Keysight PXIe Precision Source/Measure Unit

M9601A PXIe Precision Source/Measure Unit
M9602A/M9603A PXIe Precision Source/Measure Unit
M9614A/M9615A PXIe 5-Channel Precision Source/Measure Unit

KEYSIGHT TECHNOLOGIES

User's Guide

Notices

Copyright Notice

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This product has been designed and tested in accordance with accepted industry standards, and has been supplied in a safe condition. To review the Declaration of Conformity, go to www.keysight.com/go/conformity.

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Safety Summary

The following general safety precautions must be observed during all phases of operation, service, and repair of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual may impair the protections provided by the product. In addition, it violates safety standards of design, manufacture, and intended use of the product. Keysight Technologies assumes no liability for customer's failure to comply with these requirements.

- 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 operation instructions.

- This product is INDOOR USE product.

- This product complies with POLLUTION DEGREE 2 defined in IEC 61010-1.

- If an instrument is marked CAT I (IEC Measurement Category I), or it is not marked with a measurement category, its measurement terminals must not be connected to line-voltage mains.

- System installation, safety and performance are the responsibility of the assembler of the system.

WARNING

The persons who plan, supervise, consign, and implement the installation, start-up, maintenance, and delivery of this product are required to carefully read documents related to the equipment and take and implement safety measures to prevent accidents. Also, safety and performance of the system in which the equipment is installed are the responsibility of the assembler responsible for the system construction.

WARNING

Equipment built in the system may be heavy. So there is the possibility of physical disability in the person by moving the equipment to a high place or moving it from a high place. To prevent accidents, take appropriate safety work means.

DANGEROUS PROCEDURE WARNINGS

Warnings, such as above WARNING, shall be complied. Procedures throughout in this manual prevent you from potentially hazard. Their instructions contained in the warnings must be followed.

BEFORE APPLYING POWER

Verify that all safety precautions are taken. Make all connections to the instrument before applying power. Note the instrument's external markings described under “Safety Symbols”.

GROUND THE INSTRUMENT

This is Safety Class I instrument. To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The power terminal and the power cable must meet International Electrotechnical Commission (IEC) safety standards.

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

DO NOT REMOVE COVERS

No operator serviceable parts inside. Refer servicing to qualified personnel. To prevent electrical shock do not remove covers.

IN CASE OF DAMAGE

Instruments that appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel. Return the instrument to a Keysight Technologies sales or service office for services and repair to ensure that safety features are maintained.

USE ONLY THE SPECIFIC ACCESSORIES

Specific accessories satisfy the requirements for specific characteristics for using the instrument. Use the specific accessories, cables, adapters, and so on for safety reasons.

Safety Symbols

The general definitions of safety symbols used on equipment or in manuals are listed below.


Direct current.

Alternating current.


Earth ground terminal.


Protective conductor terminal. For protection against electrical shock in case of a fault. Used with field wiring terminals to indicate the terminal which must be connected to ground before operating equipment.


Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.


Grounded terminal which indicates the earth potential.


On supply.

Off supply.

Standby supply. The equipment will be marked with this symbol is not completely disconnected from AC mains when power switch is in the standby position.

In position of a bi-stable push switch.


Out position of a bi-stable push switch.


Hazardous voltage and potential for electrical shock. Do not touch terminals that have this symbol when the equipment is on.


Hot surface. Avoid contact. Surfaces are hot and may cause personal injury if touched.


Low temperature or freezing conditions. Avoid contact. Surfaces are cold and may cause personal injury if touched.


Heavy object. Lifting can cause back injury. Use mechanical lifting device to move.

Caution, refer to accompanying documentation. The equipment will be marked with this symbol when it is necessary for the user to refer to the instruction manual.

Read operator's manual. To indicate that the operator's manual or card should be read before continuing the operation.

Affixed to product containing static sensitive devices--use anti-static handling procedures to prevent electrostatic discharge damage to component.

CAT I

IEC Measurement Category I

The CE mark shows that the product complies with all applicable European Directives.

The CSA mark is a registered trademark of the Canadian Standards Association.

The RCM mark is a registered trademark of the Australian Communications Authority. This signifies compliance with the Australian EMC Framework Regulations under the terms of the Radio communications Act.

ICES/NMB-001

This ISM device complies with Canadian ICES-001.
Cet appareil ISM est conforme à la norme NMB-001 du Canada.

CAN ICES/NMB-001(A)

This ISM device complies with Canadian ICES-001 Class A.
Cet appareil ISM est conforme à la norme NMB-001 classe A du Canada.

ISM GROUP 1 CLASS A

This is the symbol for an Industrial, Scientific and Medical, Group 1 Class A product. (CISPR 11)

Korea's safety and EMC mark

China RoHS - Environmentally Green Product Label

China RoHS - Product with Toxic Substance 40 yr EPUP

The Chinese mark for paper-based packaging materials; Paperboard and Corrugated Fiberboard

Plastic Material Coding Identification

The UKCA mark shows that the product complies with all applicable UK regulations.

CAUTION

A CAUTION denotes a hazard. It calls attention to an operating procedure or practice, 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.

WARNING

A WARNING denotes a hazard. It calls attention to an operating procedure or practice, 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.

Waste Electrical and Electronic Equipment (WEEE)

The crossed out wheeled bin symbol indicates that separate collection for waste electric and electronic equipment (WEEE) is required, as obligated by the EU DIRECTIVE and other National legislation.

Please refer to http://keysight.com/go/take-back to understand your Trade in options with Keysight in addition to product takeback instructions.

South Korean EMC Declaration

Information to the user:

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 environment.

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

(*) 사용자 안내문은 "업무용 방송통신기자재"에만 적용한다.

Cleaning Precautions

To prevent electrical shock, disconnect the Keysight Technologies instrument from mains before cleaning. Use a dry cloth or one slightly dampened with water to clean the external case parts. Do not attempt to clean internally. To clean the connectors, use alcohol in a well-ventilated area. Allow all residual alcohol moisture to evaporate, and the fumes to dissipate prior to energizing the instrument.

In This Manual

This manual describes the functions of the Keysight Technologies PXIe Precision Source/Measure Unit (SMU). This manual consists of the following chapters.

1. "Introduction"

   This chapter outlines the basic features of Keysight PXIe Precision SMU.

2. "Function Details"

   This chapter describes the functions, parameters, and operation of Keysight PXIe Precision SMU.

3. "Initial Settings"

   This chapter shows the initial settings of Keysight PXIe Precision SMU.

NOTE

For the specifications of Keysight PXIe Precision Source/Measure Unit, see the data sheets.

To get the latest information including the data sheets, go to www.keysight.com and search by the product model numbers (e.g. M9601A). You can see the product page and then click "Technical Support."

NOTE

The information is subject to change without notice due to the future enhancement.

The actual screen images on the software may be different from the images shown in this manual.

Contents

1 Introduction

This chapter outlines the basic features of Keysight PXIe Precision Source/Measure Unit (SMU).

Keysight PXIe Precision Source/Measure Unit

Keysight PXIe Precision SMU includes the products shown in Table 1-1.

Table 1-1 Keysight PXIe Precision Source/Measure Unit

Model Number	
M9601A	PXIe Precision Source/Measure Unit, 1.25 MSa/s, 10 fA, 210 V, 315 mA
M9602A	PXIe Source/Measure Unit, 15 MSa/s, 1 pA, 60 V, 3.5 A DC/10.5 A pulse
M9603A	PXIe Precision Source/Measure Unit, 15 MSa/s, 100 fA, 60 V, 3.5 A DC/10.5 A pulse
M9614A	PXIe 5-Channel Source/Measure Unit, 500 kSa/s, 100 pA, 30 V, 500 mA
M9615A	PXIe 5-Channel Precision Source/Measure Unit, 500 kSa/s, 10 pA, 30 V, 500 mA

Related Documentation

This *User's Guide* and the documentation listed below can be found on the Keysight web site. To get the latest technical information, visit www.keysight.com and type the product model number in the Search box.

- Data Sheet
- Configuration Guide
- Startup Guide
- Soft Front Panel User's Guide
- SCPI Programmer's Guide
- SCPI Help
- IVI.NET Driver Reference
- IVI-C Driver Reference
- LabVIEW Driver Help

For detailed specifications, refer to the data sheet.

For the product instructions and the installation procedures, see the *Startup Guide*.

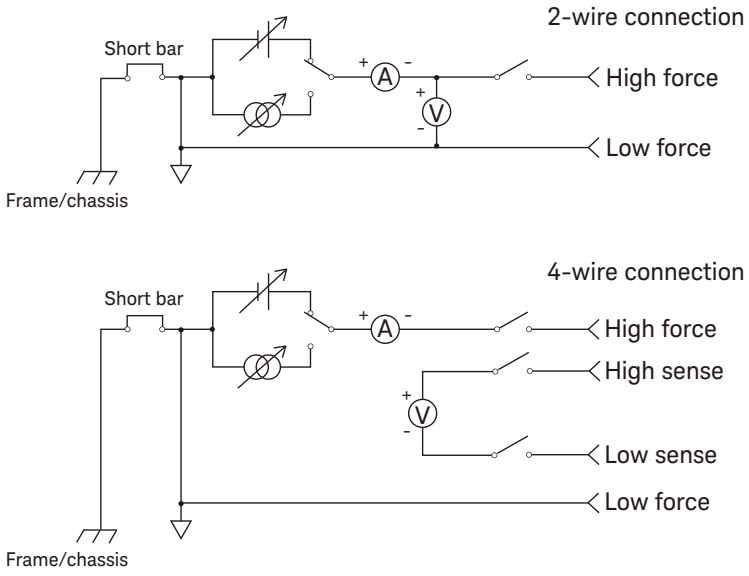
To refer the online help for SCPI and drivers, after the software installation, open the Windows Start menu, and select from the Keysight M960x Source/Measure Unit menu.

Source/Measure Unit

The source/measure unit (SMU) can apply voltage or current, and can measure current or voltage.

Figure 1-1 shows a simplified circuit diagrams of Keysight PXIe Precision SMU.

Figure 1-1 Simplified SMU Circuit Diagram



2-Wire Connection and 4-Wire Connection

When connecting a device under test (DUT), you can choose the connection type either 2-wire connection or 4-wire connection.

If you want to simplify the connections, use 2-wire connection by connecting the force terminals only, while the sense terminals remain open.

To make 4-wire connection, well known as Kelvin connection, use both force and sense terminals. Connecting the force and sense lines together at the terminal of the DUT minimizes the measurement error by the residual resistance of the test leads or cables. This connection is effective in low resistance measurements and high current measurements.

Floating

When the Keysight PXIe Precision SMU module is shipped from the factory, the Low force terminal is connected to the frame/chassis terminal by the short bar. The short bar must be connected to perform the grounded measurement.

If you want to perform the floating measurement or if you want to connect another instrument's ground to the Low force, remove the short bar, and leave the terminals open. Then use the Low force terminal on the triaxial or D-sub connector to connect the other instrument.

CAUTION For the floating measurement, do not apply voltage over ±40 V to the Low force terminal. Doing so will damage the Keysight PXIe Precision SMU module.

CAUTION Do not apply current or voltage to the frame/chassis terminal. Doing so will damage the Keysight PXIe Precision SMU module.

WARNING To prevent electrical shock, do not touch any of measurement circuit at any time while a floating measurement is in progress. Also use accessories that comply with IEC 61010-031. All terminals and the extended conductors must be isolated by using insulation caps, sleeves, etc.

Afin d'éviter toute décharge électrique, ne touchez aucune mesure de circuit à tout moment lorsque la mesure de flotte est en cours. Utiliser également des accessoires qui sont conformes à la norme IEC 61010-031. Toutes les bornes et les conducteurs prolongés doivent être isolés en utilisant des bouchons d'isolation, des manchons, etc.

Front Panel Features

This section outlines the front panel features including the LED indicators, measurement terminals, and trigger and interlock terminals. Refer to the *Startup Guide* for details such as connecting terminals, output voltage, or interlock circuits.

LED Indicators

Keysight PXIe Precision SMU has two LED indicators: Access and Status. These indicators show the status of the module. See Table 1-2 for the meanings. If the emergency shutdown occurs, both indicators turn red.

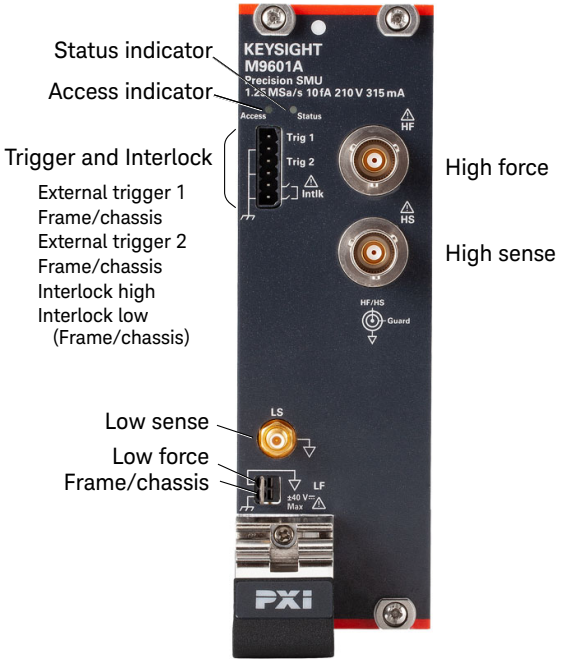
Table 1-2 LED Status

LED	LED state	Status
Access	Solid Green	The module is turned on, the initialization is completed, and the operation is ready.
	Flashing Green	The “Identify PXIe module” feature is on.
	Solid Red	Emergency shutdown occurs.
	Off	The control session is closed.
Status	Solid Green	Output is enabled and the output voltage is within ±42 V.
	Solid Yellow	Output is enabled and the output voltage is over ±42 V.
	Solid Red	Emergency shutdown occurs.
	Off	Output is disabled.

M9601A

Figure 1-2 shows the M9601A front panel. There are two LED indicators, measurement terminals, and a 6-pin terminal block of trigger and interlock.

Figure 1-2 M9601A Front Panel



WARNING

There are potentially hazardous voltages (±210 V) present at the High force, High sense, and Guard terminals of this instrument. To prevent electrical shock, the following safety precautions must be observed during the use of the instrument.

- Use a three-conductor AC power cord to connect the cabinet (if used) and the instrument to an electrical ground (safety ground).
- If an interlock circuit is not installed in your test fixture or connection interface, you must install and connect the interlock circuit that opens the interlock terminal when the shielding box access door is opened.
- If you change the connection interface, test fixture, prober, and such, connect an interlock cable to the one actually used.
- Confirm periodically that the interlock function works normally.
- Before touching the connections on the High force, High sense, and Guard terminals, turn the instrument off and discharge any capacitors. If you do *not* turn the instrument off, complete *all* of the following items, regardless of the instrument settings.
  - Disable the output, and confirm that the Status indicator turns off.
  - Confirm that the Status indicator does not turn yellow.
  - Open the fixture cover or the shielding box access door (open interlock).
  - Discharge any capacitors connected to a channel.
- Warn persons working around the instrument about dangerous conditions.

WARNING

Une tension dangereuse (max. ± pour; 210 Vdc) émanant du dispositif l'instrument peut être sortie aux bornes High force, High sense et Guard. Les précautions suivantes doivent être obserées contre commotion électrique accidentelle.

- Utilisez un cordon d'alimentation CA à trois connecteurs pour connecter la cabine (si utilisée) et l'instrument à la mise électrique à la terre (sol de sécurité).
- Si un circuit de sécurité n'est pas installé dans votre test d'installation ou dans votre interface de connexion, vous devez installer et connecter le circuit de sécurité qui ouvre la borne d'enclenchement lorsque la porte d'accès à la protection de la boîte est ouverte.
- Si vous changez l'interface de connexion, un test d'installation, la sonde, ou toute autre élément, connectez un cordon d'enclenchement à celui utilisé actuellement.
- Vérifiez régulièrement que la fonction de verrouillage fonctionne normalement.
- Avant de toucher les connexions des bornes High force, High sense et Guard, éteignez l'instrument et déchargez tous les condensateurs. Si vous n'éteignez pas l'appareil, complétez tous les éléments suivants, indépendamment des réglages de l'appareil.
  - Désactiver la sortie, et confirmez que la LED Status est éteint.
  - Vérifiez que la LED Status ne devienne pas jaune.
  - Ouvrez le couvercle d'appareil ou la protection du boîtier de la porte d'accès (verrouillage ouvert).
  - Déchargez tous les condensateurs connectés au réseau.
- Déchargez tous les condensateurs connectés au réseau.

Measurement Terminals

The M9601A has the following measurement terminals.

HF and HS High force, High sense, Low force, and Guard terminals (Triaxial connector)

Each connector has three conductors: core, inner shield, and outer shield. The outer shield is Low force, and the inner shield is Guard.

LS Low sense terminal (SMB connector)

The connector has two conductors: core and shield. The shield is Low force.

LF and frame/chassis Low force terminal and frame/chassis terminal

These terminals are connected together by using the short bar when the M9601A is shipped from the factory. The short bar must be connected to perform the grounded measurement.

Trigger and Interlock Terminals

The M9601A has a 6-pin terminal block on the front panel. The pin assignment of the terminal block is shown in Figure 1-2. You can connect these terminals by using a connector-terminal block furnished with the M9601A and ferrule terminal cables such as Keysight PX0101A-001 BNC to ferrule terminal cable.

Trig 1 and Trig 2 External trigger 1 and 2 terminals

Intlk Interlock terminals

CAUTION Do not connect the interlock terminals to anything other than the interlock circuit. Applying current or voltage to the terminals may damage the M9601A.

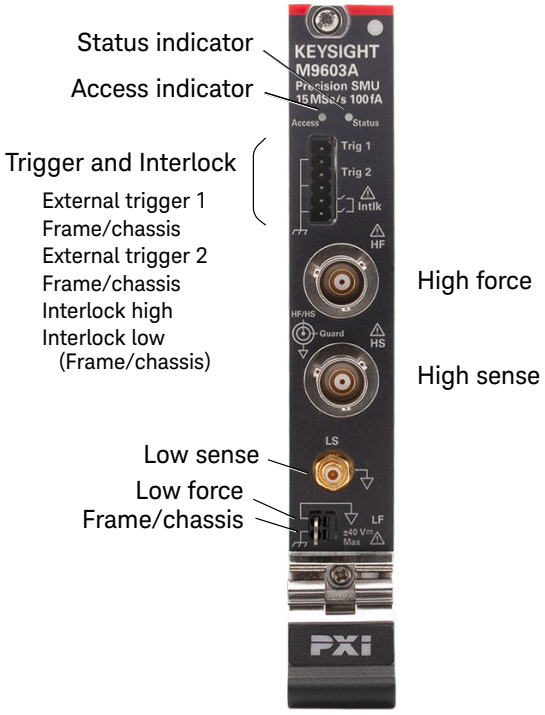
WARNING Dangerous voltage, instrument maximum output voltage may appear at the High force, High sense, and Guard terminals if the interlock terminals are closed or the interlock circuit is closed.

Une tension dangereuse, une tension de sortie maximale de l'appareil peut apparaître aux bornes High force, High sense et Guard si la borne Interlock est fermée.

M9602A and M9603A

Figure 1-3 shows the M9602A/M9603A front panel. There are two LED indicators, measurement terminals, and a 6-pin terminal block of trigger and interlock.

Figure 1-3 M9602A/M9603A Front Panel



WARNING

There are potentially hazardous voltages (±60.6 V) present at the High force, High sense, and Guard terminals of this instrument. To prevent electrical shock, the following safety precautions must be observed during the use of the instrument.

- Use a three-conductor AC power cord to connect the cabinet (if used) and the instrument to an electrical ground (safety ground).
- If an interlock circuit is not installed in your test fixture or connection interface, you must install and connect the interlock circuit that opens the interlock terminal when the shielding box access door is opened.
- If you change the connection interface, test fixture, prober, and such, connect an interlock cable to the one actually used.
- Confirm periodically that the interlock function works normally.
- Before touching the connections on the High force, High sense, and Guard terminals, turn the instrument off and discharge any capacitors. If you do *not* turn the instrument off, complete *all* of the following items, regardless of the instrument settings.
  - Disable the output, and confirm that the Status indicator turns off.
  - Confirm that the Status indicator does not turn yellow.
  - Open the fixture cover or the shielding box access door (open interlock).
  - Discharge any capacitors connected to a channel.
- Warn persons working around the instrument about dangerous conditions.

WARNING

Une tension dangereuse (max. ± pour; 60.6 Vdc) émanant du dispositif l'instrument peut être sortie aux bornes High force, High sense et Guard. Les précautions suivantes doivent être obserées contre commotion électrique accidentelle.

- Utilisez un cordon d'alimentation CA à trois connecteurs pour connecter la cabine (si utilisée) et l'instrument à la mise électrique à la terre (sol de sécurité).
- Si un circuit de sécurité n'est pas installé dans votre test d'installation ou dans votre interface de connexion, vous devez installer et connecter le circuit de sécurité qui ouvre la borne d'enclenchement lorsque la porte d'accès à la protection de la boîte est ouverte.
- Si vous changez l'interface de connexion, un test d'installation, la sonde, ou toute autre élément, connectez un cordon d'enclenchement à celui utilisé actuellement.
- Vérifiez régulièrement que la fonction de verrouillage fonctionne normalement.
- Avant de toucher les connexions des bornes High force, High sense et Guard, éteignez l'instrument et déchargez tous les condensateurs. Si vous n'éteignez pas l'appareil, complétez tous les éléments suivants, indépendamment des réglages de l'appareil.
  - Désactiver la sortie, et confirmez que la LED Status est éteint.
  - Vérifiez que la LED Status ne devienne pas jaune.
  - Ouvrez le couvercle d'appareil ou la protection du boîtier de la porte d'accès (verrouillage ouvert).
  - Déchargez tous les condensateurs connectés au réseau.
- Déchargez tous les condensateurs connectés au réseau.

Measurement Terminals

The M9602A/M9603A has the following measurement terminals.

HF and HS High force, High sense, Low force, and Guard terminals (Triaxial connector)

Each connector has three conductors: core, inner shield, and outer shield. The outer shield is Low force, and the inner shield is Guard.

LS Low sense terminal (SMB connector)

The connector has two conductors: core and shield. The shield is Low force.

LF and frame/chassis Low force terminal and frame/chassis terminal

These terminals are connected together by using the short bar when the M9602A/M9603A is shipped from the factory. The short bar must be connected to perform the grounded measurement.

Trigger and Interlock Terminals

The M9602A/M9603A has a 6-pin terminal block on the front panel. The pin assignment of the terminal block is shown in Figure 1-3. You can connect these terminals by using a connector-terminal block furnished with the M9601A and ferrule terminal cables such as Keysight PX0101A-001 BNC to ferrule terminal cable.

Trig 1 and Trig 2 External trigger 1 and 2 terminals

Intlk Interlock terminals

CAUTION Do not connect the interlock terminals to anything other than the interlock circuit. Applying current or voltage to the terminals may damage the M9602A/M9603A.

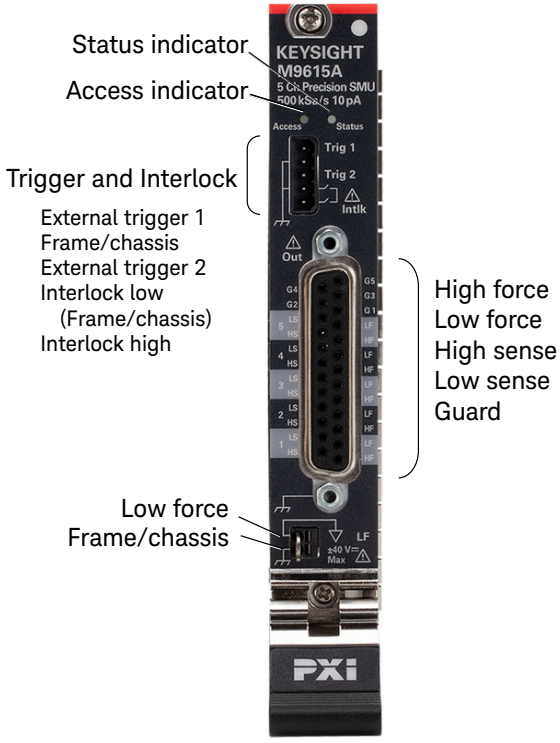
WARNING Dangerous voltage, instrument maximum output voltage may appear at the High force, High sense, and Guard terminals if the interlock terminals are closed or the interlock circuit is closed.

Une tension dangereuse, une tension de sortie maximale de l'appareil peut apparaître aux bornes High force, High sense et Guard si la borne Interlock est fermée.

M9614A and M9615A

Figure 1-4 shows the M9614A/M9615A front panel. There are two LED indicators, measurement terminals, and a 5-pin terminal block of trigger and interlock.

Figure 1-4 M9614A/M9615A Front Panel



WARNING Use a three-conductor AC power cord to connect the cabinet (if used) and the instrument to an electrical ground (safety ground).

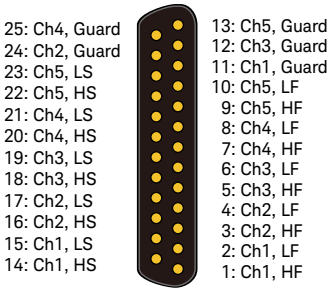
Utilisez un cordon d'alimentation CA à trois connecteurs pour connecter la cabine (si utilisée) et l'instrument à la mise électrique à la terre (sol de sécurité).

Measurement Terminals

The M9614A/M9615A has the following measurement terminals.

HF, LF, HS, LS High force (HF), Low force (LF), High sense (HF), Low sense (LS), and Guard terminals (D-sub connector)

The D-sub connector has 25 positions and consists of five-channel interfaces as shown in the following figure. Each channel has five terminals: HF, LF, HS, LS, and Guard. Although LF is shared by all channels, it is recommended to use each HF terminal with the LF terminal of the same channel.



LF and frame/chassis Low force terminal and frame/chassis terminal

These terminals are connected together by using the short bar when the M9614A/M9615A is shipped from the factory. The short bar must be connected to perform the grounded measurement.

Trigger and Interlock Terminals

The M9614A/M9615A has a 5-pin terminal block on the front panel. The pin assignment of the terminal block is shown in Figure 1-4. You can connect these terminals by using a connector-terminal block furnished with the M9614A/M9615A and ferrule terminal cables such as Keysight PX0101A-001 BNC to ferrule terminal cable.

Trig 1 and Trig 2 External trigger 1 and 2 terminals

Intlk Interlock terminals

CAUTION **Do not connect the interlock terminals to anything other than the interlock circuit. Applying current or voltage to the terminals may damage the M9614A/M9615A.**

Software and Drivers

Users can control the Keysight PXIe Precision SMU modules using the following software and drivers. For installation procedures, refer to the *Startup Guide*.

- M960x PXIe Source Measure Unit Soft Front Panel (Soft Front Panel, SFP)

  The Soft Front Panel has a graphical user interface and allows users to quickly and easily control the modules. See "Soft Front Panel" on page 30.

- SCPI (Standard Commands for Programmable Instruments)

  Users can use M960x SCPI Server and M960x SCPI Startup Manager to control the modules with SCPI programming. See "SCPI Programming" on page 34.

- IVI.NET or IVI-C drivers
- LabVIEW driver

The following are required.

- Microsoft Windows 7 Professional SP1 or later (32-bit and 64-bit), Windows 8.1 Professional (32-bit and 64-bit), or Windows 10 (32-bit and 64-bit)
- Microsoft .NET Framework 4.5.2 or later
- Keysight IO Libraries Suite 2019 or later

In this manual, the functions and operation are outlined mainly with the Soft Front Panel. The IVI.NET and SCPI commands are also shown.

Soft Front Panel

This section briefly outlines how to use the Soft Front Panel for Keysight PXIe Precision SMU. For further information, refer to the *Startup Guide* and the *Soft Front Panel User's Guide*. For detailed operation such as setting parameters, see Chapter 2, "Function Details."

Soft Front Panel Overview

To launch M960x PXIe Source Measure Unit Soft Front Panel (Soft Front Panel), open the Windows Start menu, and select **Keysight M960x Source Measure Unit** > **M960x SFP**. In the Connect to Instrument dialog box, highlight the modules to connect, and click **Connect** to launch the Soft Front Panel.

To open the *Soft Front Panel User's Guide* on the Soft Front Panel, click **Help** > **Contents**.

To open the driver reference (Online Help) on the Soft Front Panel, click **Help** > **Driver Help** > **IVI.NET** or **IVI-C**.

Figures 1-5, 1-6, and 1-7 show examples of the instrument panel layout for 1-channel, 2-channel, and 5-channel. The Soft Front Panel has the large and small instrument panels.

If one or two channels of Keysight PXIe Precision SMU are connected, the large instrument panels are displayed.

If three or more channels are connected, the Soft Front Panel has the small and large layouts as shown in Figure 1-7. The small layout shows the small instrument panels of all channels. The large layout shows the large instrument panel of one channel and the small instrument panels of other channels.

To change the layout, click the Small layout or Large layout button.

To change the large instrument panel to the small one, click the Restore Down icon. To change the small instrument panel to the large one, click the Maximize icon.

Figure 1-5 Instrument Panel for 1-Channel Layout

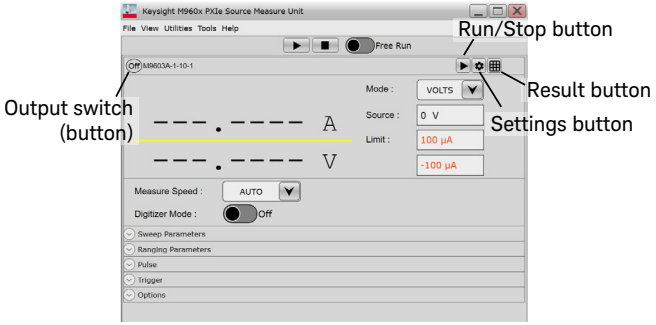


Figure 1-6 Instrument Panels for 2-Channel Layout

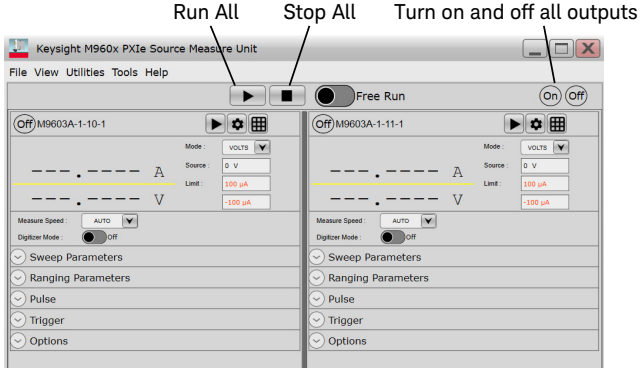
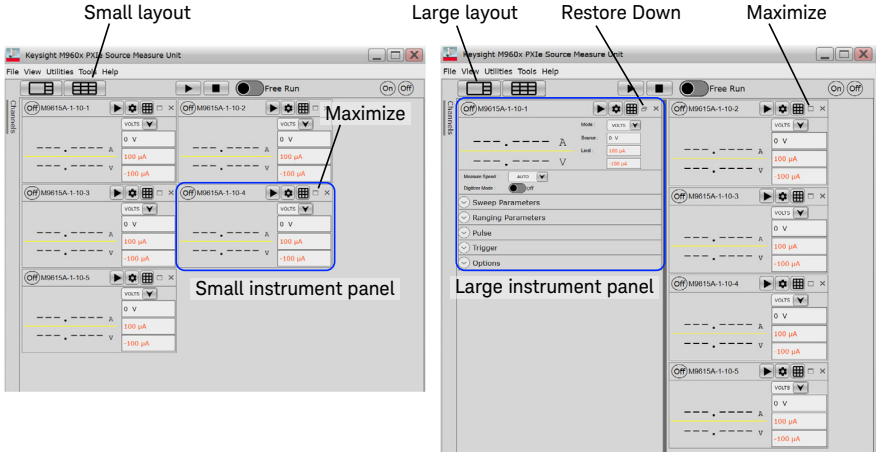
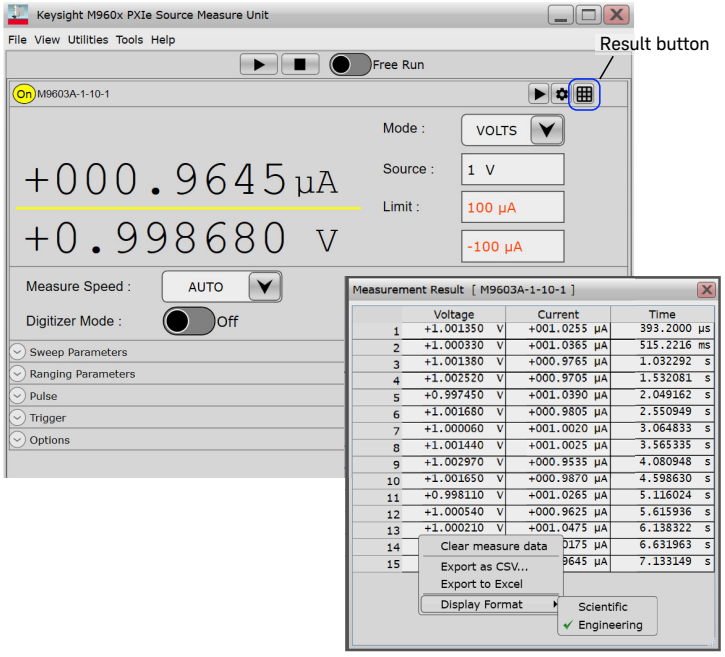


Figure 1-7 Instrument Panels for 5-Channel Layout



Measurement Result

To display and save the measurement data on the Soft Front Panel, click the Result button to open the Measurement Result dialog box.



Right-click anywhere in the Measurement Result dialog box to show the menu, and select from the following.

Clear measure data Deletes all data.

Export as CSV... Saves the data as a CSV file.

Export to Excel Opens the data on Microsoft Excel.

Display format Selects the format from **Scientific** or **Engineering**.

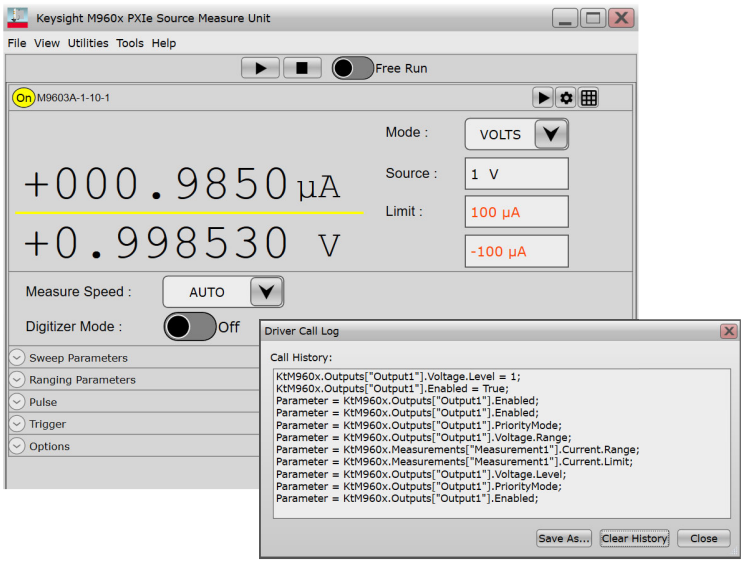
Monitor Driver Calls

The Soft Front Panel includes the tool, Monitor Driver Calls.

To launch Monitor Driver Calls, click **Tools** > **Monitor Driver Calls**, then the Driver Call Log dialog box appears as shown in Figure 1-8.

When the driver calls are performed via the Soft Front Panel, they are listed in the Driver Call Log dialog box. You can see which driver calls are performed when you operate the module with the Soft Front Panel.

Figure 1-8 Monitor Driver Calls



SCPI Programming

This section briefly outlines the settings for SCPI programming of Keysight PXIe Precision SMU.

For SCPI programming, run the SCPI server on the controller as described in "SCPI Server" on page 34.

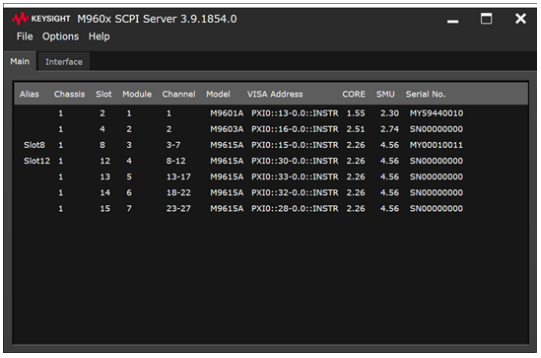
Only the LAN interface is used for connecting the controller with an external PC for programming.

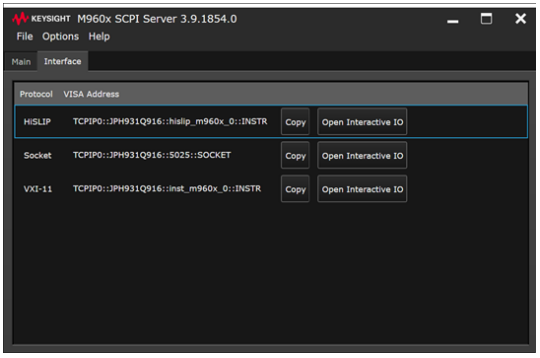
For more information on SCPI programming, refer to the *SCPI Programmer's Guide*, which includes overviews, examples, and command references.

SCPI Server

To launch the SCPI server, open the Windows Start menu and select **Keysight M960x Source Measure Unit > M960x SCPI Server**. In the Connect to Instrument dialog box, set the module configuration, protocols, and options, and then click **OK** to launch the SCPI server.

The Main tab of the application window shows the module configuration, and the Interface tab shows the VISA address for each protocol. The SCPI server continues to run even if you close the window.





You can also launch the SCPI server with the specified configuration by the M960x SCPI Startup Manager or the command line interface. When you launch the SCPI server with the specified configuration, the Connect to Instrument dialog box is skipped.

When the SCPI server is running, the hidden icon is in the taskbar.To open the shortcut menu, click the Show hidden icons arrow next to the notification area in the taskbar and right-click the icon. To stop the SCPI server, select **Exit** from the menu.

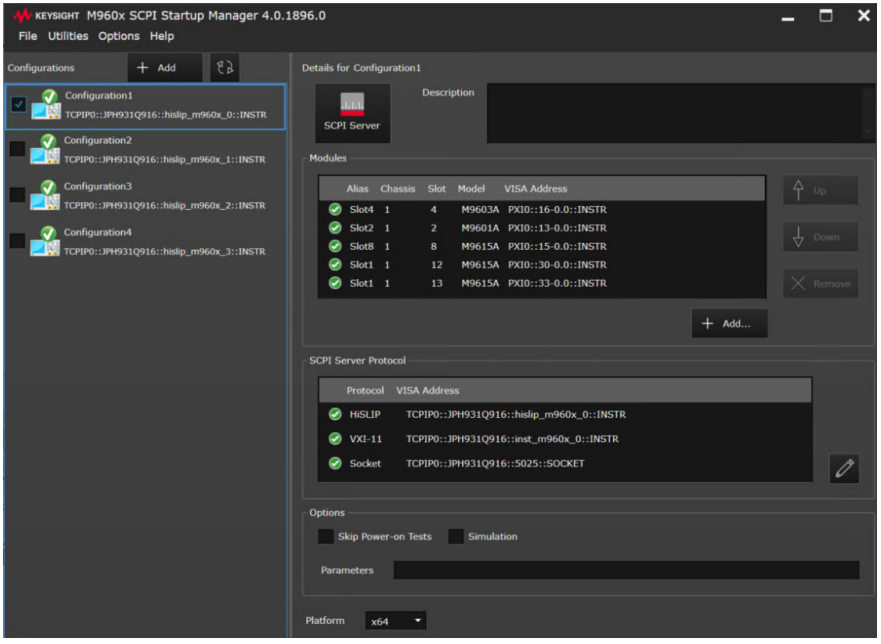
For more information on the SCPI server, refer to the *SCPI Help*.

SCPI Startup Manager

To launch the SCPI Startup Manager, open the Windows Start menu and select **Keysight M960x Source Measure Unit > M960x SCPI Startup Manager**.

The SCPI Startup Manager allows you to specify and save the configuration including module settings, SCPI server protocols, and options, and launch the SCPI server with the selected configuration. You can also set the SCPI server to start automatically when you sign in to Windows.

For more information on the SCPI Startup Manager, refer to the *SCPI Help*.



Accessories

This section outlines accessories for Keysight PXIe Precision SMU.

Keysight provides cables such as BNC-to-ferrule terminal cables, BNC-to-SMB cables, Triaxial-to-SMB cables. For the complete lists of accessories, refer to the data sheets.

The D-sub to SMB adapter and the Low Noise Filter Adapter are also available for M9614A/M9615A. The following sections outline them.

D-sub to SMB Adapter

The following D-sub to SMB adapter is available for M9614A and M9615A.

- Keysight PX0106A Dsub25-to-5 SMB adapter for M9614/15

The adapter is attached to the D-sub connector on the front panel of the M9614A/M9615A module and has five SMB connectors for outputs as shown below.

WARNING The body of the D-sub to SMB adapter is electrically at the same potential as the Low force. To prevent electrical shock, do not touch any of measurement circuit at any time while a floating measurement in progress. Also use accessories that comply with IEC 61010-031. All terminals and the extended conductors must be isolated by using insulation caps, sleeves, etc.

Low Noise Filter Adapter

The following external filter is available for M9614A and M9615A to apply low-noise and clean output signal.

- Keysight PX0107A Low Noise Filter Adapter for M9614/15

For using the low noise filter adapter, see "Low Noise Filter Adapter (M9614A and M9615A)" on page 52.

WARNING The body of the low noise filter adapter is electrically at the same potential as the Low force. To prevent electrical shock, do not touch any of measurement circuit at any time while a floating measurement in progress. Also use accessories that comply with IEC 61010-031. All terminals and the extended conductors must be isolated by using insulation caps, sleeves, etc.

2 Function Details

This chapter describes the functions, parameters, and operation of Keysight PXIe Precision Source/Measure Unit (SMU) with the Soft Front Panel. The Command lists of IVI.NET drivers and the SCPI commands are also provided. For further information on programming, refer to the online help for SCPI and drivers.

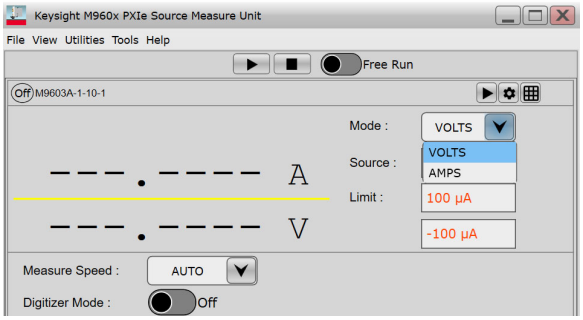
DC Source and Spot Measurement

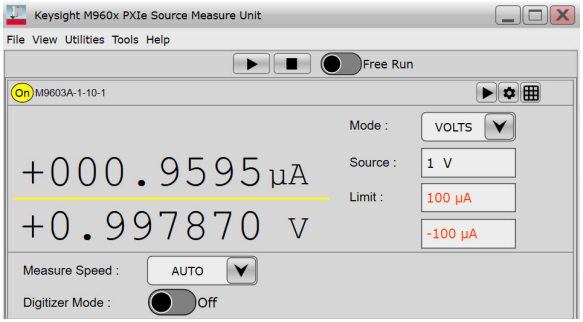
Keysight PXIe Precision SMU can be used as a DC voltage or current source and a DC current or voltage meter.

To Apply DC Voltage or Current

Use the Soft Front Panel as follows.

- Select the source mode from **VOLTS** or **AMPS** in the Mode menu on the instrument panel.
- Type the source value in the Source box.
- Set the Limit. See "To Set Limit" on page 43.
- Press the output button, then the button changes to **On**, and the module starts applying voltage or current.





To Perform Spot Measurement

Use the Soft Front Panel as follows to perform spot (one-shot) measurements.

- Apply DC voltage or current. See "To Apply DC Voltage or Current" on page 40.
- Switch the run mode to **Free Run**.
- Press the Run button to perform repetitive spot measurements.

Command List for DC Source and Spot Measurement

The following tables show the IVI.NET and SCPI commands to apply DC voltage or current and perform spot measurements.

Table 2-1 Command List to Apply DC Voltage or Current

Command	Description	Default
Outputs[chName].PriorityMode [:SOURce[ch]]:FUNCtion:MODE[?]	Selects the source mode. For the IVI.NET commands: Voltage | Current For the SCPI commands: VOLTage | CURRent	Voltage
Outputs[chName].Voltage.Level Outputs[chName].Current.Level [:SOURce[ch]]:VOLTage[:LEVel][:IMMediate][:AMPLitude][?] [:SOURce[ch]]:CURRent[:LEVel][:IMMediate][:AMPLitude][?]	Specifies the output source value.	
Measurements[chName].Current.Limit Measurements[chName].Voltage.Limit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel][:BOTH][?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel][:BOTH][?]	Sets the Limit value as the absolute value for positive and negative.	
Measurements[chName].Current.PositiveLimit Measurements[chName].Voltage.PositiveLimit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel]:POStive[?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel]:POStive[?]	Sets the positive Limit value.	

Command	Description	Default
Measurements[chName].Current.NegativeLimit Measurements[chName].Voltage.NegativeLimit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel]:NEGative[?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel]:NEGative[?]	Sets the negative Limit value.	
Outputs[chName].Enabled :OUTPut[ch][:STATe][?]	Enables or disables the source output.	false

Table 2-2 Command List to Perform Spot Measurement

Command	Description	Default
Measurements.Measure(measureType, chNum...) :MEASure? [(@ch list)] :MEASure:CURRent[:DC]? [(@ch list)] :MEASure:VOLTage[:DC]? [(@ch list)]	Executes a spot (one-shot) measurement and returns the measurement result data. For the IVI.NET commands: measureType = All | Voltage | Current | Resistance The All data consists of Voltage, Current, Resistance, Status, Time, and Source. For the SCPI commands, it measures only current or voltage.	

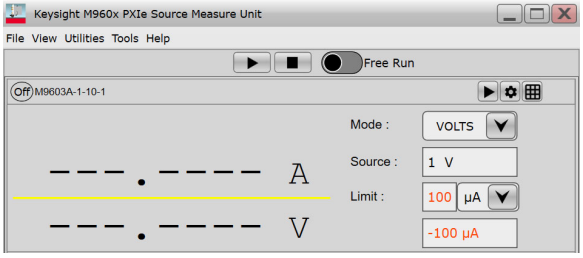
Limit (Compliance)

Limit or Compliance is the output limiter for preventing damage to a device under test (DUT) due to overcurrent or overvoltage. The voltage Limit is for the current source, and the current Limit is for the voltage source.

When a channel output value reaches the Limit, the channel acts as a constant voltage source or a constant current source; The channel keeps the output value constant.

To Set Limit

Using the Soft Front Panel, type the value and select the unit in the Limit box on the instrument panel.



The following should be considered for the Limit setting.

- The minimum value of voltage Limit is 1% of the range for M9602A/M9603A and M9614A/M9615A.

  For M9601A, the minimum value of voltage Limit is 1% of the range for 6 V range to 200 V range, or 50 mV for 500 mV range and 2 V range.

- The minimum value of current Limit is 1% of the range for M9602A/M9603A and M9614A/M9615A.

  For M9601A, the minimum value of current Limit is 1% of the range for 100 nA range to 300 mA range, or 1 nA for 1 nA range and 10 nA range.

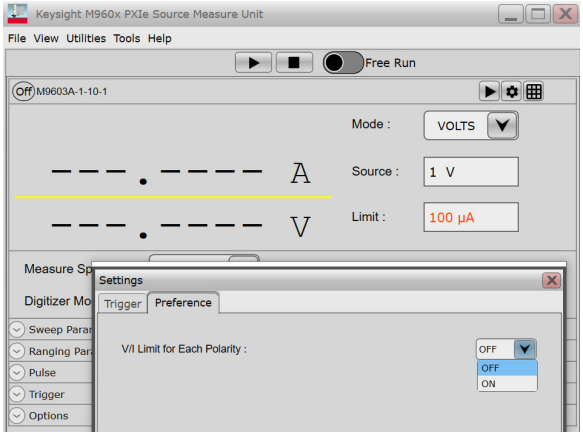
- Limit can be set with the same resolution and accuracy as output current or output voltage.

- If the current Limit value is too low, the SMU may require a long settling time.

- The positive and negative Limit values can be set individually.

  The positive and negative Limit values can also be set simultaneously. Using the Soft Front Panel, disable V/I Limit for Each Polarity.

  To disable the polarity settings, press the Settings button on the instrument panel, click the Preference tab in the Settings dialog box, and select **OFF** from the V/I Limit for Each Polarity menu. Then the only one Limit box is displayed on the instrument panel.



Command List to Set Limit

The following table shows the IVI.NET and SCPI commands to set Limit.

Table 2-3 Command List for Limit (Compliance)

Command	Description	Default
Measurements[chName].Current.Limit Measurements[chName].Voltage.Limit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel][:BOTH][?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel][:BOTH][?]	Sets the Limit value as the absolute value for positive and negative.	
Measurements[chName].Current.PositiveLimit Measurements[chName].Voltage.PositiveLimit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel]:POStive[?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel]:POStive[?]	Sets the positive Limit value.	
Measurements[chName].Current.NegativeLimit Measurements[chName].Voltage.NegativeLimit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel]:NEGative[?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel]:NEGative[?]	Sets the negative Limit value.	

Operation Mode

The following operation modes for source outputs can be selected depending on the device under test (DUT) or application.

Standard	Default This mode is commonly used and enables applying and measuring voltage or current with the specified Limit values. For specific purposes, consider other modes.
PowerSupply	Power supply mode This mode enables applying voltage with the faster slew rate. See "Power Supply Mode" on page 46.
HighCapacitance	High capacitance mode Available for M9602A and M9603A This mode is effective in measuring a capacitive load. See "High Capacitance Mode" on page 47.
LaserDiode	Laser diode mode Available for M9602A and M9603A This mode is effective in measuring with pulse current. See "Laser Diode Mode" on page 47.

Power Supply Mode

Power supply mode is effective in using the module as a power supply. This mode enables applying voltage with the faster slew rate. For further information on the slew rate, refer to the data sheet.

Inrush current may occur when the output voltage transfers from 0 V to the specified value. When the inrush current reaches the current Limit, the Keysight PXIe Precision SMU module generally slows the voltage slew rate to keep the current below the Limit. This may increase the power-on time. Power supply mode maintains the slew rate while the inrush current exceeds the Limit.

Power supply mode is available for the following conditions.

- Voltage source and current measurement

- Measurement ranging mode is selected from FIXED or SEAMLESS. See "Measurement Range (Sense Range)" on page 79.
- When the measurement ranging mode is FIXED, the measurement range is selected from all ranges for M9601A, from 1 μA to 5 A ranges for M9602A, from 100 nA to 5 A ranges for M9603A, from 100 μA to 500 mA ranges for M9614A, from 10 μA to 500 mA ranges for M9615A.

NOTE In the power supply mode, the current that exceeds the Limit can flow into the device under test for a certain period of time.

High Capacitance Mode

High capacitance mode is effective in measuring a capacitive load greater than 0.01 μF. This mode is available for M9602A and M9603A.

If the measurement result data is not stable, enable this function. Then the measurement data may become stable. For example, this mode may reduce overshoot or may keep the operation stable with the rapidly changing load.

This mode can be applied to the measurements of capacitive devices up to 100 μF.

High capacitance mode is available for the following conditions.

- Voltage source and current measurement
- Measurement ranging mode is selected from FIXED or SEAMLESS. See "Measurement Range (Sense Range)" on page 79.
- Measurement range is set from 10 μA to 5 A when the measurement ranging mode is FIXED.

Laser Diode Mode

Laser diode mode is effective in applying pulse currents with the fast rise time and measuring devices such as a laser diode or a vertical cavity surface emitting laser (VCSEL). This mode is available for M9602A and M9603A.

When the laser diode mode is selected, the current source mode can apply pulse currents with the faster rise time than that in the standard mode at 1 mA, 10 mA, and 500 mA ranges, and at 5 A range with the pulse range priority of TRANSIENT. For the pulse range priority, see "Pulse Range Priority" on page 78.

The voltage source mode can apply pulse voltages with the faster rise time than that in the standard mode at 500 mA range.

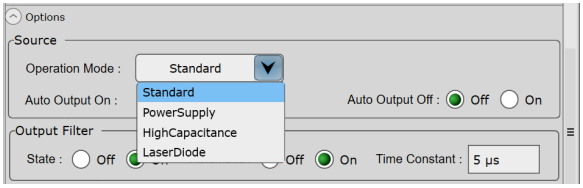
When the voltage applied to the devices such as a laser diode or VCSEL exceeds a threshold, current will starts to flow. The voltage source mode commonly can apply pulse currents with the faster rise time to these diode devices at 500 mA range than the current source mode.

If the pulse peak of voltage source is set high enough, the current flowing through the device under test (DUT) is limited to the Limit value. Therefore, in this voltage source operation, the peak of the current pulse will be the specified Limit value.

Setting the pulse peak of voltage source higher will result in a faster rise time, but may also result in a larger overshoot.

To Set Operation Mode

Using the Soft Front Panel, click the Options button on the instrument panel. If the small instrument panel is displayed, press the Settings button and click the Options tab in the Settings dialog box. Then select the mode from the Operation Mode menu.



When the operation mode except Standard is selected, the indicator appears on the instrument panel. The indicator is PS for PowerSupply, HC for HighCapacitance, and LD for LaserDiode.

Command List to Set Operation Mode

The following table shows the IVI.NET and SCPI commands to set the operation mode.

Table 2-4 Command List for Operation Mode

Command	Description	Default
Outputs[chName].OperationMode	Selects the operation mode.	Standard
:OUTPut[ch]:MODE[?]	For the IVI.NET commands: Standard | PowerSupply | HighCapacitance (for M9602A and M9603A) | LaserDiode (for M9602A and M9603A) For the SCPI commands: NORMal | PSUPply | HCAPacitance (for M9602A and M9603A) | LDIode (for M9602Aand M9603A)	NORMal

Output Filter

Keysight PXIe Precision SMU has a built-in output filter to obtain clean output signal without spikes or overshoots. However, using a filter may increase the settling time.

This function can be enabled or disabled. The module has the following settings for the output filter.

State On or Off

Enables or disables the output filter.

Automatic On or Off

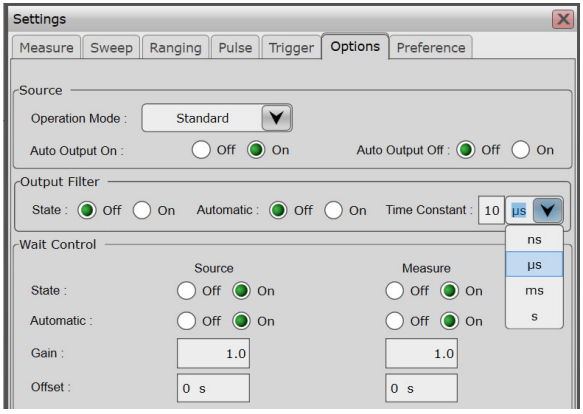
Enables or disables the function to automatically set the output filter to provide the best filter characteristics and cutoff frequency. When Automatic is set to On, the output filter is automatically set regardless of the specified Time Constant.

Time Constant Filter time constant

Specifies a filter time constant from 500 ns to 10 ms for M9601A, M9602A, and M9603A; from 2 μs to 10 ms for M9614A and M9615A.

To Set Output Filter

Using the Soft Front Panel, click the Options button on the instrument panel, or if the small instrument panel is displayed, press the Settings button and click the Options tab in the Settings dialog box. Then set each parameter.



Command List to Set Output Filter

The following table shows the IVI.NET and SCPI commands to set the output filter.

Table 2-5 Command List for Output Filter

Command	Description	Default
Outputs[chName].Filter.AutoEnabled :OUTPut[ch]:FILTer[:LPASs]:AUTO[?]	Enables or disables the function to automatically set the output filter.	true
Outputs[chName].Filter.CutOffFrequency :OUTPut[ch]:FILTer[:LPASs]:FREQuency[?]	Specifies the filter cutoff frequency.	
Outputs[chName].Filter.TimeConstant :OUTPut[ch]:FILTer[:LPASs]:TCONstant[?]	Specifies the filter time constant.	
Outputs[chName].Filter.Enabled :OUTPut[ch]:FILTer[:LPASs][:STATe][?]	Enables or disables the output filter.	true

Low Noise Filter Adapter (M9614A and M9615A)

The M9614A and M9615A PXIe 5-channel SMU can be equipped with an external filter, Keysight PX0107A Low Noise Filter Adapter for M9614/15, to apply low-noise and clean output signal.

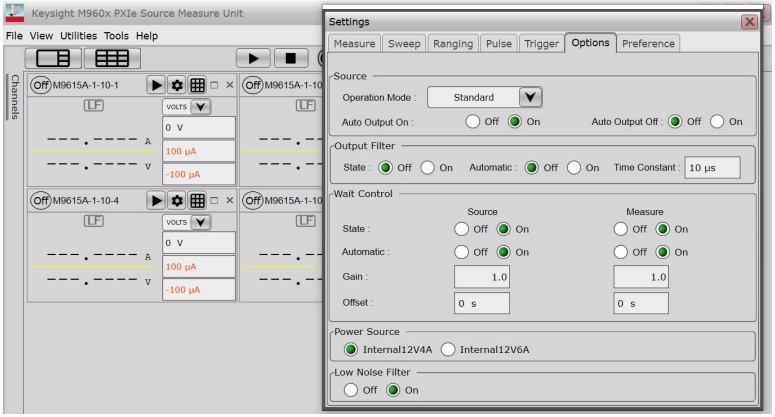
The adapter is attached to the D-sub connector on the front panel of the M9614A/M9615A and has five SMB connectors for outputs as shown below.

Figure 2-1 **Low Noise Filter**

For the supplemental characteristics of the adapter, refer to the data sheet.

To Use Low Noise Filter Adapter

Using the Soft Front Panel, click the Options button on the instrument panel, or if the small instrument panel is displayed, press the Settings button on the instrument panel and click the Options tab in the Settings dialog box. Then select **On** from the Low Noise Filter options. The low noise filter is enabled and LF indicators appear on the panels of all five channels.



The low noise filter setting is initialized and set to off by turning on the M9614A/M9615A or the reset command. When using the low noise filter adapter, the setting must be enabled after the module is powered off and then turned on, or after the module is reset.

WARNING **The body of the low noise filter adapter is electrically at the same potential as the Low force. To prevent electrical shock, do not touch any of measurement circuit at any time while a floating measurement in progress. Also use accessories that comply with IEC 61010-031. All terminals and the extended conductors must be isolated by using insulation caps, sleeves, etc.**

NOTE When using the low noise filter adapter, the output current should be limited to ±150 mA. If you set an output current value outside the range and press the output switch on the soft front panel to supply current with the low noise filter enabled, an error message appears.

CAUTION **Before making the output on with PX0107A Low Noise Filter Adapter, ensure that the low noise filter setting is enabled. Failure to heed this caution may result in damage to the M9614A/M9615A.**

Command List to Use Low Noise Filter Adapter

The following table shows the IVI.NET and SCPI commands to set the low noise filter adapter.

Table 2-6 Command List for Low Noise Filter Adapter

Command	Description	Default
Modules[module].ExternalFilterEnabled :SYSTem:MODule[n]:FILTer:EXTernal[:STATe][?]	Enables or disables the low noise filter adapter.	false

Source Output and Measurement Timing

The source output and measurement timing can be controlled by the following parameters. See Figure 2-2.

Source delay The time from the trigger to the start of a source output

Measure delay The time from the trigger to the start of a measurement

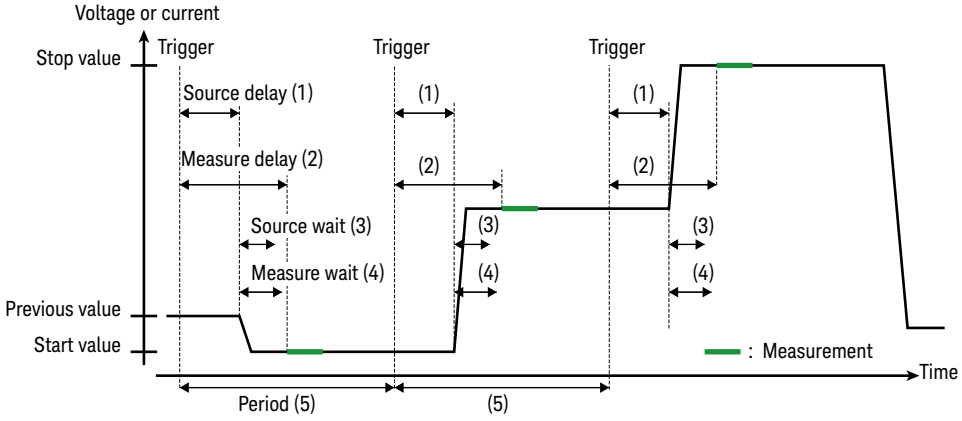
Source wait The time that the source output value cannot be changed after the source channel starts output

Measure wait The time that the measurement cannot be started after the source channel starts output

Period The trigger interval

Period can be defined for the TIMER or AUTO (AINT) trigger source and individually for the source output and measurement actions. For the trigger source, see "Trigger Source" on page 101.

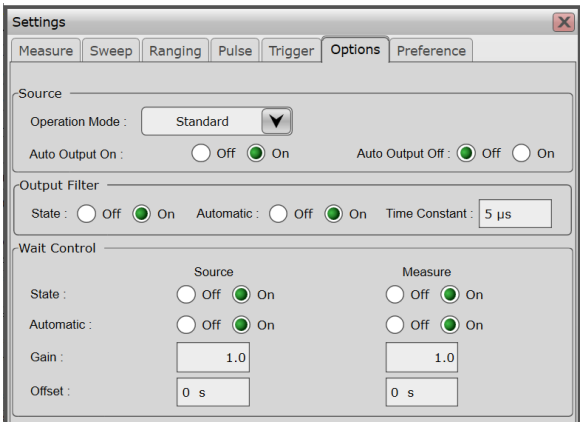
Figure 2-2 Source Output and Measurement Timing (Sweep Output Example)



To Set Timing Parameters

To set Source delay, Measure delay, and Period, see "To Set Trigger Parameter" on page 103.

To set Source wait and Measure wait, using the Soft Front Panel, click the Options button on the instrument panel, or if the small instrument panel is displayed, press the Settings button and click the Options tab in the Settings dialog box. Then set the following parameters.



State On or Off

Enables or disables the wait time.

Automatic On or Off

Enables or disabls the automatic wait time.

Gain and Offset Parameters for calculating the wait time as the following formulas

- If State = On and Automatic = On,

  wait time = Gain × initial wait time + Offset
- If State = On and Automatic = Off,

  wait time = Offset
- If State = Off,

  wait time = 0

The initial wait time is automatically set and cannot be changed.

The wait control settings are ignored if the trigger source is TIMER.

Measurement Time

The measurement time depends on the aperture time, measurement range, and other measurement conditions. It can be expressed by the following equation.

Measurement time = Aperture time + Overhead time

Aperture time is the time required to acquire the measurement data. For accurate and reliable measurement, the aperture time should be increased. This value can be specified.

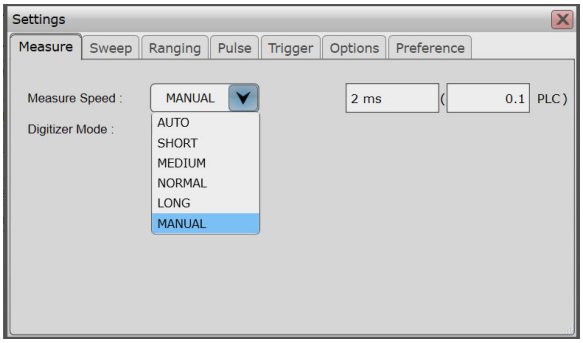
Overhead time includes other factors such as range change or data compensation. This value depends on the measurement conditions and cannot be specified.

To Set Measurement Speed

Measurement Speed is selected to set the aperture time as follows.

AUTO	For M9601A, 1 PLC for 1nA range to 100 nA range, 0.1 PLC for 1 μA range to 300 mA range. For M9602A/M9603A, 1 PLC for 100 nA range and 1 μA range, 0.1 PLC for other ranges For M9614A/M9615A, 0.1 PLC
SHORT	0.01 PLC
MEDIUM	0.1 PLC
NORMAL	1 PLC
LONG	10 PLC
MANUAL	The value specified from 800 ns to 13.422 s for M9601A, 66.667 ns to 2.237 s for M9602A/M9603A, and 2 μs to 2.097 s for M9614A/M9615A. The value can be specified also in PLC.

You can select an option from the Measurement Speed menu on the instrument panel. If the small instrument panel is displayed, press the Settings button and click the Measure tab in the Settings dialog box. When selecting **MANUAL**, type the value.



Command List to Set Timing

The following tables show the IVI.NET and SCPI commands to set the source output and measurement timing.

Table 2-7 Command List for Measurement Time (Aperture Time)

Command	Description	Default
Measurements[chName].Voltage.Aperture Measurements[chName].Current.Aperture :SENSe[ch]:VOLTage[:DC]:APERture[?] :SENSe[ch]:CURRent[:DC]:APERture[?]	Specifies the aperture time. The specified value is common to voltage and current.	
Measurements[chName].Voltage.NPLC Measurements[chName].Current.NPLC :SENSe[ch]:VOLTage[:DC]:NPLCycles[?] :SENSe[ch]:CURRent[:DC]:NPLCycles[?]	Specifies the aperture time in PLC. The specified value is common to voltage and current.	

Command	Description	Default
Measurements[chName].Voltage.ApertureAutoEnabled Measurements[chName].Voltage.NPLCAutoEnabled Measurements[chName].Current.ApertureAutoEnabled Measurements[chName].Current.NPLCAutoEnabled :SENSe[ch]:VOLTage[:DC]:APERture:AUTO[?] :SENSe[ch]:VOLTage[:DC]:NPLCycles:AUTO[?] :SENSe[ch]:CURRent[:DC]:APERture:AUTO[?] :SENSe[ch]:CURRent[:DC]:NPLCycles:AUTO[?]	Enables or disables the function to automatically set the aperture time. The specified setting is common to voltage and current.	true

Table 2-8 Command List for Trigger Parameters

Command	Description	Default
Transients[chName].Trigger.Delay :TRIGger[ch]:TRANsient:DELay[?]	Specifies the source delay.	
Measurements[chName].Trigger.Delay :TRIGger[ch]:ACQuire:DELay[?]	Specifies the measure delay.	
Transients[chName].Trigger.Timer :TRIGger[ch]:TRANsient:TIMer[?]	Specifies the source period.	
Measurements[chName].Trigger.Timer :TRIGger[ch]:ACQuire:TIMer[?]	Specifies the measure period.	

Command	Description	Default
Transients[chName].Trigger.Count Measurements[chName].Trigger.Count :TRIGger[ch]:TRANsient:COUNt[?] :TRIGger[ch]:ACQuire:COUNt[?]	Specifies the number of source or measurement counts.	
Transients[chName].Trigger.Source Measurements[chName].Trigger.Source :TRIGger[ch]:TRANsient:SOURce[:SIGNal][?] :TRIGger[ch]:ACQuire:SOURce[:SIGNal][?]	Selects the trigger source. For the IVI.NET commands: Aint | Timer | Pxi0 | Pxi1 | Pxi2 | Pxi3 | Pxi4 | Pxi5 | Pxi6 | Pxi7 | External1 | External2 For the SCPI commands: AINT | TIMer | PXI0 | PXI1 | PXI2 | PXI3 | PXI4 | PXI5 | PXI6 | PXI7 | EXT1 | EXT2	Aint

Table 2-9 Command List for Wait Time

Command	Description	Default
Outputs[chName].WaitTime.AutoEnabled Measurements[chName].WaitTime.AutoEnabled [:SOURce[ch]]:WAIT:AUTO[?] :SENSe[ch]:WAIT:AUTO[?]	Enables or disables the function to automatically set the wait time.	true
Outputs[chName].WaitTime.Gain Measurements[chName].WaitTime.Gain [:SOURce[ch]]:WAIT:GAIN[?] :SENSe[ch]:WAIT:GAIN[?]	Specifies the Gain parameter for calculating the wait time.	1
Outputs[chName].WaitTime.Offset Measurements[chName].WaitTime.Offset [:SOURce[ch]]:WAIT:OFFSet[?] :SENSe[ch]:WAIT:OFFSet[?]	Specifies the Offset parameter in seconds for calculating the wait time.	0
Outputs[chName].WaitTime.Enabled Measurements[chName].WaitTime.Enabled [:SOURce[ch]]:WAIT[:STATe][?] :SENSe[ch]:WAIT[:STATe][?]	Enables or disables the wait time.	true

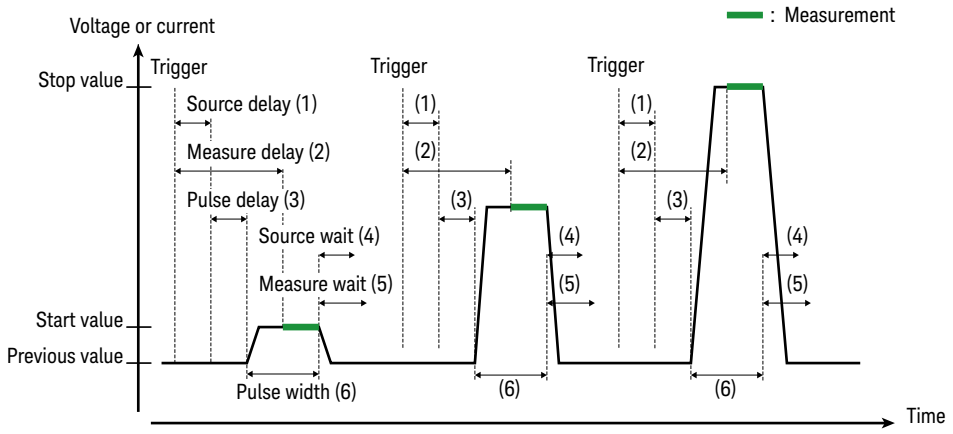
Pulse Output

Keysight PXIe Precision SMU can apply pulse voltage or current. Figure 2-3 shows a pulse sweep output example.

The pulse output and measurement timing can be controlled by the following parameters. See Figure 2-3.

Source delay	The time from the trigger to the start of a source output
Measure delay	The time from the trigger to the start of a measurement
Pulse delay	The time from the start of a source output to the start of a pulse (peak) output
Source wait	The time the source output value cannot be changed after the trailing edge of a pulse
Measure wait	The time the measurement cannot be started after the trailing edge of a pulse
Pulse width	The time from the start of a pulse output to the end of a pulse (peak) output The available values are 20 μs to 1 s for M9601A, 5 μs to 1 s for M9602A/M9603A, 50 μs to 1 s for M9614A/M9615A.

Figure 2-3 Pulse Output and Measurement Timing (Sweep Output Example)

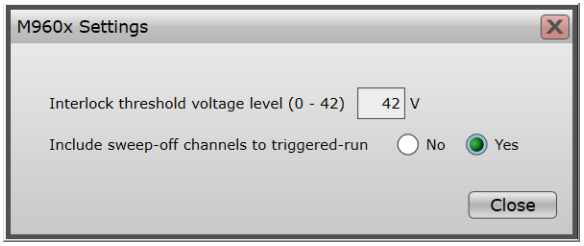


To Set Pulse Output

To set Source delay and Measure delay, see "To Set Trigger Parameter" on page 103.

To set Source wait and Measure wait, see "To Set Timing Parameters" on page 54.

To set and apply pulse output on the Soft Front Panel, click **Utilities** > **M960x Settings...** and select **Yes** from "Include sweep-off channels to triggered-run" options. This option enables the trigger system to run in output modes other than sweep mode.



To set the pulse parameters, click the Pulse button on the instrument panel, or if the small instrument panel is displayed, press the Settings button on the instrument panel and click the Pulse tab in the Settings dialog box. Then set the following parameters.

Base — Pulse base voltage or current

Peak — Pulse peak voltage or current

When the sweep output is enabled, the pulse peak value is determined by each sweep step.

Delay — Pulse delay in Figures 2-3

Width — Pulse width in Figures 2-3

Range Priority — Range priority mode only for M9602A and M9603A

For more details, see "Pulse Range Priority" on page 78.

NOTE Pulse parameters should be set within the range of available values. Each output range has the maximum values of peak, base, and duty cycle, and the programmable range of width. For details, refer to the data sheet.

The positive and negative Limit values also should be considered.

Command List to Set Pulse Output

For the command lists for the aperture time and the trigger parameters, see Tables 2-7 and 2-8.

The following table shows the IVI.NET and SCPI commands to set the pulse parameters.

Table 2-10 Command List for Pulse Output

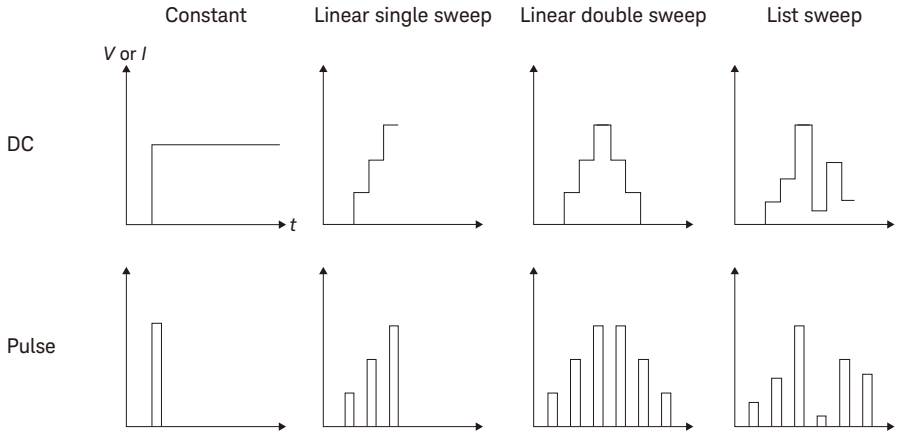
Command	Description	Default
Outputs[chName].Voltage.BaseLevel Outputs[chName].Current.BaseLevel [:SOURce[ch]]:VOLTage:BASE:LEVel[?] [:SOURce[ch]]:CURRent:BASE:LEVel[?]	Specifies the pulse base voltage or current.	
Outputs[chName].Voltage.BaseType Outputs[chName].Current.BaseType [:SOURce[ch]]:VOLTage:BASE[:TYPE][?] [:SOURce[ch]]:CURRent:BASE[:TYPE][?]	Selects the type of pulse base. For the IVI.NET commands: Manual | Immediate | Triggered | Start | Stop For the SCPI commands: MANual | IMMediate | TRIGgered | STARt | STOP	Immediate
Outputs[chName].Voltage.TriggeredLevel Outputs[chName].Current.TriggeredLevel [:SOURce[ch]]:VOLTage[:LEVel]:TRIGgered[:AMPLitude][?] [:SOURce[ch]]:CURRent[:LEVel]:TRIGgered[:AMPLitude][?]	Specifies the pulse peak voltage or current for pulse output. This command specifies the output value when the trigger event is detected.	
Outputs[chName].Pulse.Delay [:SOURce[ch]]:PULSe:DELay[?]	Specifies the pulse delay.	

Command	Description	Default
Outputs[chName].Pulse.Width [:SOURce[ch]]:PULSe:WIDTh	Specifies the pulse width.	
Outputs[chName].Pulse.RangePriority [:SOURce[ch]]:PULSe:RPRiority	Selects the range priority. Available for current source mode of M9602A/M9603A. For the IVI.NET commands: Noise | Transient | Power For the SCPI commands: NOISe | TRANsient | POWer	Transient

Sweep Output

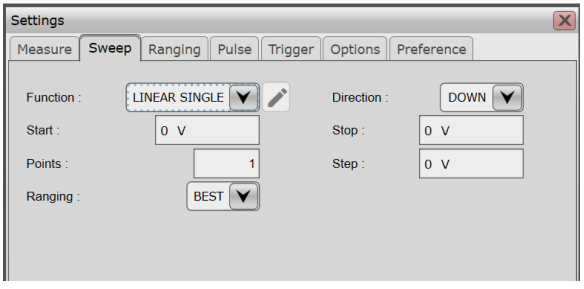
Keysight PXIe Precision SMU has the function to apply a sweep voltage or current in several shapes as shown in Figure 2-4 and performs the measurement for each sweep step as shown in Figures 2-2 and 2-3.

Figure 2-4 **Variety of Sweep Outputs**



To Set Sweep Parameters

Using the Soft Front Panel, click the Sweep Parameters button on the instrument panel, or if the small instrument panel is displayed, press the Settings button and click the Sweep tab in the Setting dialog box.



Function The type of sweep output

OFF	Disabling the sweep output
LINEAR SINGLE	Sweep from the start to the stop in a linear incremental step
LINEAR DOUBLE	Sweep from the start to stop and then to the start in a linear incremental step
LIST	Sweep defined by the list sweep setup. See "List Sweep" on page 69.

The following parameters are available for LINEAR SINGLE and LINEAR DOUBLE.

Direction UP or DOWN

The direction from the start to the stop

Start The sweep start value

Stop The sweep stop value

Points The number of sweep steps

Step The sweep step value or the incremental step value

Ranging BEST or FIXED

The ranging mode when performing the sweep output. For more information of the ranging modes, see "Output Range (Source Range)" on page 77.

To Set the Output Value After the Sweep

The output value after the sweep can be specified by programming. This function is not available for the Soft Front Panel.

To set output value after the sweep, using commands, enable the function and select the output value from the following. Also see Table 2-12 on page 68.

Triggered The value specified by the command `Outputs[chName].Voltage(Current).TriggeredLevel`.

Start The sweep start value

Stop The sweep stop value

Base The pulse base value in the pulse parameters

Also see "To Set Pulse Output" on page 61.

Manual	The specified value
Immediate	The DC source value

NOTE When the output value after the sweep is set to Triggered, the output value after the pulse sweep output is set to the pulse peak value. If the pulse peak value is outside the DC range, an error message appears.

Command List to Set Sweep Output

The following tables show the IVI.NET and SCPI commands to set the sweep parameters.

Table 2-11 Command List for Sweep Output

Command	Description	Default
Transients[chName].Voltage.Mode Transients[chName].Current.Mode [:SOURce[ch]]:VOLTage:MODE[?] [:SOURce[ch]]:CURRent:MODE[?]	Selects the mode for setting the output value when a trigger event is detected. For the IVI.NET commands: Fixed | List | Sweep For the SCPI commands: FIXed | LIST | SWEep Fixed sets the output value specified by the TriggeredLevel command. List sets the output value specified in the list. Sweep sets the output value specified by the sweep parameters.	Fixed
Outputs[chName].Voltage.TriggeredLevel Outputs[chName].Current.TriggeredLevel [:SOURce[ch]]:VOLTage[:LEVel]:TRIGgered[:AMPLitude][?] [:SOURce[ch]]:CURRent[:LEVel]:TRIGgered[:AMPLitude][?]	Specifies the output value when a trigger event is detected. This command specifies the peak value for pulse outputs.	

Command	Description	Default
Transients[chName].Sweep.Mode [:SOURce[ch]]:SWEep:STAir[?]	Selects the function of linear sweep. For the IVI.NET commands: Single | Double For the SCPI commands: SINGle | DOUBle	Single
Transients[chName].Sweep.Direction [:SOURce[ch]]:SWEep:DIRection[?]	Selects the sweep direction. For the IVI.NET commands: Up | Down For the SCPI commands: UP | DOWN	Up
Transients[chName].Voltage.Start Transients[chName].Current.Start [:SOURce[ch]]:VOLTage:STARt[?] [:SOURce[ch]]:CURRent:STARt[?]	Specifies the sweep start value.	
Transients[chName].Voltage.Stop Transients[chName].Current.Stop [:SOURce[ch]]:VOLTage:STOP[?] [:SOURce[ch]]:CURRent:STOP[?]	Specifies the sweep stop value.	
Transients[chName].Voltage.SweepPoints Transients[chName].Current.SweepPoints [:SOURce[ch]]:VOLTage:POINts[?] [:SOURce[ch]]:CURRent:POINts[?]	Specifies the number of sweep steps.	

Command	Description	Default
Transients[chName].Voltage.Step Transients[chName].Current.Step [:SOURce[ch]]:VOLTage:STEP[?] [:SOURce[ch]]:CURRent:STEP[?]	Specifies the sweep step value.	
Transients[chName].Sweep.OutputRangingMode [:SOURce[ch]]:SWEep:RANGing[?]	Selects the output ranging mode of the linear sweep. For the IVI.NET commands: Best | Fixed For the SCPI commands: BEST | FIXed	Best

Table 2-12 Command List for Output Value After the Sweep

Command	Description	Default
Outputs[chName].Voltage.PostEnabled Outputs[chName].Current.PostEnabled [:SOURce[ch]]:VOLTage:POST[:STATe] [:SOURce[ch]]:CURRent:POST[:STATe]	Enables or disables setting the output value after the sweep.	true
Outputs[chName].Voltage.PostType Outputs[chName].Current.PostType [:SOURce[ch]]:VOLTage:POST:TYPE [:SOURce[ch]]:CURRent:POST:TYPE	Selects the output value after the sweep. For the IVI.NET commands: Triggered | Start | Stop | Base | Manual | Immediate For the SCPI commands: TRIGgered | STARt | STOP | BASE | MANual | IMMediate See "To Set the Output Value After the Sweep" on page 65.	Immediate
Outputs[chName].Voltage.PostLevel Outputs[chName].Current.PostLevel [:SOURce[ch]]:VOLTage:POST:LEVel [:SOURce[ch]]:CURRent:POST:LEVel	Specifies the output value after the sweep.	

List Sweep

Keysight PXIe Precision SMU has the function to apply an arbitrary waveform output by specifying a list of output values and measure voltage or current at each output step. The source output and the measurement are performed at the specified interval. The minimum interval is 4 μs.

To Set List Sweep

The source output and measurement timing is controlled by the trigger system. The interval can be set to a constant value when the trigger source is set to TIMER or AUTO (AINT).

To set these trigger parameters, see "To Set Trigger Parameter" on page 103. The interval is set by **Period**. The number of output values is set by **Count**.

To set the list sweep, press the Sweep Parameters button on the instrument panel, or if the small instrument panel is displayed, press the Settings button and click the Sweep tab in the Settings dialog box. Select **LIST** from the Function menu. Also see "To Set Sweep Parameters" on page 64.

Command List to Set List Sweep

The following table shows the IVI.NET and SCPI commands to set the list sweep output.

Table 2-13 Command List for List Sweep

Command	Description	Default
Transients[chName].Voltage.Mode Transients[chName].Current.Mode [:SOURce[ch]]:VOLTage:MODE[?] [:SOURce[ch]]:CURRent:MODE[?]	Selects the mode for setting the output value when a trigger event is detected. For the IVI.NET commands: Fixed | List | Sweep For the SCPI commands: FIXed | LIST | SWEep Fixed sets the output value specified by the TriggeredLevel command. List sets the output value specified in the list. Sweep sets the output value specified by the sweep parameters.	Fixed
Outputs[chName].Voltage.TriggeredLevel Outputs[chName].Current.TriggeredLevel [:SOURce[ch]]:VOLTage[:LEVel]:TRIGgered[:AMPLitude][?] [:SOURce[ch]]:CURRent[:LEVel]:TRIGgered[:AMPLitude][?]	Specifies the output value when a trigger event is detected.	
Transients[chName].Voltage.ConfigureList(list) Transients[chName].Current.ConfigureList(list) [:SOURce[ch]]:LIST:VOLTage [:SOURce[ch]]:LIST:CURRent	Initializes the list sweep and specifies the list data in double array.	
Transients[chName].Voltage.AppendList(list) Transients[chName].Current.AppendList(list) [:SOURce[ch]]:LIST:VOLTage:APPend [:SOURce[ch]]:LIST:CURRent:APPend	Appends the list data in double array.	
Transients[chName].Voltage.QueryList() Transients[chName].Current.QueryList() [:SOURce[ch]]:LIST:VOLTage? [:SOURce[ch]]:LIST:CURRent?	Returns the list data.	

Command	Description	Default
Transients[chName].Voltage.ListStartPoint Transients[chName].Current.ListStartPoint [:SOURce[ch]]:LIST:VOLTage:STARt [:SOURce[ch]]:LIST:CURRent:STARt	Specifies the list start point by the index.	
Transients[chName].Voltage.ListPoints Transients[chName].Current.ListPoints [:SOURce[ch]]:LIST:VOLTage:POINts? [:SOURce[ch]]:LIST:CURRent:POINts?	Returns the number of list sweep points.	

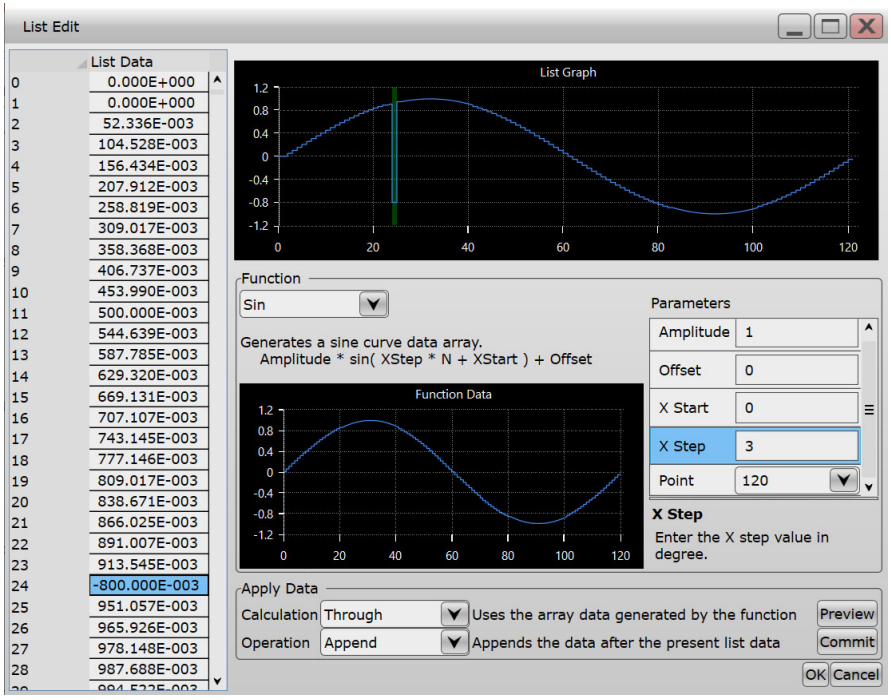
To Edit List Data on the Soft Front Panel

The Soft Front Panel provides a tool editing the list data. This tool is not available for programming.

Press the List Edit button  beside the Function menu, then the List Edit dialog box appears.

Figure 2-5 shows an example setup of the List Edit dialog box with an image of the output waveform.

Figure 2-5 List Edit Dialog Box



List Graph Displays the shape of the list sweep output.

List Data Lists the data index in the left column and the output values in the right column.

To specify the output value, click a row and type the value into the cell in the right column.

To edit the list, right-click anywhere in the List Data, then the following edit menu appears.

Select all rows Selects the cells in the all rows.

Insert row Inserts a blank row above the selected cell.

Delete row(s) Deletes the values in the selected rows.

Delete all rows Deletes the values in the all rows.

Copy row(s) Copies the values in the selected rows. The copied values can be pasted in other application software.

Function Specifies the data array according to the functions: Line, Log, Sin, Random, Power, Bezier Curve, and Copied Data. For more details, see "To Set the Data Array" on page 73.

Apply Data Specifies how to calculate and apply the data array to the output values. For more details, see "To Set Apply Data" on page 75.

To Set the Data Array

In the List Edit dialog box, the data array is specified according to the following functions. Select the function from the menu and then set the parameters.

NOTE Selected Rows is that the user selects in List Data. To select Start of Selected Rows and End of Selected Rows, the first and last cells of the selected rows must contain values. To select Number of Selected Rows, two or more rows must be selected in List Data.

Line Generates a straight line data array from the start value to the end value.

- **Start** Specifies the start value by selecting from Start of Selected Rows or End of Selected Rows or typing the value.
- **End** Specifies the end value by selecting from Start of Selected Rows or End of Selected Rows or typing the value.
- **Point** Specifies the number of data by selecting Number of Selected Rows or typing the value.

Log Generates an exponential curve data array from the start value to the end value.

Start and End must be non-zero values of the same polarity.

- **Start** Specifies the start value by selecting from Start of Selected Rows or End of Selected Rows or typing the value.
- **End** Specifies the end value by selecting from Start of Selected Rows or End of Selected Rows or typing the value.

	Point	Specifies the number of data by selecting Number of Selected Rows or typing the value.
Sin	Generates a sine curve data array.	
	Amplitude	Specifies the amplitude.
	Offset	Specifies the offset.
	X Start	Specifies the start on the x-axis in degree.
	X Step	Specifies the step on the x-axis in degree.
	Point	Specifies the number of data by selecting Number of Selected Rows or typing the value.
Random	Generates a random data array.	
	Amplitude	Specifies the amplitude.
	Offset	Specifies the offset.
	Point	Specifies the number of data by selecting Number of Selected Rows or typing the value.
Power	Generates a data array expressed in the following power function.	
	$\text{Amplitude} \times X^{\text{YValue}} + \text{Offset}$	
	X Source	Selects the base X from SelectedData or LinearData. LinearData expresses X in the following formula.
		$X = \text{XStep} \times N + \text{XStart}, N = 0 \text{ to } N-1$
	Amplitude	Specifies the amplitude.
	Offset	Specifies the offset.
	X Start	Specifies the XStart value.
	X Step	Specifies the XStep value.
	Y Value	Specifies the YValue value. YValue is the exponent or power of the power function.

	Point	Specifies the number of data by selecting Number of Selected Rows or typing the value.
Bezier Curve	Generates a Bézier curve fitted on the selected data.	
Copied Data	Uses the copied data as the data array. Select rows in List Data and copy them by using the shortcut menu.	

To Set Apply Data

In the List Edit dialog box, Apply Data menu specifies how to calculate the output values with the data array and apply the output values to List Data.

Calculation	Selects the calculation method of the output values.	
	Through	Uses the data array as the output values.
	Add	Adds the data array and the selected data.
	Subtract	Subtracts the data array from the selected data.
	Multiply	Multiplies the data array and the selected data.
	Divide	Divides the selected data by the data array.
	Minimum	Uses the smaller of the data array and the selected data.
	Maximum	Uses the larger of the data array and the selected data.

If the number of values in the data array is less than the number of selected rows, the number of output values is the same as the number of values in the data array.

If the number of selected rows is less than the number of values in the data array, the output value is calculated as follows.

- Zero is used instead of the selected data for Add, Subtract, and Multiply.
- Zero is used as the output value for Divide.
- The data array is used as the output value for Minimum and Maximum.

Operation Selects how to apply the output values to List Data.

- **Append** Appends the output values to the end of List Data.
- **Insert** Inserts the output values above the selected row.
- **Replace** Replaces the selected rows with the output values.

Preview Displays the shape of the list sweep output on List Graph according to the Calculation and Operation settings.

Commit Applies the output values to List Data.

Ranging Mode

Keysight PXIe Precision SMU has several ranging modes for setting output and measurement ranges.

Output Range (Source Range)

The following ranging modes are available for the output range settings.

FIXED Fixed range

The specified range is used. This mode is available for all types of output.

AUTO Auto range

AUTO is enabled, and the range is automatically selected to provide the best resolution of the output value. You can also specify the minimum range in the auto range operation.

This mode is available for outputs except the linear sweep output. For the list sweep output, see "AUTO Range for List Sweep Output" on page 78.

BEST Best range

The minimum range covering the whole sweep output is automatically selected. This mode is available for the linear sweep output.

The following table summarizes which ranging mode can be used in each case of outputs. For the shapes of output, see Figures 2-4.

Table 2-14 Ranging Mode for Output

	FIXED	AUTO	BEST
Constant output	✓	✓	
Linear sweep output	✓		✓
List sweep output	✓	✓	

AUTO Range for List Sweep Output

The list sweep output has two types of the auto range operation according to the trigger source settings. For the trigger source, see "Trigger Source" on page 101.

TIMER trigger source The output range is selected to provide the best resolution of the maximum output value in the list. The output range does not change during the list sweep.

AUTO trigger source The output range is selected at each output point as follows and may change at each output point.

- The maximum range is defined as the range to provide the best resolution of the maximum output value in the list.
- If the maximum range is smaller than the minimum range specified in the ranging parameters, the maximum range is used as the minimum range.
- At each output point, the output range is the larger of the minimum range and the range that provides the best resolution of the output value.

Pulse Output Range

Pulse output ranges may differ from DC output ranges depending on the product models or other conditions.

M9602A M9603A Current output ranges are automatically set according to Range Priority in the Pulse parameters. For more details, see "Pulse Range Priority" on page 78.

Voltage output ranges are selected according to the Limit value.

M9601A M9614A M9615A Pulse output ranges are determined basically in the same way as DC output ranges, but the following are different.

AUTO	The output range is selected according to the larger of the DC source value and the pulse peak value.
FIXED	If the pulse peak value is outside the specified output range, an error message appears.

Pulse Range Priority

Range Priority is available for the current pulse outputs of M9602A and M9603A. With this function, the output range is automatically selected according to the measurement purpose.

NOISE	High resolution

The output range is selected to provide the best resolution of the output value.

TRANSIENT Fast rise time

The output range is selected to provide the faster rise time. The maximum values of pulse width and duty cycle (period) are limited.

POWER Large power applying

This option covers a wider range of widths and bases with one output range. The rise time may become slower than the transient mode.

To set the pulse range priority, see "To Set Pulse Output" on page 61.

Measurement Range (Sense Range)

When the Limit (Compliance) value is specified, the measurement range is set to the minimum range that includes the Limit value.

Other ranges can also be specified by the FIXED ranging mode after the Limit value is set. Then the smaller range is used as the measurement range during the measurement.

The following ranging modes are available for measurement range settings.

FIXED Fixed range

The range is specified. This mode is available for all types of measurement. If the specified range is smaller than the measurement range defined by the Limit value, the specified range is used as the measurement range during the measurement.

SEAMLESS Seamless current measurement ranging

Available for the current measurement by M9602A/M9603A and M9614A/M9615A. This mode enables users to measure current with the best resolution without changing ranges. For more details, see "Seamless Current Measurement Ranging (M9602A and M9603A)" on page 83 and "Seamless Current Measurement Ranging (M9614A and M9615A)" on page 85.

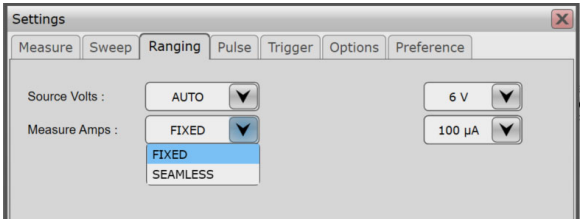
If the range specified in the FIXED mode is smaller than the range defined by the Limit value, the measurement range changes at the start and end of the measurement; The measurement range changes to the specified range when the measurement starts, and the measurement range changes back to the range defined by the Limit value when the measurement is completed.

To Set Ranging Mode

Using the Soft Front Panel, click the Ranging Parameters button on the instrument panel, or if the small instrument panel is displayed, press the Settings button and click the Ranging tab in the Settings dialog box.

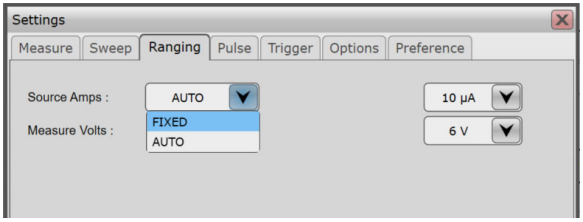
Voltage source mode

Select **FIXED** or **AUTO** from the Source Volts menu and **FIXED** or **SEAMLESS** (if available) from the Measure Amps menu.



Current source mode

Select **FIXED** or **AUTO** from the Source Amps menu. Only **FIXED** is available for the voltage measurement, so the Measure Volts options are not shown.



Selecting range

When **FIXED** is selected, the range should be selected from the menu.

When **AUTO** is selected, the minimum range in the auto range operation can be specified. However, the minimum range setting is ignored for constant outputs initiated by the trigger system.

When **SEAMLESS** is selected for M9614A or M9615A, the minimum range in the seamless current measurement ranging can be specified. For further information, see "Seamless Current Measurement Ranging (M9614A and M9615A)" on page 85.

Linear sweep output

When the linear sweep output is enabled, the ranging mode for the output (**FIXED** or **BEST**) is specified in the sweep parameters. See "To Set Sweep Parameters" on page 64. When **FIXED** is selected in the sweep parameters, **FIXED** should be selected and the range should be specified in the ranging parameters.

Command List to Set Ranging Mode

The following tables show the IVI.NET and SCPI commands for the ranging mode.

Table 2-15 Command List for Output Range

Command	Description	Default
Outputs[chName].Voltage.AutoRangeEnabled Outputs[chName].Current.AutoRangeEnabled [:SOURce[ch]]:VOLTage:RANGe:AUTO [:SOURce[ch]]:CURRent:RANGe:AUTO	Enables or disables the AUTO output ranging mode.	true
Outputs[chName].Voltage.RangeLowerLimit Outputs[chName].Current.RangeLowerLimit [:SOURce[ch]]:VOLTage:RANGe:AUTO:LLIMit [:SOURce[ch]]:CURRent:RANGe:AUTO:LLIMit	Specifies the minimum range in the auto range operation.	
Outputs[chName].Voltage.Range Outputs[chName].Current.Range [:SOURce[ch]]:VOLTage:RANGe [:SOURce[ch]]:CURRent:RANGe	Specifies the output range (source range). When the output range is specified, the AUTO output ranging mode is disabled.	

Table 2-16 Command List for Measurement Range

Command	Description	Default
Measurements[chName].Current.Range Measurements[chName].Voltage.Range :SENSe[ch]:CURRent[:DC]:RANGe[:UPPer] :SENSe[ch]:VOLTage[:DC]:RANGe[:UPPer]	Specifies the measurement range (sense range).	
Measurements[chName].Current.SeamlessRanging.Enabled :SENSe[ch]:CURRent[:DC]:RANGe:SLESs[:STATe][?]	Enables or disables the seamless current measurement ranging. For M9614A and M9615A, simultaneously enables or disables the power supply mode.	false
Measurements[chName].Current.SeamlessRanging.RangeLowerLimit :SENSe[ch]:CURRent[:DC]:RANGe:SLESs:LLIMit[?]	Specifies the minimum range in the seamless current measurement ranging.	

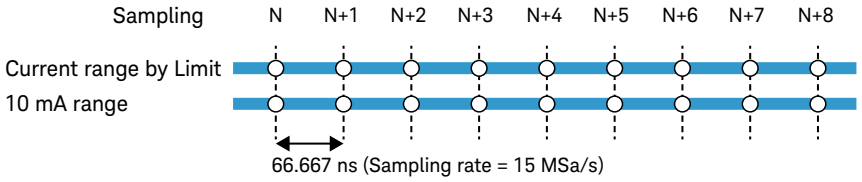
Seamless Current Measurement Ranging (M9602A and M9603A)

This section describes the seamless current measurement ranging of M9602A and M9603A. This function enables current measurement with the best resolution over multiple ranges without changing the range. It is useful for measuring dynamically changing currents.

This function is available for only the voltage source mode.

In this function, a current measurement is performed at multiple ranges simultaneously, and then the value with the best resolution is automatically selected. The M9602A/M9603A uses the 10 mA range in addition to the minimum range including the Limit value.

During the measurement, the measured values at the two ranges are acquired simultaneously. The minimum value and the resolution of the aperture time is 66.667 ns. For the aperture time, see "Measurement Time" on page 56.



When the Limit value is set to be less than or equal to ±10.5 mA, the seamless current measurement ranging is automatically disabled, and the measurement range is set to the minimum range including the Limit value.

To Set Seamless Current Measurement Ranging

Using the Soft Front Panel, click the Ranging Parameters button on the instrument panel, or if the small instrument panel is displayed, press the Settings button and click the Ranging tab in the Settings dialog box. Then select **SEAMLESS** from the Measure Amps menu.

Also see "To Set Ranging Mode" on page 80.

Command List to Set Seamless Current Measurement Ranging

The following tables show the IVI.NET and SCPI commands for the seamless current measurement ranging.

Table 2-17 Command List for Seamless Current Measurement Ranging of M9602A/ M9603A

Command	Description	Default
Measurements[chName].Current.SeamlessRanging .Enabled :SENSe[ch]:CURRent[:DC]:RANGe:SLESs[:STATe][?]	Enables or disables the seamless current measurement ranging.	false

Table 2-18 Command List for Limit (Compliance)

Command	Description	Default
Measurements[chName].Current.Limit Measurements[chName].Voltage.Limit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel][:BOTH][?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel][:BOTH][?]	Sets the Limit value as the absolute value for positive and negative.	
Measurements[chName].Current.PositiveLimit Measurements[chName].Voltage.PositiveLimit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel]:POStive[?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel]:POStive[?]	Sets the positive Limit value.	
Measurements[chName].Current.NegativeLimit Measurements[chName].Voltage.NegativeLimit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel]:NEGative[?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel]:NEGative[?]	Sets the negative Limit value.	

Seamless Current Measurement Ranging (M9614A and M9615A)

This section describes the seamless current measurement ranging of M9614A and M9615A. This function enables current measurement with the best resolution over multiple ranges without changing the range. It is useful for measuring dynamically changing currents.

This function is available for only the voltage source mode.

In this function, a current measurement is performed at multiple ranges simultaneously, and then the value with the best resolution is automatically selected.

The following should be considered when the seamless current measurement ranging is enabled.

- The operation mode is internally set to the power supply mode regardless of the setting.

  For the power supply mode, see "Power Supply Mode" on page 46.

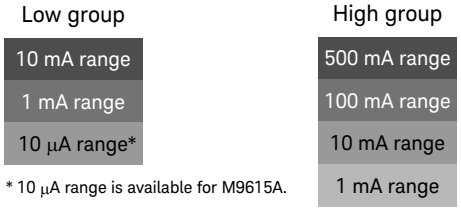
- The output voltage is limited to ±25 V for the low group with 30 V range.

  For the low group, see "Current Ranges for Seamless Current Measurement Ranging" on page 85.

Current Ranges for Seamless Current Measurement Ranging

For the seamless current measurement ranging, the M9614A/M9615A has two range groups: a low group and a high group.

Low group	10 μA, 1 mA, and 10 mA ranges 10 μA range is available for only M9615A and not available for M9614A.
High group	1 mA, 10 mA, 100 mA, and 500 mA ranges



The M9614A/M9615A automatically selects the low group or the high group according to the Limit value. If the Limit is specified greater than 10 mA, the high group is selected. Otherwise, the low group is selected.

The seamless current measurement ranging uses up to four current ranges in the selected range group.

The Limit is valid in the seamless current measurement ranging. The M9614A/M9615A does not use the larger current range than the range defined by the Limit as the minimum range including the Limit value.

You can specify the minimum range in the seamless current measurement ranging. The smaller range than the minimum range is not used, and you can avoid a settling time issue. The settling time of a smaller current range is generally longer than that of a larger current range. The current output at the smaller current range may not settle enough during the measurement. This may result in unexpected measurement values.

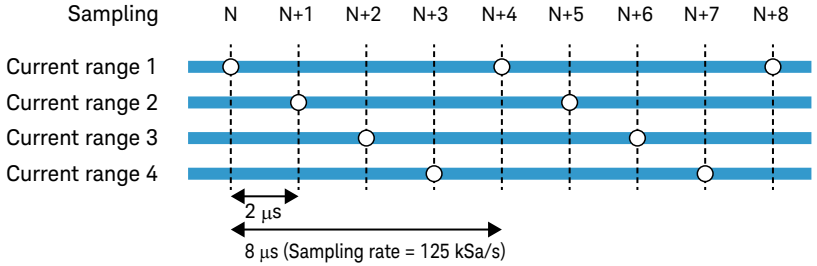
If the minimum range is set to the larger range than the measurement range defined by the Limit value, the seamless current measurement ranging uses only the range defined by the Limit value.

NOTE It is recommended to measure in the low group with a sufficiently large Limit value. If the output current reaches the Limit value in the low group, the measurement value is automatically set to positive or negative infinity.

Measurement Time for Seamless Current Measurement Ranging

During the measurement, the measured values at the four current ranges are acquired in sequence at the interval of 2 μs. Therefore, the measurement interval for each range is four times that of the other ranging modes, and the sampling rate is one fourth. The minimum value and the resolution of the aperture time is 8 μs regardless of the number of ranges used.

For the aperture time, see "Measurement Time" on page 56.



To Set Seamless Current Measurement Ranging

Using the Soft Front Panel, click the Ranging Parameters button on the instrument panel, or if the small instrument panel is displayed, press the Settings button and click the Ranging tab in the Settings dialog box. Then select **SEAMLESS** from the Measure Amps menu and specify the minimum range in the seamless current measurement ranging.

Also see "To Set Ranging Mode" on page 80.

Command List to Set Seamless Current Measurement Ranging

The following tables show the IVI.NET and SCPI commands for the seamless current measurement ranging.

Table 2-19 Command List for Seamless Current Measurement Ranging of M9614A/ M9615A

Command	Description	Default
Measurements[chName].Current.SeamlessRanging .Enabled :SENSe[ch]:CURRent[:DC]:RANGe:SLESs[:STATe][?]	Enables or disables the seamless current measurement ranging. For M9614A and M9615A, simultaneously enables or disables the power supply mode.	false
Measurements[chName].Current.SeamlessRanging .RangeLowerLimit :SENSe[ch]:CURRent[:DC]:RANGe:SLESs:LLIMit[?]	Specifies the minimum range in the seamless current measurement ranging.	

Table 2-20 Command List for Limit (Compliance)

Command	Description	Default
Measurements[chName].Current.Limit Measurements[chName].Voltage.Limit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel][:BOTH][?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel][:BOTH][?]	Sets the Limit value as the absolute value for positive and negative.	
Measurements[chName].Current.PositiveLimit Measurements[chName].Voltage.PositiveLimit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel]:POStive[?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel]:POStive[?]	Sets the positive Limit value.	
Measurements[chName].Current.NegativeLimit Measurements[chName].Voltage.NegativeLimit :SENSe[ch]:CURRent[:DC]:PROTection[:LEVel]:NEGative[?] :SENSe[ch]:VOLTage[:DC]:PROTection[:LEVel]:NEGative[?]	Sets the negative Limit value.	

Output Resistance (M9601A)

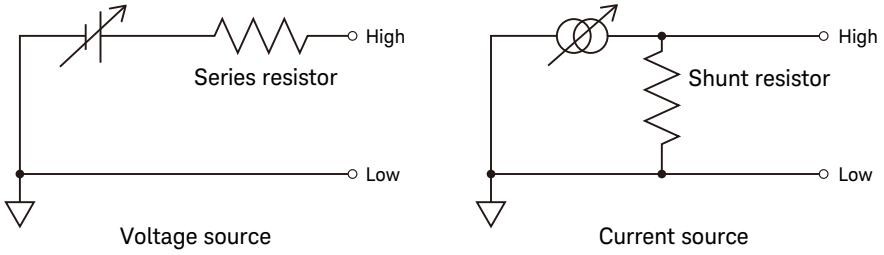
An ideal voltage source has a zero-Ω output impedance, and an ideal current source has an infinite output impedance. However, you cannot expect such ideal conditions in actual application environments.

The output resistance function enables the M9601A to work as a voltage source with a built-in constant series resistor or a current source with a built-in constant shunt resistor as shown in Figure 2-6. For example, when the High and Low terminals are shorted, the M9601A tries to apply 0.1 A with the setting of 0.1 V output voltage and 1 Ω output resistance.

Instead of installing a built-in resistor, the M9601A monitors the load current or voltage and adjusts the output to apply voltage or current as if the built-in resistor were installed.

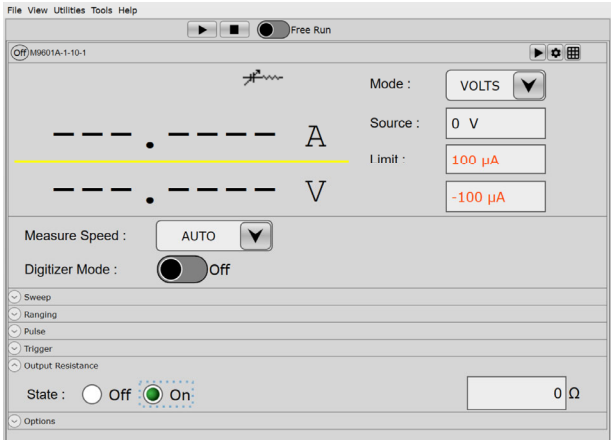
Users can specify the series resistance from –20 MΩ to +20 MΩ or the shunt resistance from 0.2 Ω to 2 GΩ. Note that actual applicable resistance values depend on the circuit characteristics and the load.

Figure 2-6 Simplified Diagram of Output Resistance



To Set Output Resistance

Using the Soft Front Panel, click the Output Resistance button on the instrument panel, or if the small instrument panel displayed, press the Settings button on the instrument panel and click the Output Resistance tab in the Settings dialog box. Then select **On** from the State options and set the resistance value.



Command List to Set Output Resistance

The following table shows the IVI.NET and SCPI commands to set the output resistance.

Table 2-21 Command List for Limit (Compliance)

Command	Description	Default
Outputs[chName].Resistance.Enabled :OUTPut[ch]:RESistance[:STATe]	Enables or disables the output resistance.	false
Outputs[chName].Resistance.OperationMode :OUTPut[ch]:RESistance:MODE	Selects the operation mode of the output resistance. Fixed mode is only available.	Fixed
Outputs[chName].Resistance.Series :OUTPut[ch]:RESistance:SERies[:LEVel]	Sets the series resistance.	0

Command	Description	Default
Outputs[chName].Resistance.Shunt :OUTPut[ch]:RESistance:SHUNt[:LEVel]	Sets the shunt resistance.	2E9
Outputs[chName].Resistance.Filter.Enabled :OUTPut[ch]:RESistance:FILTer[:LPASs][:STATe]	Enables or disables the output resistance filter.	false
Outputs[chName].Resistance.Filter.CutOffFrequency Outputs[chName].Resistance.Filter.TimeConstant :OUTPut[ch]:RESistance:FILTer[:LPASs]:FREQuency :OUTPut[ch]:RESistance:FILTer[:LPASs]:TCONstant	Sets the cutoff frequency or the time constant of the output resistance filter. This setting is ignored if the function to automatically set the output resistance filter is enabled.	32 kHz for the cutoff frequency 5 μs for the time constant
Outputs[chName].Resistance.Filter.AutoEnabled :OUTPut[ch]:RESistance:FILTer[:LPASs]:AUTO	Enables or disables the function to automatically set the output resistance filter.	false

Output Off Mode

The output off mode is the condition immediately after the source output is turned off. The mode should be specified by programming before enabling the source output. For more details, refer to the *Online Help*. You cannot specify the output off mode using the Soft Front Panel.

The following settings are available for the output off mode.

High impedance

- Output switch: off
- The voltage source setup is not changed if the voltage output value is less than or equal to 42 V.

  If the voltage output value is greater than 42 V, the output value is set to 42 V.
- For M9601A, M9614A, and M9615A, the current source setup is not changed.
- For M9602A and M9603A, the current source setup is not changed if the current output value and range are less than or equal to 10 mA and 10 mA range.

  If the current output value and range are greater than 10 mA and 10 mA range, the output value is set to 10 mA, and the output range is set to 10 mA range.

Normal

- Output switch: off
- Source function: voltage source
- Voltage output value: 0 V
- Current Limit: 100 μA at the 100 μA range

Zero

- Source function: voltage source
- Voltage output value: 0 V
- Current Limit: 100 μA at the 100 μA range

NOTE The output off mode is ignored if an emergency condition such as interlock open or over voltage is detected. Then the output voltage is immediately set to 0 V, and the output switch is set to off.

Command List to Set Output Off Mode

The following table shows the IVI.NET and SCPI commands for the output off mode.

Table 2-22 Command List for Output Off Mode

Command	Description	Default
Outputs[chName].OffCondition :OUTPut[ch]:OFF:MODE	Selects the output off mode. For the IVI.NET commands: Zero | HiZ | Normal For the SCPI commands: ZERO | HIZ | NORMal	Normal

Automatic Output On/Off

Keysight PXIe Precision SMU has output on/off settings when the trigger system changes the status. These settings are enabled or disabled individually.

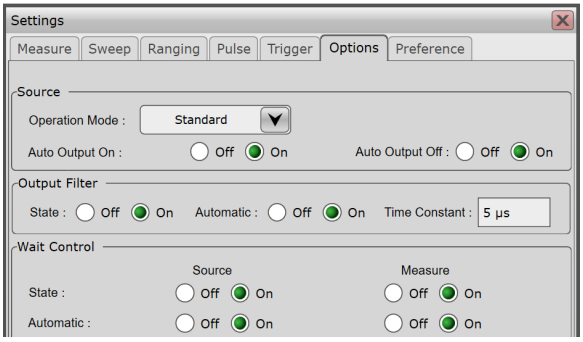
Auto Output On The source output is automatically turned on just before the trigger system is initiated by programming.

When the trigger system is initiated on the Soft Front Panel, this setting is ignored.

Auto Output Off The source output is automatically turned off when all trigger systems change the status from busy to idle.

To Set Automatic Output On/Off

Using the Soft Front Panel, click the Options button on the instrument panel, or if the small instrument panel is displayed, press the Settings button and click the Options tab in the Settings dialog box. Then select **On** or **Off**.



Command List to Set Automatic Output On/Off

The following table shows the IVI.NET and SCPI commands for the automatic output on/off.

Table 2-23 Command List for Automatic Output On/Off

Command	Description	Default
Outputs[chName].AutoOnEnabled :OUTPut[ch]:ON:AUTO	Enables or disables the function to automatically turn on the source output just before the trigger system is initiated by programming.	true
Outputs[chName].AutoOffEnabled :OUTPut[ch]:OFF:AUTO	Enable or disables the function to automatically turn off the source output when all trigger systems change the status from busy to idle.	false

Interlock

The interlock function is designed to prevent electrical shock when a user touches the measurement terminals and also to prevent DUT damages caused by undesirable high voltage.

To perform high voltage measurement greater than ±42 V, the interlock terminals should be connected to an interlock circuit. For details on installing the interlock circuit, refer to the *Startup Guide*.

Keysight PXIe Precision SMU cannot apply high voltage over the interlock threshold voltage level if the interlock terminals are open. The interlock threshold voltage level is programmable within ±42 V, and the default value is ±42 V. Set the threshold voltage to the voltage you think still safe.

If the threshold voltage level is set to 0 V, the interlock function is the same as inhibit control.

The interlock function works as shown below.

- When the interlock terminals are open, the maximum output is limited to the threshold voltage level.
- When the interlock terminals are shorted, the module can apply the maximum output voltage.
- If the interlock terminals are opened in a high voltage condition over the threshold voltage level, the output voltage is immediately set to 0 V, and the output switch is set to off.

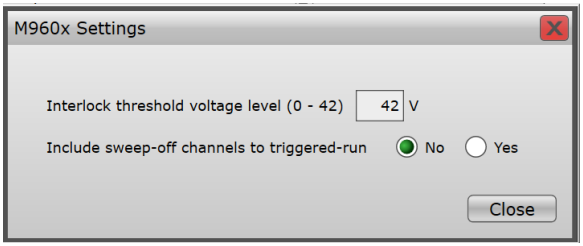
WARNING

Hazardous voltage, instrument maximum output voltage may appear at the High force, High sense, and Guard terminals if the interlock terminal is closed. To prevent electrical shock, do *not* expose these lines.

Une tension dangereuse, une tension de sortie maximale de l'appareil peut apparaître aux bornes High force, High sense et Guard si le couvercle de l'équipement est fermé. Afin d'éviter toute décharge électrique, n'exposez pas ces lignes.

To Set the Interlock Threshold Voltage

On the Soft Front Panel, click **Utilities** > **M960x Settings...** and type the value in the box.



Command List to Set Interlock

The following table shows the IVI.NET and SCPI commands for the interlock.

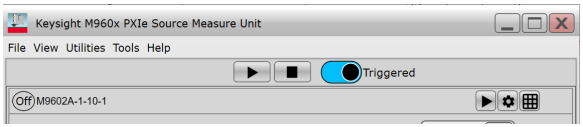
Table 2-24 Command List for Interlock

Command	Description	Default
System.InterlockThresholdVoltage :SYSTem:INTerlock:VOLTage[:LEVel][?]	Specifies the interlock threshold voltage from 0.0 to 42.0. This parameter is the non-volatile setting.	
Modules[module].InterlockTripped :SYSTem:INTerlock:MODule[n]:TRIPped?	Returns whether interlock terminals are open or shorted.	

Trigger System

Keysight PXIe Precision SMU supports the ARM-TRIGGER model described in *1999 SCPI Command Reference*.

To initiate the trigger system, on the Soft Front Panel, switch to **Triggered** and press the Run button in the instrument panel.



For the trigger setup parameters, see "To Set Trigger Parameter" on page 103 and "Trigger Signal Configuration" on page 106.

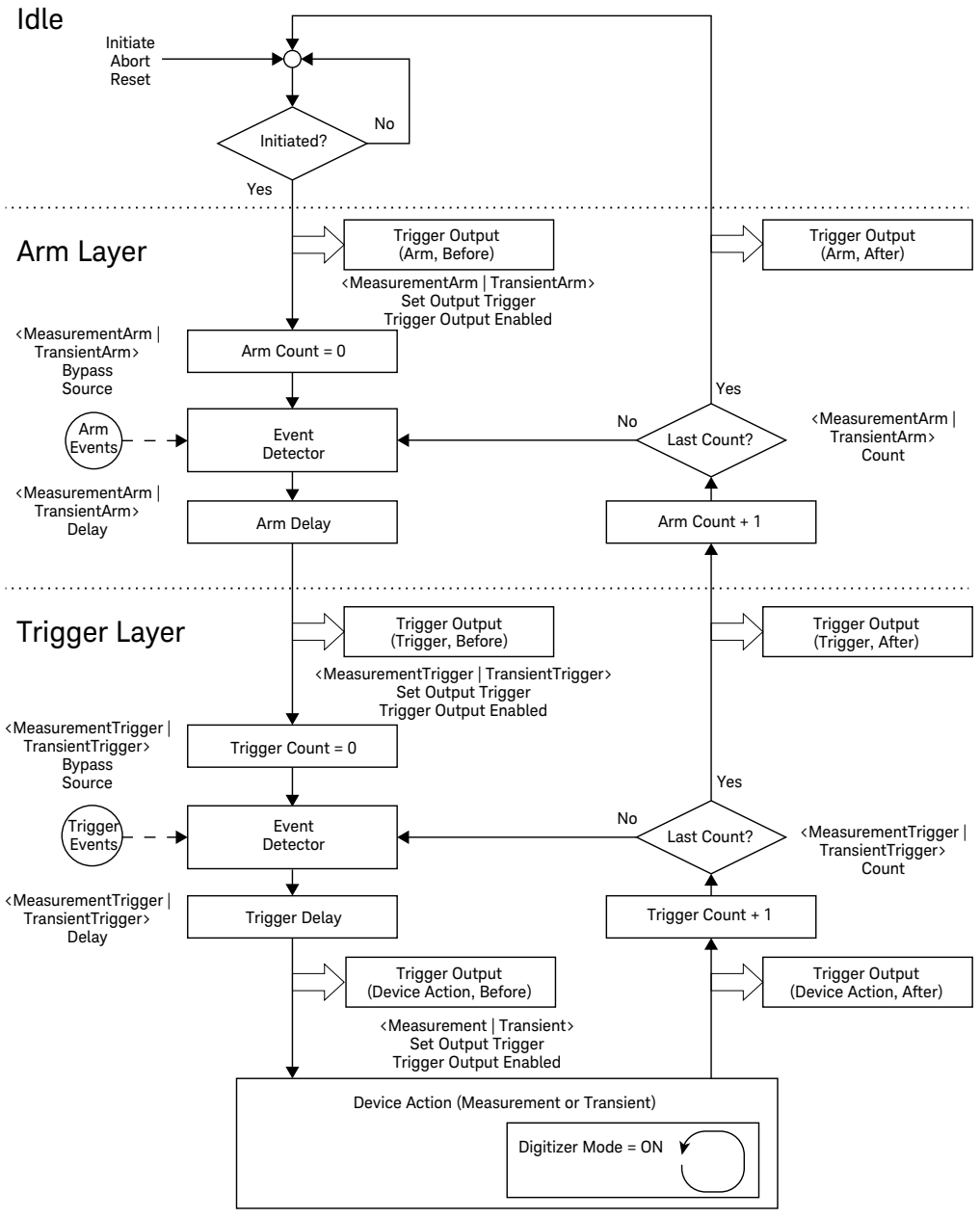
Operation summary of the trigger model is described below. Also see Figure 2-7.

1. When the trigger system is initiated, the control state moves to the arm layer and the arm count is set to zero.
2. The trigger system waits for the arm event that is a signal from the trigger source of the arm.
3. When the arm event is detected and the arm delay time elapses, the control state moves to the trigger layer and the trigger count is set to zero.
4. The trigger system waits for the trigger event that is a signal from the trigger source of the trigger.
5. When the trigger event is detected and the trigger delay time elapses, the device action is executed and the trigger count increases by one.
6. Steps of 4 and 5 are repeated until the trigger count reaches the specified value. Then the control state moves to the arm layer and the arm count increases by one.
7. Steps of 2 to 6 are repeated until the arm count reaches the specified vale. Then the control state moves to the Idle layer.

This trigger model is independently applied to two device actions: Transient (source output) and Acquire (measurement). These two device actions can start simultaneously or separately.

Multiple modules can perform the synchronous operation or asynchronous operation. For the synchronous operation, see “Module Synchronous Operation” on page 124.

Figure 2-7 Keysight PXIe Precision Source/Measure Unit Trigger System



Trigger Source

The trigger source must be set to the arm event and the trigger event individually.

AUTO (AINT) Triggers at the specified interval

The timing is controlled by the software. Depending on the controller, the interval may be larger than the specified value.

TIMER Triggers at the specified interval

The timing is controlled by the hardware.

EXT1, EXT2 Triggers synchronizing with a signal from an external trigger

PXI0, PXI1,..., PXI7

Triggers synchronizing with a signal from the PXIe chassis backplane

Device Action

Keysight PXIe Precision SMU provides the following device actions. Also see Figure 2-8.

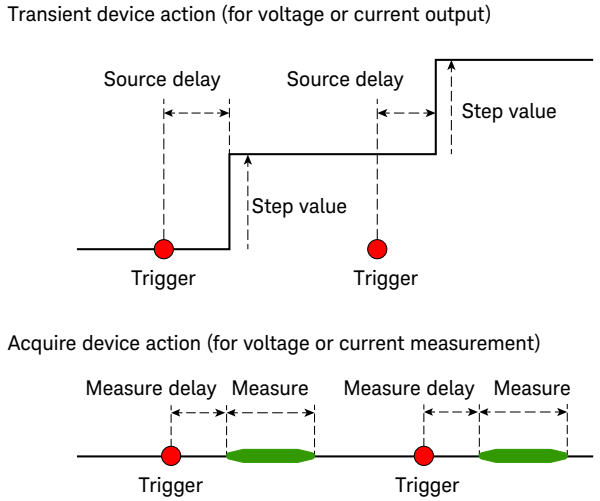
Transient Source (output)

When the trigger event is detected and the source delay time elapses, the one output value is started to apply.

Acquire Measurement

When the trigger event is detected and the measure delay time elapses, the one measurement value is acquired.

Figure 2-8 Transient and Acquire Device Actions



Digitizer Mode in the Trigger System

The digitizer mode enables users to acquire multiple measurement values without increasing the trigger count.

Generally, only one measurement is performed in one device action. To acquire multiple measurement values, the trigger process needs to be repeated.

When the digitizer mode is enabled, multiple measurements are performed in one device action shown in Figure 2-7. For more details, see "Digitizer Mode" on page 117.

Trigger Output

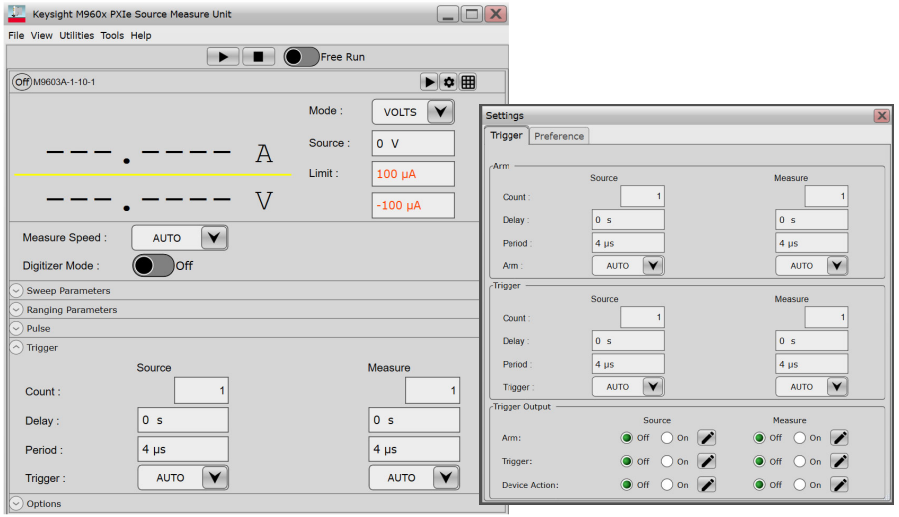
Keysight PXIe Precision SMU provides the trigger output at the timing shown in Figure 2-7. The trigger output terminal can be selected from the external trigger terminals on the front panel (EXT1 and EXT2) and the trigger lines on the PXIe chassis backplane (PXI0, PXI1, ..., PXI7).

The trigger output timing and the setup parameters are shown in Table 2-25. For setting the trigger output parameters, see "To Set Trigger Output" on page 105.

Table 2-25 Trigger Output Timing and Setup Parameters

Trigger output timing	Layer	Action	Trigger Output	Output Trigger Timing
Starting Arm loop	Arm	Source or Measure	On	Before
Ending Arm loop	Arm		On	After
Starting Trigger loop	Trigger		On	Before
Ending Trigger loop	Trigger		On	After
Starting Transient device action	Device Action	Source	On	Before
Ending Transient device action	Device Action	Source	On	After
Starting Acquire device action	Device Action	Measure	On	Before
Ending Acquire device action	Device Action	Measure	On	After

To Set Trigger Parameter



Using the Soft Front Panel, press the Settings button and click the Trigger tab in the Settings dialog box. To set the trigger parameters for Trigger, you can also use the Trigger pane clicking the Trigger button on the instrument panel.

For M9614A/M9615A PXIe 5-Channel SMU, you can set the trigger parameters of each channel.

The following parameters are set for the source output trigger (Transient device action) in the Source column, for the measurement trigger (Acquire device action) in the Measure column.

Count Specifies the number of counts.

1 to 500000 for M9602A, M9603A, M9614A, and M9615A

1 to 1000000 for M9601A

For Transient device action, the infinite trigger count is available. To set the trigger count to infinity using the Soft Front Panel, type –1 in the Settings dialog box.

The maximum Count is limited according to the following, Arm Count × Trigger Count × Sampling Points ≤ 500000 (1000000 for M9601A), where Sampling Points is the Points parameter of the digitizer mode described in "Digitizer Mode" on page 117.

If the count settings exceeds the limit, an error message will be displayed when the trigger system is initiated. The limit is not applicable when users set the infinite trigger count for Transient device action.

Delay Specifies the delay time from 0 to 100000 s.

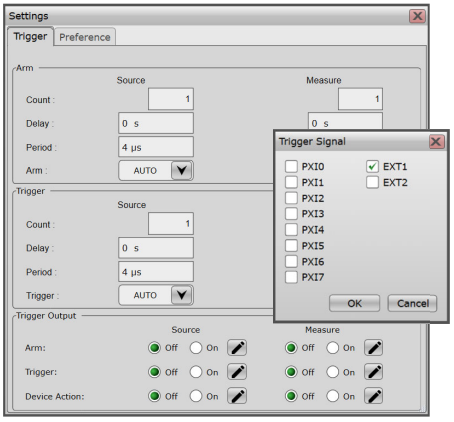
Period Specifies the interval from 4 μs to 100000 s. This parameter is available for the trigger source of TIMER and AUTO (AINT). For the AUTO (AINT) trigger source, also see "Trigger Source" on page 101.

Arm or Trigger Selects the trigger source from AUTO, TIMER, PXI0, PXI1, PXI2, PXI3, PXI4, PXI5, PXI6, PXI7, EXT1, or EXT2. See "Trigger Source" on page 101.

To Set Trigger Output

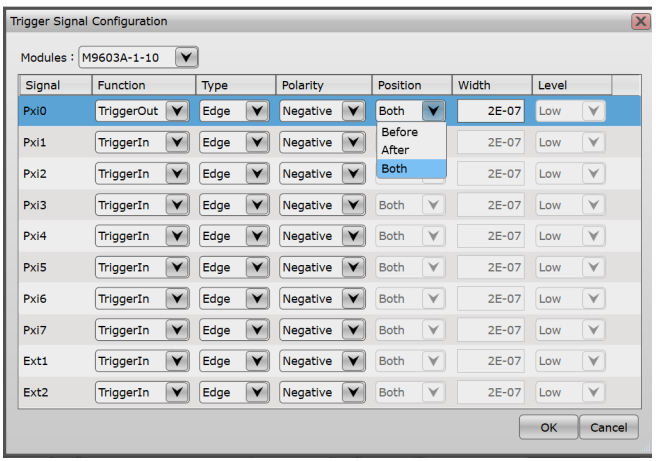
To enable or disable trigger outputs, select **Off** or **ON** in the Trigger Output pane.

To specify the trigger output terminal, click the output trigger button beside the Off or On menu, and then select the terminal in the Trigger Signal dialog box.



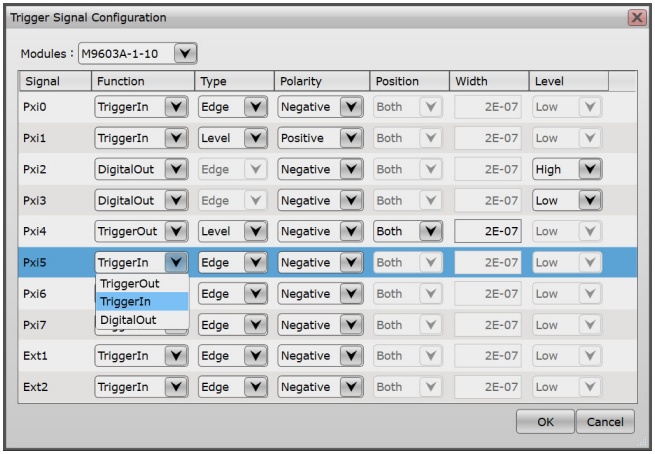
There are six settings for the trigger outputs: Arm, Trigger, and Device Action for Source or Measure. You can enable them and select the trigger output terminal of them individually.

To select the output trigger timing on the Soft Front Panel, click **Utilities** > **M960x Trigger Signals** > **Configuration...**, select **TriggerOut** in the Function column, and then select the timing from Before, After, or Both in the Position column. Also see "Trigger Signal Configuration" on page 106.



Trigger Signal Configuration

To configure the settings of the external trigger terminals and the trigger lines on the PXIe chassis backplane, using the Soft Front Panel, click **Utilities** > **M960x Trigger Signals** > **Configuration...**. Then the Trigger Signal Configuration dialog box appears.



Function Selects the function of the signal.

TriggerOut Sets the signal to the trigger output.

Type, Polarity, Position, and Width are available for the trigger output. See "TriggerOut" on page 107.

TriggerIn Sets the signal to the trigger input.

Type and Polarity are available for the trigger input. See "TriggerIn" on page 107.

DigitalOut Sets the signal to the digital output.

Polarity and Level are available for the digital output. See "DigitalOut" on page 107.

The Function should be consistent with the settings in the Trigger tab in the Settings dialog box. For example, only the signals set to the trigger input can be used for the trigger source. If the settings are inconsistent, an error message will be displayed when the trigger system is initiated.

To specify the Function, set the parameters as follows.

TriggerOut	Type	**Edge** or **Level** can be selected. When **Edge** is selected, the signal with the pulse width specified in Width is output at the timing specified in Position. When **Level** is selected, the signal is output at the Before timing and is retained until the After timing. The Position setting is ignored.
	Polarity	When **Negative** is selected, the voltage base is set to 0 V. When **Positive** is selected, the voltage base is set to 3.3 V.
	Position	**After** specifies that the trigger output timing is after the Arm, Trigger, or Device Action. **Before** specifies that the trigger output timing is before the Arm, Trigger, or Device Action. **Both** specifies that the timing is both **After** and **Before**.
	Width	The pulse width is specified from 200 ns to 12.8 μs when the Edge type is selected.
TriggerIn	Type	**Edge** or **Level** can be selected, however, only **Edge** is valid. When **Level** is selected, **Edge** is applied. The trigger is detected when the signal transfers from Low to High.
	Polarity	When **Negative** is selected, Low is 3.3 V and High is 0 V. When **Positive** is selected, Low is 0 V, High is 3.3 V.
DigitalOut	Polarity	**Positive** sets the positive logic. **Negative** sets the negative logic.
	Level	**High** or **Low** is selected as the output voltage. For example, when the Positive is set in the polarity, **High** sets the output voltage to 3.3 V, and **Low** sets the output voltage to 0 V.

Command List to Set Trigger System

The following tables show the IVI.NET and SCPI commands for the trigger system.

Table 2-26 Command List for Trigger System Control

Command	Description	Default
Trigger.Initiate(chNum...) :INITiate[:IMMediate][:ALL]	Initiates the trigger system.	
System.WaitForOperationComplete(timeoutMs) *OPC?	Waits until all the operation is completed. For the IVI.NET command: Returns false for the time out. For the SCPI command: Returns 1 when the operation is complete.	
Trigger.Abort(chNum...) :ABORt[:ALL]	Aborts the trigger system.	

Table 2-27 Command List for Arm Layer

Command	Description	Default
Transients[chName].Arm.Delay Measurements[chName].Arm.Delay :ARM[ch]:TRANsient:DELay[?] :ARM[ch]:ACQuire:DELay[?]	Specifies the source delay or measure delay for the arm.	0 s
Transients[chName].Arm.Timer Measurements[chName].Arm.Timer :ARM[ch]:TRANsient:TIMer[?] :ARM[ch]:ACQuire:TIMer[?]	Specifies the source period or measure period for the arm.	4 μs

Command	Description	Default
Transients[chName].Arm.Count Measurements[chName].Arm.Count :ARM[ch]:TRANsient:COUNt[?] :ARM[ch]:ACQuire:COUNt[?]	Specifies the number of source or measurement counts for the arm. For Transient device action, 2147483647 (0x7FFFFFFF) or INFinity indicates infinity.	1
Transients[chName].Arm.Source Measurements[chName].Arm.Source :ARM[ch]:TRANsient:SOURce[:SIGNal][?] :ARM[ch]:ACQuire:SOURce[:SIGNal][?]	Selects the trigger source for the arm. For the IVI.NET commands: Aint | Timer | Pxi0 | Pxi1 | Pxi2 | Pxi3 | Pxi4 | Pxi5 | Pxi6 | Pxi7 | External1 | External2 For the SCPI commands: AINT | TIMer | PXI0 | PXI1 | PXI2 | PXI3 | PXI4 | PXI5 | PXI6 | PXI7 | EXT1 | EXT2	Aint
Transients[chName].Arm.Bypass Measurements[chName].Arm.Bypass :ARM[ch]:TRANsient[:LAYer]:BYPass[?] :ARM[ch]:ACQuire[:LAYer]:BYPass[?]	Enables or disables the function to bypass the event detector of the arm layer for the first time in the arm loop. For the IVI.NET commands: Off | Once For the SCPI commands: OFF | ONCE	Off
Transients[chName].Arm.TriggerOutputEnabled Measurements[chName].Arm.TriggerOutputEnabled :ARM[ch]:TRANsient[:LAYer]:TOUTput[:STATe][?] :ARM[ch]:ACQuire[:LAYer]:TOUTput[:STATe][?]	Enables or disables the trigger output at the start or end of the arm loop.	false

Command	Description	Default
Transients[chName].Arm.SetOutputTrigger(...) Measurements[chName].Arm.SetOutputTrigger(...) :ARM[ch]:TRANsient[:LAYer]:TOUTput:SIGNal :ARM[ch]:ACQuire[:LAYer]:TOUTput:SIGNal	Selects the trigger output at the start or end of the arm loop. For the IVI.NET commands: Pxi0 | Pxi1 | Pxi2 | Pxi3 | Pxi4 | Pxi5 | Pxi6 | Pxi7 | External1 | External2 For the SCPI commands: PXI0 | PXI1 | PXI2 | PXI3 | PXI4 | PXI5 | PXI6 | PXI7 | EXT1 | EXT2	External1
Transients[chName].Arm.GetOutputTrigger() Measurements[chName].Arm.GetOutputTrigger() :ARM[ch]:TRANsient[:LAYer]:TOUTput:SIGNal? :ARM[ch]:ACQuire[:LAYer]:TOUTput:SIGNal?	Returns the trigger output at the start or end of the arm loop.	

Table 2-28 Command List for Trigger Layer

Command	Description	Default
Transients[chName].Trigger.Delay Measurements[chName].Trigger.Delay :TRIGger[ch]:TRANsient:DELay[?] :TRIGger[ch]:ACQuire:DELay[?]	Specifies the source delay or measure delay.	0 s
Transients[chName].Trigger.Timer Measurements[chName].Trigger.Timer :TRIGger[ch]:TRANsient:TIMer[?] :TRIGger[ch]:ACQuire:TIMer[?]	Specifies the source period or measure period.	4 μs
Transients[chName].Trigger.Count Measurements[chName].Trigger.Count :TRIGger[ch]:TRANsient:COUNt[?] :TRIGger[ch]:ACQuire:COUNt[?]	Specifies the number of source or measurement counts. For Transient device action, 2147483647 (0x7FFFFFFF) or INFinity indicates infinity.	1

Command	Description	Default
Transients[chName].Trigger.Source Measurements[chName].Trigger.Source :TRIGger[ch]:TRANsient:SOURce[:SIGNal][?] :TRIGger[ch]:ACQuire:SOURce[:SIGNal][?]	Selects the trigger source. For the IVI.NET commands: Aint | Timer | Pxi0 | Pxi1 | Pxi2 | Pxi3 | Pxi4 | Pxi5 | Pxi6 | Pxi7 | External1 | External2 For the SCPI commands: AINT | TIMer | PXI0 | PXI1 | PXI2 | PXI3 | PXI4 | PXI5 | PXI6 | PXI7 | EXT1 | EXT2	Aint
Transients[chName].Trigger.Bypass Measurements[chName].Trigger.Bypass :TRIGger[ch]:TRANsient[:LAYer]:BYPass[?] :TRIGger[ch]:ACQuire[:LAYer]:BYPass[?]	Enables or disables the function to bypass the event detector of the trigger layer for the first time in the trigger loop. For the IVI.NET commands: Off | Once For the SCPI commands: OFF | ONCE	Off
Transients[chName].Trigger.TriggerOutputEnabled Measurements[chName].Trigger.TriggerOutputEnabled :TRIGger[ch]:TRANsient[:LAYer]:TOUTput[:STATe][?] :TRIGger[ch]:ACQuire[:LAYer]:TOUTput[:STATe][?]	Enables or disables the trigger output at the start or end of the trigger loop.	false

Command	Description	Default
Transients[chName].Trigger.SetOutputTrigger(...) Measurements[chName].Trigger.SetOutputTrigger(...) :TRIGger[ch]:TRANsient[:LAYer]:TOUTput:SIGNal :TRIGger[ch]:ACQuire[:LAYer]:TOUTput:SIGNal	Selects the trigger output at the start or end of the trigger loop. For the IVI.NET commands: Pxi0 | Pxi1 | Pxi2 | Pxi3 | Pxi4 | Pxi5 | Pxi6 | Pxi7 | External1 | External2 For the SCPI commands: PXI0 | PXI1 | PXI2 | PXI3 | PXI4 | PXI5 | PXI6 | PXI7 | EXT1 | EXT2	External1
Transients[chName].Trigger.GetOutputTrigger() Measurements[chName].Trigger.GetOutputTrigger() :TRIGger[ch]:TRANsient[:LAYer]:TOUTput:SIGNal? :TRIGger[ch]:ACQuire[:LAYer]:TOUTput:SIGNal?	Returns the trigger output at the start or end of the trigger loop.	

Table 2-29 Command List for Device Action

Command	Description	Default
Transients[chName].TriggerOutputEnabled Measurements[chName].TriggerOutputEnabled [:SOURce[ch]]:TOUTput[:STATe][?] :SENSe[ch]:TOUTput[:STATe][?]	Enables or disables the trigger output at the start or end of the device action.	false
Transients[chName].SetOutputTrigger(...) Measurements[chName].SetOutputTrigger(...) [:SOURce[ch]]:TOUTput:SIGNal :SENSe[ch]:TOUTput:SIGNal	Selects the trigger output at the start or end of the device action. For the IVI.NET commands: Pxi0 | Pxi1 | Pxi2 | Pxi3 | Pxi4 | Pxi5 | Pxi6 | Pxi7 | External1 | External2 For the SCPI commands: PXI0 | PXI1 | PXI2 | PXI3 | PXI4 | PXI5 | PXI6 | PXI7 | EXT1 | EXT2	External1
Transients[chName].GetOutputTrigger() Measurements[chName].GetOutputTrigger() [:SOURce[ch]]:TOUTput:SIGNal? :SENSe[ch]:TOUTput:SIGNal?	Returns the trigger output at the start or end of the device action.	

Table 2-30 Command List for Trigger Output Timing

Command	Description	Default
Modules[module].IO.Externals[signal].EdgePosition :SYSTem:MODule[n]:EXTernal[m]:TOUTput[:EDGE]:POSition[?]	Selects the trigger output timing of the external trigger. For the IVI.NET commands: signal = [“External1”] | [“External2”] for Externals Before | After | Both For the SCPI commands: BEFore | AFTer | BOTH	Both
Modules[module].IO.PXIes[signal].EdgePosition :SYSTem:MODule[n]:PXIe[m]:TOUTput[:EDGE]:POSition[?]	Selects the trigger output timing of the PXIe trigger line. For the IVI.NET commands: signal = [“PXIe0”] | [“PXIe1”] | [“PXIe2”] | [“PXIe3”] | [“PXIe4”] | [“PXIe5”] | [“PXIe6”] | [“PXIe7”] for PXIes Before | After | Both For the SCPI commands: BEFore | AFTer | BOTH	Both

Table 2-31 Command List for Trigger Signal Configuration

Command	Description	Default
Modules[module].IO.Externals[signal].Function Modules[module].IO.PXIes[signal].Function :SYSTem:MODule[n]:EXTernal[m][:FUNCtion][?] :SYSTem:MODule[n]:PXIe[m][:FUNCtion][?]	Selects the function of the signal. For the IVI.NET commands: signal = ["External1"] | ["External2"] for Externals signal = ["PXIe0"] | ["PXIe1"] | ["PXIe2"] | ["PXIe3"] | ["PXIe4"] | ["PXIe5"] | ["PXIe6"] | ["PXIe7"] for PXIes TriggerOutput | TriggerInput | DigitalOutput For the SCPI commands: TOUTput | TINPut | DOUTput	TriggerInput
Modules[module].IO.Externals[signal].Type Modules[module].IO.PXIes[signal].Type :SYSTem:MODule[n]:EXTernal[m]:TOUTput:TYPE[?] :SYSTem:MODule[n]:PXIe[m]:TOUTput:TYPE[?]	Selects the type of the signal. For the IVI.NET commands: signal = ["External1"] | ["External2"] for Externals signal = ["PXIe0"] | ["PXIe1"] | ["PXIe2"] | ["PXIe3"] | ["PXIe4"] | ["PXIe5"] | ["PXIe6"] | ["PXIe7"] for PXIes Edge | Level For the SCPI commands: EDGE | LEVel	Edge

Command	Description	Default
Modules[module].IO.Externals[signal].Polarity Modules[module].IO.PXIes[signal].Polarity :SYSTem:MODule[n]:EXTernal[m]:POLarity[?] :SYSTem:MODule[n]:PXIe[m]:POLarity[?]	Selects the polarity of the signal. For the IVI.NET commands: signal = ["External1"] | ["External2"] for Externals signal = ["PXIe0"] | ["PXIe1"] | ["PXIe2"] | ["PXIe3"] | ["PXIe4"] | ["PXIe5"] | ["PXIe6"] | ["PXIe7"] for PXIes Positive | Negative For the SCPI commands: POSitive | NEGative	Negative
Modules[module].IO.Externals[signal].EdgeWidth Modules[module].IO.PXIes[signal].EdgeWidth :SYSTem:MODule[n]:EXTernal[m]:TOUTput[:EDGE]:WIDth[?] :SYSTem:MODule[n]:PXIe[m]:TOUTput[:EDGE]:WIDth[?]	Specifies the pulse width of the trigger from 200 ns to 12.8 μs. For the IVI.NET commands: signal = ["External1"] | ["External2"] for Externals signal = ["PXIe0"] | ["PXIe1"] | ["PXIe2"] | ["PXIe3"] | ["PXIe4"] | ["PXIe5"] | ["PXIe6"] | ["PXIe7"] for PXIes	

Command	Description	Default
Modules[module].IO.Externals[signal].Level Modules[module].IO.PXIes[signal].Level :SYSTem:MODule[n]:EXTernal[m]:LEVel[?] :SYSTem:MODule[n]:PXIe[m]:LEVel[?]	Selects the level of the signal. For the IVI.NET commands: signal = ["External1"] | ["External2"] for Externals signal = ["PXIe0"] | ["PXIe1"] | ["PXIe2"] | ["PXIe3"] | ["PXIe4"] | ["PXIe5"] | ["PXIe6"] | ["PXIe7"] for PXIes High | Low For the SCPI commands: HIGH | LOW	Low
Modules[module].IO.Externals[signal].Read() Modules[module].IO.PXIes[signal].Read() :SYSTem:MODule[n]:EXTernal[m]:READ? :SYSTem:MODule[n]:PXIe[m]:READ?	Returns the level of the signal. For the IVI.NET commands: signal = ["External1"] | ["External2"] for Externals signal = ["PXIe0"] | ["PXIe1"] | ["PXIe2"] | ["PXIe3"] | ["PXIe4"] | ["PXIe5"] | ["PXIe6"] | ["PXIe7"] for PXIes	

Digitizer Mode

The digitizer mode enables users to acquire multiple measurement values without increasing the trigger count as shown in Figure 2-7 on page 100.

Keysight PXIe Precision SMU can acquire multiple values at the minimum interval of 800 ns for M9601A or 66.6 ns for M9602A/M9603A, which is shorter than the minimum period of trigger TIMER 4 μs.

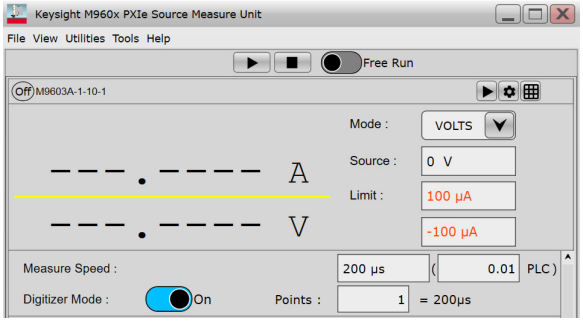
The M9614A/M9615A can acquire multiple values at the minimum interval of 2 μs. If the seamless current measurement ranging is enabled, the minimum interval is 8 μs.

As described in "Digitizer Mode in the Trigger System" on page 102, only one measurement is generally performed in one device action. To acquire multiple measurement values without the digitizer mode, the trigger process needs to be repeated.

When the digitizer mode is enabled, multiple measurements are performed in one device action. The number of measurements should be specified.

To Set Digitizer Mode

On the Soft Front Panel, switch **Digitizer Mode** to **On**, type the number of measurements in **Points** and the measurement time in **Measured Speed**.



Command List to Set Digitizer Mode

The following table shows the IVI.NET and SCPI commands to set the digitizer mode.

Table 2-32 Command List for Digitizer Mode

Command	Description	Default
Measurements[chName].AcquisitionMode :SENSe[ch]:FUNCtion:MODE[?]	Selects the sampling mode. When selecting Sampling, the digitizer mode is enabled. For the IVI.NET commands: Normal | Sampling For the SCPI commands: NORMal | SAMPling	Normal
Measurements[chName].Sampling.Points :SENSe[ch]:SAMPling:POINts[?]	Specifies the number of sampling points. The total sampling time in the digitizer mode is calculated by the number of sampling points and the aperture time.	
Measurements[chName].Sampling.TotalTime :SENSe[ch]:SAMPling:TIME[?]	Specifies the total sampling time in the digitizer mode. The number of sampling points is calculated by the total sampling time in the digitizer mode and the aperture time.	
Measurements[chName].Voltage.Aperture Measurements[chName].Current.Aperture :SENSe[ch]:VOLTage[:DC]:APERture[?] :SENSe[ch]:CURRent[:DC]:APERture[?]	Specifies the aperture time.	
Measurements[chName].Voltage.NPLC Measurements[chName].Current.NPLC :SENSe[ch]:VOLTage[:DC]:NPLCycles[?] :SENSe[ch]:CURRent[:DC]:NPLCycles[?]	Specifies the aperture time in PLC.	

Sampling Measurement

Keysight PXIe Precision SMU provides several sampling measurements using the trigger system. For M9614A/M9615A PXIe 5-Channel Precision SMU, the trigger settings can be specified for each channel.

Sweep Measurement with TIMER Trigger

Figures 2-9 shows an example of sweep measurements with the trigger source of TIMER, or triggers at the specified interval. This allows users to measure at the accurate interval. The minimum interval is 4 μs.

Table 2-33 shows the trigger setting for Figure 2-9.

To perform the sampling measurement,

- Set the sweep and trigger parameters. For setting parameters, see "To Set Sweep Parameters" on page 64 and "To Set Trigger Parameter" on page 103.
- Initiate the trigger system.

Figure 2-9 Example of Sweep Measurement with TIMER Trigger

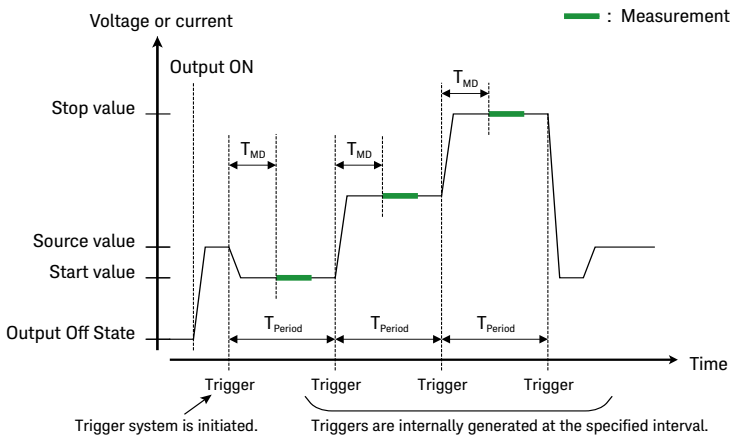


Table 2-33 Trigger Setting for Figures 2-9

Parameter	Source	Measure
Count	Number of sweep steps	
Delay	0	T_{MD}
Period	T_{Period}	
Trigger source	TIMER	

Pulse Measurement with TIMER Trigger

Figure 2-10 shows an example of pulse measurements with the trigger source of TIMER, or triggers at the specified interval. This allows users to measure at the accurate interval. The minimum interval is 4 μs.

Table 2-34 shows the trigger setting for Figure 2-10.

To perform the sampling measurement,

- Set the pulse and trigger parameters. For setting parameters, see "To Set Pulse Output" on page 61 and "To Set Trigger Parameter" on page 103.
- Initiate the trigger system.

Figure 2-10 Example of Pulse Measurement with TIMER Trigger

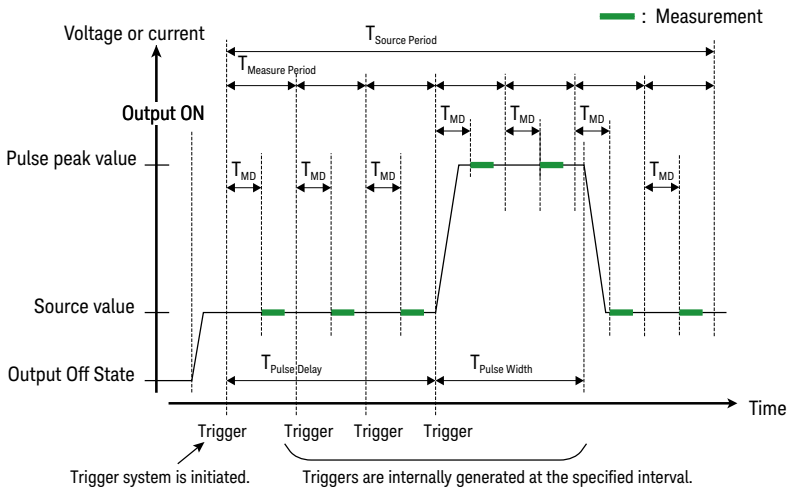


Table 2-34 Trigger Setting for Figures 2-10

Parameter	Source	Measure
Count	1	Number of measurements
Delay	0	T_{MD}
Period	$T_{Source\ Period}$	$T_{Measure\ Period}$
Trigger source	TIMER	

Pulse Measurement with Digitizer Mode

Figures 2-11 shows an example of pulse measurements with the digitizer mode. As described in "Digitizer Mode" on page 117, the digitizer mode is effective in high-speed measurements.

Table 2-35 shows the trigger setting for Figures 2-11.

To perform the pulse measurement with the digitizer mode,

- Enable the digitizer mode and specify the number of measurements and the measurement time. Also see "To Set Digitizer Mode" on page 117.
- Set the pulse and trigger parameters. For setting parameters, see "To Set Pulse Output" on page 61 and "To Set Trigger Parameter" on page 103.
- Initiate the trigger system.

Figure 2-11 Example of Pulse Measurement with Digitizer Mode

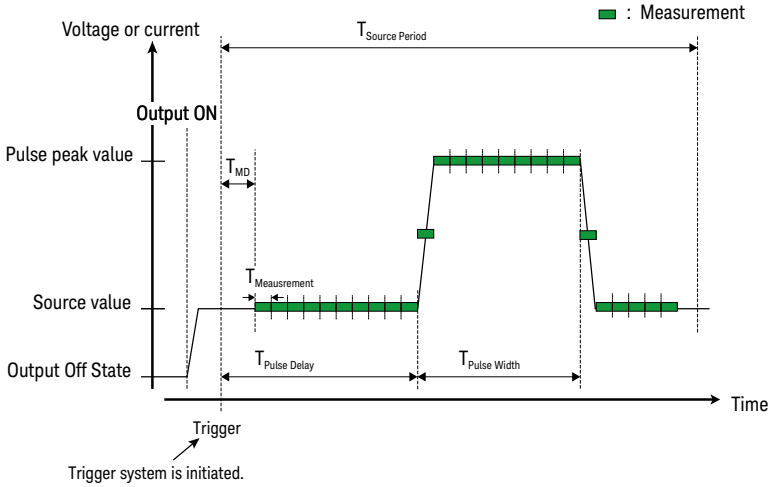


Table 2-35 Trigger Setting for Figures 2-11

Parameter	Source	Measure
Count	1	
Delay	0	T_{MD}
Period	$T_{Source\ Period}$	
Trigger source	TIMER	

Repeated Pulse Measurement with Digitizer Mode

Figures 2-12 shows an example of pulse measurements with the trigger source of TIMER and the digitizer mode.

Table 2-36 shows the trigger setting for Figures 2-12.

To perform the repeated pulse measurement with the trigger source of TIMER and the digitizer mode,

- Enable the digitizer mode and specify the number of measurements and the measurement time. Also see “To Set Digitizer Mode” on page 117.

- Set the pulse and trigger parameters. For setting parameters, see "To Set Pulse Output" on page 61 and "To Set Trigger Parameter" on page 103.
- Initiate the trigger system.

Figure 2-12 Example of Repeated Pulse Measurement with Digitizer Mode

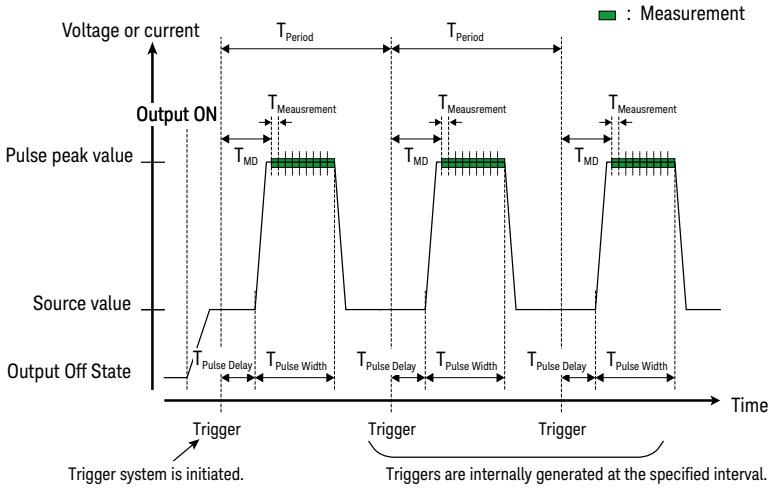


Table 2-36 Trigger Setting for Figures 2-12

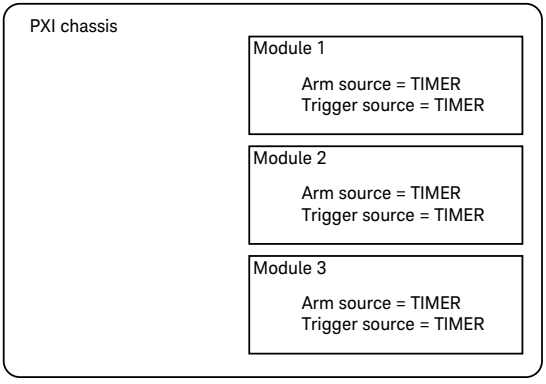
Parameter	Source	Measure
Count	Number of pulses	
Delay	0	T_{MD}
Period	T_{Period}	
Trigger source	TIMER	

Module Synchronous Operation

Keysight PXIe Precision SMU has several ways to perform module synchronous operation. You can synchronize the multiple modules using the trigger system. This section describes the five examples of them.

Synchronous Operation with TIMER Trigger

All modules have the trigger and arm source set to TIMER. To set the trigger parameter, see "To Set Trigger Parameter" on page 103.



This is quite simple operation and easy to perform. However, the delay among the modules may be dozens of microseconds. The delay may vary according to the operation system and the module configuration because the software initiates the modules in order.

Synchronous Operation with Sync Line

All modules are synchronized with the clock of the PXI chassis. This operation is not available for the Soft Front Panel. You need to perform this operation by programming.

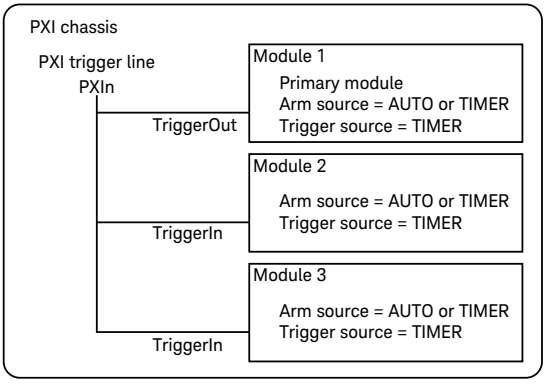
This operation uses one of the external triggers or PXI trigger lines as the sync line. The external triggers are the external trigger terminals on the front panel (EXT1 or EXT2). The PXI trigger lines are eight trigger lines on the PXIe chassis backplane (PXI0, PXI1, ..., PXI7).

To perform this operation by programming,

1. Select one of the modules as the primary module.
2. Select one of the external triggers or PXI trigger lines as the sync line.
3. Set the sync line to the trigger output for the primary module and to the trigger input for other modules.
4. Enable and execute the synchronization via the sync line.

For the command list, see "Command List to Set Synchronous Operation with Sync Line" on page 129. For more information, refer to the *Online Help*.

The following figure shows an example using a PXI trigger line.



Once you have synchronized the modules using the sync line, you can use the sync line as the usual external trigger or PXI trigger line. The synchronization with the sync line is valid until the module is powered off.

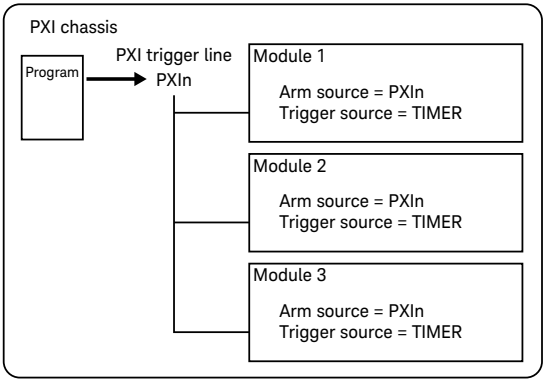
This operation minimizes the delay among the modules. However, this operation cannot synchronize PXIe modules other than Keysight PXIe Precision SMU.

NOTE The only one module can use the PXI trigger line as the trigger output. When performing a sync line operation with a PXI trigger line, ensure that modules other than the primary module do not use the PXI trigger line as the trigger output.

NOTE When performing a module synchronous operation with a PXI trigger line, you may need to configure the PXI trigger bus on the PXI chassis beforehand. For more information, refer to the PXI chassis manuals.

Synchronous Operation with PXI Trigger Line

All modules have the arm source set to the PXI trigger line, PXI*n*, where *n* is 0 to 7. The PXI trigger lines are eight trigger lines on the PXIe chassis backplane. The modules are synchronized with the signal input to the PXI trigger line.



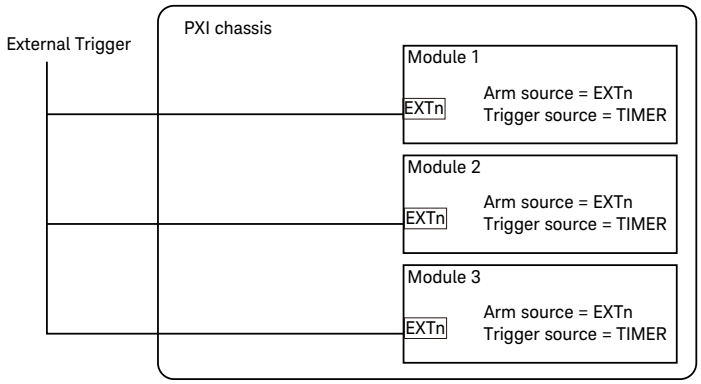
You can synchronize all PXIe modules which select the PXI trigger line as the trigger input.

The delay among the modules may be hundreds of nanoseconds to a few microseconds. To minimize the delay among the Keysight PXIe Precision SMU modules, you can perform the sync line operation before using the PXI trigger line as the arm source. See “Synchronous Operation with Sync Line” on page 124.

NOTE When performing a module synchronous operation with a PXI trigger line, you may need to configure the PXI trigger bus on the PXI chassis beforehand. For more information, refer to the PXI chassis manuals.

Synchronous Operation with External Trigger Terminal

You can synchronize the modules using an external trigger source and the external trigger terminals. The module has two trigger terminals on the front panel: External trigger 1 (EXT1) and 2 (EXT2). To operate this synchronization, connect the external trigger source to each module with cables and set the arm source to EXT1 or EXT2.



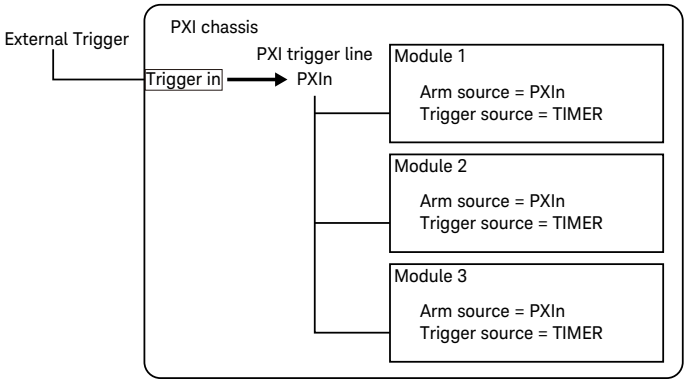
This operation allows you to easily synchronize the modules with other instruments. You cannot synchronize PXIe modules which have no external trigger input.

The delay among the modules may be hundreds of nanoseconds to a few microseconds. To minimize the delay among the Keysight PXIe Precision SMU modules, you can perform the sync line operation before using the PXI trigger line as the arm source. See “Synchronous Operation with Sync Line” on page 124.

Synchronous Operation with Trigger Input on the Chassis

If your PXI chassis has a trigger input terminal, you can synchronize the modules using the external trigger source and the trigger input terminal on the chassis.

The PXI trigger line is used to synchronize the modules. The PXI trigger lines are eight trigger lines on the PXIe chassis backplane. The arm source should be set to the PXI trigger line (PXI0, PXI1, ..., or PXI7).



You need only a cable connecting to the external trigger source and the trigger input terminal. This operation is not available for the PXI chassis without the trigger input terminal.

The delay among the modules may be hundreds of nanoseconds to a few microseconds. To minimize the delay among the Keysight PXIe Precision SMU modules, you can perform the sync line operation before using the PXI trigger line as the arm source. See “Synchronous Operation with Sync Line” on page 124.

NOTE When performing a module synchronous operation with a PXI trigger line, you may need to configure the PXI trigger bus on the PXI chassis beforehand. For more information, refer to the PXI chassis manuals.

Command List to Set Synchronous Operation with Sync Line

The following table shows the IVI.NET and SCPI commands for the synchronous operation with the sync line.

Table 2-37 Command List for Synchronous Operation with Sync Line

Command	Description	Default
Modules[module].IO.Externals[signal].Function Modules[module].IO.PXIes[signal].Function :SYSTem:MODule[n]:EXTernal[m][:FUNCtion][?] :SYSTem:MODule[n]:PXIe[m][:FUNCtion][?]	Selects the function of the signal. For the IVI.NET commands: signal = [“External1”] | [“External2”] for Externals signal = [“PXIe0”] | [“PXIe1”] | [“PXIe2”] | [“PXIe3”] | [“PXIe4”] | [“PXIe5”] | [“PXIe6”] | [“PXIe7”] for PXIes TriggerOutput | TriggerInput | DigitalOutput For the SCPI commands: TOUTput | TINPut | DOUTput	TriggerInput
System.Group.ResetSyncSetting() :SYSTem:GROup:SYNC:RESet	Initializes the external triggers and the PXI trigger lines for the synchronous operation.	
System.Group.SyncEnabled :SYSTem:GROup:SYNC[:STATe][?]	Enables or disables the synchronous operation with the sync line.	false
System.Group.SyncMasterModule :SYSTem:GROup:SYNC:MASTer[:MODule][?]	Selects the primary module for the sync line operation.	1
System.Group.SyncTriggerLine :SYSTem:GROup:SYNC:SIGNal[?]	Selects the trigger line as the sync line. For the IVI.NET commands: Pxi0 | Pxi1 | Pxi2 | Pxi3 | Pxi4 | Pxi5 | Pxi6 | Pxi7 | External1 | External2 For the SCPI commands: PXI0 | PXI1 | PXI2 | PXI3 | PXI4 | PXI5 | PXI6 | PXI7 | EXT1 | EXT2	Pxi0

Command	Description	Default
System.Group.SyncExecute() :SYSTem:GROup:SYNC:EXECute?	Executes synchronization.	
System.Group.SyncTest() :SYSTem:GROup:SYNC:TEST?	Checks the sync line.	

Measurement Data

After the measurement, you can acquire the result data by programming. For showing the measurement result on the Soft Front Panel, see "Measurement Result" on page 32.

Command List to Acquire the Measurement Data

The following table shows the IVI.NET and SCPI commands to acquire the measurement data. For further information on the commands, refer to the *Online Help*.

Table 2-38 Command List for Measurement Data

Command	Description	Default
Measurements.Measure(measureType, chNum...) :MEASure? [(@ch list)] :MEASure:CURRent[:DC]? [(@ch list)] :MEASure:VOLTage[:DC]? [(@ch list)] :MEASure:RTVoltage[:DC]? [(@ch list)]	Executes a spot (one-shot) measurement and returns the measurement result data. For the IVI.NET commands: measureType = All | Voltage | Current | Resistance The measurement result data does not include values of the remote transient voltage measurement. For the SCPI commands, it measures only current or voltage. RTVoltage is available for M9602A and M9603A.	

Command	Description	Default
Measurements.FetchScalarData(fetchType, chNum...) :FETCH[:SCALar]? [(@ch list)] :FETCh[:SCALar]:[CURRent | RESistance | RTVoltage | SOURce | STATus | TIME | VOLTage]? [(@ch list)]	Returns the latest measurement data. For the IVI.NET commands: fetchType = All | Voltage | Current | Resistance | Status | Time | Source | RemoteTransientVoltage (available for M9602A and M9603A) For the SCPI commands, RTVoltage is available for M9602A and M9603A.	
Measurements.FetchArrayData(fetchType, chNum...) :FETCh:ARRAY? :FETCh:ARRAY:[VOLTage | CURRent | RESistance | STATus | TIME | SOURce | RTVoltage]?	Returns the measured data in a double array. Users can execute this command after the trigger system finishes. For the IVI.NET commands: fetchType = All | Voltage | Current | Resistance | Status | Time | Source | RemoteTransientVoltage (available for M9602A and M9603A) For the SCPI commands, RTVoltage is available for M9602A and M9603A.	

Remote Transient Voltage Measurement (M9602A and M9603A)

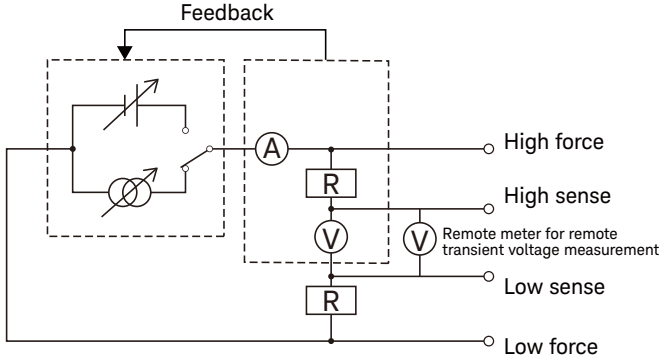
M9602A and M9603A provide the remote transient voltage measurement. This function is effective in measuring pulse voltage with the width of a few to dozens of microseconds.

This function is available for only the current source mode.

This function is available all current and voltage ranges.

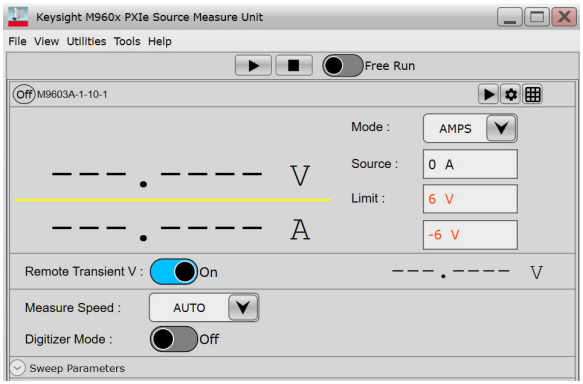
The remote transient voltage measurement has a dedicated voltmeter with higher bandwidth as shown in Figure 2-13. It reduces the influence of capacitance, inductance, and voltage drop on the measurement cable of the 4-wire connection when applying narrow pulsed current.

Figure 2-13 Remote Transient Voltage Measurement (M9602A and M9603A)



To Enable Remote Transient Voltage Measurement

On the Soft Front Panel, switch **Remote Transient V** to **On**.



Command List to Set Remote Transient Voltage Measurement

The following table shows the IVI.NET and SCPI commands for the remote transient voltage measurement.

To acquire the spot measurement data of remote transient voltage measurement using the commands, execute `Measurements.Measure()` and then `Measurements.FetchScalarData(RemoteTransientVoltage)`. For the SCPI command, only execute `:MEASure:RTVoltage[:DC]?`.

To acquire the measurement data by the trigger system operation, using the commands, execute `Trigger.Initiate(chNum...)` and then `Measurements.FetchArrayData(RemoteTransientVoltage)`.

Table 2-39 Command List for Remote Transient Voltage Measurement

Command	Description	Default
Measurements[chName].RemoteTransientVoltage.Enabled :SENSe[ch]:RTVoltage[:DC][:STATe]	Enables or disables the remote transient voltage measurement.	false
Measurements.Measure(measureType, chNum...) :MEASure? [(@ch list)] :MEASure:CURRent[:DC]? [(@ch list)] :MEASure:VOLTage[:DC]? [(@ch list)] :MEASure:RTVoltage[:DC]? [(@ch list)]	Executes a spot (one-shot) measurement and returns the measurement result data. For the IVI.NET commands: measureType = All | Voltage | Current | Resistance The measurement result data does not include values of the remote transient voltage measurement. For the SCPI commands, it measures only current or voltage. RTVoltage is available for M9602A and M9603A.	
Measurements.FetchScalarData(fetchType, chNum...) :FETCH[:SCALar]? [(@ch list)] :FETCh[:SCALar]:[CURRent | RESistance | RTVoltage | SOURce | STATus | TIME | VOLTage]? [(@ch list)]	Returns the latest measurement data. fetchType = All | Voltage | Current | Resistance | Status | Time | Source | RemoteTransientVoltage (available for M9602A and M9603A)	
Trigger.Initiate(chNum...) :INITiate[:IMMediate][:ALL]	Initiates the trigger system.	
Measurements.FetchArrayData(fetchType, chNum...) :FETCh:ARRAY? :FETCh:ARRAY:[VOLTage | CURRent | RESistance | STATus | TIME | SOURce | RTVoltage]?	Returns the measured data in a double array. Users can execute this command after the trigger system finishes. fetchType = All | Voltage | Current | Resistance | Status | Time | Source | RemoteTransientVoltage (available for M9602A and M9603A)	

Protection from Emergency

The protection from emergency is effective in preventing damages to the module due to high temperature, over voltage, over current, or other conditions.

Keysight PXIe Precision SMU provides two types of protection. One is an emergency shutdown and the other is an immediate output-off.

When the over temperature or the system error such as power supply failure or internal communication failure is detected, the emergency shutdown occurs. The module is powered off and two LED indicators turn red.

When the emergency including the over voltage, over current, and interlock open is detected, the output is automatically turned off; the output voltage is immediately set to 0 V, the output switch is set to off, and the “Status” LED indicator turns off. If the emergency condition continues for a certain period of time after the immediate output-off, the emergency shutdown occurs.

If the emergency shutdown occurs, perform the self test to solve the shutdown condition. On the Soft Front Panel, click **Utilities > Self Test...** to open the Self Test dialog box. Then click **Run Self Test**.

Line Frequency

Line frequency (power line frequency) must be set properly according to the AC power at your site. This setting is non-volatile and not changed by power-on or reset. The default setting is 50 Hz.

NOTE

You must specify the line frequency by programming before the operation, if necessary.

This setting is not available for the Soft Front Panel.

Command List to Set Line Frequency

The following table shows the command list for the line frequency.

Table 2-40 Command List for Line Frequency

Command	Description	Default
System.LineFrequency :SYSTem:LFRequency[?]	Specifies and returns the line frequency. This parameter is the non-volatile setting.	50 Hz

Chassis Current Capacity

For M9602A/M9603A and M9614A/M9615A, the maximum output values of available voltage and current depend on the PXI chassis current capacity. For the maximum output values, refer to the data sheet. For further information about the PXI chassis current capacity, refer to the PXI chassis documentation.

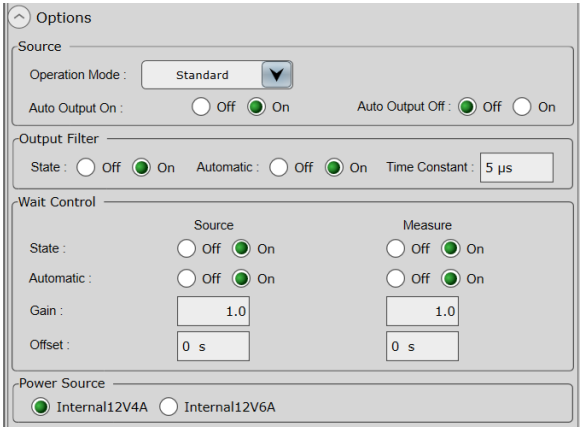
NOTE Before the operation, you must specify the current capacity of the PXI chassis according to the chassis specification.

To Set Chassis Current Capacity

Using the Soft Front Panel, click the Option button on the instrument panel, if the small instrument panel is displayed, press the Settings button and click the Options tab in the Setting dialog box.

If the PXI chassis current capacity is 4 A at +12 V for a PXI slot, select **Internal12V4A** from the Power Source options.

If the PXI chassis current capacity is 6 A at +12 V for a PXI slot, select **Internal12V6A** from the Power Source options.



Command List to Set Chassis Current Capacity

The following table shows the command list for the chassis current capacity.

Table 2-41 Command List for Chassis Current Capacity

Command	Description	Default
Modules[module].PowerSource :SYSTem:MODule[n]:PSUPply:SOURce[?]	Selects the chassis current capacity. For the IVI.NET commands: Internal12V4A | Internal12V6A (for M9602A, M9603A, M9614A, and M9615A) For the SCPI commands: INT12V4A | INT12V6A (for M9602A, M9603A, M9614A, and M9615A)	Internal12V4A

3 Initial Settings

Keysight PXIe Precision Source/Measure Unit (SMU) is initialized when you turn on or reset it. This chapter shows the initial settings.

Initial Settings of M9601A

Table 3-1 shows the Initial settings of the M9601A.

The line frequency and the interlock threshold voltage are non-volatile settings. These do not change when you turn on or reset the module.

The other settings are initialized and set to the defaults when you turn on or reset the module. You need to set it as needed.

Table 3-1 M9601A Initial Settings

Setup item	Power on	Reset	Factory Default
Automatic timestamp reset	Enabled		
Line frequency	(Not Changed)		50 Hz
Interlock threshold voltage	(Not Changed)		42 V
Operation mode	Standard		
Output state	Disabled		
Output auto filter enable	Enabled		
Output low pass filter enable	Enabled		
Output low pass filter time constant	5 μs		
Output low pass filter cut-off frequency	32 kHz		
Output off mode	Normal		
Output priority mode	Voltage		
Output shape	DC		
Automatic output on	Enabled		
Automatic output off	Disabled		
Voltage output level	0 V		
Voltage limit	20 V		

Setup item	Power on	Reset	Factory Default
Automatic voltage output ranging	Enabled		
Voltage output range	20 V		
Voltage output range lower limit	0.5 V		
Voltage output mode	Fixed		
Voltage sweep points	1		
Voltage sweep start	0 V		
Voltage sweep stop	0 V		
Voltage list points	1		
Voltage list values	0 V		
Triggered voltage output level	0 V		
Voltage base type	Immediate		
Voltage base manual level	0 V		
Voltage post type	Immediate		
Voltage post manual level	0 V		
Current output level	0 A		
Current limit	100 μA		
Automatic current output ranging	Enabled		
Current output range	100 μA		
Current output ranging lower limit	1 nA		
Current output mode	Fixed		
Current sweep points	1		
Current sweep start	0 A		
Current sweep stop	0 A		
Current list points	1		

Setup item	Power on	Reset	Factory Default
Current list values	0 A		
Triggered current output level	0 A		
Current base type	Immediate		
Current base manual level	0 A		
Current post type	Immediate		
Current post manual level	0 A		
Sweep direction	Up		
Double sweeping	Disabled		
Sweep ranging	Best		
Continuous triggered output	Disabled		
Pulse delay	0 s		
Pulse width	20 μs		
Automatic output wait time	Enabled		
Output wait time gain	1		
Output wait time offset	0		
Measure function	All		
Acquisition mode	Normal		
Automatic aperture	Enabled		
Aperture time	0.1 PLC		
Voltage measure range	20 V		
Current measure range	100 μA		
Automatic measure wait time	Enabled		
Measure wait time gain	1		
Measure wait time offset	0		

Setup item	Power on	Reset	Factory Default
Sampling measure points	1		
Sampling measure total time	0.1 PLC		
ARM count	1		
ARM bypass	Disabled		
ARM delay	0 s		
ARM source	AInt		
ARM timer	4 μs		
ARM trigger output enable	Disabled		
ARM trigger output signal	External1		
Trigger count	1		
Trigger bypass	Disabled		
Trigger delay	0 s		
Trigger source	AInt		
Trigger timer	4 μs		
Trigger output enable	Disabled		
Trigger output signal	External1		
Transient action trigger output enable	Disabled		
Transient action trigger output signal	External1		
Measure action trigger output enable	Disabled		
Measure action trigger output signal	External1		
Group synchronization enabled	Disabled	(Not Changed)	
Group synchronization master module	1	(Not Changed)	
Group synchronization trigger line	PXI0	(Not Changed)	
External trigger function	TriggerInput		

Setup item	Power on	Reset	Factory Default
External trigger level	Low		
External trigger polarity	Negative		
External trigger output type	Edge		
External trigger edge position	Both		
External trigger edge width	200 ns		
PXIe trigger function	TriggerInput		
PXIe trigger level	Low		
PXIe trigger polarity	Negative		
PXIe trigger output type	Edge		
PXIe trigger edge position	Both		
PXIe trigger edge width	200 ns		

Initial Settings of M9602A and M9603A

Table 3-2 shows the Initial settings of the M9602A and M9603A.

The line frequency and the interlock threshold voltage are non-volatile settings. These do not change when you turn on or reset the module.

The other settings are initialized and set to the defaults when you turn on or reset the module. You need to set it as needed.

Table 3-2 M9602A and M9603A Initial Settings

Setup item	Power on	Reset	Factory Default
Automatic timestamp reset	Enabled		
Line frequency	(Not Changed)		50 Hz
Interlock threshold voltage	(Not Changed)		42 V
Operation mode	Standard		
Output state	Disabled		
Output auto filter enable	Enabled		
Output low pass filter enable	Enabled		
Output low pass filter time constant	5 μs		
Output low pass filter cut-off frequency	32 kHz		
Output off mode	Normal		
Output priority mode	Voltage		
Output shape	DC		
Automatic output on	Enabled		
Automatic output off	Disabled		
Voltage output level	0 V		
Voltage limit	6 V		

Setup item	Power on	Reset	Factory Default
Automatic voltage output ranging	Enabled		
Automatic voltage limit ranging	Enabled		
Automatic voltage limit range lower limit	6 V		
Voltage output range	6 V		
Voltage output range lower limit	6 V		
Voltage output mode	Fixed		
Voltage sweep points	1		
Voltage sweep start	0 V		
Voltage sweep stop	0 V		
Voltage list points	1		
Voltage list values	0 V		
Triggered voltage output level	0 V		
Voltage base type	Immediate		
Voltage base manual level	0 V		
Voltage post type	Immediate		
Voltage post manual level	0 V		
Current output level	0 A		
Current limit	100 μA		
Automatic current output ranging	Enabled		
Automatic current limit ranging	Enabled		
Automatic current limit range lower limit	1 μA for M9602A 100 nA for M9603A		
Current output range	100 μA		
Current output ranging lower limit	1 μA 100 nA for M9603A		

Setup item	Power on	Reset	Factory Default
Current output mode	Fixed		
Current sweep points	1		
Current sweep start	0 A		
Current sweep stop	0 A		
Current list points	1		
Current list values	0 A		
Triggered current output level	0 A		
Current base type	Immediate		
Current base manual level	0 A		
Current post type	Immediate		
Current post manual level	0 A		
Sweep direction	Up		
Double sweeping	Disabled		
Sweep ranging	Best		
Continuous triggered output	Disabled		
Pulse delay	0 s		
Pulse width	100 μs		
Automatic output wait time	Enabled		
Output wait time gain	1		
Output wait time offset	0		
Measure function	All		
Acquisition mode	Normal		
Automatic aperture	Enabled		
Aperture time	0.1 PLC		

Setup item	Power on	Reset	Factory Default
Voltage measure range	2 V		
Current measure range	100 μA		
Automatic measure wait time	Enabled		
Measure wait time gain	1		
Measure wait time offset	0		
Sampling measure points	1		
Sampling measure total time	0.1 PLC		
Seamless ranging current measure	Disabled		
Seamless ranging current measure lower limit	10 mA		
ARM count	1		
ARM bypass	Disabled		
ARM delay	0 s		
ARM source	AInt		
ARM timer	4 μs		
ARM trigger output enable	Disabled		
ARM trigger output signal	External1		
Trigger count	1		
Trigger bypass	Disabled		
Trigger delay	0 s		
Trigger source	AInt		
Trigger timer	4 μs		
Trigger output enable	Disabled		
Trigger output signal	External1		
Transient action trigger output enable	Disabled		

Setup item	Power on	Reset	Factory Default
Transient action trigger output signal	External1		
Measure action trigger output enable	Disabled		
Measure action trigger output signal	External1		
Group synchronization enabled	Disabled	(Not Changed)	
Group synchronization master module	1	(Not Changed)	
Group synchronization trigger line	PXI0	(Not Changed)	
External trigger function	TriggerInput		
External trigger level	Low		
External trigger polarity	Negative		
External trigger output type	Edge		
External trigger edge position	Both		
External trigger edge width	200 ns		
PXIe trigger function	TriggerInput		
PXIe trigger level	Low		
PXIe trigger polarity	Negative		
PXIe trigger output type	Edge		
PXIe trigger edge position	Both		
PXIe trigger edge width	200 ns		
Power Source	Internal12V4A		

Initial Settings of M9614A and M9615A

Table 3-3 shows the Initial settings of the M9614A and M9615A.

The line frequency and the interlock threshold voltage are non-volatile settings. These do not change when you turn on or reset the module.

The other settings are initialized and set to the defaults when you turn on or reset the module. You need to set it as needed.

Table 3-3 M9614A and M9615A Initial Settings

Setup item	Power on	Reset	Factory Default
Automatic timestamp reset	Enabled		
Line frequency	(Not Changed)		50 Hz
Interlock threshold voltage	(Not Changed)		42 V
Operation mode	Standard		
Output state	Disabled		
Output auto filter enable	Enabled		
Output low pass filter enable	Enabled		
Output low pass filter time constant	5 μs		
Output low pass filter cut-off frequency	32 kHz		
Output off mode	Normal		
Output priority mode	Voltage		
Output shape	DC		
Automatic output on	Enabled		
Automatic output off	Disabled		
Voltage output level	0 V		
Voltage limit	6 V		

Setup item	Power on	Reset	Factory Default
Automatic voltage output ranging	Enabled		
Voltage output range	6 V		
Voltage output range lower limit	6 V		
Voltage output mode	Fixed		
Voltage sweep points	1		
Voltage sweep start	0 V		
Voltage sweep stop	0 V		
Voltage list points	1		
Voltage list values	0 V		
Triggered voltage output level	0 V		
Voltage base type	Immediate		
Voltage base manual level	0 V		
Voltage post type	Immediate		
Voltage post manual level	0 V		
Current output level	0 A		
Current limit	100 μA		
Automatic current output ranging	Enabled		
Current output range	100 μA		
Current output ranging lower limit	100 μA for M9614A 10 μA for M9615A		
Current output mode	Fixed		
Current sweep points	1		
Current sweep start	0 A		
Current sweep stop	0 A		
Current list points	1		

Setup item	Power on	Reset	Factory Default
Current list values	0 A		
Triggered current output level	0 A		
Current base type	Immediate		
Current base manual level	0 A		
Current post type	Immediate		
Current post manual level	0 A		
Sweep direction	Up		
Double sweeping	Disabled		
Sweep ranging	Best		
Continuous triggered output	Disabled		
Pulse delay	0 s		
Pulse width	100 μs		
Automatic output wait time	Enabled		
Output wait time gain	1		
Output wait time offset	0		
Measure function	All		
Acquisition mode	Normal		
Automatic aperture	Enabled		
Aperture time	0.1 PLC		
Voltage measure range	2 V		
Current measure range	100 μA		
Automatic measure wait time	Enabled		
Measure wait time gain	1		
Measure wait time offset	0		

Setup item	Power on	Reset	Factory Default
Sampling measure points	1		
Sampling measure total time	0.1 PLC		
Seamless ranging current measure	Disabled		
Seamless ranging current measure lower limit	100 μA		
ARM count	1		
ARM bypass	Disabled		
ARM delay	0 s		
ARM source	AInt		
ARM timer	4 μs		
ARM trigger output enable	Disabled		
ARM trigger output signal	External1		
Trigger count	1		
Trigger bypass	Disabled		
Trigger delay	0 s		
Trigger source	AInt		
Trigger timer	4 μs		
Trigger output enable	Disabled		
Trigger output signal	External1		
Transient action trigger output enable	Disabled		
Transient action trigger output signal	External1		
Measure action trigger output enable	Disabled		
Measure action trigger output signal	External1		
Group synchronization enabled	Disabled	(Not Changed)	
Group synchronization master module	1	(Not Changed)	

Setup item	Power on	Reset	Factory Default
Group synchronization trigger line	PXI0	(Not Changed)	
External trigger function	TriggerInput		
External trigger level	Low		
External trigger polarity	Negative		
External trigger output type	Edge		
External trigger edge position	Both		
External trigger edge width	200 ns		
PXIe trigger function	TriggerInput		
PXIe trigger level	Low		
PXIe trigger polarity	Negative		
PXIe trigger output type	Edge		
PXIe trigger edge position	Both		
PXIe trigger edge width	200 ns		
Power Source	Internal12V4A		

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