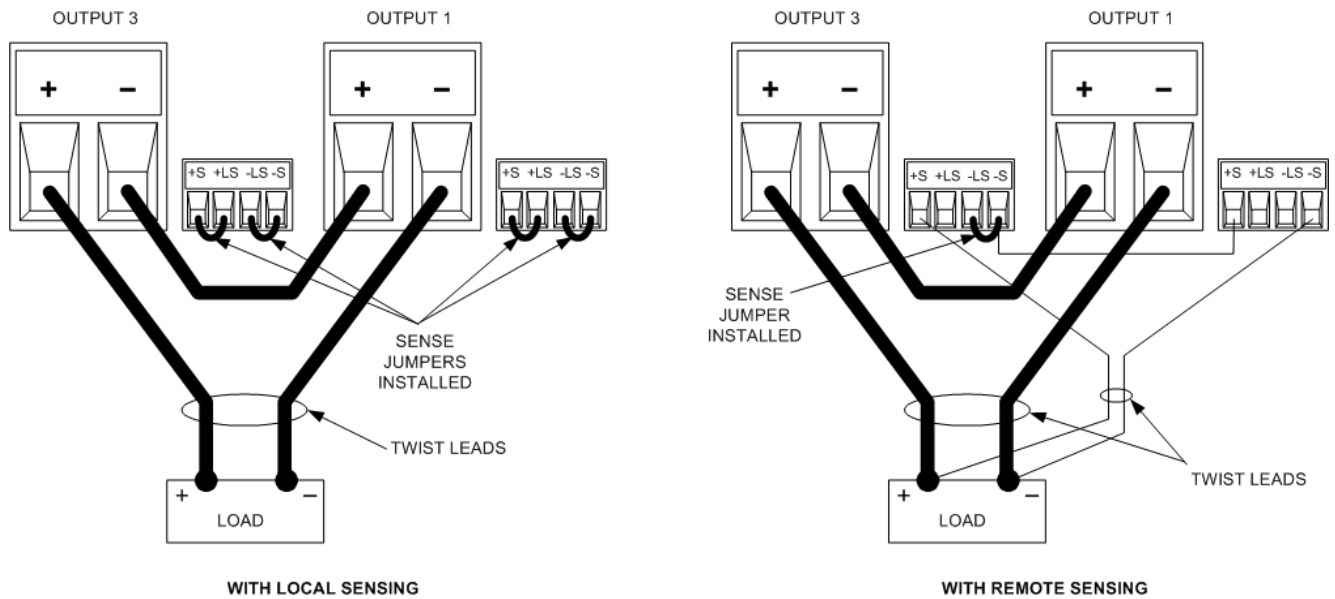
Setting the Outputs

Outputs connected together in series cannot be grouped.

To program outputs connected in series, first program the current limit of each output to the total desired current limit point. Then program the voltage of each output so that the sum of both voltages equals the total desired operating voltage. The simplest way to accomplish this is to program each output to one half of the total desired operating voltage.

> **NOTE**   The operating mode of each output is determined by the output's programmed settings, operating point, and load condition. Because these conditions may change during series operation, the front panel status indicator will reflect these changes. This is normal. Momentary status changes are also normal.

Effect on Specifications

Specifications for outputs operating in series can be obtained from the specifications for single outputs. Most specifications are expressed as a constant or a percentage (or ppm) plus a constant. For series operation, the percentage portion remains unchanged while constant portions or any constants are changed as indicated.

Voltage: All series specifications referring to voltage are twice the single output specification except for programming resolution, which is the same as for a single output.

Current: All series specifications referring to current are the same as for a single output except for CC load effect, CC load cross regulation, CC source effect, and CC short term drift. These are twice the current programming accuracy (including the percentage portion) at all operating points.

Load Transient Recovery Time: Load transient specifications are typically twice the single output.

Auxiliary Measurement Connections

> **NOTE**   This information only applies to Keysight Models N6781A and N6785A.

The auxiliary voltage measurement input is located on the rear panel of the Keysight N6781A and N6785A. It is primarily used for battery voltage rundown measurements, but it is also suitable for general purpose DC measurements.

The auxiliary voltage measurement input is isolated from other commons. It has a bandwidth of about 2 kHz. It has one input range: −20 to +20 VDC.

As shown in the following figure, auxiliary voltage measurements cannot be made on test points that are at a greater potential than ±60 VDC from ground. Refer to Auxiliary Voltage Measurements for more information.

> **CAUTION**   When using the auxiliary voltage measurement input, no output terminal or measurement input terminal may be more than ± 60 VDC from any other terminal and chassis ground.
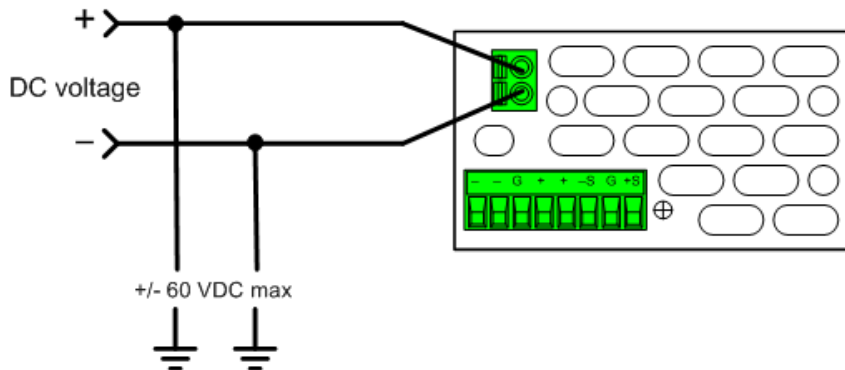
Interface Connections

GPIB Connections

USB Connections

LAN Connections - site and private

Digital Port Connections

This section describes how to connect to the various communication interfaces on your power system. For further information about configuring the remote interfaces, refer to Remote Interface Configuration.

> **NOTE**   If you have not already done so, install the Keysight IO Libraries Suite, which can be found at www.keysight.com/find/iolib. For detailed information about interface connections, refer to the Keysight Technologies USB/LAN/GPIB Interfaces Connectivity Guide included with the Keysight IO Libraries Suite.

GPIB Connections

The following figure illustrates a typical GPIB interface system.
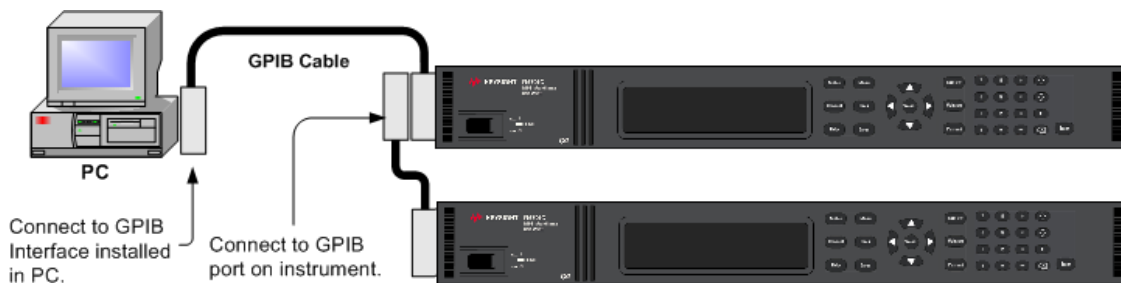
1. If you do not have a GPIB interface card installed on your computer, turn off your computer and install the GPIB card

2. Connect your instrument to the GPIB interface card using a GPIB interface cable.

3. Use the Connection Expert utility of the Keysight IO Libraries Suite to configure the GPIB card's parameters.

4. The power system is shipped with its GPIB address set to 5. Use the front panel menu if you need to change the GPIB address.

5. You can now use Interactive IO within the Connection Expert to communicate with your instrument, or you can program your instrument using the various programming environments.

USB Connections

The following figure illustrates a typical USB interface system.
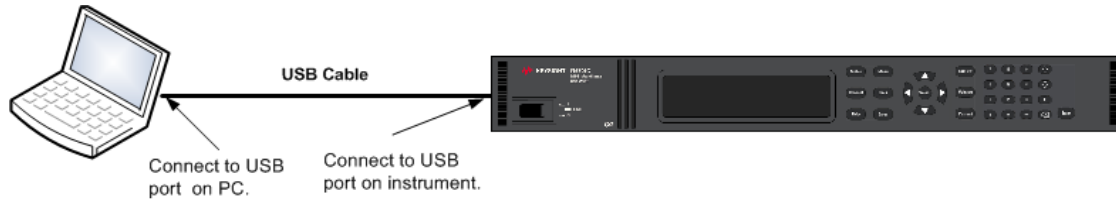
1. Connect your instrument to the USB port on your computer using a USB cable.

2. With the Connection Expert utility of the Keysight IO Libraries Suite running, the computer will automatically recognize the instrument. This may take several seconds. When the instrument is recognized, your computer will display the VISA alias, IDN string, and VISA address. This information is located in the USB folder. You can view the instrument's USB connect string from the front panel menu.

3. You can now use Interactive IO within the Connection Expert to communicate with your instrument, or you can program your instrument using the various programming environments.

LAN Connections - site and private

A **site LAN** is a local area network in which LAN-enabled instruments and computers are connected to the network through routers, hubs, and/or switches. They are typically large, centrally-managed networks with services such as DHCP and DNS servers. The following figure illustrates a typical site LAN system.
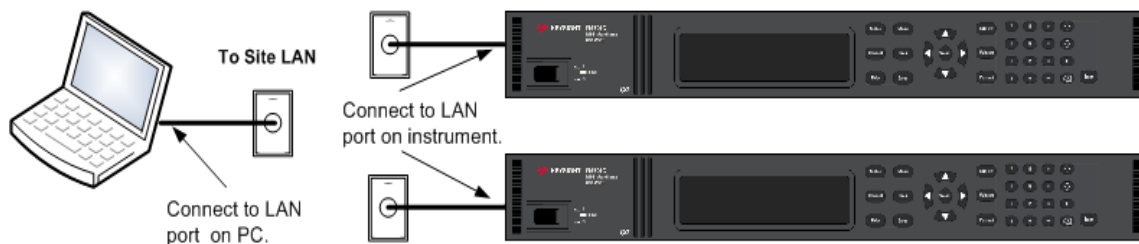
1. Connect the instrument to the site LAN or to your computer using a LAN cable. The as-shipped instrument LAN settings are configured to automatically obtain an IP address from the network using a DHCP server (DHCP is set On). The DHCP server will register the instrument's hostname with the dynamic DNS server. The hostname as well as the IP address can then be used to communicate with the instrument. The front panel **Lan** indicator will come on when the LAN port has been configured.

> NOTE   If you need to manually configure any instrument LAN settings, refer to Remote Interface Configuration for information about configuring the LAN settings from the front panel of the instrument.

2. Use the Connection Expert utility of the Keysight IO Libraries Suite to add the power system and verify a connection. To add the instrument, you can request the Connection Expert to discover the instrument. If the instrument cannot be found, add the instrument using its hostname or IP address.

> **NOTE** If this does not work, refer to "Troubleshooting Guidelines" in the Keysight Technologies USB/LAN/GPIB Interfaces Connectivity Guide included with the Keysight IO Libraries Suite.

3. You can now use Interactive IO within the Connection Expert to communicate with your instrument, or you can program your instrument using the various programming environments. You can also use the Web browser on your computer to communicate with the instrument as described under Using the Web Interface.

A **private LAN** is a network in which LAN-enabled instruments and computers are directly connected, and not connected to a site LAN. They are typically small, with no centrally-managed resources. The following figure illustrates a typical private LAN system.
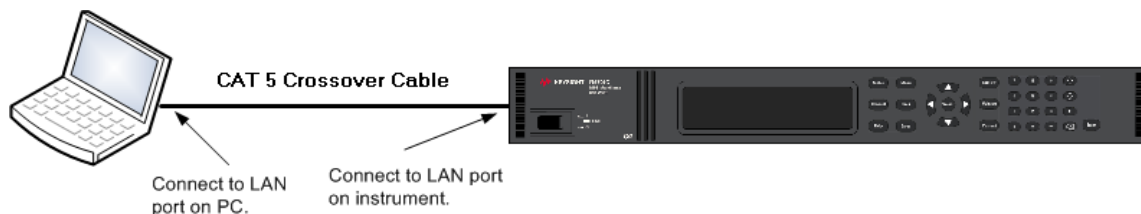
1. Connect the instrument to the computer using a LAN crossover cable. Alternatively, connect the computer and the instrument to a standalone hub or switch using regular LAN cables.

> **NOTE** Make sure your computer is configured to obtain its address from DHCP and that NetBIOS over TCP/IP is enabled. Note that if the computer had been connected to a site LAN, it may still retain previous network settings from the site LAN. Wait one minute after disconnecting it from the site LAN before connecting it to the private LAN. This allows Windows to sense that it is on a different network and restart the network configuration.

2. The factory-shipped instrument LAN settings are configured to automatically obtain an IP address from a site network using a DHCP server. You can leave these settings as they are. Most Keysight products and most computers will automatically choose an IP address using auto-IP if a DHCP server is not present. Each assigns itself an IP address from the block 169.254.nnn. Note that this may take up to one minute. The front panel Lan indicator will come on when the LAN port has been configured.

> **NOTE** Turning off DHCP reduces the time required to fully configure a network connection when the power system is turned on. To manually configure the instrument LAN settings, refer to Remote Interface Configuration for information about configuring the LAN settings from the front panel of the instrument.

3. Use the Connection Expert utility of the Keysight IO Libraries Suite to add the power system and verify a connection. To add the instrument, you can request the Connection Expert to discover the instrument. If the instrument cannot be found, add the instrument using its hostname or IP address.

> **NOTE** If this does not work, refer to "Troubleshooting Guidelines" in the Keysight Technologies USB/LAN/GPIB Interfaces Connectivity Guide included with the Keysight IO Libraries Suite.

4. You can now use Interactive IO within the Connection Expert to communicate with your instrument, or you can program your instrument using the various programming environments. You can also use the Web browser on your computer to communicate with the instrument as described under Using the Web Interface.

Digital Port Connections

An 8-pin connector and a quick-disconnect connector plug are provided on each instrument for accessing the five digital control port functions. The digital control connector accepts wires sizes from AWG 14 to AWG 30. Note that wire sizes smaller than AWG 24 are not recommended. Disconnect the connector plug to make your wire connections.

1. Insert wires

2. Tighten screws

3. Signal common

4. Digital IO signals

5. FLT/INH signals

6. Output couple controls
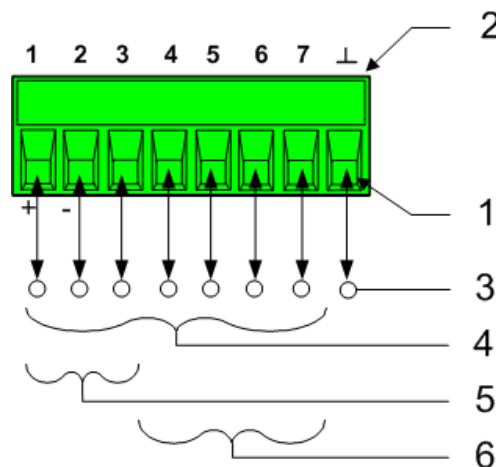
> **NOTE** It is good engineering practice to twist and shield all signal wires to and from the digital connectors. If shielded wire is used, connect only one end of the shield to chassis ground to prevent ground loops.

Pin Functions

The following chart describes the possible pin configuration for the digital port functions. For a complete description of the electrical characteristics of the digital I/O port, refer to the product Specifications.

2 Installation

Pin Function	Available configurable pins
Digital I/O and Digital In	Pins 1 through 7
External Trigger In/Out	Pins 1 through 7
Fault Out	Pins 1 and 2
Inhibit In	Pin 3
Output State	Pins 4 through 7
Common	Pin 8

In addition to the configurable pin functions, the active signal polarity for each pin is also configurable. When Positive polarity is selected, a logical true signal is a voltage high at the pin. When Negative polarity is selected, a logical true signal is a voltage low at the pin.

For information on configuring the digital port functions, Refer to Using the Digital Control Port.

Keysight N6700C Series User's Guide

3
Getting Started

Using the Front Panel

Remote Interface Configuration

KEYSIGHT
TECHNOLOGIES

Using the Front Panel

Turn the Unit On

Set the Output Voltage

Set the Output Current

Enable the Output

Use the Front Panel Menu

Set the Over-Voltage Protection

This section describes how to get started using your power system. It discusses turning the unit on, using the front panel controls, and navigating the front panel command menu. A map of the front panel menu structure is found in under Front Panel Menu Reference.

This section also contains information on how to configure the three remote interfaces that are provided on the back of the instrument.

| NOTE | Detailed information on configuring the remote interfaces is included in the Keysight Technologies USB/LAN/GPIB Interfaces Connectivity Guide, which is available on the Automation-Ready CD included with this product. |

Turn the Unit On

| NOTE | It may take 20 seconds or so for the power system to initialize before it is ready for use. |

After you have connected the line cord, turn the unit on with the front panel power switch. The front panel display will light up after a few seconds.

A power-on self-test occurs automatically when you turn the unit on. This test assures you that the instrument is operational. If the self-test fails, the front panel **Err** indicator comes on. Press the Error key to display the list of errors on the front panel. Refer to Error Messages in the Operating and Service Guide document for more information.

When the front panel display appears, you can use the front panel controls to enter voltage and current values.
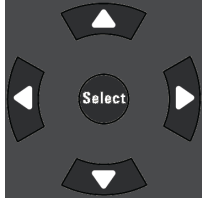
Select an Output Channel

Press Channel to select the output channel that you wish to program.

Set the Output Voltage

Method 1 – Use the Navigation and Arrow Keys

Navigation keys

Use the left and right navigation keys to navigate to the setting that you wish to change. In the display below, channel 1's voltage setting is selected. Enter a value using the numeric keypad. Then press Enter.

0.0000V   0.0000A

1 OFF Set: 12.523   0.0000A

Arrow keys ⬆⬇

You can also use the numeric arrow keys to adjust the value up or down, and switch between + and − limits on Model N6784A. When the output is on and the unit is operating in CV mode, the output voltage changes immediately. Otherwise, the value will become effective when the output is turned on.

Method 2 - Use the Voltage key to enter a value

Voltage

Press Voltage to select the voltage entry field. In the display below, channel 1's voltage setting is selected. Enter the desired setting using the numeric keypad. Then press Enter.
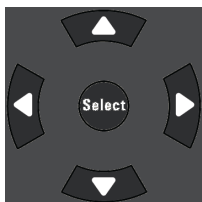

Chan 1:\Output\Settings\Voltage

Voltage   12.523

NOTE   If you make a mistake, either use the ⬅ backspace key to delete the number, press Back to back out of the menu, or press Meter to return to meter mode.

Set the Output Current

Method 1 – Use the Navigation and Arrow Keys

Navigation keys

Use the left and right navigation keys to navigate to the setting that you wish to change. In the display below, channel 1's current setting is selected. Enter a value using the numeric keypad. Then press Enter.

0.0000V   0.0000A

1 OFF Set: 12.523V   2

Arrow keys ⬆⬇   You can also use the arrow keys to adjust the value up or down and switch between + and − limits on Models N678xA SMU. When the output is on and the unit is operating in CC mode, the output current changes immediately. Otherwise, the value will become effective when the output is turned on

Method 2 - Use the Current key to enter a value

Current   Press Current to select the current entry field. In the display below, channel 1's current setting is selected. Enter the desired setting using the numeric keypad. Then press Enter.

```
Chan 1:\Output\Settings\Current


        Current    2.0000
```

NOTE   If you make a mistake, either use the ⬅ backspace key to delete the number, press Back to back out of the menu, or press Meter to return to meter mode.

Enable the Output

Use the On/Off key to enable the output

On/Off   If a load is connected to the output, the front panel display will indicate that it is drawing current. Otherwise, the current reading will be zero. The status indicator next to the channel number indicates the output's status. In this case, the output channel is in constant voltage mode.

```
12.5230V   0.1789A

 1  CV  Set: 12.523V    2.000A
```

NOTE   For a description of the status indicators, refer to Front Panel Display – At a Glance.

Use the Front Panel Menu

The front panel command menu lets you access most of the power system's functions. The actual function controls are located at the lowest menu level. Briefly:

- Press the **Menu** key to access the command menu.

- Press the left and right (◄, ►) navigation keys to move across the menu commands.

- Press the center **Select** key to select a command and move down to the next level in the menu.

- Press the **Help** key at the lowest menu level to display help information about the function controls.

For a map of the front panel menu commands, refer to Front Panel Menu Reference. The following example shows you how to navigate the front panel command menu to program the over-voltage protection function.

Menu example - setting over-voltage protection

Press Menu to access the front panel command menu. The first line identifies the output channel that is being controlled followed by the menu path. Since the top level is displayed, the path is empty.

The second line indicates the commands that are available at the present menu level. In this case, the top-level menu commands are shown, with the Output command highlighted.

The third line indicates which commands are available under the Output command. Selecting the highlighted command accesses this lower level.

```
Chan 1:\
Output Measure Transient Protect States System
Settings, Mode, Sequence, Short, Advanced
```
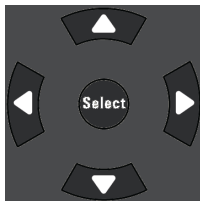
Press the right navigation ▶ key to traverse the menu until the Protect command is highlighted. Press Select to select the Protect command.

```
Chan 1:\
Output Measure Transient Protect States System
OVP, OCP, OPP, OT, Inh, Coupling, WDog, Osc, Clear
```
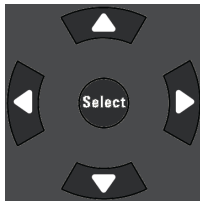
The menu path now lets you select from the available Protect commands on the second line. The OVP command is highlighted. The third line has a brief description of the OVP command. Press Select to select the OVP command.

```
Chan 1:\Protect
OVP OCP OPP OT Inh Coupling WDog Osc Clear
Overvoltage protection settings.
```
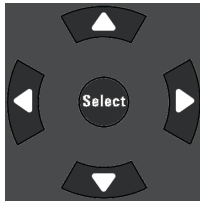
4, 4, Enter

The command menu is now at the function control level. This is the lowest level in this path. Use the navigation keys to highlight the OVP Level control as shown below. Enter the desired over-voltage protection level using the numeric keypad. Then press Enter.

Chan 1:\Protect\OVP

OVP Level 44.000
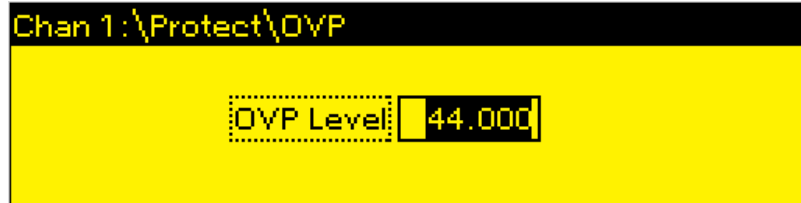
Press **Channel** at any time to select a different output channel. This can save time because you can directly access the OVP control of each channel without having to navigate through the menu levels.

Chan 2:\Protect\OVP

OVP Level 54.000
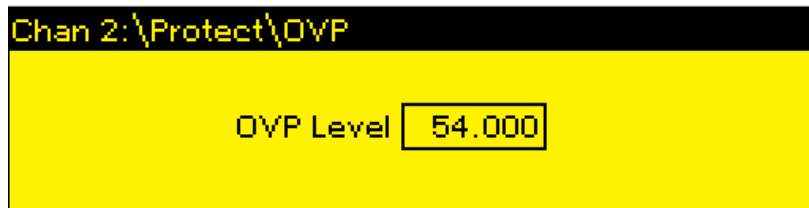
NOTE   If you program an over-voltage protection level that is lower than the present output voltage, the over-voltage protection circuit will trip and turn the output off. The front panel status indicator will show OV.

Exit the Command Menu

There are two ways to exit the command menu

Press **Meter** to immediately return to the metering screen. This is the quickest way to return to metering mode.

Press **Back** to back up one level at a time in the command menu. This method may be more convenient if there are other menu commands to be given.

In Case of Trouble

Press the **Help** key to obtain additional help about any function control menu level. Press the Back key to exit the Help menu.

The front panel Err indicator comes on if self-test fails or if other operating problems occur with your instrument. Press the Error key to display the list of errors. Refer to the Service and Maintenance section in the Operating and Service Guide document for further information.

Remote Interface Configuration

USB Configuration

GPIB Configuration

LAN Configuration

Modifying the LAN Settings

Using the Web Interface

Using Telnet

Using Sockets

Securing the Interfaces

This Keysight N6700 MPS supports remote interface communication over three interfaces: GPIB, USB, and LAN. All three interfaces are live at power on. For information on connecting the interfaces, refer to Interface Connections.

The front panel **IO** indicator comes on whenever there is activity on the remote interfaces. The front panel **Lan** indicator comes on when the LAN port is connected and configured.

Power system mainframes provide Ethernet connection monitoring. With Ethernet connection monitoring, the instrument's LAN port is continually monitored, and automatically reconfigured when the instrument is unplugged for a minimum of 20 seconds and then reconnected to a network.

USB Configuration

There are no configurable USB parameters. You can retrieve the USB connect string using the front panel menu:

Front Panel Menu Reference	SCPI Command
Select **System\IO\USB**	Not available
The dialog displays the USB connect string.	

GPIB Configuration

Each device on the GPIB (IEEE-488) interface must have a unique whole number address between 0 and 30. The instrument ships with the address set to 5. Your computer's GPIB interface card address must not conflict with any instrument on the interface bus. This setting is non-volatile; it will not be changed by power cycling or *RST. Use the front panel menu to change the GPIB address:

Front Panel Menu Reference	SCPI Command
Select **System\IO\GPIB**	Not available
Use the numeric keys to enter a new value from 0 to 30. Then press **Enter**.	

LAN Configuration

The following sections describe the primary LAN configuration functions on the front-panel menus. Note that there are no SCPI commands to configure the LAN parameters. All LAN configuration must be done from the front panel.

> **NOTE**   After changing the LAN settings, you must Save the changes. Select: **System\IO\LAN\Apply**. Selecting Apply cycles power to the instrument and activates the settings. LAN settings are nonvolatile, they will not be changed by power cycling or *RST. If you do not want to save your changes select: **System\IO\LAN\Cancel**. Selecting Cancel cancels all changes.

When shipped, DHCP is on, which may enable communication over LAN. The letters DHCP stands for Dynamic Host Configuration Protocol, a protocol for assigning dynamic IP addresses to devices on a network. With dynamic addressing, a device can have a different IP address every time it connects to the network.

Viewing Active Settings

To view the currently active LAN settings:

Front Panel Menu Reference	SCPI Command
Select **System\IO\LAN\Settings**	Not available
Displays the active LAN settings. Use the up and down arrow key to scroll through the list.	

The currently active settings for the IP Address, Subnet Mask, and Default Gateway may be different from the front panel configuration menu settings - depending on the configuration of the network. If the settings are different, it is because the network has automatically assigned its own settings.

Resetting the LAN

You can perform an LXI LCI reset if the LAN settings. This resets DHCP, DNS server address configuration, mDNS state, mDNS service name and web password. These settings are optimized for connecting your instrument to a site network. They should also work well for other network configurations.

You can also reset the LAN to the as-shipped settings. This returns **ALL** LAN settings to the as-shipped values and restarts networking. All default LAN settings are listed under Non-volatile Settings in the Operating and Service Guide document .

Front Panel Menu Reference	SCPI Command
Select **System\IO\LAN\Reset**	Not available
Select **System\IO\LAN\Defaults**	
Select **Reset**. This activates the selected LAN settings and restarts networking.	

Modifying the LAN Settings

As shipped from the factory, the power system's pre-configured settings should work in most LAN environments. If you need to manually configure these settings, press the Menu key, then use the navigation keys to select the LAN Modify menu. In the Modify menu you can then access the following items: IP, Name, DNS, WINS, mDNS, and Services.

Refer to Non-Volatile Settings in the Operating and Service Guide document for information on the factory-shipped LAN settings.

IP Address

Front Panel Menu Reference	SCPI Command
Select **System\IO\LAN\Modify\IP**	Not available
Select Auto or Manual. See below for a full description.	

- **Auto** – This parameter automatically configures the addressing of the instrument. When selected, the instrument will first try to obtain an IP address from a DHCP server. If a DHCP server is found, the DHCP server will assign an IP address, Subnet Mask, and Default Gateway to the instrument. If a DHCP server is unavailable, the instrument will try to obtain an IP address using AutoIP. AutoIP automatically assigns an IP address, Subnet Mask, and Default Gateway addresses on net-works that do not have a DHCP server. (The letters DHCP stands for Dynamic Host Configuration Protocol, a protocol for assigning dynamic IP addresses to devices on a network. With dynamic addressing, a device can have a different IP address every time it connects to the network.)

- **Manual** – This parameter allows you to manually configure the addressing of the instrument by entering values in the following three fields. These fields only appear when Manual is selected.

- **IP Address** – This value is the Internet Protocol (IP) address of the instrument. An IP address is required for all IP and TCP/IP communications with the instrument. An IP Address consists of 4 decimal numbers separated by periods. Each decimal number ranges from 0 through 255 with no leading zeros (for example, 169.254.2.20).

- **Subnet Mask** – This value is used to enable the instrument to determine if a client IP address is on the same local subnet. The same numbering notation applies as for the IP Address. When a client IP address is on a different subnet, all packets must be sent to the Default Gateway.

- **DEF Gateway** - This value is the IP Address of the default gateway that allows the instrument to communicate with systems that are not on the local subnet, as determined by the subnet mask setting. The same numbering notation applies as for the IP Address. A value of 0.0.0.0 indicates that no default gateway is defined.

Dot-notation addresses ("nnn.nnn.nnn.nnn" where "nnn" is a byte value from 0 to 255) must be expressed with care, as most PC web software interprets byte values with leading zeros as octal (base 8) numbers. For example, "192.168.020.011" is actually equivalent to decimal "192.168.16.9" because ".020" is interpreted as "16" expressed in octal, and ".011" as "9". To avoid confusion, use only decimal values from 0 to 255, with no leading zeros.

Host Name

A hostname is the host portion of the domain name, which is translated into an IP address. To configure the hostname of the instrument:

Front Panel Menu Reference	SCPI Command
Select **System\IO\LAN\Modify\Name**	Not available
You can enter any value from the numeric keypad. For additional characters, use the up/down navigation keys to enter an alpha character by scrolling through the selection list that appears when you press the keys. Use the left/right navigation keys to traverse the text field. Use the backspace key to delete a value. Press Enter when you are finished.	

- **Host name** - This field registers the supplied name with the selected naming service. If the field is left blank, no name is registered. A hostname may contain upper and lower case letters, numbers and dashes(-). The maximum length is 15 characters.

  Each power system is shipped with a default hostname with the format: Keysight-modelnumber-serialnumber, where modelnumber is the mainframe's 6-character model number (e.g. N6700C), and serialnumber is the last five characters of the 10-character mainframe serial number located on the label on the top of the unit (e.g. 45678 if the serial number is MY12345678).

DNS Server and WINS Server

DNS is an internet service that translates domain names into IP addresses. It is also needed for the instrument to find and display its hostname assigned by the network. Normally, DHCP discovers the DNS address information; you only need to change this if DHCP is unused or not functional.

WINS configures the Windows service of the instrument. This is similar to the DNS service that translates domain names into IP addresses.

To manually configure the DNS and WINS services:

Front Panel Menu Reference	SCPI Command
Select **System\IO\LAN\Modify\DNS**	Not available
Select **System\IO\LAN\Modify\WINS**	
Select Primary Address or Secondary Address. See below for a full description.	

- **Primary Address** - This field enters the primary address of the server. Contact your LAN administrator for server details. The same numbering notation applies as for the IP Address. A value of 0.0.0.0 indicates that no default server is defined.

- **Secondary Address** - This field enters the secondary address of the server. Contact your LAN administrator for server details. The same numbering notation applies as for the IP Address. A value of 0.0.0.0 indicates that no default server is defined.

Dot-notation addresses ("nnn.nnn.nnn.nnn" where "nnn" is a byte value from 0 to 255) must be expressed with care, as most PC web software interprets byte values with leading zeros as octal (base 8) numbers. For example, "192.168.020.011" is actually equivalent to decimal "192.168.16.9" because ".020" is interpreted as "16" expressed in octal, and ".011" as "9". To avoid confusion, use only decimal values from 0 to 255, with no leading zeros.

mDNS Service Name

The mDNS service name is registered with the selected naming service. To configure the mDNS service name of the instrument:

Front Panel Menu Reference	SCPI Command
Select **System\IO\LAN\Modify\Name**	Not available
You can enter any value from the numeric keypad. For additional characters, use the up/down navigation keys to enter an alpha character by scrolling through the selection list that appears when you press the keys. Use the left/right navigation keys to traverse the text field. Use the backspace key to delete a value. Press Enter when you are finished.	

- **mDNS Service Name** - This field registers the service name with the selected naming service. If the field is left blank, no name is registered. A service name may contain upper and lower case letters, numbers and dashes(-).

  Each power system is shipped with a default service name with the format: Keysight-modelnumber-serialnumber, where modelnumber is the mainframe's 6-character model number (e.g. N6700C), and serialnumber is the last five characters of the 10-character mainframe serial number located on the label on the top of the unit (e.g. 45678 if the serial number is MY12345678).

Services

This selects the LAN services to enable or disable.

Front Panel Menu Reference	SCPI Command
Select **System\IO\LAN\Modify\Services**	Not available
Check or uncheck the services that you wish to enable or disable	

- The configurable services include: VXI-11, Telnet, Web control, Sockets, mDNS, and HiSLIP.

- You must enable Web control if you wish to remotely control your instrument using its built-in Web interface.

Using the Web Interface

Your power system has a built-in Web interface that lets you control it directly from the Web browser on your computer. With the Web interface, you can access the front panel control functions including the LAN configuration parameters. Up to six simultaneous connections are allowed. With multiple connections, performance will be reduced.
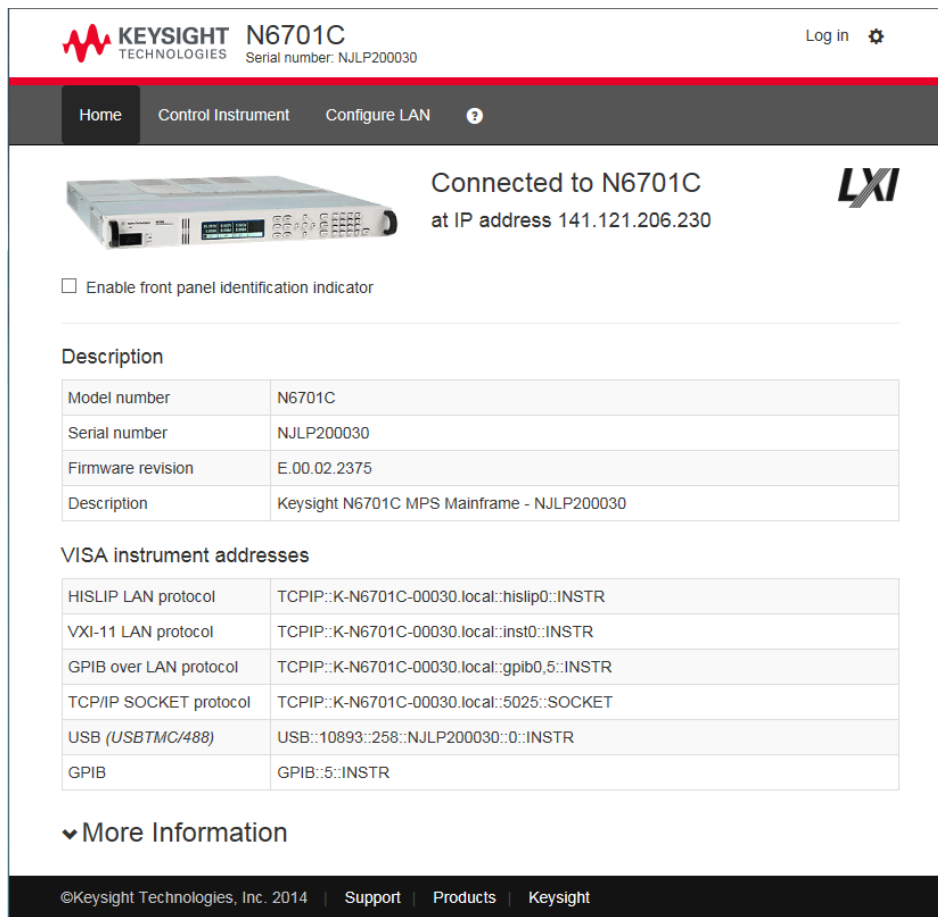
> **NOTE**   The built-in Web interface only operates over the LAN. It requires a Web browser. You also need the Java Plug-in version 7+. This is included in the Java Runtime Environment.

The Web interface is enabled when shipped. To launch the Web interface:

1. Open the Web browser on your computer.

2. Enter the instrument's hostname or IP address into the browser's Address field. The following home page will appear.

3. Click on the Control Instrument tab on the top of the page to begin controlling your instrument.

4. For additional help about any of the pages, click on the ? icon on the top of the page.

If desired, you can control access to the Web interface using password protection. As shipped, no password is set. To set a password, click Log In on the top of the page. Refer to the on-line help for additional information about setting a password.

When you click the Control Instrument tab, a representation of the front panel appears on the display. Use your mouse to control the front panel buttons in the same way that you would control the actual front panel of the instrument.

Using Telnet

In an MS-DOS Command Prompt box type: telnet hostname 5024 where hostname is the instrument's hostname or IP address, and 5024 is the instrument's telnet port.

You should get a Telnet session box with a title indicating that you are connected to the power system. Type the SCPI commands at the prompt.

Using Sockets

> **NOTE** Power supplies allow any combination of up to four simultaneous data socket, control socket, and telnet connections to be made.

Keysight instruments have standardized on using port 5025 for SCPI socket services. A data socket on this port can be used to send and receive ASCII/SCPI commands, queries, and query responses. All commands must be terminated with a newline for the message to be parsed. All query responses will also be terminated with a newline.

The socket programming interface also allows a control socket connection. The control socket can be used by a client to send device clear and to receive service requests. Unlike the data socket, which uses a fixed port number, the port number for a control socket varies and must be obtained by sending the following SCPI query to the data socket: SYSTem:COMMunicate:TCPip:CONTrol?

After the port number is obtained, a control socket connection can be opened. As with the data socket, all commands to the control socket must be terminated with a newline, and all query responses returned on the control socket will be terminated with a newline.

To send a device clear, send the string "DCL" to the control socket. When the power system has finished performing the device clear it echoes the string "DCL" back to the control socket.

Service requests are enabled for control sockets using the Service Request Enable register. Once service requests have been enabled, the client program listens on the control connection. When SRQ goes true the instrument will send the string "SRQ +nn" to the client. The "nn" is the status byte value, which the client can use to determine the source of the service request.

Securing the Interfaces

The USB interface, GPIB interface, and LAN interface are enabled when shipped. To enable or disable the interfaces from the front panel:

Front Panel Menu Reference	SCPI Command
Select **System\Admin\IO**	Not available
Enable or disable the interfaces by checking or unchecking the following items:	
Enable GPIB, Enable USB, and Enable LAN services	
Then press **Select**.	

If you cannot access the Admin menu, it may be password protected. Refer to Password Protection for more information.

> **NOTE** The LAN must be enabled in order to enable the Web server.

4

Operating the Power System

KEYSIGHT
TECHNOLOGIES

Programming the Output

Select a Channel View

Select an Output Channel

Set the Output Voltage

Set the Output Current

Set the Output Resistance

Set the Output Power

Set the Output Mode

Set the Slew Rate

Enable the Output

Sequence Multiple Outputs

Program the Output Relays

Set the Output Bandwidth

Set the Output Turn-Off Mode
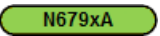
Programming an Input Short

Enable Under-Voltage Inhibit

| NOTE | When the power system is first turned on, it may take about 20 seconds or so to initialize the instrument before it is ready for use. |

If a menu item is grayed-out, it is not available for the module, or not available in the mode that is presently selected.

Keysight N679xA Load Module input terminals are referred to as "Outputs" throughout this document N679xA .

Select a Channel View

Front Panel Menu Reference	SCPI Command
Press the Meter key to toggle between single-channel and multiple-channel view.	To select single-channel view: DISP:VIEW METER1
	To select multiple-channel view: DISP:VIEW METER4

Select an Output Channel

Front Panel Menu Reference	SCPI Command
Press the Channel key to select an output channel.	Enter the selected channel(s) in the command's parameter list. OUTP:STAT? (@1,2)

Set the Output Voltage

Front Panel Menu Reference	SCPI Command
Press the Voltage key. Enter a voltage value. Then press **Select**.	To set output 1 to 5 V: VOLT 5,(@1) To set all outputs to 10 V: VOLT 10,(@1:4)

For models with multiple ranges, you can select a lower range if you need better output resolution.

Front Panel Menu Reference	SCPI Command
Press the Voltage key. Select a lower range. Then press **Select**.	To select the lower range, program a value that falls within the range: VOLT:RANG 5,(@1)

For Keysight Models N678xA SMU `N678xA SMU` operating in current priority mode, you can specify a Voltage limit, which limits the output voltage at the specified value. In current priority mode, the output current remains at its programmed setting as long as the output voltage is within the positive or negative limit. Check Tracking to let the negative voltage limit track the positive voltage limit.

Front Panel Menu Reference	SCPI Command
Press the Voltage key. Specify a + Voltage limit and or a – Voltage limit. Then press **Select**. Check the Tracking box if you want the – limit to track the + limit.	To select the voltage limit: VOLT:LIM 5,(@1) To select the negative voltage limit: VOLT:LIM:NEG 3,(@1) To enable voltage limit tracking: VOLT:LIM:COUP ON,(@1)

Set the Output Current

Front Panel Menu Reference	SCPI Command
Press the Current key. Enter a current value. Then press **Select**.	To set output 1 to 1 A: CURR 1,(@1) To set all outputs to 2 A: CURR 2,(@1:4)

For models with multiple ranges, you can select a lower range if you need better output resolution.

Front Panel Menu Reference	SCPI Command
Press the Current key. Select a lower range. Then press **Select**.	To select the lower range, program a value that falls within the range: CURR:RANG 1,(@1)

For Keysight Models N678xA SMU, N6783A, and N679xA `N678xA SMU` `N6783A` `N679xA` operating in voltage priority mode, you can specify a positive and negative current limit, which limits the output current at the specified value. In voltage priority mode, the output voltage remains at its programmed setting as long as the load current is within the positive or negative limit.

For Models N678xA SMU, check Tracking to let the negative current limit track the positive current limit. The negative current limit of Model N6783A-MFG is not programmable, but is fixed at -2A.

Front Panel Menu Reference	SCPI Command
Press the Current key. Specify a + Current limit and or a – Current limit. Then press **Select**. On N678xA SMU, check Tracking if you want the – limit to track the + limit.	To select the current limit: CURR:LIM 5,(@1) To select the negative current limit: CURR:LIM:NEG 3,(@1) To enable current limit tracking: CURR:LIM:COUP ON,(@1)

Set the Output Resistance

For Keysight Models N6781A and N6785A `N6781A, N6785A`, output resistance programming is primarily used in battery testing applications, and only applies in Voltage priority mode. Values are programmed in Ohms, from –40 mΩ to +1 Ω.

Front Panel Menu Reference	SCPI Command
Select **Output\Settings\Resistance**. Check Enable to enable resistance programming. Enter a value. Then press **Select**.	To enable resistance programming: VOLT:RES:STAT ON, (@1) To set the output resistance to 0.5 Ω: VOLT:RES 0.5,(@1)

For Keysight Models N679xA `N679xA`, the following commands program the load resistance. Resistance may be programmed in any of three overlapping ranges. The load module selects the range that corresponds to the resistance value that you program.

NOTE   The resistance selection must previously be selected under Output Mode.

Front Panel Menu Reference	SCPI Command
Select **Output\Settings\Resistance**. Enter a resistance value. Then press **Select**.	To set the output resistance to 60 Ω: RES 60,(@1)

You can manually select a lower resistance range if you need better output resolution. The following ranges can be selected:

	N6791A	N6792A
High resistance range	from 30 Ω to 8 kΩ	from 15 Ω to 8 kΩ
Medium resistance range	from 2 Ω to 100 Ω	from 2 Ω to 100 Ω
Low resistance range	from 0.08 Ω to 3 Ω	from 0.04 Ω to 3 Ω

Front Panel Menu Reference	SCPI Command
Select **Output\Settings\Resistance**. Select a lower range. Then press **Select**.	To select the lower range, program a value that falls within the range: RES:RANG 1,(@1)

NOTE   When changing ranges, the load input will be turned off, then back on again.

Set the Output Power

For Keysight N679xA load modules $\boxed{\text{N679xA}}$, the following commands program the input power limit. The maximum programmable output power is either 100 W or 200 W, depending on which load module is being programmed.

NOTE   The power selection must previously be selected under Output Mode.

Front Panel Menu Reference	SCPI Command
Select **Output\Settings\Power**. Enter a Power Limit value. Then press **Select**.	To set the inout power to 50 W: POW 50,(@1)

You can also select a lower power range if you need better output resolution. The following ranges can be selected:

	N6791A	N6792A
High power range	from 0.3 W to 100 W	from 0.5 W to 200 W
Low power range	from 0.04 W to 10 W	from 0.1 W to 20 W

Front Panel Menu Reference	SCPI Command
Select **Output\Settings\Power**. Select a Range from the dropdown. Then press **Select**.	To select the lower range, program a value that falls within the range: POW:RANG 5,(@1)

> **NOTE**   When changing ranges, the load input will be turned off, then back on again.

Set the Output Mode

> **NOTE**   This information applies to Keysight Models N678xA SMU and N679xA only.
>
> N678xA SMU   N679xA

For Keysight Models N678xA SMU and N679xA, you can select either Voltage priority or Current priority mode. Power and Resistance priority modes are only available for N679xA load modules.

Voltage priority mode applies to Keysight Models N678xA SMU and N679xA. In this mode, the output is controlled by a bi-polar constant voltage feedback loop, which maintains the voltage at its positive or negative programmed setting. The voltage will remain at its programmed setting as long as the load current remains within the current limit.

Current priority mode applies to Keysight Models N678xA SMU and N679xA. In this mode, the output is controlled by a bi-polar constant current feedback loop, which maintains the current at its programmed setting. The current will remain at its programmed setting as long as the load voltage remains within the voltage limit.

Power priority mode applies to Keysight Models N679xA. In this mode, the load module will maintain the output power at the specified programmed power level.

Resistance priority mode applies to Keysight Models N679xA. In this mode, the load module will sink a current linearly proportional to the input voltage in accordance with the programmed resistance.

Front Panel Menu Reference	SCPI Command
Select **Output\Mode**. Select either Current, Voltage, Power, or Resistance priority. Then press **Select**.	To set output 1 to current priority: FUNC CURR,(@1)

> **NOTE**   When switching between Current, Voltage, Power, or Resistance priority, the output is turned off and the output settings revert to their power-on or *RST values. Refer to Operating Mode Tutorial for information about priority mode operation.

Set the Slew Rate

The voltage slew rate determines the rate at which the voltage changes to a new programmed setting.

The current slew rate is only available on Keysight Models N678xA SMU and N679xA `N678xA SMU` `N679xA`. It determines the rate at which the current changes to a new programmed setting.

Power and resistance slew rates ars only available on Keysight Models N679xA `N679xA`. They determines the rate at which the power or resistance changes to a new programmed setting.

Front Panel Menu Reference	SCPI Command
Select **Output\Advanced\Slew** Then select Voltage, Current, Power, or Resistance Enter the slew rate in the Slew Rate field. Then press **Select**. Check the Max slew rate box if you want to program the fastest slew rate.	To set the voltage slew rate to 5 V/s VOLT:SLEW 5,(@1) To set the current slew rate to 1 A/s CURR:SLEW 1,(@1) To set the power slew rate to 10 W/s POW:SLEW 10,(@1) To set the resistance slew rate to 6 Ω/s RES:SLEW 6,(@1) To set the fastest voltage slew rate: VOLT:SLEW MAX,(@1)

There are separate slew rates for positive and negative going transitions. The slew rate settings are absolute values. There is also a tracking mode setting to have the negative slew track the positive setting.

When set to MAXimum, INFinity, or to a very large value, the slew rate will be limited by the analog performance of the control circuit. The slowest or minimum slew rate is model-dependent and is a function of the full scale range. For other ranges the minimum slew rate is proportional to the full scale range.

Enable the Output

Front Panel Menu Reference	SCPI Command
Press the On/Off key. To enable/disable ALL outputs using the On/Off key, select **System\Preferences\Keys.** Check On/Off key affects all channels. Then press **Select**.	To enable only output 1: OUTP ON,(@1) To enable outputs 1-4: OUTP ON,(@1:4)

Because of internal circuit start-up procedures and any installed relay options, output on may take between 35 and 50 milliseconds to complete its function. Conversely, output off may take between 20 and 25 milliseconds to complete its function.

To mitigate these built-in delays, you can program the output to zero volts rather than using the output on/off function.

Sequence Multiple Outputs

Turn-on and turn-off delays control the power-up and power-down sequencing of the output channels in relation to each other.

Front Panel Menu Reference	SCPI Command
Press the Channel key to select an output. Then select **Output\Sequence\Delay**. Select either Turn-on delay or Turn-off delay. Enter a delay in seconds. Then press **Select**. Select **System\Preferences\Keys**. Check On/Off key affects all channels. Then press **Select**.	To program a 50 ms turn-on delay for output 1 and a 100 ms turn-on delay for output 2: OUTP:DEL:RISE 0.05,(@1) OUTP:DEL:RISE 0.1,(@2) To program a 200 ms turn-off delay for outputs 3 and 4: OUTP:DEL:FALL 0.2,(@3,4)

Output turn-on characteristics vary across the power module types - DC Power, Autoranging, Precision, and Source/Measure. When output channels of the same module type are programmed off-to-on, output sequencing is determined by the programmed turn-on delays.

When outputs of different module types are sequenced, there may be additional offsets of a few milliseconds from one output to another that must be accounted for. Specifying a common delay offset assures that the programmed turn-on delays will be synchronized to start at the completion of the common delay offset. Select the delay offset of the slowest power module in the mainframe and use that as the common delay offset. (See Synchronizing Output Turn-On for more information.)

Front Panel Menu Reference	SCPI Command
In the front panel menu, select **Output\Sequence\Couple**. **Max delay offset for this frame** displays the delay offset of the slowest power module in the frame. Enter this value into the **Delay offset** field in milliseconds. Then press **Select**.	To query the delay offset of the slowest power module in the mainframe (the maximum delay offset): OUTP:COUP:MAX:DOFF? To specify the common delay offset for the mainframe: OUTP:COUP:DOFF 0.051

Program the Output Relays

Output relay availability and options are described under Options. Option 761 provides double-pole, double-throw relays that disconnect both the output and sense terminals. Option 760 is the same as option 761 but adds output reversal relays. Note that a small AC network is always present across the output terminals.

Front Panel Menu Reference	SCPI Command
Not Available	To leave the relays closed when output 1 is turned off: OUTP OFF,NOR,(@1) To leave the relays open when output 1 is turned on: OUTP ON,NOR,(@1)

If you have Option 761 installed, the normal operating mode of the relay is to open and close as the output is turned on or off. The relays are only opened or closed when the output is at a safe state (zero voltage; zero current). Note however, that you can program the output state on or off while leaving the relay state unchanged.

If you have Option 760 installed, you can also reverse the polarity of the output and sense terminals. Note that this command briefly turns the output off while the output and sense terminal polarities are switched. Also note that if this option is installed in Model N6742B, the maximum output current will be limited to 10A.

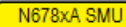| Front Panel Menu Reference	SCPI Command
Select **Output\Advanced\Pol**. Check the Reverse box. Uncheck the Reverse box to return the polarity to normal. Then press **Select**.	To switch the output and sense terminal polarities of output 1: OUTP:REL:POL REV,(@1) To return the polarities back to normal: OUTP:REL:POL NORM,(@1)

NOTE   When the output polarity has been reversed, the voltage meter on the front panel display will show a bar over the voltage reading: $10.001\overline{V}$

Set the Output Bandwidth

NOTE   This information applies to Keysight Models N678xA SMU only. N678xA SMU

Keysight Models N678xA SMU have several voltage bandwidth settings that let you optimize output response time with capacitive loads.

The Low bandwidth setting provides stability with a wide range of capacitive loads. Additional settings provide faster output response when the load capacitance is restricted to smaller values.

If capacitive loads cause the output to oscillate on the Low bandwidth or any other bandwidth setting, a protection function will detect the oscillation and latch the output off. This condition is annunciated by the OSC status bit. Oscillation usually occurs with load capacitances that fall outside the indicated ranges. At power-on the oscillation protection function is enabled.

Select a bandwidth according to the following load capacitances and load lead lengths:

Setting	Load Capacitance	Sensing	Maximum distance from sense point to capacitor	ESR @100 kHz	Minimum frequency
Low	0–150 µF	Local or Remote	Full lead length [1]	50 to 200 mΩ	1440 Hz
High1	0–1 µF	Remote only	6 inches (155 mm)	50 to 200 mΩ	33,000 Hz
High2	0–7 µF	Remote only	6 inches (155 mm)	50 to 200 mΩ	20,500 Hz
High3	7–150 µF	Remote only	6 inches (155 mm)	50 to 200 mΩ	8300 Hz

Note 1 Refer to Keysight N678xA SMU Wiring for additional information on allowable load lead lengths.

The frequency parameter sets the pole frequency associated with a voltage bandwidth range. The power-on default for each range is the minimum frequency. This is optimized for no overshoot with the worst-case load capacitance for that range. If the load capacitance is not worst-case, or if some output overshoot is acceptable, the output voltage transition times can be reduced by increasing the frequency limit.

Front Panel Menu Reference	SCPI Command
Select **Output\Advanced\Bandwidth**. Select a bandwidth from the ranges listed. Then press **Select**. Optionally, enter a different frequency limit for the specified range. Then press **Select**.	To select a voltage bandwidth: VOLT:BWID HIGH1,(@1) To select a different frequency limit, use: VOLT:BWID:LEV HIGH1, <frequency>, (@1)

Set the Output Turn-Off Mode

NOTE   This information applies to Keysight Models N678xA SMU only. N678xA SMU

This lets you specify high impedance or low impedance mode at output turn-on and turn-off.

Low impedance - At turn-on the output relays are closed after which the output is programmed to the set value. At turn-off the output is first programmed to zero, after which the output relays are opened.

High impedance – At turn-on the output is programmed to the set value after which the output relays are closed. At turn-off the output relays are opened while the output remains at its set value. This reduces current pulses that may be undesirable in some applications.

Front Panel Menu Reference	SCPI Command
Select **Output\Advanced\Tmode**. Select either High or Low impedance. Then press **Select**.	To set output 1 to a high impedance mode: OUTP:TMOD HIGHZ,(@1)

Programming an Input Short

NOTE   This information applies to Keysight Models N679xA only. N679xA

This simulates a short circuit on the input of the N679xA load module. It works in all priority modes - it temporarily overrides input and slew settings. Note that the output on/off and the output protection functions take precedence over an input short. An input-short condition is annunciated by the SH status bit.

Front Panel Menu Reference	SCPI Command
Select **Output\Short**. Check Enable short to short the input. Uncheck to open the short. Then press **Select**.	To short output 1: OUTP:SHOR ON,(@1)

Enable Under-Voltage Inhibit

| NOTE | This information applies to Keysight Models N679xA only. N679xA |

When the under-voltage inhibit function is enabled, the N679xA load modules are prevented from sinking current until the voltage-on level is exceeded. This condition is annunciated by the UVI status bit. The following modes can be specified:

Off - turns the under-voltage inhibit function off.

Live - turns the input off whenever the voltage drops below the voltage-on setting. Turns the input back on when the voltage reaches the voltage-on setting.

Latched - lets the load sink current when the voltage subsequently drops below the voltage-on setting. An under-voltage inhibit condition is annunciated by the UVI status bit.

Note that under-voltage inhibit is not available when load modules are grouped or when the unit is operating in CV mode.

Front Panel Menu Reference	SCPI Command
Select **Output\Advanced\UVI**	To set the voltage-on value to 3 V VOLT:INH:VON 3, (@1)
Enter a voltage value in the Voltage On box.	
Select either Live or Latched mode to enable. Then press **Select**.	To enable and set the under-voltage inhibit function: VOLT:INH:VON:MODE LATC|LIVE, (@1)

Stepping the Output

Enable the output to respond to trigger commands

Program the step trigger levels

Selects the transient trigger source

Initiate the transient trigger system

Trigger the output step

Generating Trigger-Out Signals

The transient system lets you step the output voltage, current, resistance, or power up or down in response to triggered events. This section describes the procedure to generate triggered output steps.

Enable the output to respond to trigger commands

First, you must enable the output to respond to Step triggers. Unless an output is enabled to respond to triggers, nothing will happen even if you have programmed a trigger level and generated a trigger for the output. Resistance and Power step triggers apply to N679xA . The parameters apply to the selected Arb type (Voltage, Current, Power, or Resistance).

Use the following commands to enable an output to respond to step triggers:

Front Panel Menu Reference	SCPI Command
Select **Transient\Mode**. Set dropdown of the the specified function to Step. Then press **Select**.	To enable the specified function to respond to step triggers, use: VOLT:MODE STEP,(@1) CURR:MODE STEP,(@1) RES:MODE STEP,(@1) POW:MODE STEP,(@1)

> **NOTE** In Step mode, the triggered value becomes the immediate value when the trigger is received. In Fixed mode, trigger signals are ignored; the immediate values remain in effect when a trigger is received.

Program the step trigger levels

Next, use the following commands to program a triggered level. The output will go to this level when the trigger is received. Resistance and Power trigger levels apply to N679xA .

If you have a model that has multiple ranges, the selected triggered settings must be within the same range that the output channel is presently operating in

Front Panel Menu Reference	SCPI Command
Select **Transient\Step**. Enter a value. Then press **Select**.	To set a trigger level for output 1 use: VOLT:TRIG 15,(@1) CURR:TRIG 1,(@1) RES:TRIG 50,(@1) POW:TRIG 75,(@1)

Selects the transient trigger source

Select a trigger source from the following:

Bus Selects GPIB device trigger, *TRG, or <GET> (Group Execute Trigger).

Imm An immediate trigger command either from the front panel or over the bus will generate an immediate trigger.

Ext Selects all digital port pins that have been configured as trigger inputs.

Pin<n>Selects a specific pin that is configured as a Trigger Input on the digital port.<n> specifies the pin number. The selected pin must be configured as a Trigger Input in order to be used as a trigger source (refer to Trigger Input).

Transient<n> Selects the output channel's transient system as the trigger source. <n> specifies the channel. When you select a channel, you must also set up that channel's transient system to generate a trigger out signal. Refer to Generate Trigger Out Signals.

Use the following commands to select a trigger source:

Front Panel Menu Reference	SCPI Command
To select Bus triggers, select **Transient\TrigSource**. Under Transient trigger source, select Bus. To select Digital pin triggers, select **Transient\TrigSource**. Then select one of the digital port pins. (Ext selects all pins that have been configured as trigger inputs.) To select Transient output triggers, select **Transient\TrigSource**. Then select one of the output channels. Then press **Select**.	To select Bus triggers for output 1: TRIG:TRAN:SOUR BUS,(@1) To select Immediate triggers for output 1: TRIG:TRAN:SOUR IMM,(@1) To select Digital pin triggers: TRIG:TRAN:SOUR PIN<n>,(@1) where n is the pin number. To select Transient output triggers: TRIG:TRAN:SOUR TRAN<n>,(@1) where n is the output channel that will generate the trigger signal

Initiate the transient trigger system

When the power system is turned on, the trigger system is in the idle state. In this state, the trigger system is disabled, ignoring all triggers. Initiating the trigger system moves it from the idle state to the initiated state, which enables the power system to receive triggers. To initiate the trigger system, use:.

Front Panel Menu Reference	SCPI Command
Select **Transient\Control**. Navigate to Initiate. Then press **Select**.	To initiate the transient trigger system: INIT:TRAN (@1)

It takes a few milliseconds for the instrument to be ready to receive a trigger signal after receiving the INITiate:TRANsient command.

If a trigger occurs before the trigger system is ready for it, the trigger will be ignored. You can test the WTG_tran bit in the operation status register to know when the instrument is ready to receive a trigger.

Front Panel Menu Reference	SCPI Command
Not Available	To query the WTG_tran bit (bit 4): STAT:OPER:COND? (@1)

If a bit value of 16 is returned in the query, the WTG_tran bit is true, and the instrument is ready to receive the trigger signal. Refer to Status Tutorial in the Operating and Service Guide document for more information.

> **NOTE**   Unless INITiate:CONTinuous:TRANsient is programmed, it will be necessary to initiate the transient trigger system each time a triggered action is desired

Trigger the output step

The trigger system is waiting for a trigger signal in the initiated state. You can immediately trigger the output as follows:

Front Panel Menu Reference	SCPI Command
Select **Transient\Control**. Navigate to Trigger. This generates an immediate trigger signal regardless of the trigger source setting. Then press **Select**.	To generate a transient trigger: TRIG:TRAN (@1) Alternatively, you can also program a *TRG or an IEEE-488 <get> command.

As previously discussed, a trigger can also be generated by another output channel or by a trigger signal applied to an input pin on the digital port connector. If any of these systems are configured as the trigger source, the instrument will wait indefinitely for the trigger signal. If the trigger does not occur, you must manually return the trigger system to the idle state.

The following commands return the trigger system to the idle state:

Front Panel Menu Reference	SCPI Command
Select **Transient\Control**. Navigate to Abort. Then press **Select**.	ABOR:TRAN (@1)

When a trigger is received, the triggered functions are set to their programmed trigger levels. When the triggered actions are completed, the trigger system returns to the idle state.

You can test the TRAN_active bit in the Operation Status register to know when the transient trigger system has returned to the idle state.

Front Panel Menu Reference	SCPI Command
Not Available	To query the TRAN_active bit (bit 6): STAT:OPER:COND?

If a bit value of 64 is returned in the query, the TRAN_active bit is true, and the transient action is NOT complete. When the TRAN_active bit is false, the transient action is complete. Refer to Status Tutorial in the Operating and Service Guide document for more information.

Generating Trigger-Out Signals

Each output channel can generate trigger signals that can be used by other output channels, or routed to a pin on the digital port that has been configured as a trigger output (TOUT). Use the following commands to program transient trigger signals that are generated when an output Step occurs.

Front Panel Menu Reference	SCPI Command
Use the Channel key to select the channel that is the trigger source. Select **Transient\Step**. Check Enable Trig out. Then press **Select**.	To program channel 3's step function to generate a trigger signal, use STEP:TOUT ON,(@3)

Synchronizing Output Turn-On

Synchronizing Output Turn-On Delays

Synchronizing Multiple Mainframes

Synchronization Operation

This function lets you accurately synchronize output turn-on sequences by letting you specify a common delay offset, which serves as a reference point for the user-programmed turn-on delays. This same reference point also makes it possible to connect multiple Keysight N6700C-series mainframes together and program accurate turn-on sequences across multiple mainframes.

Note that there is no delay offset when outputs turn off. Outputs start executing their programmed turn-off delays as soon as an output Off command is received.

Synchronizing Output Turn-On Delays

All N6700 series power modules that are installed in Keysight N6700C mainframes exhibit a minimum delay offset that applies from the time that a command to turn on the output is received until the output actually turns on. If you specify a user-programmed turn-on delay, this delay will be added to the minimum delay offset, resulting in a turn-on delay that is actually longer than the one you programmed. The minimum delay offset is shown as follows:

Power Modules	Options and Mode	Delay Offset
N673xB, N674xB, N677xA	Without relays	32 ms
	With relay option 760	58 ms
N6751A, N6752A	Without relays	25 ms
	With relay option 760	51 ms
N6753A, N6754A	Without relays	18 ms
	With relay option 760	44 ms
N6761A, N6762A	Voltage Priority - without relays	32 ms
	Voltage Priority - with relay option 760	58 ms
	Current Priority - without relays	23 ms
	Current Priority - with relay option 760	45 ms
N6781A, N6782A, N6784A	Voltage Priority - Low Z mode; or Current Priority	25.6 ms
	Voltage Priority - High Z mode	24.8 ms
With relays programmed closed	Voltage Priority - Low Z mode; or Current Priority	5.2 ms
	Voltage Priority - High Z mode	7.3 ms
N6785A, N6786A	Voltage Priority - Low Z mode; or Current Priority	35.9 ms
	Voltage Priority - High Z mode	34.9 ms
With relays programmed closed	Voltage Priority - Low Z mode; or Current Priority	5.2 ms
	Voltage Priority - High Z mode	7.3 ms

To determine which power modules are installed in your mainframe, select **System\About\Module** from the front panel. For models N676xA, send OUTPut:PMODe? to query the priority mode. For models N678xA, send FUNCtion? to query the priority mode.

To determine the actual turn-on delay between the "on" event (such as pressing the Output On key or sending an Output On command), you must add the programmed turn-on delay to the minimum delay offset as shown in the following example. In this example, if you program delay values of 10 ms, 20 ms, 30 ms, and 40 ms for output channels 1 through 4 respectively, the actual output delays will be 68 ms, 45 ms, 81 ms, and 72 ms for output channels 1 through 4.
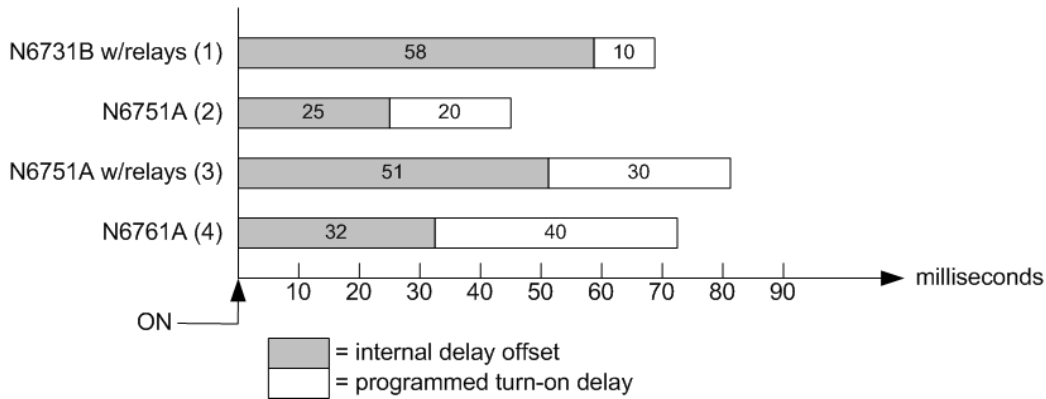
To synchronize power modules with different minimum delay offsets as shown above, you can specify a common delay offset parameter. By setting the common delay offset to be greater than or equal to the largest minimum delay offset, you can synchronize the programmed turn-on delays as shown in the following example.
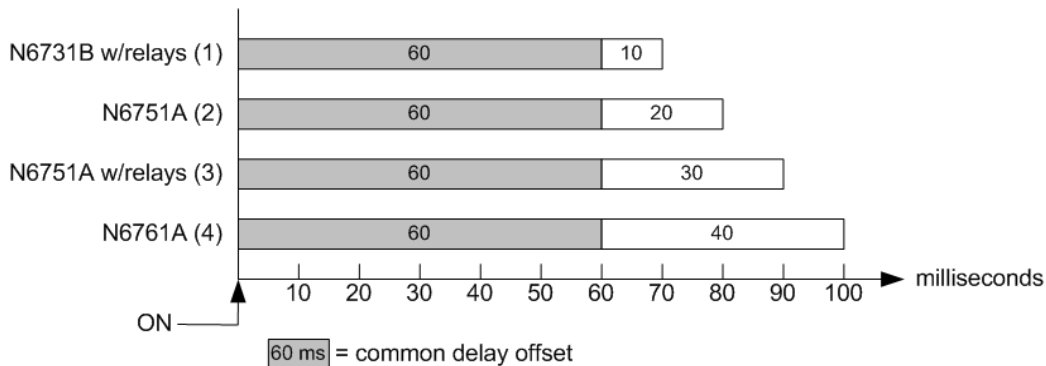
Since there will be an additional delay due to the common delay offset, you will need to account for the additional delay time. As shown in the previous example, if you program a common delay of 60 ms and user-programmed delays of 10 ms, 20 ms, 30 ms, and 40 ms for output channels 1 through 4, the actual output delays from the "on" event will be 70 ms, 80 ms, 90 ms, and 100 ms respectively.

Even though this 60 ms delay offset will be seen on all outputs, the additional delay time will not affect most applications because the relative delay times between output module turn-on will still be 10 ms, 20, ms, 30 ms, and 40 ms – the exact values originally specified.

Step 1. Enable the Synchronization Function

Output turn-on synchronization must be enabled on the mainframe as follows:

Front Panel Menu Reference	SCPI Command
In the front panel menu, select **Output\Sequence\Couple**.	To enable, send: OUTP:COUP ON
Check the Enable box. Then press **Select**. To disable, uncheck the box.	To disable, send: OUTP:COUP OFF

Step 2. Specify which Output Channels will be Synchronized

Select the output channels that will be synchronized:

Front Panel Menu Reference	SCPI Command
In the front panel menu, select **Output\Sequence\Couple**.	To specify a channel or channels: OUTP:COUP:CHAN 1,2,3,4
Check which channels will be coupled. Then press **Select**. To remove a channel, uncheck the box.	

Step 3. Specify the Turn-On Delays for each Output Channel

Turn-on delays can be specified for all coupled output channels. Any delay sequence can be implemented. There are no restrictions on what the sequence is or what channel comes up first:

Front Panel Menu Reference	SCPI Command
For channels 1, 2, 3, and 4, select **Output\Sequence\Delay**. Specify the Turn-on delay for each channel in seconds. Then press **Select**.	Program a turn-on delays for channels 1 through 4: OUTP:DEL:RISE .01,(@1) OUTP:DEL:RISe .02,(@2) OUTP:DEL:RISE .03,(@3) OUTP:DEL:RISE .04,(@4)

Step 4. Specify Common Delay Offset

This step is required if you have power modules with **different** minimum delay offsets. Specifying a common delay offset assures that the user-programmed turn-on delays will be synchronized to start at the completion of the common delay offset. Select the delay offset of the slowest power module in the mainframe and use that as the common delay offset:

Front Panel Menu Reference	SCPI Command
In the front panel menu, select **Output\Sequence\Couple**. The **Max delay offset for this frame** field displays the delay offset of the slowest power module in the frame. Enter the delay offset value of the slowest power module in the **Delay offset** field in milliseconds. Then press **Select**.	To query the delay offset of the slowest power module in the mainframe (the maximum delay offset) in seconds: OUTP:COUP:MAX:DOFF? To specify the common delay offset for the mainframe in seconds: OUTP:COUP:DOFF .051

Note that you can program a common delay that is longer than the maximum delay offset of the mainframe. You may choose a longer value to make your program flexible for future configurations that may have power modules with longer delay offsets. However, if you program a value that is

shorter than the maximum delay offset, you may experience improper synchronization across all outputs.

| NOTE | There is no need to specify a delay offset when outputs turn off. Outputs start executing their turn-off delays as soon as an output Off command is received. |

Synchronizing Multiple Mainframes

The output turn-on synchronization function can be used across multiple mainframes that have coupled output channels. Each mainframe that will be synchronized must have at least one coupled channel. Note that cross-frame synchronization must be enabled for any mainframe that contains synchronized output channels.

Step 1. Configure the output channels on each mainframe (refer to previous steps 1- 3)

Step 2. Specify a common delay offset for all of the synchronized output channels

This step is required if you have power modules with *different* minimum delay offsets. The delay value must be the largest delay offset of all synchronized output channels regardless of the mainframe in which they are installed. This same value must be specified as the common delay offset for each mainframe.

| Front Panel Menu Reference	SCPI Command
In the front panel menu of each mainframe, select **Output\Sequence\Couple**. In the Delay offset field, enter the delay offset value of the slowest power module of all the mainframes in milliseconds. Then press **Select**. The **Max delay offset for this frame** field displays the delay offset of the slowest power module in this frame.	To specify the common delay offset for each mainframe in seconds: OUTP:COUP:DOFF .051 To return the delay offset of the slowest power module in each mainframe (the maximum delay offset) in seconds: OUTP:COUP:MAX:DOFF?.

Step 3. Connect and configure the digital connector pins of the synchronized mainframes

| NOTE | Only pins 4 through 7 can be configured as synchronization pins. You cannot configure more than one ON couple and one OFF couple pin per mainframe. The polarity of the pins is not programmable. |

The digital connector pins of the synchronized mainframes that contain coupled channels must be connected together as shown in the following figure. In this example, pin 6 will be configured as the output On control. Pin 7 will be configured as the output Off control. The ground or Common pins also need to be connected together.
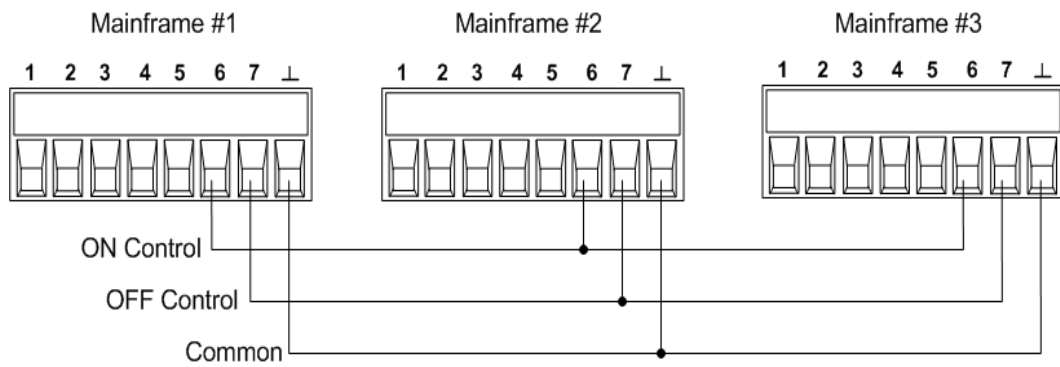
Only two of the digital connector pins on each mainframe can be configured as "ONCouple" and "OFFCouple" on each synchronized mainframe. The designated pins will function as both an input and an output, with a negative transition on one pin providing the synchronization signal to the other pins.

Front Panel Menu Reference	SCPI Command
For mainframe #1, select **System\IO\DigPort\Pins**.	To configure pin 6 of mainframe #1 as the ON control: DIG:PIN6:FUNC ONC
Select pin 6, then Function, then On Couple.	
Select **Pins**., select pin 7, then Function, then Off Couple.	To configure pin 7 of mainframe #1 as the OFF control: DIG:PIN7:FUNC OFFC
Repeat these steps for mainframes #2 and #3.	Repeat these commands for mainframes #2 and #3.

Synchronization Operation

Once configured and enabled, turning the output on or off on any coupled channel will cause all coupled channels on all configured mainframes to turn on or off according to their user-programmed delays. This applies to the front panel On/Off key, the Web server, and to SCPI commands.

If a mainframe has its ON/OFF key coupled (located in the **System\Preferences\Keys** menu), turning the output on or off on any coupled channel will cause all coupled channels as well as non-coupled channels on *that mainframe* to turn on or off.

Programming Output Lists

Output Lists

Program an Output Pulse or Pulse Train

Program an Arbitrary List

NOTE   The output List function requires (Option 054) to be installed on models N673xA. N674xA, N675xA, and N677xA.

Output Lists

Output current, voltage, power, and resistance may be list-controlled. For Models N678xA SMU, only the parameters associated with one of the priority modes may be list controlled. Power and Resistance lists only apply to Models N679xA loads. List mode lets you generate complex sequences of output changes with rapid, precise timing, which may be synchronized with internal or external signals. Lists can contain up to 512 individually programmed steps, and can be programmed to repeat themselves.

The current, voltage, power, and resistance lists are paced by a separate list that defines the duration or dwell of each step. Each of the up to 512 steps can have an individual dwell time associated with it, which specifies the time in seconds that the list will remain at that step before moving on to the next step. Dwell times can be programmed from 0 to 262.144 seconds. The default dwell time is 0.001 seconds.

If you need an output list to closely follow external events, then a trigger-paced list is more appropriate. In a trigger-paced list, the list advances one step for each trigger received. As previously discussed, a number of trigger sources can be selected to generate triggers. With a trigger-paced list, you do not need to program a dwell time for each step. If you do program a dwell time, triggers that are received during the dwell period are ignored.

Lists can also be configured to generate trigger signals at specified steps. This is accomplished by two additional lists: a beginning-of-step (BOST) and an end-of-step (EOST) list. These lists define which steps will generate a trigger signal and if the trigger occurs at the beginning or end of the step. These trigger signals can be used to synchronize other events with the list.

When either a voltage, current, power, or resistance list is programmed, the associated dwell, BOST, and EOST lists must all be set to the same number of steps, otherwise an error will occur when the list is run. For convenience, a list may be programmed with only one step or value. In this case, a single-step list is treated as if it had the same number of steps as the other lists, with all values being equal to the one value.

> **NOTE**   List data is not stored in non-volatile memory. This means that list data that is sent to the instrument either from the front panel or over the bus will be lost when the power system is turned off. However, list data can be saved as part of a saved instrument state. Refer to Instrument State Storage .

Program an Output Pulse or Pulse Train

The following procedure shows how to generate an output pulse train using the List function as illustrated in the following figure.
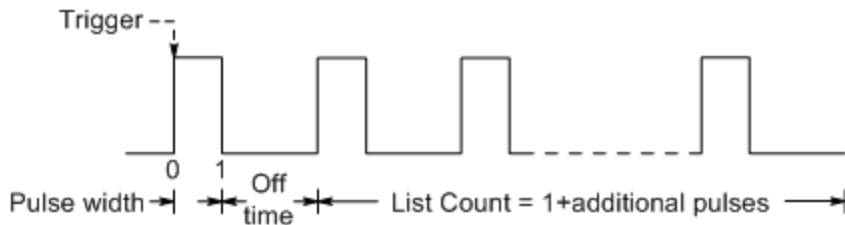
Step 1. Set the voltage, current, power, or resistance function for which you want to generate a pulse to List mode. This example programs a voltage pulse. Resistance and Power modes apply to **N679xA**. The parameters apply to the selected Arb type (Voltage, Current, Power, or Resistance).

Front Panel Menu Reference	SCPI Command
Select **Transient\Mode**. Set the voltage mode to List. Then press **Select**.	To program output 1, use VOLT:MODE LIST,(@1)

Step 2. Set the amplitude and width of the pulse. For example, to generate a pulse with an amplitude of 15 V and a pulse width of 1 second, use:

Front Panel Menu Reference	SCPI Command
Select **Transient\List\Config**. Select List Step 0 and enter a voltage value of 15. Then press **Select**. Enter a dwell value of 1 for List Step 0. Then press **Select**.	To program output 1, use LIST:VOLT 15,(@1) LIST:DWEL 1,(@1)

Step 3. Set the list pacing to Auto, so that as each dwell time elapses, the next step is immediately output.

Front Panel Menu Reference	SCPI Command
Select **Transient\List\Pace**. Select Dwell paced. Then press **Select**.	LIST:STEP AUTO,(@1)

> **NOTE**   If you only wish to program a single pulse, skip steps 4 and 5 and go to step 6.

Step 4. If you want to generate a pulse train, you must specify the off time between pulses. To do this you must program another step. For a voltage list, you must specify an amplitude and an off time. For example, to program an off time of 2 seconds with an amplitude of 0 V between pulses, use:

Front Panel Menu Reference	SCPI Command
Select **Transient\List\Config**. Select List Step 1 and enter a voltage value of 0. Then press **Select**. Enter a dwell value of 2 for List Step 1. Then press **Select**.	To program output 1, use LIST:VOLT 15,0,@1) LIST:DWEL 1,2,(@1)

Step 5. To generate a pulse train, you can simply repeat the pulse as needed. For example, to program a pulse train of 50 pulses, use:

Front Panel Menu Reference	SCPI Command
Select **Transient\List\Repeat**. Enter the number of list repetitions (50). Then press **Select**.	To program output 1, use LIST:COUN 50,(@1)

Step 6. Specify if you want the output pulse to generate a trigger signal that can be used to trigger actions on other output channels or on any external equipment connected to the digital port. For example, to generate a trigger signal at the end of the pulse, use:

Front Panel Menu Reference	SCPI Command
Select **Transient\List\Config**. Select List Step 0 and enter a value of 1 in the Tout end step field. Then press **Select**.	To program a trigger at the End of the pulse for output 1, use LIST:TOUT:EOST 1,0(@1) You must program a value of 0 (no trigger) for step 1 as a placeholder.

Step 7. Specify the output state after the pulse has completed. For example, to return the output to the state it was in before the pulse, use:

Front Panel Menu Reference	SCPI Command
Select **Transient\List\Terminate**. Select Return to start settings. Then press **Select**.	To program output 1, use LIST:TERM:LAST 0, (@1)

Step 8. Select the trigger source that will generate the pulse or pulse train.

Select a trigger source from the following:

- **Bus** Selects GPIB device trigger, *TRG, or <GET> (Group Execute Trigger).
- **Imm** An immediate trigger command either from the front panel or over the bus will generate an immediate trigger.

- **Ext** Selects all digital port pins that have been configured as trigger inputs.

- **Pin<n>**Selects a specific pin that is configured as a Trigger Input on the digital port.<n> specifies the pin number. The selected pin must be configured as a Trigger Input in order to be used as a trigger source (refer to Trigger Input).

- **Transient<n>** Selects the output channel's transient system as the trigger source. <n> specifies the channel. When you select a channel, you must also set up that channel's transient system to generate a trigger out signal. Refer to Generate Trigger Out Signals.

For example, to select Bus triggers as the trigger source, use:

Front Panel Menu Reference	SCPI Command
Select **Transient\TrigSource**. Under Transient trigger source, select Bus. Then press **Select**.	To program output 1, use: TRIG:TRAN:SOUR BUS,(@1)

**Step 9.** Initiate the transient trigger system. To enable the trigger system for one transient event or trigger use:

Front Panel Menu Reference	SCPI Command
Select **Transient\Control**. Navigate to Initiate. Then press **Select**.	To program output 1, use: INIT:TRAN (@1)

Step 10. Trigger the output pulse or pulse train.

Front Panel Menu Reference	SCPI Command
Select **Transient\Control**. Navigate to Trigger. Then press **Select**.	*TRG

Program an Arbitrary List

The following procedure shows how to generate the list of voltage changes as illustrated in the following figure.
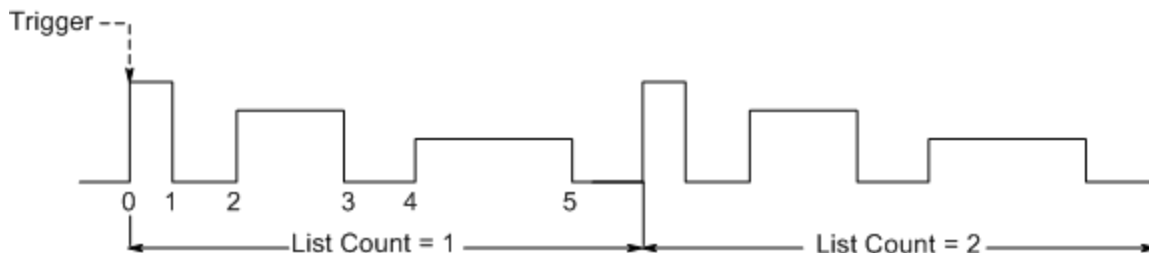
Step 1. Set the voltage, current, power, or resistance function for which you want to generate a list to List mode. This example programs a voltage list. Resistance and Power modes apply to N679xA

Front Panel Menu Reference	SCPI Command
Select **Transient\Mode**. Set the voltage mode to List. Then press **Select**.	To program output 1, use VOLT:MODE LIST,(@1)

Step 2. Program the list of values for the List function. The order in which the values are entered determines the order in which the values will be output. To generate the voltage list shown in the figure, a list may include the following values: 9, 0, 6, 0, 3, 0

Front Panel Menu Reference	SCPI Command
Select **Transient\List\Config**. Select the List Step number and enter a voltage value. Then press **Select**. Repeat this for each step. Use the ⬆⬇ keys to select the next step.	To program output 1, use LIST:VOLT 9,0,6,0,3,0,(@1)

Step 3. Determine the time interval, in seconds, that the output remains at each step in the list before it advances to the next step. To specify the six dwell intervals in the figure, a list may include the following values: 2, 3, 5, 3, 7, 3

Front Panel Menu Reference	SCPI Command
Select **Transient\List\Config**. Select the List Step number and enter a voltage value. Then press **Select**. Repeat this for each step. Use the ⬆⬇ keys to select the next step.	To program output 1, use LIST:DWEL 2,3,5,3,7,3,(@1)

> **NOTE** The number of dwell steps must equal the number of voltage steps. If a dwell list has only one value, that value will be applied to all steps in the list.

Step 4. Determine how the list is paced. To pace the list by dwell time, set the list pacing to Dwell-paced on the front panel menu. (Set the LIST:STEP command to AUTO.) As each dwell time elapses, the next step is immediately output.
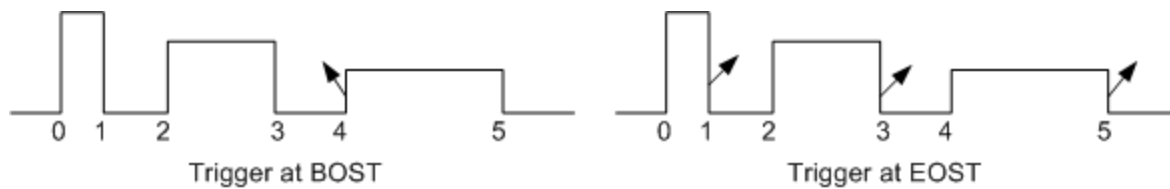
Front Panel Menu Reference	SCPI Command
Select **Transient\List\Pace**. Select Dwell paced. Then press **Select**.	LIST:STEP AUTO,(@1)

In a trigger-paced list, the list advances one step for each trigger received. To enable trigger-paced lists, select Trigger-paced on the front panel menu. (Set the LIST:STEP command to ONCE.)

The dwell time associated with each step determines the minimum time that the output remains at the step. If a trigger is received before the dwell time completes, the trigger is ignored. To ensure that no triggers are lost in a trigger-paced list, set the dwell time to zero.

Step 5. Specify if you want the list to generate trigger signals that can be used to trigger actions on other output channels or on external equipment connected to the digital port.

Front Panel Menu Reference	SCPI Command
Select **Transient\List\Config**.	To program a trigger at the start of step 4 for output 1, use
Select the List Step number.	LIST:TOUT:BOST 0,0,0,0,1,0,@(1)
To generate a trigger, enter a 1 in the Tout begin step or Tout end step field. If a zero is entered, no trigger is generated for the step.	To program a trigger at the end of step 0, 2, and 4 for output 1, use
Repeat this for each step. Use the ⬆ ⬇ keys to select the next step.	LIST:TOUT:EOST 1,0,1,0,1,0,(@1)

Trigger at BOST   Trigger at EOST

Step 6. Specify how you want the list to terminate. For example, if you want the list to remain at the values of the last list step when finished, use:

Front Panel Menu Reference	SCPI Command
Select **Transient\List\Terminate**.	To program output 1, use
Select Stop at last step settings. Then press **Select**.	LIST:TERM:LAST 1,(@1)

Step 7. If applicable, specify how many times you want the list to repeat. Sending the INFinity parameter in the SCPI command makes the list repeat indefinitely. At reset, the list count is set to 1.

Front Panel Menu Reference	SCPI Command
Select **Transient\List\Repeat**.	To program the output 1 list to repeat 2 times, use
Enter the number of List repetitions (2). Then press **Select**.	LIST:COUN 2,(@1)

Step 8. Select a trigger source, then initiate, and trigger the list. This is previously described under Program an Output Pulse or Pulse Train.

Generating Arbitrary Waveforms

Arbitrary Waveform Description

Configuring Step Arbs

Configuring Pulse Arbs

Configuring Ramp Arbs

Configuring Trapezoid Arbs

Configuring Staircase Arbs

Configuring Exponential Arbs

Configuring Sinusiod Arbs

Configuring Constant-Dwell Arbs

Configuring an Arb Sequence

Configuring User-Defined Arbs

Configuring Steps Common to all Arbs

Running the Arb

NOTE	The Arbitrary waveform function requires Option 054 to be installed on models N673xA. N674xA, N675xA, and N677xA.

Arbitrary Waveform Description

Each output on the power system can be modulated by the built-in arbitrary waveform generator function. This allows the output to act as a DC bias transient generator or an arbitrary waveform generator. The maximum bandwidth is based on the type of power module that is installed. This is documented in the Keysight N6700 Modular Power System Family Specifications Guide.

The arbitrary waveform generator has a variable dwell period, where each point in the waveform is defined by the current, voltage, power, or resistance setting along with the dwell time or duration to stay at that setting. Waveforms can be generated by specifying only a small number of points. For example, a pulse would only take three points to define it. However, sine, ramp, trapezoid, and exponential waveforms have 100 points assigned to the portion of their waveform that continuously changes. Constant-dwell waveforms can have up to 65,535 points assigned to them.

Each waveform can be set to repeat continuously or repeat a specific number of times. For example, to generate a pulse train of 10 identical pulses, you can program the parameters for one pulse and then specify that you want it to repeat 10 times.

For the user-defined waveforms, you can specify up to 511 step-points for each waveform. You can specify a different dwell time for each of the step-points. The output will step through the user-defined values, staying at each point for the programmed dwell time, and then moving on to the next point.

You can combine a number of individual arbitrary waveforms into an Arb sequence, as long as the total number of points of all waveforms does not exceed 511 points.

Configuring Step Arbs

Step 1. Select the Arb Type and Shape. Power and Resistance types apply to N679xA.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Function**. Select a Voltage, Current, Power, or Resistance Arb Type. Then select the Step Shape. Then press **Select**.	To select a current, voltage, power, or resistance step Arb, use: ARB:FUNC:TYPE CURR|VOLT|POW|RES,(@1) ARB:FUNC:SHAP STEP,(@1)

Step 2. Configure the step parameters. The parameters apply to the selected Arb type (Voltage, Current, Power, or Resistance).
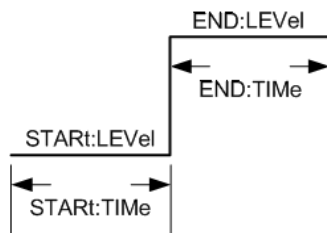
Enter the values for the level before and after the step.

Enter the time before the step.

| Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Config\Step\Level**. Enter the Start and End level in volts. Then press **Select**. Select **Transient\Arb\Config\Step\Time**. Enter the Start and End time in seconds. Then press **Select**.	To configure a voltage step Arb, use: ARB:VOLT:STEP:STAR 0, (@1) ARB:VOLT:STEP:END 10, (@1) ARB:VOLT:STEP:STAR:TIM 0.25,(@1)

Step 3. Configure the final steps common to all Arbs. Refer to Configuring Steps Common to all Arbs at the end of this section.

Configuring Pulse Arbs

Step 1. Select the Arb Type and Shape. Power and Resistance types apply to N679xA.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Function**. Select a Voltage, Current, Power, or Resistance Arb Type. Then select the Pulse Shape. Then press **Select**.	To select a current, voltage, power, or resistance pulse Arb, use: ARB:FUNC:TYPE VOLT|CURR|POW|RES,(@1) ARB:FUNC:SHAP PULS,(@1)

Step 2. Configure the pulse parameters. The parameters apply to the selected Arb type (Voltage, Current, Power, or Resistance).
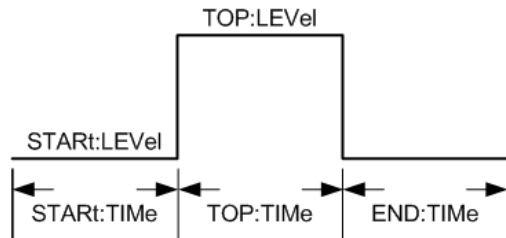
Enter the values for the level before and during the top of the pulse.

Enter the time before the pulse, the time of the pulse, the time after the pulse. A pulse frequency can only be specified directly using SCPI commands. The pulse frequency can also be specified using the Time parameters.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Config\Pulse\Level**. Enter the Start and Top level in volts. Then press **Select**. Select **Transient\Arb\Config\Pulse\Time**. Enter the Start, Top, and End times in seconds. Then press **Select**.	To configure a voltage pulse Arb, use: ARB:VOLT:PULS:STAR 0,(@1) ARB:VOLT:PULS:TOP 10,(@1) ARB:VOLT:PULS:STAR:TIM 0.25,(@1) ARB:VOLT:PULS:TOP:TIM 0.5,(@1) ARB:VOLT:PULS:END:TIM 0.25,(@1) ARB:VOLT:PULS:FREQ 1,(@1)

Step 3. Configure the final steps common to all Arbs. Refer to Configuring Steps Common to all Arbs at the end of this section.

Configuring Ramp Arbs

Step 1. Select the Arb Type and Shape. Power and Resistance types apply to N679xA.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Function**. Select a Voltage, Current, Power, or Resistance Arb Type. Then select the Ramp Shape. Then press **Select**.	To select a current, voltage, power, or resistance ramp Arb, use: ARB:FUNC:TYPE VOLT|CURR|POW|RES,(@1) ARB:FUNC:SHAP RAMP,(@1)

Step 2. Configure the ramp parameters. The parameters apply to the selected Arb type (Voltage, Current, Power, or Resistance).
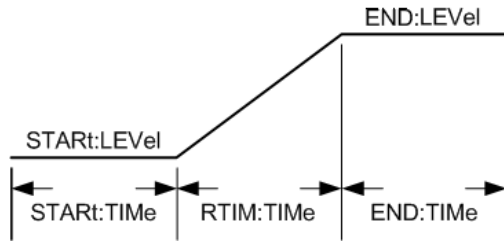
Enter the values for the level before and after the ramp.

Enter the time before the ramp, the rise-time of the ramp, and the time after the ramp.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Config\Ramp\Level**. Enter the Start and End level in volts. Then press **Select**. Select **Transient\Arb\Config\Ramp\Time**. Enter the Start, Rise, and End times in seconds. Then press **Select**.	To configure a voltage ramp Arb, use: ARB:VOLT:RAMP:STAR 0, (@1) ARB:VOLT:RAMP:END 10, (@1) ARB:VOLT:RAMP:STAR:TIM 0.25,(@1) ARB:VOLT:RAMP:RTIM:TIM 0.5,(@1) ARB:VOLT:RAMP:END:TIM 0.25,(@1)

Step 3. Configure the final steps common to all Arbs. Refer to Configuring Steps Common to all Arbs at the end of this section.

Configuring Trapezoid Arbs

Step 1. Select the Arb Type and Shape. Power and Resistance types apply to N679xA.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Function**. Select a Voltage, Current, Power, or Resistance Arb Type. Then select the Trapezoid Shape. Then press **Select.**.	To select a current, voltage, power, or resistance trapezoid Arb, use: ARB:FUNC:TYPE VOLT|CURR|POW|RES,(@1) ARB:FUNC:SHAP TRAP,(@1)

Step 2. Configure the trapezoid parameters. The parameters apply to the selected Arb type (Voltage, Current, Power, or Resistance).
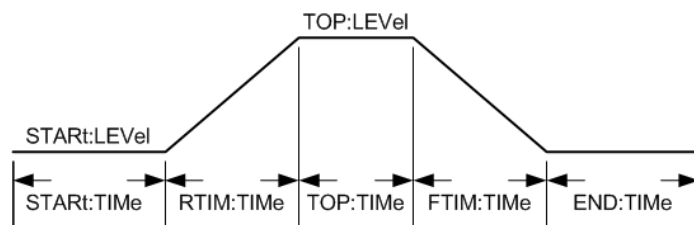
Enter the values for the level before and during the top of the trapezoid.

Enter the time before the trapezoid, the rise-time, top-time, fall-time, and the time after the trapezoid.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Config\Trap\Level**. Enter the Start and Top level in volts. Then press **Select**. Select **Transient\Arb\Config\Trap\Time**. Enter the Start, Rise, Top, Fall, and End times in seconds.. Then press **Select**.	To configure a voltage trapezoid Arb, use: ARB:VOLT:TRAP:STAR 0, (@1) ARB:VOLT:TRAP:TOP 10,(@1) ARB:VOLT:TRAP:STAR:TIM 0.25,(@1) ARB:VOLT:TRAP:RTIM:TIM 0.5,(@1) ARB:VOLT:TRAP:TOP:TIM 0.5,(@1) ARB:VOLT:TRAP:FTIM:TIM 0.5,(@1) ARB:VOLT:TRAP:END:TIM 0.25,(@1)

Step 3. Configure the final steps common to all Arbs. Refer to Configuring Steps Common to all Arbs at the end of this section.

Configuring Staircase Arbs

Step 1. Select the Arb Type and Shape. Power and Resistance types apply to N679xA.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Function**. Select a Voltage, Current, Power, or Resistance Arb Type. Then select the Staircase Shape. Then press **Select**.	To select a current, voltage, power, or resistance staircase Arb, use: ARB:FUNC:TYPE VOLT|CURR|POW|RES,(@1) ARB:FUNC:SHAP STAIR,(@1)

Step 2. Configure the staircase parameters. The parameters apply to the selected Arb type (Voltage, Current, Power, or Resistance).
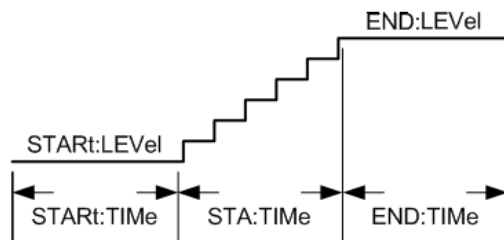
Enter the values for the level before and after the staircase.

Enter the time before the staircase, the stair-time of the ramp, and the time after the staircase.

Then enter the total number of steps.

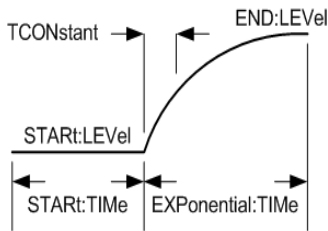| Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Config\Stair\Level**. Enter the Start and End level in volts. Then press **Select**. Select **Transient\Arb\Config\Stair\Time**. Enter the Start, Stair, and End times in seconds. Enter the number of steps. Then press **Select**.	To configure a voltage staircase Arb, use: ARB:VOLT:STA:STAR 0,(@1) ARB:VOLT:STA:END 10,(@1) ARB:VOLT:STA:STAR:TIM 0.25,(@1) ARB:VOLT:STA:TIM 0.5,(@1) ARB:VOLT:STA:END:TIM 0.25,(@1) ARB:VOLT:STA:NST 6,(@1)

Step 3. Configure the final steps common to all Arbs. Refer to Configuring Steps Common to all Arbs at the end of this section.

Configuring Exponential Arbs

Step 1. Select the Arb Type and Shape. Power and Resistance types apply to N679xA.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Function**. Select a Voltage, Current, Power, or Resistance Arb Type. Then select the Exponential Shape. Then press **Select**.	To select a current, voltage, power, or resistance exponential Arb, use: ARB:FUNC:TYPE VOLT|CURR|POW|RES,(@1) ARB:FUNC:SHAP EXP,(@1)

Step 2. Configure the exponential parameters. The parameters apply to the selected Arb type (Voltage, Current, Power, or Resistance).

Enter the values for the level before and after the exponential.

Enter the time before the exponential, the exponential time, and the time constant of the exponential.

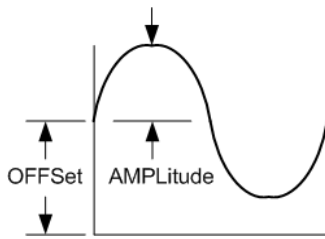| Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Config\Exp\Level**. Enter the Start and End level in volts. Then press **Select**. Select **Transient\Arb\Config\Exp\Time**. Enter the Start, Time, and Time Constant (TC) in seconds. Then press **Select**.	To configure a voltage step Arb, use: ARB:VOLT:EXP:STAR 0, (@1) ARB:VOLT:EXP:END 10, (@1) ARB:VOLT:EXP:STAR:TIM 0.25,(@1) ARB:VOLT:EXP:TIM 0.5,(@1) ARB:VOLT:EXP:TCON 0.25,(@1)

Step 3. Configure the final steps common to all Arbs. Refer to Configuring Steps Common to all Arbs at the end of this section.

Configuring Sinusoid Arbs

Step 1. Select the Arb Type and Shape. Power and Resistance types apply to N679xA.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Function**. Select a Voltage, Current, Power, or Resistance Arb Type. Then select the Sine Shape. Then press **Select**.	To select a current, voltage, power, or resistance sinusoid Arb, use: ARB:FUNC:TYPE VOLT|CURR|POW|RES,(@1) ARB:FUNC:SHAP SIN,(@1)

Step 2. Configure the sinusoid parameters. The parameters apply to the selected Arb type (Voltage, Current, Power, or Resistance).

Enter the amplitude, offset, and frequency of the sinusoid Arb.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Config\Sine**. Enter the Amplitude and Offset in volts. Enter the Frequency in Hertz. Then press **Select**.	To configure a voltage sinusoid Arb, use: ARB:VOLT:SIN:AMPL 10, (@1) ARB:VOLT:SIN:OFFS 5, (@1) ARB:VOLT:SIN:FREQ 10,(@1)

Step 3. Configure the final steps common to all Arbs. Refer to Configuring Steps Common to all Arbs at the end of this section.

Configuring Constant-Dwell Arbs
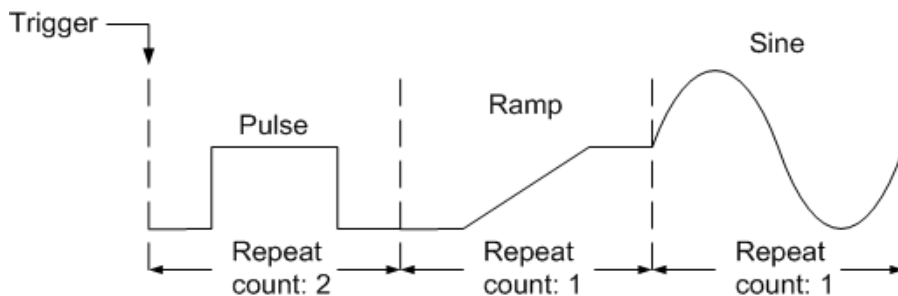
Constant-Dwell (CD)Arbs are a unique type of Arb that have some useful differences from other types. CD Arbs are not limited to 511 points, they can contain up to 65,535 points. Unlike other Arbs, they do not have separate dwell values associated with each point; a single dwell value applies to every point in the CD Arb. Also, the minimum dwell time of a CD Arb is 10 .24 microseconds, instead of the 1 microsecond resolution of the other Arbs.

A CD Arb can run along with other Arbs on other outputs. If multiple outputs run a CD Arb, all CD Arbs must have the same dwell time. If a repeat count is specified, all CD Arbs must have the same length and repeat count.

Step 1. Select the Arb Type and Shape. Power and Resistance types apply to N679xA .

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Function**. Select a Voltage, Current, Power, or Resistance Arb Type. Then select the CD Shape. Then press **Select**.	To select a current, voltage, power, or resistance CD Arb, use: ARB:FUNC:TYPE VOLT|CURR|POW|RES,(@1) ARB:FUNC:SHAP CD,(@1)

Step 2. Configure the CD parameters. The parameters apply to the selected Arb type (Voltage, Current, Power, or Resistance).

Enter the dwell time that will be used for each point in the CD Arb.

Program the number of points in the CD Arb. Assign a value for each point.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Config\CD**. Enter a Dwell time in seconds. Select a point number and enter a value for that point. Then press **Select**.	To configure a voltage CD Arb of 10 points, use: ARB:VOLT:CDW:DWEL 0.01,(@1) ARB:VOLT:CDW 1,2,3,4,5,6,7,8,9,10,(@1)

Step 3. Configure the final steps common to all Arbs. Refer to Configuring Steps Common to all Arbs at the end of this section.

Configuring an Arb Sequence

> **NOTE**   Arb Sequences can only be programmed using SCPI commands. However, individual Arbs within the sequence can be programed from the front panel and with SCPI commands as previously discussed.

The Arb Sequence allows multiple and different Arbs to run one after another is succession. Any of the standard Arb types, except for constant-dwell Arbs, can be included in the Arb sequence. All Arbs in the sequence must be of the same type; either voltage, current, resistance, or power.

As with single Arbs, each Arb in the sequence has its own repeat count, can be set for dwell or trigger pacing, and can be set to repeat continuously. Note also that a repeat count can be set for the entire sequence, and it can also be set to repeat continuously.

Sequence steps must be specified sequentially. The last value in the parameter list is the sequence step number. When a step is added, all Arb parameters must be entered.

The following figure illustrates a sequence comprised of a pulse Arb, a ramp Arb, and a sine Arb. The repeat count value indicates how many times each Arb repeats before moving to the next type.

Front Panel Menu Reference	SCPI Command
Not available	To set up output 1 to program a sequence of voltage waveforms, use: ARB:FUNC:TYPE VOLT,(@1) ARB:FUNC:SHAP SEQ,(@1) ARB:SEQ:RESet (@1) To program step 0 as a voltage pulse: ARB:SEQ:STEP:FUNC:SHAP PULS,0,(@1) ARB:SEQ:STEP:VOLT:PULS:TOP 10,0,(@1) ARB:SEQ:STEP:VOLT:PULS:STAR:TIM 0.25,0,(@1) ARB:SEQ:STEP:VOLT:PULS:TOP:TIM 0.5,0,(@1) ARB:SEQ:STEP:VOLT:PULS:END:TIM 0.25,0,(@1) To program step 1 as a voltage ramp: ARB:SEQ:STEP:FUNC:SHAP RAMP,1,(@1) ARB:SEQ:STEP:VOLT:RAMP:END 10,1,(@1) ARB:SEQ:STEP:VOLT:RAMP:STAR:TIM 0.25,1,(@1) ARB:SEQ:STEP:VOLT:RAMP:RTIM:TIM 0.5,1,(@1) ARB:SEQ:STEP:VOLT:RAMP:END:TIM 0.25,1,(@1) To program step 2 as a voltage sine wave: ARB:SEQ:STEP:FUNC:SHAP SIN,2,(@1) ARB:SEQ:STEP:VOLT:SIN:AMPL 10.0,2,(@1) ARB:SEQ:STEP:VOLT:SIN:OFFS 20.0,2,(@1) ARB:SEQ:STEP:VOLT:SIN:FREQ 0.067,2,(@1) To repeat step 0 twice: ARB:SEQ:STEP:COUN 2,0,(@1) Specify if the next step will start when the dwell time has elapsed or when an external trigger is received. To set the pacing for step 2 to triggered: ARB:SEQ:STEP:PAC TRIG,2,(@1) To select the trigger source for step 2: TRIG:ARB:SOUR BUS,2,(@1) To end the sequence at the last Arb value: ARB:SEQ:TERM:LAST ON,(@1) Set a repeat count for the entire sequence. To make the entire sequence repeat twice: ARB:SEQ:COUN 3,(@1) To set up the transient trigger system and trigger the sequence: VOLT:MODE ARB,(@1) INIT:TRAN (@1) *TRG

Configuring User-Defined Arbs

NOTE	User-Defined Arbs can only be programed using SCPI commands. Refer to User-Defined commands in the Operating and Service Guide document. Resistance and Powerntypes apply to N679xA . The parameters apply to the selected Arb type (Voltage, Current, Power, or Resistance).

Front Panel Menu Reference	SCPI Command
Not available	To set up the Arb type (current, voltage, power, or resistance) and shape, use: ARB:FUNC:TYPE VOLT|CURR|POW|RES,(@1) ARB:FUNC:SHAP UDEF,(@1) To specify the voltage value of five steps: ARB:VOLT:UDEF:LEV 1,2,3,4,5,(@1) To specify the time that the output stays at the voltage steps: ARB:VOLT:UDEF:DWEL 1,2,3,2,1,(@1) To generate an external trigger signal at the start of a voltage step (the trigger is generated at the start of step #3): ARB:VOLT:UDEF:BOST 0,0,1,0,0,(@1)

Configuring Steps Common to all Arbs

Step 4. Specify what happens when the Arb completes.

Select whether the output returns to the DC value that was in effect before the Arb started, or whether the output should remain at the last Arb value.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Terminate**. Specify Return to start setting or Stop at last Arb setting. Then press **Select**.	To specify a setting when the Arb ends, use: ARB:TERM:LAST OFF,(@1)

Step 5. Specify the repeat count of the Arb.

Specify if the Arb should repeat, either continuously (INFinity), or only for a specified repeat count. A repeat count of 1 runs the Arb once.

Front Panel Menu Reference	SCPI Command
Select **Transient\Arb\Repeat**. Specify a repeat count, or run the Arb continuously. Then press **Select**.	To specify an Arb count, use: ARB:COUN 1,(@1)

Running the Arb

Step 6. Enable the Arb function to respond to output triggers.

Front Panel Menu Reference	SCPI Command
Select **Transient\Mode**. For voltage, current, power, or resistance Arb triggering, set the mode to Arb. Then press **Select**.	To enable the Arb to respond to triggers, use: VOLT:MODE ARB,(@1) CURR:MODE ARB,(@1) POW:MODE ARB,(@1) RES:MODE ARB,(@1)

Step 7. Select the Arb trigger source.

Select a trigger source from the following:

- **Bus** Selects GPIB device trigger, *TRG, or <GET> (Group Execute Trigger).

- **Imm** An immediate trigger command either from the front panel or over the bus will generate an immediate trigger.

- **Ext** Selects all digital port pins that have been configured as trigger inputs.

- **Pin<n>**Selects a specific pin that is configured as a Trigger Input on the digital port. <n> specifies the pin number. The selected pin must be configured as a Trigger Input in order to be used as a trigger source (refer to Trigger Input).

Use the following commands to select a trigger source:

Front Panel Menu Reference	SCPI Command
Select **Transient\TrigSource**. Under Arb trigger source, select Bus. To select Digital pin triggers, select **Transient\TrigSource**. Then select one of the digital port pins. (Ext selects all pins that have been configured as trigger inputs.) Then press **Select**.	To select Bus triggers for Arbs, use: TRIG:ARB:SOUR BUS,(@1) To select Immediate triggers for output 1: TRIG:ARB:SOUR IMM,(@1) To select Digital pin triggers: TRIG:ARB:SOUR PIN<n>,(@1) where n is the pin number.

Step 8. Initiate and Trigger the Arb.

Front Panel Menu Reference	SCPI Command
Select **Transient\Control**. Select Initiate. Wait a second, then select Trigger to generate an immediate trigger signal regardless of the trigger source setting.	To initiate the transient trigger system and generate a trigger: INIT:TRAN (@1) TRIG:TRAN (@1) Alternatively, you can also program a *TRG or an IEEE-488 <get> command.

NOTE It takes a few milliseconds for the instrument to be ready to receive a trigger signal after receiving the INIT:TRAN command. If a trigger occurs before the trigger system is ready for it, the trigger will be ignored. You can test the WTG_tran bit (bit 4) in the operation status register to know when the instrument is ready to receive a trigger after being initiated.

Making Measurements

Basic DC Measurements

Measurement Ranges

Seamless Measurements

Simultaneous Measurements

Auxiliary Voltage Measurements

Basic DC Measurements

Each output channel has its own measurement capability. The output voltage and current is measured by acquiring a number of samples at the selected time interval, applying a window function to the samples, and averaging the samples.

The default time interval and number of samples yield a measurement time of 21 milliseconds per reading (1024 data samples at 20.48 microsecond intervals). The windowing function is Rectangular.

Use the following commands to make a simple measurement. Models that have simultaneous voltage and current measurement capability let you measure power (refer to Model Differences).

Front Panel Menu Reference	SCPI Command
Select the **Meter** key.	MEAS:VOLT? (@1) MEAS:CURR? (@1) MEAS:POW? (@1)

Measurement Ranges

Some models have multiple voltage and current measurement ranges (refer to Model Differences). Selecting a lower measurement range provides greater measurement accuracy, provided the measurement does not exceed the range.

Front Panel Menu Reference	SCPI Command
Select **Measure\Range**. Select the lower measurement range from the voltage or current dropdown menu. Then press **Select**.	To set the 5 V measurement range: SENS:VOLT:RANG 5,(@1) To set the 1 A measurement range: SENS:CURR:RANG 1,(@1)

The maximum measurable current is the maximum rating of the range. If the measurement exceeds the range, an "Overload" error will occur. Examples of programming measurement ranges are:

3.06 A range To select, program values > 0.1 A and ≤ 3.06 A.
0.10 A range To select, program values > 200 µA and ≤ 0.1 A.
200 µA range (option 2UA) To select, program values ≤ 200 µA.

Seamless Measurements

| NOTE | Seamless measurement autoranging for both voltage and current measurements is available on models N678xA SMU and with Option SMR. `N678xA SMU` `Option SMR` |

Seamless measurement autoranging enables a wide dynamic measurement range with no data lost when transitioning across ranges. Seamless autoranging does not include the 10 µA range, which must be selected manually.

Front Panel Menu Reference	SCPI Command
Select **Measure\Range**. Select Auto from the voltage or current dropdown menu. Then press **Select**.	To enable seamless voltage or current autoranging on channel 1: SENS:VOLT:RANG:AUTO ON,(@1) SENS:CURR:RANG:AUTO ON, (@1)

Simultaneous Measurements

Some models have simultaneous voltage and current measurement capability (refer to Model Differences). In this case BOTH voltage and current can be acquired on any measurement.

Front Panel Menu Reference	SCPI Command
Not available	Select the measurement function: SENS:FUNC:VOLT ON,(@1) SENS:FUNC:CURR ON,(@1)
	Initiate and trigger the measurement system: INIT:ACQ (@1) TRIG:ACQ (@1)
	Fetch the voltage, current, or power measurement: FETC:VOLT? (@1) FETC:CURR? (@1) FETC:POW? (@1)

Auxiliary Voltage Measurements

| NOTE | This information applies to models N6781A and N6785A only. `N6781A, N6785A` |

Keysight Models N6781A and N6785A have an auxiliary voltage measurement input, whose primary use is for battery voltage rundown measurements. It may also be suitable for other applications including general purpose DC voltage measurements between +/-20 VDC. The auxiliary voltage measurement input is isolated from other commons. It has a bandwidth of about 2 kHz. It has one input range: –20 to +20 VDC.

Auxiliary voltage measurements cannot be made along with output voltage measurements. When the auxiliary voltage measurement input is selected, the voltage measurement input will be switched to the Aux Voltage inputs instead of the normal + and – sense terminals.

To enable auxiliary voltage measurements:

Front Panel Menu Reference	SCPI Command
Select **Measure\Input**. Select Auxiliary. Then press **Select**. Select Main to reconnect the voltage measurement input to the output terminals.	To enable auxiliary measurements: SENS:FUNC:VOLT:INP AUX,(@1) Take the auxiliary voltage measurement: MEAS:VOLT? (@1)

> **NOTE**   When the auxiliary voltage measurement terminals are left unconnected, the front panel meter will indicate a voltage reading of approximately 1.6V. This is a normal indication which does not affect the voltage measurement once the auxiliary measurement terminals are connected.

Using the Digitizer

Measurement Types

Programming the Digitizer

Synchronizing Digitizer Measurements

NOTE	The Digitizer function requires ⬭ Option 054 to be installed on models N673xA. N674xA, N675xA, and N677xA.
	When a remote interface measurement is in progress, the front panel display may indicate "-- -- -- -- --". Front panel measurements resume when the remote measurement completes.

Measurement Types

In addition to the DC (or average) measurements discussed under Making Measurements, the following digitized measurements are also available. These can only be measured using the corresponding SCPI command.

ACDC – is a calculation that returns the total RMS measurement (AC + DC).

HIGH – is a calculation that generates a histogram of the waveform using 16 bins between the maximum and minimum data points. The bin containing the most data points above the 50% point is the high bin. The average of all the data points in the high bin is returned as the High level. If no high bin contains more than 1.25% of the total number of acquired points, then the maximum data point is returned.

LOW – is a calculation that generates a histogram of the waveform using 16 bins between the maximum and minimum data points. The bin containing the most data points below the 50% point is the low bin. The average of all the data points in the low bin is returned as the Low level. If no low bin contains more than 1.25% of the total number of acquired points, then the minimum data point is returned.

MAX – is the maximum value of the digitized measurement.

MIN – is the minimum value of the digitized measurement.

Array queries are also available to return ALL values in the voltage and current measurement buffer. No averaging is applied, only raw data is returned from the buffer.

Programming the Digitizer

The digitizer function lets you access the enhanced voltage and current measurement capabilities of the N6700C power system. You can:

Select a measurement function and range.

Adjust the measurement sample rate.

Specify a measurement window that can attenuate AC noise.

Trigger the measurement

Retrieve the measurement array data.

Select a Measurement Function and Range

The following commands select a measurement function. To enable the measurement function, use:

Front Panel Menu Reference	SCPI Command
Not available	To enable voltage or current measurements: SENS:FUNC:VOLT ON, (@1) SENS:FUNC:CURR ON, (@2)
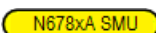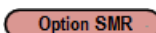
If a power module has simultaneous measurements (refer to Model Differences), you can enable BOTH voltage and current measurements on the same output channel.

Some power modules also have multiple measurement ranges. Selecting a lower measurement range provides greater measurement accuracy, provided that the measurement does not exceed the range. To select lower measurement ranges, use:

Front Panel Menu Reference	SCPI Command
Select **Measure\Range**. Select the lower measurement range from the voltage or current dropdown menu. Then press **Select**.	To set the 5 V measurement range: SENS:VOLT:RANG 5, (@1) To set the 1 A measurement range: SENS:CURR:RANG 1, (@1)

Seamless Measurements

**NOTE**   Seamless measurement autoranging for both voltage and current measurements is available on models N678xA SMU and with Option SMR. `N678xA SMU` `Option SMR`

Seamless measurement autoranging enables a wide dynamic measurement range with no data lost when transitioning across ranges. Seamless autoranging does not include the 10 µA range, which must be selected manually.

Front Panel Menu Reference	SCPI Command
Select **Measure\Range**. Select Auto from the voltage or current dropdown menu. Then press **Select**.	To enable seamless voltage or current autoranging: SENS:VOLT:RANG:AUTO ON, (@1) SENS:CURR:RANG:AUTO ON, (@1)

Adjust the Measurement Sample Rate

The following figure illustrates the relationship between measurement samples (or points), and the time interval between samples in a typical measurement. You can fine tune the measurement by specifying the number of points in the measurement as well as the time interval between points.
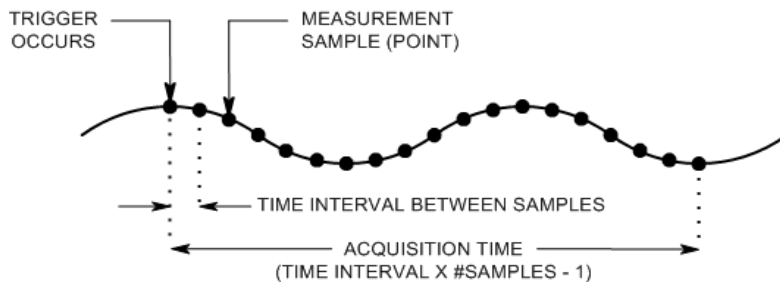
You can vary the measurement data sampling rate as follows:

Front Panel Menu Reference	SCPI Command
Select **Measure\Sweep**. Enter the number of points. Then press **Select**. Enter the time interval. Then press **Select**.	To set the time interval to 60µs with 4096 samples, use: SENS:SWE:TINT 60E-6, (@1) SENS:SWE:POIN 4096, (@1)

The maximum number of sample points that are available for all measurements is 512 K points (K = 1024). If you specify a voltage measurement with 500 K points on channel 1 for example, you will only have 12 K points available for all other measurements.

Time interval values can range from 5.12 microseconds (for one parameter on Models N678xA SMU) to 40,000 seconds. Note that the shortest time interval (fastest speed) that can be specified depends on the number of parameters that are being measured, the model that is doing the measuring, and the time interval resolution. You can only measure up to 4 parameters with the time interval resolution set to 20 microseconds.

1 parameter (models N678xA SMU only)	5.12 µs
1 or 2 parameters (all models)	10.24 µs
3 or 4 parameters (all models), with 20 µs programmed resolution	20.48 µs
5 to 8 parameters (all models), with 40 µs programmed resolution	40.96 µs

Time interval values from 10.24 up to 20.48 microseconds are rounded to the nearest 10.24-microsecond increment. Values above 20.48 microseconds are rounded to the nearest 20.48-microsecond increment when the resolution is set to RES20. Values above 40.96 microseconds are rounded to the nearest 40.96-microsecond increment when the resolution is set to RES40.

You can change the time interval resolution as follows:

Front Panel Menu Reference	SCPI Command
Not available	To set the resolution to 20 or 40 microseconds: SENS:SWE:TINT:RES RES20 SENS:SWE:TINT:RES RES40

Specify a Window Function

Windowing is a signal conditioning process that reduces the error in average measurements made in the presence of periodic signals and noise. Two window functions are available: Rectangular and Hanning. At power-on, the measurement window is Rectangular.

The Rectangular window calculates average measurements without any signal conditioning. However, in the presence of periodic signals such AC line ripple, a Rectangular window can introduce errors when calculating average measurements. This can occur when a non-integral number of cycles of data has been acquired due to the last partial cycle of acquired data.

One way of dealing with AC line ripple is to use a Hanning window. The Hanning window applies a cos4 weighting function to the data when calculating average measurements. This attenuates the AC noise in the measurement window. The best attenuation is achieved when at least three or more waveform cycles are in the measurement.

Front Panel Menu Reference	SCPI Command
Select **Measure\Window**. Select Auto from the voltage or current dropdown menu. Then press **Select**.	To select the Hanning window function: SENS:WIND HANN,(@1)

Trigger the Measurement

The following commands trigger and return measurement data:

Front Panel Menu Reference	SCPI Command
Select the **Meter** key. Front panel meters can only measure average voltage and current.	To measure average voltage & current: MEAS:VOLT? (@1) MEAS:CURR? (@1) To measure RMS voltage & current: MEAS:VOLT:ACDC? (@1) MEAS:CURR:ACDC? (@1) To measure the high or low level of a pulse: MEAS:VOLT:HIGH? (@1) MEAS:CURR:HIGH? (@1) MEAS:VOLT:LOW? (@1) MEAS:CURR:LOW? (@1) To measure the maximum or minimum value: MEAS:VOLT:MAX? (@1) MEAS:CURR:MAX? (@1) MEAS:VOLT:MIN? (@1) MEAS:CURR:MIN? (@1) To measure power: MEAS:POW? (@1)

Power measurements require simultaneous measurement capability (refer to Model Differences).

Array queries return all values in the voltage and current measurement buffer. No averaging is applied, only raw data is returned from the buffer.

Front Panel Menu Reference	SCPI Command
Not available	MEAS:ARR:VOLT? (@1) MEAS:ARR:POW? (@1) MEAS:ARR:CURR? (@1)

Retrieving the Measurement Array Data

Once a measurement finishes, you may wish to retrieve the array data without initiating a new measurement. Use FETCh queries to return the array data from the last measurement. Fetch queries do not alter the data in the measurement buffer. The commands are:

Front Panel Menu Reference	SCPI Command
Not available	FETC:ARR:VOLT? (@1) FEAS:ARR:POW? (@1) FETC:ARR:CURR? (@1)

Power measurements require simultaneous measurement capability (refer to Model Differences).

If a FETCh query is sent before the measurement is started or before it is finished, the response will be delayed until the measurement trigger occurs and the acquisition completes. This may tie up the computer if the measurement trigger does not occur immediately. You can test the MEAS_active bit in the operation status register to know when the measurement has completed as explained in the following section.

Synchronizing Digitizer Measurements

Use the measurement trigger system to synchronize the acquisition of measurements with a Bus, Transient, or an external trigger. Then use FETCh commands to return voltage or current information from the acquired data. Briefly, to make a triggered measurement:

Select the measurement function

Capture pre-trigger data (optional)

Select the measurement trigger source

Initiate the measurement trigger system

Trigger the measurement

Fetch the measurement

Select the Measurement Function

The following commands select a measurement function:

Front Panel Menu Reference	SCPI Command
Not available	To enable voltage measurements: SENS:FUNC:VOLT ON, (@1)
	To enable current measurements: SENS:FUNC:CURR ON, (@2)

Some power modules have two measurement converters, which allow simultaneous voltage and current measurements (refer to Model Differences). In that case, BOTH voltage and current measurements can be enabled. If a power module has only one converter, the parameter that it measures (either voltage or current) must be specified.

Capture Pre-Trigger Data (optional)

The measurement system lets you capture data before, after, or at the trigger signal. As shown in the following figure, you can move the block of data being read into the acquisition buffer with reference to the trigger. This allows pre- or post-trigger data sampling.
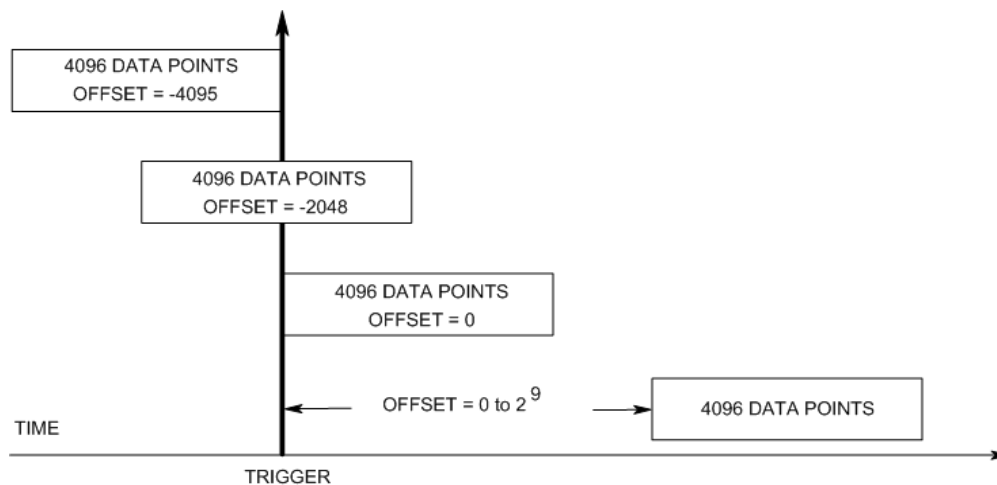
To offset the beginning of the acquisition buffer relative to the acquisition trigger:

Front Panel Menu Reference	SCPI Command
Select **Measure\Sweep**. Enter an Offset value. Then press **Select**.	To offset the measurement by 100 points: SENS:SWE:OFFS:POIN 100, (@1)

When the value is 0, all measurement samples are taken after the trigger. Positive values represent the delay after the trigger occurs but before the samples are acquired. This can be used to exclude measurement samples that occur during the delay time. (Delay time = offset x sample period). Negative values represent data samples taken prior to the trigger. This lets you acquire measurement samples prior to the trigger.

> **NOTE** If, during a pre-trigger data acquisition, a trigger occurs before the pre-trigger data count is completed, the measurement system ignores this trigger. This will prevent the completion of the measurement if another trigger is not generated.

Select the Measurement Trigger Source

> **NOTE** A TRIGger:ACQuire[:IMMediate] command over the bus will always generate an immediate measurement trigger, regardless of the selected trigger source.

Unless you are using TRIGger:ACQuire[:IMMediate], select a trigger source from the following:

Bus – Selects GPIB device trigger, *TRG, or <GET> (Group Execute Trigger).

External – Selects all digital port pins that have been configured as trigger inputs.

Pin<n> – Selects a specific pin that is configured as a Trigger Input on the digital port. <n> specifies the pin number. The selected pin must be configured as a Trigger Input in order to be used as a trigger source (see Using the Digital Port).

Transient<n> – Selects the output channel's transient system as the trigger source. <n> specifies the channel. When you select a channel, you must also set up that channel's transient system to generate a trigger out signal. See Generate Trigger Out Signals and Program an Arbitrary List.

Use the following commands to select a trigger source:

Front Panel Menu Reference	SCPI Command
Not available	To select Bus triggers for output 1: TRIG:ACQ:SOUR BUS, (@1) To select a Digital pin as the trigger: TRIG:ACQ:SOUR PIN<n>, (@1) To select a Transient output as trigger: TRIG:ACQ:SOUR TRAN<n>, (@1) where n is the output channel that will generate the trigger signal.

Initiate the Measurement Trigger System

Next, you must initiate or enable the measurement trigger system.

When the power system is turned on, the trigger system is in the idle state. In this state, the trigger system is disabled, ignoring all triggers. The INITiate commands enable the trigger system to receive triggers. To initiate the trigger system, use:

Front Panel Menu Reference	SCPI Command
Not available	To initiate the measurement trigger system: INIT:ACQ (@1)

It takes a few milliseconds for the instrument to be ready to receive a trigger signal after receiving the INITiate:ACQuire command, and it can take longer for Keysight Models N678xA SMU.

If a trigger occurs before the trigger system is ready for it, the trigger will be ignored. You can test the WTG_meas bit in the operation status register to know when the instrument is ready to receive a trigger after being initiated.

Front Panel Menu Reference	SCPI Command
Not available	To query the WTG_meas bit (bit 3): STAT:OPER:COND?(@1)

If a bit value of 8 is returned in the query, the WTG_meas bit is true, and the instrument is ready to receive the trigger signal. Refer to Status Tutorial in the Operating and Service Guide document for more information.

NOTE   It will be necessary to initiate the measurement trigger system each time a triggered measurement is desired.

Trigger the Measurement

The trigger system is waiting for a trigger signal in the initiated state. You can immediately trigger the measurement as follows:

Front Panel Menu Reference	SCPI Command
Not available	To generate a measurement trigger: TRIG:ACQ (@1)
	Alternatively, if the trigger source is BUS, you can also program a *TRG or an IEEE-488 <get> command.

As previously discussed, a trigger can also be generated by another output channel or an input pin on the digital port connector. If any of these systems are configured as the trigger source, the instrument will wait indefinitely for the trigger signal. If the trigger does not occur, you must manually return the trigger system to the idle state.

The following commands return the trigger system to the idle state:

Front Panel Menu Reference	SCPI Command
Select **Measure\Control**. Then select the Abort control.	ABOR:ACQ (@1)

Fetch the Measurement

After a trigger is received and the measurement completes, the trigger system will return to the idle state. When this occurs, you can use FETCh queries to return the measurement data.

Front Panel Menu Reference	SCPI Command
Not available	To return average voltage & current: FETC:VOLT? (@1) FETC:CURR? (@1)
	To return RMS voltage & current: FETC:VOLT:ACDC? (@1) FETC:CURR:ACDC? (@1)
	To return the high or low level of a pulse: FETC:VOLT:HIGH? (@1) FETC:CURR:HIGH? (@1) FETC:VOLT:LOW? (@1) FETC:CURR:LOW? (@1)
	To return the maximum or minimum value: FETC:VOLT:MAX? (@1) FETC:CURR:MAX? (@1) FETC:VOLT:MIN? (@1) FETC:CURR:MIN? (@1)
	To return power: FETC:POW? (@1)

Power measurements require simultaneous measurement capability (refer to **Model Differences**).

If a FETCh query is sent before the measurement is finished, the response will be delayed until the measurement trigger occurs and the acquisition completes. You can test the MEAS_active bit in the operation status register to know when the measurement trigger system has returned to the idle state.

Front Panel Menu Reference	SCPI Command
Not available	To query the MEAS_active bit (bit 5): STAT:OPER:COND? (@1)

If a bit value of 32 is returned in the query, the MEAS_active bit is true, and the measurement is NOT complete. When the MEAS_active bit is false, you can retrieve the measurement. Refer to Status Tutorial in the Operating and Service Guide document for more information.

External Data Logging

Data Logging Functions

Select the Measurement Function and Range

Specify the Integration Period

Select the Elog Trigger Source

Initiate and Trigger the Elog

Periodically Retrieve the Data

Terminate the Elog

Data Logging Functions

| NOTE | The external data logging function can only be programmed using SCPI commands. |

The Keysight N6700C models have an "external" data logging function (Elog) that lets you continuously log voltage and current measurements. Data logging is external to the instrument because it can only be implemented using SCPI commands. Voltage and current measurement data is temporarily stored in a FIFO (first-in, first-out) buffer located in the instrument. However, this buffer is only large enough to hold about 20 seconds of accumulated measurements. This means that you must periodically empty the internal buffer to an external storage device; otherwise the data in the buffer will be overwritten.

The following table details the various data logging functions.

Function	Description
Data Storage	Buffers measurements for about 20 seconds and requires that the computer periodically reads measurements to prevent the internal buffer from overflowing. The computer needs to provide the external data storage.
Measurement Resources	Run independently on each output. Some outputs can be running an external data log, while the remaining outputs can be used in front panel control or used for other SCPI functions.
Measurement Functions	If a power module has only one measurement converter, then either voltage or current, but not both, can be logged.
Integration Period	Minimum integration period is 102.4 microseconds for one parameter with data format set to REAL. During the specified integration period, the samples are averaged, and min and max values are tracked.
Data viewing	No front panel view or control. Data must be collected and viewed externally.

Select the Measurement Function and Range

The following commands select a measurement function:

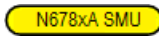| Front Panel Menu Reference	SCPI Command
Not available	To enable voltage or current measurements: SENS:ELOG:FUNC:VOLT ON, (@1) SENS:ELOG:FUNC:CURR ON, (@1) To enable min/max measurements: SENS:ELOG:FUNC:VOLT:MINM ON, (@1) SENS:ELOG:FUNC:CURR:MINM ON, (@1)

If a power module has simultaneous measurements (refer to Model Differences), you can enable BOTH voltage and current measurements on the same output channel. Power modules that do not have simultaneous measurement capability cannot externally log both voltage and current.

Some power modules also have multiple measurement ranges. Selecting a lower measurement range provides greater measurement accuracy, provided that the measurement does not exceed the range. To select lower measurement ranges, use:

Front Panel Menu Reference	SCPI Command
Not available	To set the 5 V measurement range: SENS:ELOG:VOLT:RANG 5, (@1) To set the 1 A measurement range: SENS:ELOG:CURR:RANG 1, (@1)

Seamless Measurements

> **NOTE** Seamless measurement autoranging for both voltage and current measurements is available on models N678xA SMU and with Option SMR. N678xA SMU Option SMR

Seamless measurement autoranging enables a wide dynamic measurement range with no data lost when transitioning across ranges. Seamless autoranging does not include the 10 µA range, which must be selected manually.

Front Panel Menu Reference	SCPI Command
Not available	To enable seamless elog autoranging: SENS:ELOG:VOLT:RANG:AUTO ON, (@1) SENS:ELOG:CURR:RANG:AUTO ON, (@1)

Specify the Integration Period

The integration period can be set from a minimum of 102.4 microseconds to a maximum of 60 seconds.

Front Panel Menu Reference	SCPI Command
Not available	To set an integration period of 600 microseconds: SENS:ELOG:PER 0.0006, (@1)

During the integration period, Elog samples are averaged, and the minimum and maximum values are tracked. At the end of each integration period the average, minimum, and maximum values are added to the internal FIFO buffer. You can specify up to six measurement parameters per channel: Voltage+Vmax+Vmin, and Current+Imax+Imin.

Although the absolute minimum integration period is 102.4 microseconds, the actual minimum depends on the number of measurement parameters that are being logged. The actual minimum is 102.4 microseconds times the number of parameters being logged at each interval. Note that you can measure up to 4 parameters with the time interval resolution set to 20 microseconds, and up to 24 parameters with the resolution set to 40 microseconds. When the instrument sets an integration period, the value sent is rounded to the nearest integer multiple of the chosen resolution, either 20.48 microseconds or 40.96 microseconds.

1 parameter (Voltage or Current), with 20 µs resolution	102.4 µs
2 parameters (Voltage and Current), with 20 µs resolution	204.8 µs
4 parameters (Voltage+Vmin+Vmax+Current), with 20 µs resolution	409.6 µs
8 parameters with 40 µs resolution	819.2 µs
16 parameters with 40 µs resolution	1638.4 µs
24 parameters with 40 µs resolution	2457.6 µs

You can change the time interval resolution as follows:

Front Panel Menu Reference	SCPI Command
Not available	To set the resolution: SENS:SWE:TINT:RES RES20 SENS:SWE:TINT:RES RES40

If the specified integration period is at or near the minimum logging intervals, the data format must be specified as binary. If the REAL format is not specified, the data will be in ASCII format and the minimum logging intervals will typically be up to five times longer than what can be achieved with binary format.

Front Panel Menu Reference	SCPI Command
Not available	To set the data format to REAL: FORM REAL

Select the Elog Trigger Source

The TRIGger:ELOG command generates an immediate trigger regardless of the trigger source. Unless you are using this command, select a trigger source from the following:

Bus – Selects GPIB device trigger, *TRG, or <GET> (Group Execute Trigger).

External – Selects all digital port pins that have been configured as trigger inputs.

Immediate – Selects the immediate trigger source. This triggers the data logger immediately when initiated

Pin<n> – Selects a specific pin that is configured as a Trigger Input on the digital port. <n> specifies the pin. The selected pin must be configured as a Trigger Input in order to be used as a trigger source (see Using the Digital Port).

Use the following commands to select one of the available trigger sources:

Front Panel Menu Reference	SCPI Command
Not available	To select Bus triggers: TRIG:TRAN:SOUR BUS, (@1) To select any digital pin as the trigger source: TRIG:TRAN:SOUR EXT, (@1) To select an immediate trigger: TRIG:TRAN:SOUR IMM, (@1) To select digital pin 5 as the trigger: TRIG:ACQ:SOUR PIN5, (@1)

Initiate and Trigger the Elog

When the power system is turned on, the trigger system is in the Idle state. In this state, the trigger system is disabled, ignoring all triggers. The INITiate command enables the measurement system to receive triggers. To initiate and trigger the Elog:

Front Panel Menu Reference	SCPI Command
Not available	To initiate and trigger the Elog: INIT:ELOG, (@1) TRIG:ELOG, (@1) Alternatively, if the trigger source is BUS, you can also program a *TRG or an IEEE-488 <get> command.

When triggered, the Elog starts placing data in the internal measurement buffer. Because the buffer is only large enough to hold 20 seconds of accumulated measurement your PC application must periodically retrieve (or fetch) the data from this buffer.

Periodically Retrieve the Data

Each FETCh command returns number of requested records of the data in the buffer and removes them, making room available for more data. The Elog continues until it is aborted.

An Elog record is one set of voltage and current readings for one time interval. The exact format of a record depends on which functions have been enabled for Elog sensing. If all functions are enabled, then one record will contain the following data in the specified order:
Current average
Current minimum
Current maximum
Voltage average

Voltage minimum
Voltage maximum

Front Panel Menu Reference	SCPI Command
Not available	To retrieve a maximum of 1000 records: FETC:ELOG? 1000, (@1)

ASCII data (the default) is returned as comma-separated ASCII numeric data sets of average, min, or max values terminated by a newline. ASCII queries can only fetch data from one channel at a time.

Binary data is returned as a comma-separated list of data for each channel requested. The data is a definite length binary block, with the byte order specified by the FORMat:BORDer command.

Terminate the Elog

Front Panel Menu Reference	SCPI Command
Not available	ABOR:ELOG, (@1)

Using the Digital Control Port

Bi-directional Digital IO

Digital Input

Fault Output

Inhibit Input

Fault/Inhibit System Protection

Output State

A Digital Control Port consisting of seven I/O pins is provided to access various control functions. Each pin is user-configurable. The following control functions are available for the I/O pins:

Bi-directional Digital IO

Each of the seven pins can be configured as general purpose bi-directional digital inputs and outputs. The polarity of the pins can also be configured. Pin 8 is the signal common for the digital I/O pins. Data is programmed according to the following bit assignments:

Pins	7	6	5	4	3	2	1
Bit weight	6 (msb)	5	4	3	2	1	0 (lsb)

To configure the pins for digital IO:

Front Panel Menu Reference	SCPI Command
Select **System\IO\DigPort\Pins**. Select a pin in the pin field. In the Function field, select Dig I/O. In the Polarity field, select Positive or Negative. To send data to the pins, select **System\IO\DigPort\Data**. Select the Data Out field and enter the binary word.	To configure the pin function: DIG:PIN1:FUNC DIO To select the pin polarity: DIG:PIN1:POL POS DIG:PIN1:POL NEG To send data to the pins: DIG:OUTP:DATA <data>

The digital I/O pin can be used to control both relay circuits as well as digital interface circuits. The following figure illustrates typical relay circuits as well as digital interface circuit connections using the digital I/O functions.

A) Relay Circuits   B) Digital Interface Circuits
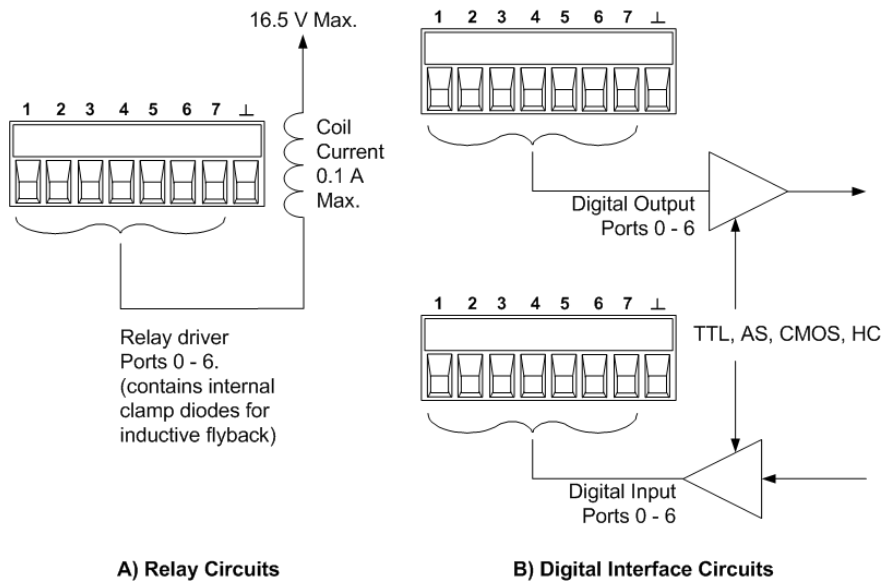
Digital Input

Each of the seven pins can be configured as digital input only. The polarity of the pins can also be configured. Pin 8 is the signal common for the digital input pins. The pin status reflects the true condition of the external signal that is applied to the pin. The pin state is not affected by the value of the binary output word.

To configure the pins for digital input only:

Front Panel Menu Reference	SCPI Command
Select **System\IO\DigPort\Pins**. Select a pin in the pin field. In the Function field, select Dig In. In the Polarity field, select Positive or Negative. To read the data from the pins, select **System\IO\DigPort\Data**. The input data is displayed as a binary number in the Data In field.	To configure the pin function: DIG:PIN1:FUNC DINP To select the pin polarity: DIG:PIN1:POL POS DIG:PIN1:POL NEG To read the pin data: DIG:INP:DATA?

External Trigger I/O

Each of the seven pins can be configured as trigger inputs or trigger outputs. The polarity of the pins can also be configured. When you program trigger polarity, POSitive means a rising edge and NEGative means a falling edge. Pin 8 is the signal common for the trigger pins.

When configured as a trigger input, you can apply either a negative-going or a positive-going pulse to the designated trigger input pin. The trigger latency is 5 microseconds. The minimum pulse width is 4

microseconds for positive-going signals, and 10 microseconds for negative-going signals. The pin's polarity setting determines which edge generates a trigger-in event.

When configured as a trigger output, the designated trigger pin will generate a 10 microsecond-wide pulse when a Trigger Out occurs. Depending on the polarity setting, it can be either positive-going (rising edge) or negative-going (falling-edge) when referenced to common.

Front Panel Menu Reference	SCPI Command
Select **System\IO\DigPort\Pins**. Select a pin in the Pin field. In the Function field, select either the Trig In or Trig Out function. In the Polarity field, select Positive or Negative.	To select the trigger output function for pin 1: DIG:PIN1:FUNC TOUT To select the trigger input function for pin 2: DIG:PIN2:FUNC TINP To select the pin polarity: DIG:PIN1:POL POS DIG:PIN2:POL NEG

Fault Output

Pins 1 and 2 can be configured as a fault-output pair. The Fault Output function enables a fault condition on any channel to generate a protection fault signal on the digital port. Refer to Protection Functions for a list of protection signals that will generate a fault.

Both pins 1 and 2 are dedicated to this function. Pin 1 is the Fault output; pin 2 is the common for pin 1. This provides for an optically-isolated output. The polarity of pin 1 can also be configured. Note that the Fault output signal remains latched until the fault condition is removed and the protection circuit is cleared. as explained under Clearing Protection Functions.

> **NOTE** Pin 2's selected function is ignored. Pin 2 should be connected to the ground of the external circuit.

Front Panel Menu Reference	SCPI Command
Select **System\IO\DigPort\Pins**. Select pin 1. In the Function field, select Fault Out. In the Polarity field, select Positive or Negative.	To configure the Fault function: DIG:PIN1:FUNC FAUL To select the pin polarity: DIG:PIN1:POL POS DIG:PIN1:POL NEG

Inhibit Input

Pin 3 can be configured as a remote inhibit input. The Inhibit Input function lets an external input signal control the output state of all the output channels in the mainframe. The polarity of pin 3 can also be configured. The input is level triggered. The signal latency is 5 microseconds. Pin 8 is the common for pin 3.

The following non-volatile inhibit input modes can be programmed:

LATChing - causes a logic-true transition on the Inhibit input to disable the output. The output will remain disabled after the inhibit signal is received.

LIVE - allows the enabled output to follow the state of the Inhibit input. When the Inhibit input is true, the output is disabled. When the Inhibit input is false, the output is re-enabled.

OFF - The Inhibit input is ignored.

To configure the Inhibit Input function:

Front Panel Menu Reference	SCPI Command
Select **System\IO\DigPort\Pins**. Select pin 3. In the Function field, select Inhibit In. In the Polarity field, select Positive or Negative. Select **Protect\Inhibit**. Select either Latching or Live. To disable the Inhibit signal, select Off.	To select the Inhibit function: DIG:PIN3:FUNC INH To select the pin polarity: DIG:PIN1:POL POS DIG:PIN1:POL NEG To set Inhibit mode to Latching: OUTP:INH:MODE LATC To set Inhibit mode to Live: OUTP:INH:MODE LIVE To disable the Inhibit signal: OUTP:INH:MODE OFF

Fault/Inhibit System Protection

The following figure illustrates some ways that you can connect the Fault/Inhibit pins of the connector.
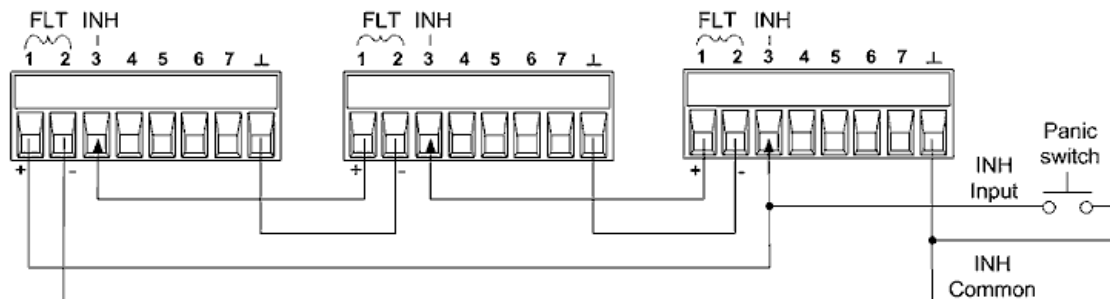
As shown in the figure, when the Fault outputs and Inhibit inputs of several instruments are daisy-chained, an internal fault condition in one of the units will disable all outputs without intervention by either the controller or external circuitry. Note that when using the Fault/Inhibit signals in this manner, both signals must be set to the same polarity.

You can also connect the Inhibit input to a manual switch or external control signal that will short the Inhibit pin to common whenever it is necessary to disable all outputs. **Negative** polarity must be programmed for all pins in this case. You can also use the Fault output to drive an external relay circuit or signal other devices whenever a user-definable fault occurs.

Clearing a System Protection Fault

To restore all instruments to a normal operating condition when a fault condition occurs in a daisy-chained system protection configuration, two fault conditions must be removed:

1. The initial protection fault or external Inhibit signal.

2. The subsequent daisy-chained fault signal (which is sourced by the Inhibit signal).

> **NOTE**   Even when the initial fault condition or external signal is removed, the fault signal is still active and will continue to shut down the outputs of all the units.

To clear the daisy-chained fault signal if the operating mode of the Inhibit input is Live, simply clear the output protection on any ONE unit as explained under Clearing Protection Functions. If the operating mode of the Inhibit input is Latched, turn off the Inhibit input on ALL units individually. To re-enable the chain, re-program the Inhibit input on each unit to Latched mode.

Output State

Only pins 4 through 7 can be configured to control the output state. This function lets you connect multiple Keysight N6700 mainframes together and synchronize the output on/off sequence across mainframes. Refer to Synchronizing Output Turn-On for detailed information.

Using the Protection Functions

Set the Over-Voltage Protection

Set the Over-Current Protection

Couple Output Protection

Set the Over-Power Protection

Query the Over-Temperature Margin

Set the Oscillation Protection

Watchdog Timer Protection

Clear Output Protection

Protection Functions

Each output has independent protection functions. A front panel status indicator will turn on when a protection function has been set. Protection functions are latching, which means that they must be cleared once they have been set. As explained under Couple Output Protection you can configure the instrument so that when a protection fault occurs on one output, ALL outputs will be turned off. Of the following protection functions, only OV, OV-, OC, OSC, PROT, and INH are user- programmable.

OV - Over-voltage protection is a hardware OVP whose trip level is a programmable value. The OVP is always enabled.

OV– – Negative voltage protection is a hardware OVP. Only applies to Keysight N6784A and N6783A.

OC - Over-current protection is a programmable function that can be enabled or disabled. When enabled, the output will be disabled when the output current teaches the current limit setting.

OT - Over-temperature protection monitors the temperature of each output and shuts down the output if any temperature exceeds the maximum factory-defined limits (see OUTPut:PROTection:TEMPerature:MARGin? in the Operating and Service Guide document).

OSC - Oscillation protection shuts down the output if an oscillation is detected on the output. Only applies to Keysight N678xA SMU.

PF - PF indicates that a power fail condition on the AC mains has disabled the output.

CP+ – CP+ indicates that a positive power limit condition has disabled the output. This protection function does not apply to all power modules. Refer to Power Limit Operation for further information.

CP– – CP– indicates that a negative power limit condition has disabled the output. This protection function does not apply to all power modules. Refer to Power Limit Operation for further information.

PROT - Prot indicates that the output is disabled, either because of a coupled protection signal from another output, or because the programmed watchdog time has expired.

INH – The Inhibit input (pin 3) on the rear panel digital connector can be programmed to act as an external shutdown signal. Refer to Inhibit Input for further information.

Set the Over-Voltage Protection

Over-voltage protection disables the output if the output voltage reaches the programmed OVP level. The OVP circuit monitors the voltage at the + and – output terminals.

For models N678xA SMU (N678xA SMU), the voltage is monitored at the + and – sense terminals rather than at the output terminals. This allows for more precise over-voltage monitoring directly at the load. Refer to Over-Voltage Protection Considerations for details. These models also have a back-up local OVP function. Refer to Local OVP for a description of the feature. Additionally, for model N6784A, you can program a negative over-voltage value. Enter the value in the -OVP field.

For models N678xA SMU and N6783A (N678xA SMU) (N6783A), you can specify a delay to prevent momentary over-voltage excursions from tripping the over-voltage protection. Enter the value in the over-voltage Delay field. These models also have negative voltage protection, which disables the output if negative voltages are detected. Negative voltage protection is indicated by the OV- annunciator.

On models with Option J01 (Option J01), the voltage is also monitored at the + and – sense terminals. This option also has tracking OVP in addition to the standard overvoltage protection. This lets you set an overvoltage protection limit that is offset from the programmed voltage. The tracking OVP threshold automatically tracks the real time programmed settings.

For models N69xA (N679xA) the over-voltage protection level is not programmable and is fixed at 110% of the rated input voltage.

Front Panel Menu Reference	SCPI Command
Select **Protect\OVP** Enter a value in the OVP level box and press Select. For J01 units, enter a value in the Tracking OVP Offset box and check the Enable box. Then press **Select**.	To set an OVP of 10 V for output 1: VOLT:PROT 10, (@1) For Models N678xA SMU: VOLT:PROT:REM 10, (@1) To enable tracking OVP for output 1: VOLT:PROT:TRAC ON, (@1) To set the tracking offset to 2V: VOLT:PROT:TRAC:OFFS 2, (@1)

Set the Over-Current Protection

When over-current protection is enabled, the power system turns off the output if the output current reaches the current limit setting and transitions from CV to CC operation.

Front Panel Menu Reference	SCPI Command
Select **Protect\OCP** Check Enable to enable OCP. Then press **Select**.	To enable OCP: CURR:PROT:STAT ON, (@1)

You can also specify an OCP delay to prevent momentary output settings, load, and status changes from tripping the over-current protection. In most cases these momentary conditions would not be considered an over-current protection fault, and having an OCP condition disable the output when they occur would be a nuisance. Specifying an OCP delay lets the OCP circuit ignore these momentary changes during the specified delay period. Once the OCP delay time has expired and the over-current condition persists, the output will shut down.

The delay can be programmed from 0 to 0.255 seconds. You can specify if the OCP delay timer is started by any transition of the output into CC operation, or only at the end of a settings change in voltage, current, or output state.

Front Panel Menu Reference	SCPI Command
Select **Protect\OCP** Enter an OCP delay value. Then press **Select**. Under Delay Start, select "CC Transition" to start the delay timer by ANY output transition into CC mode. Otherwise, the delay timer will only be started by a Settings Change in voltage, current, or output state.	To specify a 10 millisecond delay: CURR:PROT:DEL 0.01, (@1) To start the delay timer by ANY output transition into CC operation: CURR:PROT:DEL:STAR CCTR, (@1) To start the delay timer by a settings change in voltage current or output: CURR:PROT:DEL:STAR SCH, (@1)

Factors that influence how long the settings change or output load change may last include: difference between old output value and new output value, the current limit setting, and the load capacitance in CV operation or load inductance in CC operation. The delay required must be determined empirically; the output programming-response time characteristics may be used as guidelines.

Note that the time it takes the output to go into CC operation varies - depending on the magnitude of the over-current condition compared to the current limit setting. For example, if the over-current is only slightly greater than the current limit setting, it may take several tens of milliseconds for the output to set the CC status bit. If the over-current is significantly greater than the current limit setting, it may only take a few hundred microseconds or less for the output to set the CC status bit. To determine when the output will shut down, you must add the time it takes for the CC status bit to the over-current protection delay time. If the over-current persists beyond the sum of these two time intervals, the output will shut down.

Models N679xA ⬤ N679xA have an additional fixed over-current protection that is always enabled. This protection will turn the output off whenever the input current exceeds 105% of the high ranges and approximately 110% of the low current ranges.

Set the Over-Power Protection

For models N679xA ⬤ N679xA only, the over-power protection will turn the output off if the input power exceeds 110% of the module's power rating. You can program an over-power protection delay to prevent the over-power protection function from being triggered during the delay time. This

prevents momentary input power spikes from triggering the over-power protection. The delay can be programmed from 0 to 0.255 seconds.

Front Panel Menu Reference	SCPI Command
Select **Protect\OPP** Check Enable to enable OPP. Enter a delay value. Then press **Select**.	To enable over-power protection: POW:PROT:STAT ON, (@1) To specify a 10 millisecond delay: POW:PROT:DEL 0.01, (@1)

Couple Output Protection

Protection coupling lets you disable all output channels when a protection condition occurs on a single output channel. To couple output protection:

Front Panel Menu Reference	SCPI Command
Select **Protect\Coupling** Check Enable Coupling. Then press **Select**.	To enable output protection coupling: OUTP:PROT:COUP ON

Query the Over-Temperature Margin
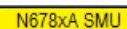
You can query the margin remaining before the over-temperature trips and shuts down the output. The temperature margin is the minimum difference between the internal temperature sensors and the fixed over-temperature trip level. The margin is returned in degrees Celsius.

Front Panel Menu Reference	SCPI Command
Select **Protect\OT** Displays the over-temperature margin. Then press **Select**.	To query the over-temperature margin: OUTP:PROT:TEMP:MARG? (@1)

Set the Oscillation Protection

NOTE   This information applies to Keysight Models N678xA SMU only. N678xA SMU

If open sense leads or capacitive loads outside the allowable range cause the output to oscillate, the oscillation protection function detects the oscillation and latches the output off. The condition is annunciated on the front panel by the OSC status annunciator.

Front Panel Menu Reference	SCPI Command
Select **Protect\OSC** Check the OSC box. Then press **Select**.	To enable oscillation protection for output 1 and 2: OUTP:PROT:OSC ON, (@1,2)

Watchdog Timer Protection

The watchdog timer, when enabled, causes all outputs to go into protection mode if there is no SCPI I/O activity on the remote interfaces (USB, LAN, GPIB) within the user-specified time period. Note that the watchdog timer function is NOT reset by activity on the front panel or when using the Web server – the outputs will still shut down after the time period has elapsed..

After the time period has expired, the outputs will be disabled, but the programmed output state is not changed. The PROT bit in the status questionable register as well as the PROT indicator on the front panel will be set.

The watchdog delay can be programmed from 1 to 3600 seconds in 1 second increments. As shipped from the factory, the watchdog timer is set to disable the outputs 60 seconds after all IO activity has ceased.

The watchdog state and delay settings are volatile, but can be saved and recalled as part of the instrument state. A watchdog protect can be cleared as described under Clear Output Protection.

Front Panel Menu Reference	SCPI Command
Select **Protect\Wdog** Check Enable Watchdog to enable the watchdog timer. Enter a value in the Watchdog Delay box. Then press **Select**.	To enable the watchdog timer: OUTP:PROT:WDOG ON To set the watchdog timer to 600 seconds: OUTP:PROT:WDOG:DEL 600

Clear Output Protection

If an over-voltage, over-current, over-temperature, power-fail condition, power-limit condition, protection condition, or inhibit signal occurs, the power system turns off the affected output channel. The appropriate operating status indicator on the front panel will be on. To clear the protection function and restore normal operation, first remove that condition that caused the protection fault. Then, clear the protection function as follows:

Front Panel Menu Reference	SCPI Command
Select **Protect\Clear** Select Clear.	To clear a protection fault: OUTP:PROT:CLE (@1)

System–Related Operations

Self-test

Instrument Identification

Instrument State Storage

Output Groups

Front Panel Display

Front Panel Keys

Password Protection

Self-test

A power-on self-test occurs automatically when you turn on the power system. This test assures you that the instrument is operational. If the self-test is successful, the power system will continue to operate normally. If the self-test fails, the front panel Err indicator comes on. Press the **Error** key to display the list of errors on the front panel. Refer to Preliminary Checkout in the Operating and Service Guide document for further Information.

Front Panel Menu Reference	SCPI Command
Cycle AC power.	*TST?

Instrument Identification

Keysight N6700C MPS mainframes are identified by the serial number located on the interface cover. Power module serial numbers are located on their top covers.

The serial number consists of a 10-character number (e.g. MY24D00013) located on the label on the top of the interface board. The first two characters indicate the country of manufacture, and the last five digits are a sequential number assigned to each mainframe.

For MPS mainframes, you can programmatically query the model number, serial number, firmware revision, backup and active firmware. For power modules, you can programmatically query the model number, serial number, installed options, voltage, current and power rating.

Front Panel Menu Reference	SCPI Command
Select **System\About\Frame**	For mainframe information: *IDN?
or	For information about the power module in channel 1:
Select **System\About\Module**	SYST:CHAN:MOD? (@1) SYST:CHAN:OPT? (@1) SYST:CHAN:SER? (@1)

Note that you have the ability to change the identity of the mainframe. This functionality is only intended for compatibility with previous "A" and "B" version mainframes.

Front Panel Menu Reference	SCPI Command
Select **System\Preferences\IDN** Check the box to identify the instrument as an Agilent product.	SYST:PERS:MAN "\<manufacturer>" SYST:PERS:MOD "\<model number>"

The IDN change and PERSona commands affects the following identification items:

- *IDN? command for vendor and model

- VISA programmatic access APIs for vendor and model

- LXI instrument web pages

- LXI XML

- LXI mDNS announcements

Instrument State Storage

The power system has ten storage locations in non-volatile memory to store instrument states. The locations are numbered 0 through 9. Any state previously stored in the same location will be overwritten.

Front Panel Menu Reference	SCPI Command
Select **States\SaveRecall**.	To save a state in location 1: *SAV 1
In the SaveRecall field, enter a location from 0 to 9. Then press **Select**. Select Save to save the state or Recall to recall a state.	To recall a state from location 1: *RCL 1

Specifying a power-on state

When shipped from the factory, the power system is configured to automatically recall the reset (*RST) settings at power-on. However, you can configure the power system to recall the settings you have stored in memory location 0 (RCL0) at power-on.

Front Panel Menu Reference	SCPI Command
Select **States\PowerOn**. Select Recall State 0. Then press **Select**.	OUTP:PON:STAT RCL0

Output Groups

NOTE   Output grouping does not apply to Keysight Models N678xA SMU.

Output channels can be configured or "grouped" to create a single output with higher current and power capability. Almost all instrument functionality is supported by grouped channels, including voltage and current programming, measurements, status, step and list transients. The following conditions apply:

- Up to four output channels can be grouped per mainframe.

- Output channels that are grouped must also be connected in parallel as described under Parallel Connections.

- Grouped channels do not have to be adjacent, but they must have identical model numbers and options installed.

- The maximum output current is the sum of the maximum of each channel in the group.

- Low current measurement ranges should not be used with grouped channels, otherwise a measurement overload error will occur. Low current output ranges, however, can be used.

- Over-current protection delay has a slightly slower response time (~10 ms) and slightly less resolution than an ungrouped channel.

- When output channels have been grouped, they are addressed using the channel number of the lowest channel in the group.

- Power limiting should not be used when Keysight N673xB, N674xB, and N677xA power modules are grouped. Refer to Power Allocation.

Front Panel Menu Reference	SCPI Command
Select **System\Groups**. In the matrix that appears, select the channels you want to group. Each row defines a separate group.	To configure a group of channels: SYST:GRO:DEF 2,3,4 This groups channels 2 through 4. To address the group, use channel 2.

To return grouped channels back to an ungrouped state, first remove the parallel connections between channels and proceed as follows:

Front Panel Menu Reference	SCPI Command
Select **System\Groups**. In the matrix, place each output channel in its own separate group.	To ungroup all channels: SYST:GRO:DEL:ALL

Reboot the unit for the changes to take effect.

Front Panel Menu Reference	SCPI Command
Cycle AC power.	SYST:REB

4 Operating the Power System

Front Panel Display

View

You can specify how the output channels are displayed at turn on.

Front Panel Menu Reference	SCPI Command
Select **System\Preferences\Display\View** Check Voltage, Current to display one channel. Check Volt, Curr, Power to display voltage, current and power in one-channel view. Check 4-channel to display all channels.	To display one channel: DISP:VIEW METER1 To display voltage, current and power in one-channel view: DISP:VIEW METER_VIP To display all channels: DISP:VIEW METER4

Contrast

You can set the contrast of the front panel display to compensate for ambient lighting conditions. The contrast can be set from 0% to 100% in increments of 1%. As-shipped, the contrast is set to 80%.

Front Panel Menu Reference	SCPI Command
Select **System\Preferences\Display\Contrast** Enter a contrast value in the Contrast box. Then press **Select**.	Not available

Screen Saver

The power system has a front panel screen saver that significantly increases the life of the LED display by turning it off during periods of inactivity. The delay can be set from 30 to 999 minutes in 1 minute increments. As shipped from the factory, the screen saver comes on one hour after activity on the front panel or interface has ceased.

When the screen saver is active, the front panel display turns off, and the LED next to the Line switch changes from green to amber. To restore the front panel display, simply press one of the front panel keys. The first action of the key turns the display on. Subsequently, the key will revert to its normal function.

If the Wake on I/O function is selected, the display is restored whenever there is activity on the remote interface. This also resets the timer on the screen saver. As shipped, Wake on I/O is active.

Front Panel Menu Reference	SCPI Command
Select **System\Preferences\Display\Saver**	Not available

Enable or disable the screen saver by checking or unchecking the Screen Saver checkbox. Then press **Select**.

Enter a value in minutes in the Saver Delay field to specify the time when the screen saver will activate.

Check Wake on I/O to activate the display with I/O bus activity.

Front Panel Keys

Lockout

You can lock the front panel keys to prevent unwanted control of the instrument from the front panel. This is the most secure way of locking the front panel keys because you need a password to unlock the front panel. The lockout setting is saved in non-volatile memory so that the front panel remains locked even after AC power is cycled.

Front Panel Menu Reference	SCPI Command
Select **System\Preferences\Lock**	Not available

Enter the password to unlock the front panel. Then select Lock.

The menu to unlock the front panel appears every time a key is pressed. Enter the password to unlock the front panel.

NOTE   If the password is lost, the SYSTem:PASSword:FPANel:RESet command can reset the front panel lockout password.

The SYSTem:COMMunicate:RLSTate RWLock command can also lock and unlock the front panel. This command is completely independent of the front panel lockout function. If you use this command to lock the front panel, the front panel will be unlocked when AC power is cycled.

Keys

You can enable or disable the front panel key clicks.

Front Panel Menu Reference	SCPI Command
Select **System\Preferences\Keys**	Not available

Check Enable key clicks to enable key clicks. Press **Select**.
Uncheck to disable key clicks.

You can configure the On/Off key to enable or disable ALL outputs.

Front Panel Menu Reference	SCPI Command
Select **System\Preferences\Keys**	Not available
Check On/Off key affects all channels. Press **Select**. The ON/Off key will now be active on ALL channels.	

Password Protection

You can password-protect all functions located in the Admin menu. These include instrument calibration, interface access, non-volatile memory reset, firmware update, and password updates.

As shipped from the factory, the Admin menu password is 0 (zero). This means that you do not have to enter a password to access the Admin menu. Simply select **System\Admin\Login** and press Enter. To password-protect the Admin menu:

Front Panel Menu Reference	SCPI Command
Select **System\Admin\Password** Enter the password. The password must be numeric, and up to 15 digits long. Then press **Select**. Log out of the Admin menu to activate the password. You can now only enter the Admin menu by providing the right password. Enter the password in the Password field.	Enter calibration mode using the original password: CAL:STAT ON, <password> To change the password: CAL:PASS <password> To exit calibration mode and activate the password: CAL:STAT OFF

If the password is lost, access can be restored by setting an internal switch to reset the password to 0. If the message "Locked out by internal switch setting" or "Calibration is inhibited by switch setting" appears, the internal switch is set to prevent the password from being changed. Refer to Calibration Switches in the Operating and Service Guide document for more information.

Mainframe Power Allocation

Mainframe Power Ratings

Mainframe Power Limit

Module Power Limit

Power Limit Allocation

Mainframe Power Ratings

For the majority of Keysight N6700C MPS configurations, full power is available from all installed power modules. However, it is possible to configure a power system in which the combined ratings of the power modules exceed the power rating of the mainframe. The power system will continue to operate normally as long as the combined module output power is within the power rating of the mainframe. The power rating of Keysight N6700C mainframes is as follows:

 Keysight N6700C : 400 W
 Keysight N6701C : 600 W
 Keysight N6702C @ nominal 100 – 120 VAC: 600 W
 Keysight N6702C @ nominal 200 – 240 VAC: 1200 W

Mainframe Power Limit

If the combined power drawn from all of the power modules exceeds the mainframe's power rating, a power fault protection event will occur. This causes ALL outputs to turn off and remain off until a protection clear command is given. This is explained under Clear Output Protection. A status bit (PF) will indicate that a power fault protection event has occurred.

The power allocation function lets you programmatically limit the power that can be sourced from individual power modules, thereby preventing the combined power from exceeding the mainframe's rated output power and causing all the outputs to turn off.

> **NOTE** For N6702C mainframes operating at 100–120 VAC nominal, the sum of the channel power limit settings cannot exceed 600W due to a restriction on the AC line current. There is no restriction when operating at 200–240 VAC nominal.

Module Power Limit

When the power limit has been set to a value less than the maximum rating on a power module, and either the output voltage or the output current increases to a point where the module exceeds the power limit setting, the module's power limit function will activate. If the power limit is left at the maximum rating, then the power module will not enable its power limit function.

For Keysight N673xB, N674xB, and N677xA power modules, the power limit function will turn the output off after a power limit condition persists for about 1 millisecond. A status bit (CP+) will indicate that the output has been turned off because of a power limit condition. To restore the output, you must first adjust the load so that it draws less power. Then you must clear the protection function as explained under Clear Output Protection. Note that on these models, it may be preferable for some applications to use the current or voltage setting to limit the output power so as to avoid turning the output off.

> **NOTE**　Power limiting should not be used when Keysight N673xB, N674xB, and N677xA power modules are grouped. When these power modules are grouped, you must reset the power limit to its maximum rated value.

For Keysight N675xA, and N676xA power modules, the power limit function will limit the output power at its programmed setting. A status bit (CP+) will indicate that the output is in power limit mode. When the power drawn by the load is reduced below the power limit setting, the output automatically returns to normal operation - either constant voltage or constant current mode.

For Keysight Models N678xA SMU, N6783A-BAT/MFG, and N679xA Loads, the power limit function does not apply.

Power Limit Allocation

The following commands program the module power limit function:

Front Panel Menu Reference	SCPI Command
Select **Output\Advanced\Power**. Enter a power limit for each output. Press **Select**.	To set a power limit on output 1: POW:LIM 100, (@1)

To query the power limits that are set, send:

Front Panel Menu Reference	SCPI Command
Select **Output\Advanced\Power**. The power allocation for all output channels is displayed in the dialog boxes.	POW:LIM? (@1:4)

To return all output channels to their default settings, you can either cycle AC power or send the following commands:

Front Panel Menu Reference	SCPI Command
Select **States\Reset**.	*RST or POW:LIM MAX, (@1:4)

> **NOTE**　When an output channel is set to MAX, it returns to its maximum rated value, and the power limit function will not activate.

Operating Mode Tutorial

Single-Quadrant Operation

Multi-Quadrant Operation

Keysight N679xA Load Module Operation

Single-Quadrant Operation

The Keysight N6700C Modular Power System can operate in either constant voltage (CV) or constant current (CC) over the rated output voltage and current. Constant voltage mode is defined as an operating mode in which the dc source maintains its output voltage at the programmed voltage setting in spite of changes in load, line, or temperature. Thus, when the load resistance changes, the output voltage remains constant while the output current changes to accommodate the change in load.

Constant current mode is defined as an operating mode in which the dc source maintains its output current at the programmed current limit in spite of changes in load, line, or temperature. Thus, when the load resistance changes, the output current remains constant while the output voltage changes to accommodate the change in load.

All DC power modules, except for Keysight Models N678xA SMU, are designed as constant voltage sources. This means that the specifications and operating characteristics are optimized for constant voltage mode operation. Note that these power modules cannot be programmed to operate in a specific mode. At turn-on, the operating mode will be determined by the voltage setting, current setting, and the load resistance. In the following figure, operating point 1 is defined by a fixed load line traversing the positive operating quadrant in the constant voltage region. Operating point 2 is defined by a fixed load line traversing the positive operating quadrant in the constant current region.
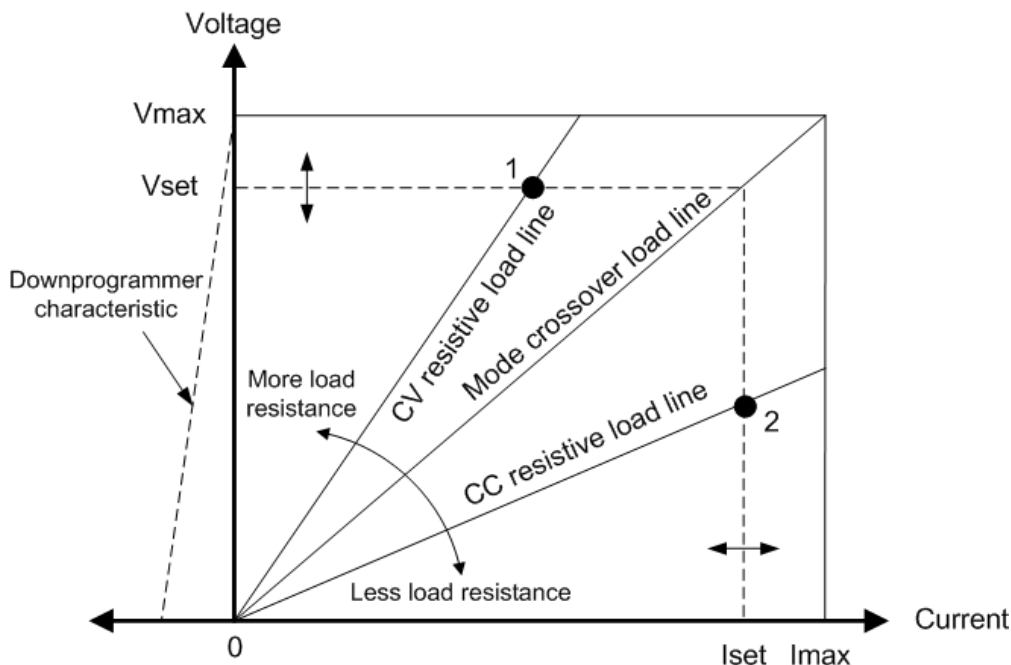
AutoRanging `N675xA, N676xA`

The following figure illustrates the autoranging output characteristic of the Keysight N675xA and N676xA power modules. Point 3 shows a situation in which the voltage and current settings are such that the operating locus is limited by the maximum output power boundary of the output. Depending on the power module, this may be greater than the output power rating of the module. In this situation, the output is not guaranteed to meet its operating specifications because it is operating in an area that is outside its specified power rating.
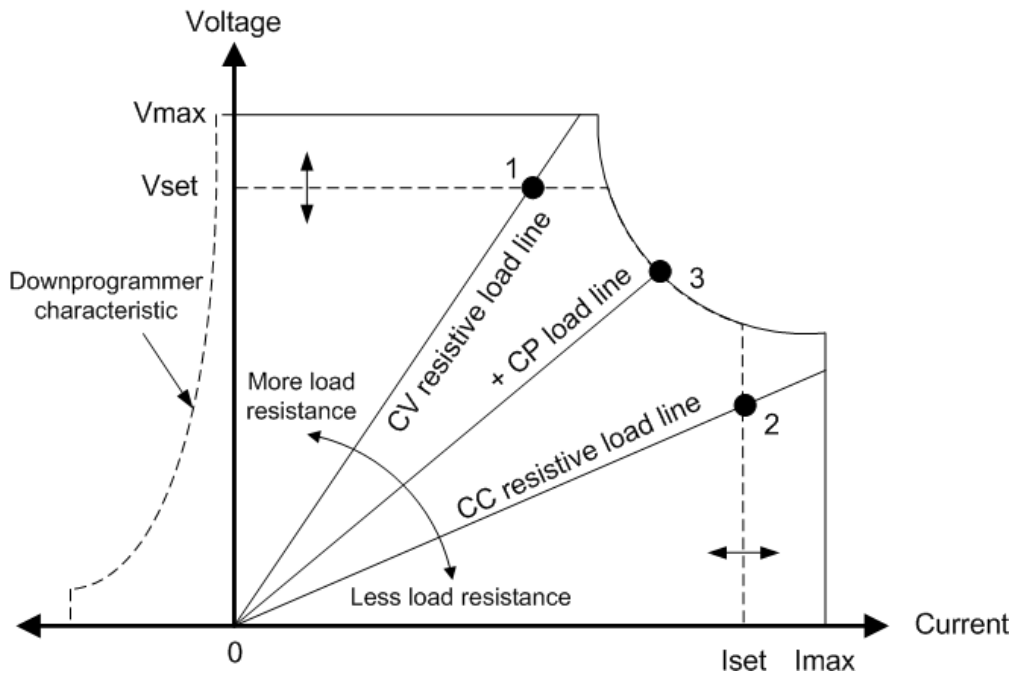
Downprogrammming

As shown by the dashed line on the left in the figures, the power system is capable of sinking current over the output voltage range from zero volts to the rated voltage. This negative current sinking capability provides fast downprogramming of the output. The negative current is not programmable.

Multi-Quadrant Operation

Keysight Models N678xA SMU `N678xA SMU` can be operated in either voltage or current priority mode. They can source as well as sink output power. Note that Keysight Models N6781A, N6782A, N6785A, and N6786A operate only in the + Voltage quadrants.

Voltage Priority Mode

In voltage priority mode, the output voltage should be programmed to the desired positive or negative value. A positive current limit value should also be set. The current limit should always be set higher than the actual output current requirement of the external load. With tracking enabled, the negative current limit tracks the positive current limit setting. With tracking disabled, you can set different values for the positive and negative current limits.

The following figure shows the voltage priority operating locus of the power modules. The area in the white quadrants shows the output as a source (sourcing power). The area in the shaded quadrants shows the output as a load (sinking power.

Key
☐ Sourcing power
▨ Sinking power
◄─► Programmable
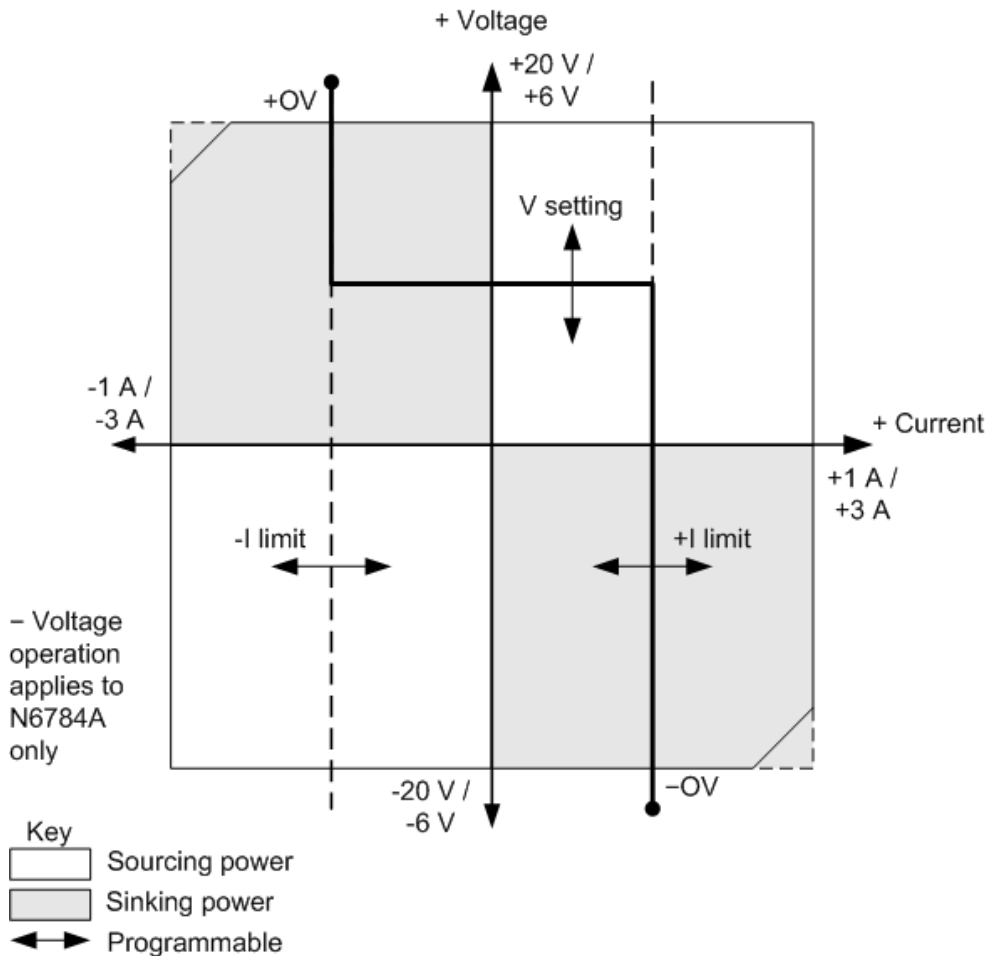
The heavy solid line illustrates the locus of possible operating points as a function of the output load. As shown by the horizontal portion of the line, the output voltage remains regulated at its programmed setting as long as the load current remains within the positive or negative current limit setting. A CV (constant voltage) status flag indicates that the output current is within the limit settings.

When the output current reaches either the positive or negative current limit, the unit no longer operates in constant voltage mode and the output voltage is no longer held constant. Instead, the power system will now regulate the output current at its current limit setting. Either a LIM+ (positive current limit), or LIM− (negative current limit) status flag is set to indicate that a current limit has been reached.

As shown by the vertical portions of the load line, when the unit is sinking power, the output voltage may continue to increase in the positive or negative direction as more current is forced into the unit. When the output voltage exceeds either the positive or negative over-voltage setting, the output will shut down, the output relays will open, and either the OV or OV− and the PROT status bits will be set. Either the user-defined over-voltage setting or the local over-voltage function can trip the over-voltage protection.

Current Priority Mode

In current priority mode, the output current should be programmed to the desired positive or negative value. A positive voltage limit value should also be set. The voltage limit should always be set higher than the actual output voltage requirement of the external load. With tracking enabled, the negative voltage limit tracks the positive voltage limit setting. With tracking disabled, you can set different values for the positive and negative voltage limits.

The following figure shows the current priority operating locus of the power modules. The area in the white quadrants shows the output as a source (sourcing power). The area in the shaded quadrants shows the output as a load (sinking power).
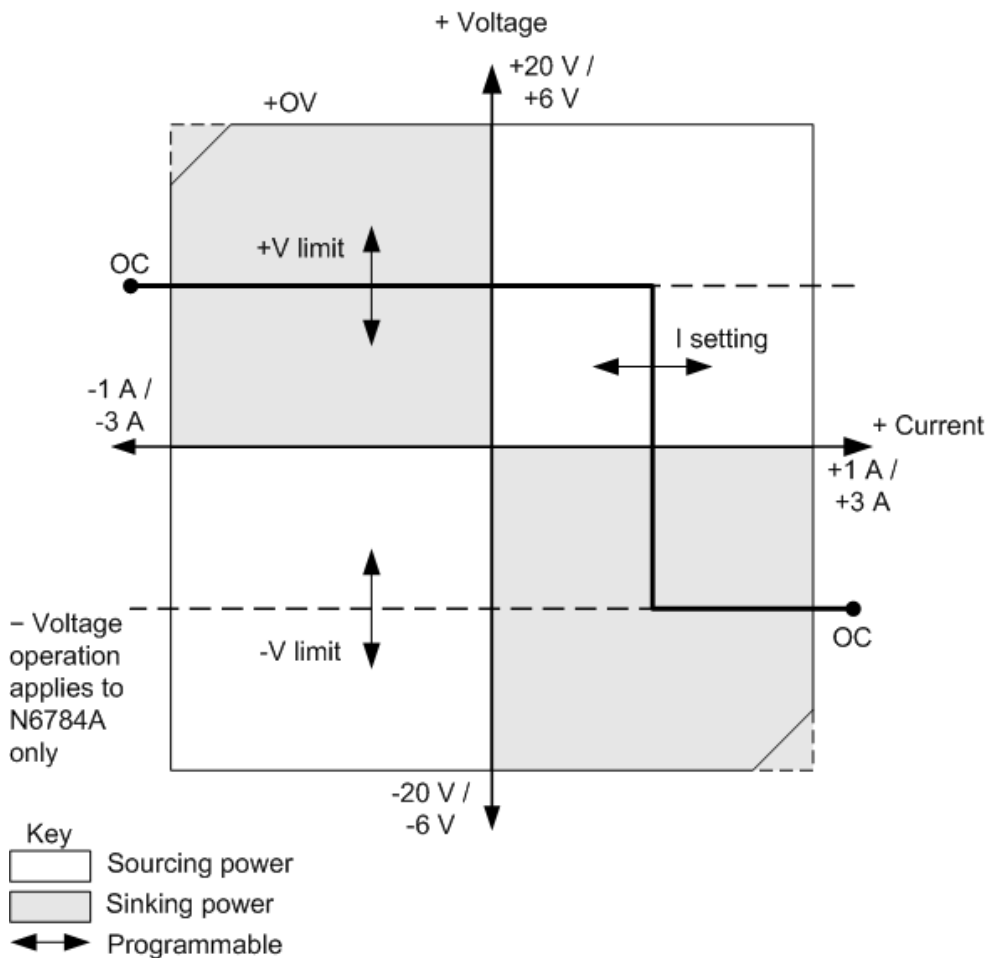
The heavy solid line illustrates the locus of possible operating points as a function of the output load. As shown by the vertical portion of the line, the output current remains regulated at its programmed setting as long as the output voltage remains within the positive or negative voltage limit setting. A CC (constant current) status flag indicates when the output voltage is within the limit settings.

If the output voltage reaches either the positive or negative voltage limit, the unit no longer operates in constant current mode and the output current is no longer held constant. Instead, the power system will now regulate the output voltage at its voltage limit setting. Either a LIM+ (positive voltage limit) or LIM– (negative voltage limit) status flag is set to indicate that either the positive or negative voltage limit has been reached.

As shown by the horizontal portions of the load line, when the unit is sinking power, the output current may continue to increase in the positive or negative direction as more current is forced into the unit. Once the current is exceeds 112% of the rated current of the range, the output will shut down, the output relays will open, and the OC and PROT status bits will be set.

Keysight N679xA Load Module Operation

The operating modes of operation for Keysight N6791xA Load modules ⬭ N679xA ⬭ are: current priority, voltage priority, power priority, and resistance priority. When programmed to a mode, a module remains in that mode until the mode is changed or until a fault condition, such as an over=power or over-temperature occurs.

Current Priority Mode

In this mode, the load module will sink a current in accordance with the programmed value regardless of the input voltage.
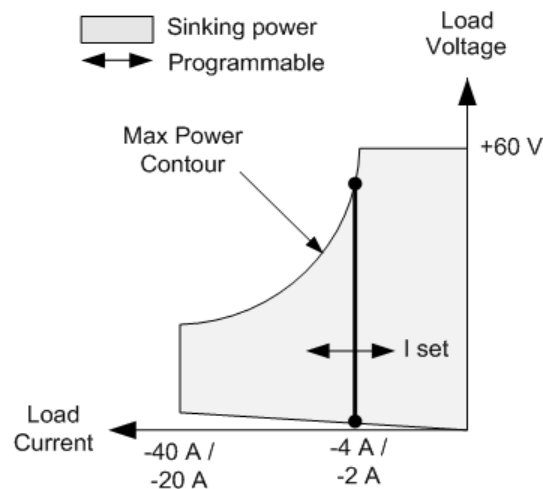
The heavy solid vertical line illustrates the locus of possible operating points as a function of the load current. A CC (constant current) status flag indicates that the load current is at the specified setting. A voltage limit is not programmable in current priority mode. Also, if the DUT imposes a voltage that is above 110% of the rated input voltage, the overvoltage protection will trip and the output will turn off.

Current may be programmed in one of two overlapping ranges, a Low range and a High range. The low range provides better programming and measurement resolution at low current settings.

Voltage Priority Mode

In this mode, the load module will attempt to sink enough current to maintain the input voltage at its programmed value.
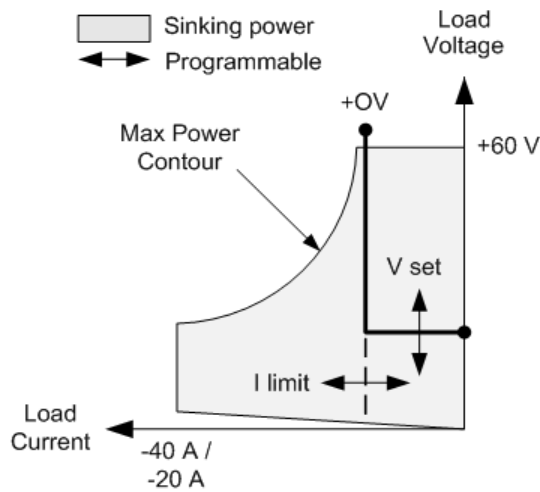
The heavy solid line illustrates the locus of possible operating points as a function of the load voltage.

Note that in voltage priority mode, a current limit can be imposed. As shown by the horizontal portion of the line, the input voltage remains regulated at its programmed setting as long as the input current remains within the current limit setting. A CV (constant voltage) status flag indicates that the input current is within the limit settings.

When the input current reaches the current limit, the unit is no longer in constant voltage operation and the input voltage is no longer held constant. Instead, the load module will now regulate the input current at its current limit setting. A CL (current limit) status flag is set to indicate that a current limit has been reached. If the input voltage increases until it exceeds 110% of the rated input voltage, the overvoltage protection will trip and the output will turn off.

Power Priority Mode

In this mode, the load module will regulate the power being drawn from the DUT according to the programmed constant power value.
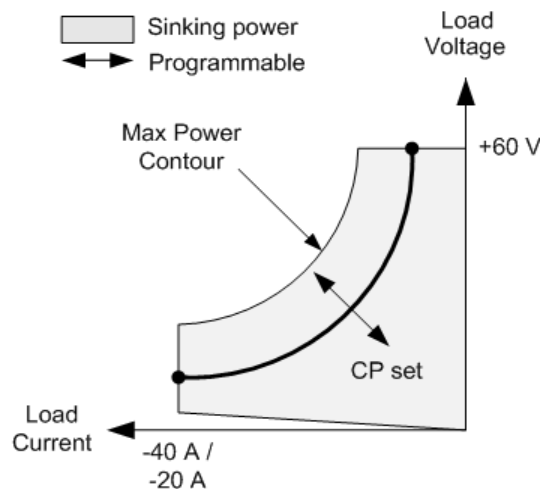
The load module regulates the input power by measuring the input voltage and current and adjusting the input power based on data streamed from the measurement ADCs.

Power may be programmed in one of two overlapping ranges, a Low range and a High range. The low range provides better programming and measurement resolution at low power settings.

The load modules have a built-in over-power protection function that will not let you exceed 110% of the power rating of the load module (the Max Power Contour).

Resistance Priority Mode

In this mode, the load module will sink current proportional to the input voltage in accordance with the programmed resistance.
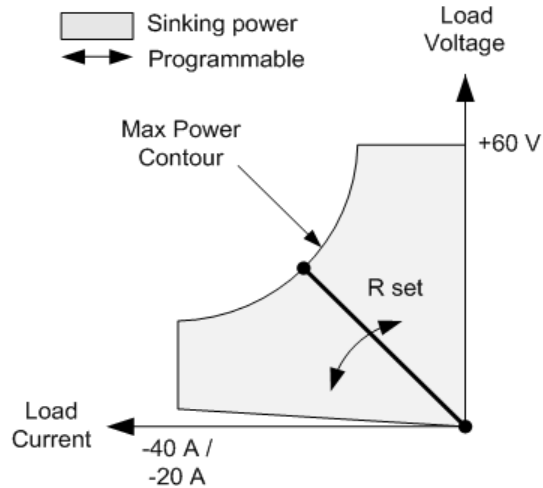
The heavy solid line illustrates the locus of possible operating points as a function of the resistance.

Resistance may be programmed in one of three overlapping ranges - a Low, Medium, and a High resistance range. The lower ranges provide better programming and measurement resolution at lower resistance settings. The load module automatically selects the resistance range that best corresponds to the resistance value that you program. If the resistance value falls in a region where ranges overlap, the load selects the range with the highest resolution for the resistance value

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