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S530 Parametric Test System

Diagnostics and Verification Manual

S530-906-01 Rev. C / January 2014

S530-906-01

A Greater Measure of Confidence

KEITHLEY
A Tektronix Company

S530 Parametric Test Systems

Diagnostic And Verification

Manual

Document number: S530-906-01 Rev. C / January 2014

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Safety precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with nonhazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the user documentation for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product warranty may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the user documentation. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, perform safe installations, and repair products. Only properly trained service personnel may perform installation and service procedures.

Keithley Instruments products are designed for use with electrical signals that are measurement, control, and data I/O connections, with low transient overvoltages, and must not be directly connected to mains voltage or to voltage sources with high transient overvoltages. Measurement Category II (as referenced in IEC 60664) connections require protection for high transient overvoltages often associated with local AC mains connections. Certain Keithley measuring instruments may be connected to mains. These instruments will be marked as category II or higher.

Unless explicitly allowed in the specifications, operating manual, and instrument labels, do not connect any instrument to mains.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30 V RMS, 42.4 V peak, or 60 VDC are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 V, no conductive part of the circuit may be exposed.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance-limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, ensure that the line cord is connected to a properly-grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

For safety, instruments and accessories must be used in accordance with the operating instructions. If the instruments or accessories are used in a manner not specified in the operating instructions, the protection provided by the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with the same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as protective earth (safety ground) connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a  screw is present, connect it to protective earth (safety ground) using the wire recommended in the user documentation.

The  symbol on an instrument means caution, risk of danger. The user must refer to the operating instructions located in the user documentation in all cases where the symbol is marked on the instrument.

The  symbol on an instrument means caution, risk of electric shock. Use standard safety precautions to avoid personal contact with these voltages.

The  symbol on an instrument shows that the surface may be hot. Avoid personal contact to prevent burns.

The  symbol indicates a connection terminal to the equipment frame.

If this  symbol is on a product, it indicates that mercury is present in the display lamp. Please note that the lamp must be properly disposed of according to federal, state, and local laws.

The **WARNING** heading in the user documentation explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in the user documentation explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits — including the power transformer, test leads, and input jacks — must be purchased from Keithley Instruments. Standard fuses with applicable national safety approvals may be used if the rating and type are the same. Other components that are not safety-related may be purchased from other suppliers as long as they are equivalent to the original component (note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product). If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water-based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., a data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

Safety precaution revision as of January 2013.

Table of Contents

Section 1

Introduction

In this section:

Overview

The S530 diagnostic software is a suite of software tests you can use to verify the correct functionality and performance of the instruments within the S530 Parametric Test System. This manual will guide you and describe how to use the S530 diagnostic software tool to verify that your S530 tester is performing correctly.

If you have any questions after reviewing this information, contact your local Keithley Instruments representative or call one of our applications engineers at 1-888-KEITHLEY (1-888-534-8453) within the U.S. and Canada. You can also visit the Keithley Instruments website at www.keithley.com for updated worldwide contact information.

The diagnostics software is available for both the KTE and ACS versions of the S530. As designed, the system control and output of the diagnostics software is identical for both versions. Where necessary, specific ACS or KTE instructions will be provided.

Start and run full diagnostics

1. Locate and run the diagnostic GUI
   a. On ACS, the diagnostics program is run by double-clicking the Diagnostics' icon (see next figure), or you can double-click the diagnostic .exe file, located in:

      C:\ACS\Diagnostics\

   b. On KTE, the diagnostics program, diags, is located in $KIBIN (default = /opt/kiS530/bin) and can be run by typing at terminal prompt:

      ```
      diags
      ```

2. After the software has started, prerequisite testing will automatically begin. This may take about 20 to 40 minutes, based on system configuration, such as the number of SMUs and pins.
3. After the prerequisite tests complete and pass, the GUI is ready to run diagnostic or system verify tests. Continue to the next step to complete a full diagnostics run on the system.
4. Verify the testing mode is set to diagnostics and that all tests are set to be executed (see the Graphical user interface (GUI) topic for more information; refer to the graphic in order to find the **Execute** button and the **All** option).
5. Click the **Execute** button (located on the right upper side of the GUI screen). The full diagnostic test will take about 30 to 75 minutes, based on system configuration, such as the number of SMUs and pins.
6. After the completion of the diagnostic testing, indication of a pass or failure will be shown in the main GUI. Information on status and results of all the tests executed can be viewed in the designated tabs located on the bottom of the GUI display (see the Graphical user interface (GUI).

NOTE

When running the diagnostic GUI without command-line arguments, as shown above, the GUI will run in default mode. This mode allows testing to continue if a failure occurs. Other GUI modes are referenced in two places: Command-line arguments and Tool bar items.

⚠ WARNING

The Diagnostics and System Verify tests output signals that present voltages at the output cables and the probe card. Ensure safe operation by following the information presented in the Safety Interlocks section of the S530 Administrative Guide.

Command-line arguments

The following command-line arguments are supported by the diagnostics GUI:

`-c testSelectionFileName`	Load the test selection file
`-o resultsFileName`	Set the output file name to 'resultsFileName'
`-s`	Enable stop on failure mode
`-p`	Enable pause on failure mode
`-n`	Test without a GUI; all tests will be executed unless the –c option is used
`-k`	Execute Kelvin tests only without GUI

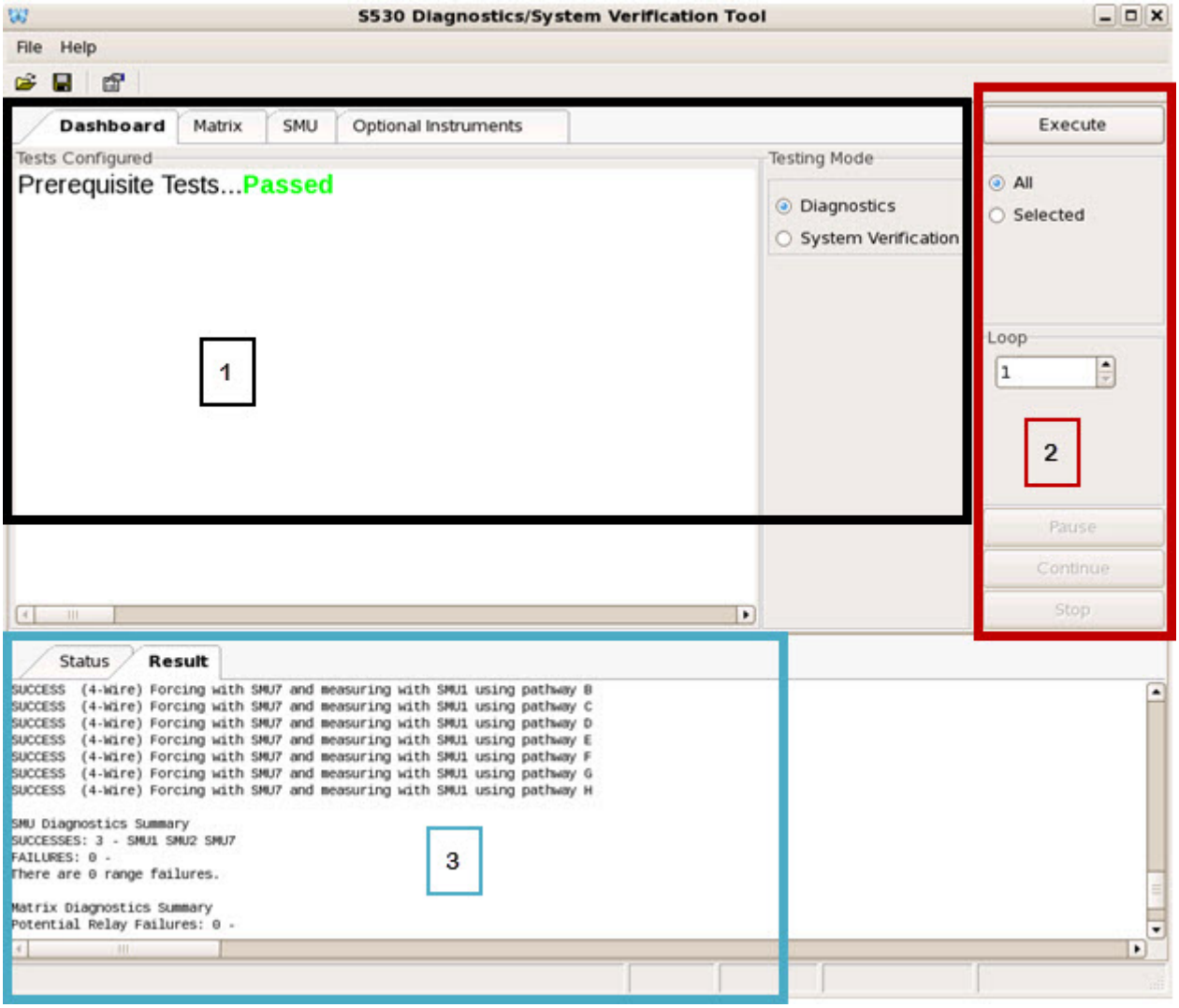
If the `-c` and `-n` switches are used together; the diagnostics system will immediately execute the tests. These switches can be used to automate/integrate the diagnostics program into your workflow.

Graphical user interface (GUI)

The diagnostics software GUI contains three distinct areas(see next figure):

- (1) Selection area
- (2) Control area
- (3) Status and Result

Figure 1: S530 KTE Diagnostics



Selection area

The selection area is the upper left side of the screen and contains four tabs:

- **Dashboard**
- **Matrix**
- **SMU**
- **Optional Instruments**

These tabs allow you to select the diagnostic tests you want to execute. Each tab is based on an instrument type or function. These tabs can be used to choose the desired test (or tests) to execute on the system.

Control area

The control area (see the previous figure) gives you the ability to **Execute**, **Pause**, **Continue**, or **Stop**, and choose a loop count to run a test (or tests) multiple times. The **All** or **Selected** radio button under the **Execute** button allows you to execute all of the diagnostic tests for all of the instruments, or you can execute the **Selected** diagnostic tests identified in the tabs (Matrix, SMU, Optional Instruments). The **Execute** button, and the **All** and **Selected** radio buttons, are only enabled while the Dashboard tab is selected.

The **Loop** number can be used to specify how many times to execute a test (or tests). You can enter the number directly in the text box or use the spinner controls to adjust. The maximum number of loops is 100.

The **Pause** button allows you to pause the diagnostic test that is running. The **Continue** button will cause the diagnostic testing to continue after a pause event. Note that the testing will pause between diagnostic tests, not in the middle of a test. The instrumentation will be placed in a safe state at this time.

The **Stop** button allows you to stop the test that is running. Once the testing has been stopped, testing can only begin again from the beginning.

Status and Result

The Status and Result area (see the previous figure) shows **Status** and test **Result** information as the diagnostic tests execute. Select the Status or Result tab in order to view the desired information. This information allows you to monitor the testing process.

The **Status** and test **Result** information can be individually cleared or saved by right-clicking within the desired information tab. If you chose to **Save** the contents, a file dialog appears and you must choose where you want to save the contents. The contents are saved as a .txt file.

Menu bar items

The **File** menu item contains the following items:

- Load test selections
- Save test selections
- Exit

The GUI allows you to select and execute diagnostic tests. In addition, you can use the **Save test selections** option to save this test selection for later use. The **Load test selections** menu option allows you to preload a previous test configuration into the GUI. The test selection file can also be specified on the command-line with the `-c` and `-n` switches to execute the selected tests.

The **Help** menu will provide online help for the GUI.

Tool bar items

The toolbar contains the following items:

- Open
- Save
- Options:

  Stop on failure (toggle button) – if selected, the **Pause on failure** button, by default, is deselected. The **Stop on failure** option causes the diagnostics testing to stop if a failure occurs. Note that the instrument and matrix connections remain active and connected so that you can troubleshoot the failure. The DiagUI title bar will display the "Pause on failure" setting when this mode is active.

  Pause on failure (toggle button) – if selected, the **Stop on failure** button, by default, is deselected. The **Pause on failure** option causes the diagnostics testing to pause if a failure occurs. Note that the instrument and matrix connections remain active and connected so that you can troubleshoot the failure. The DiagUI title bar will display the "Stop on failure" setting when this mode is active. You can press the **Continue** button to allow testing to proceed after a failure.

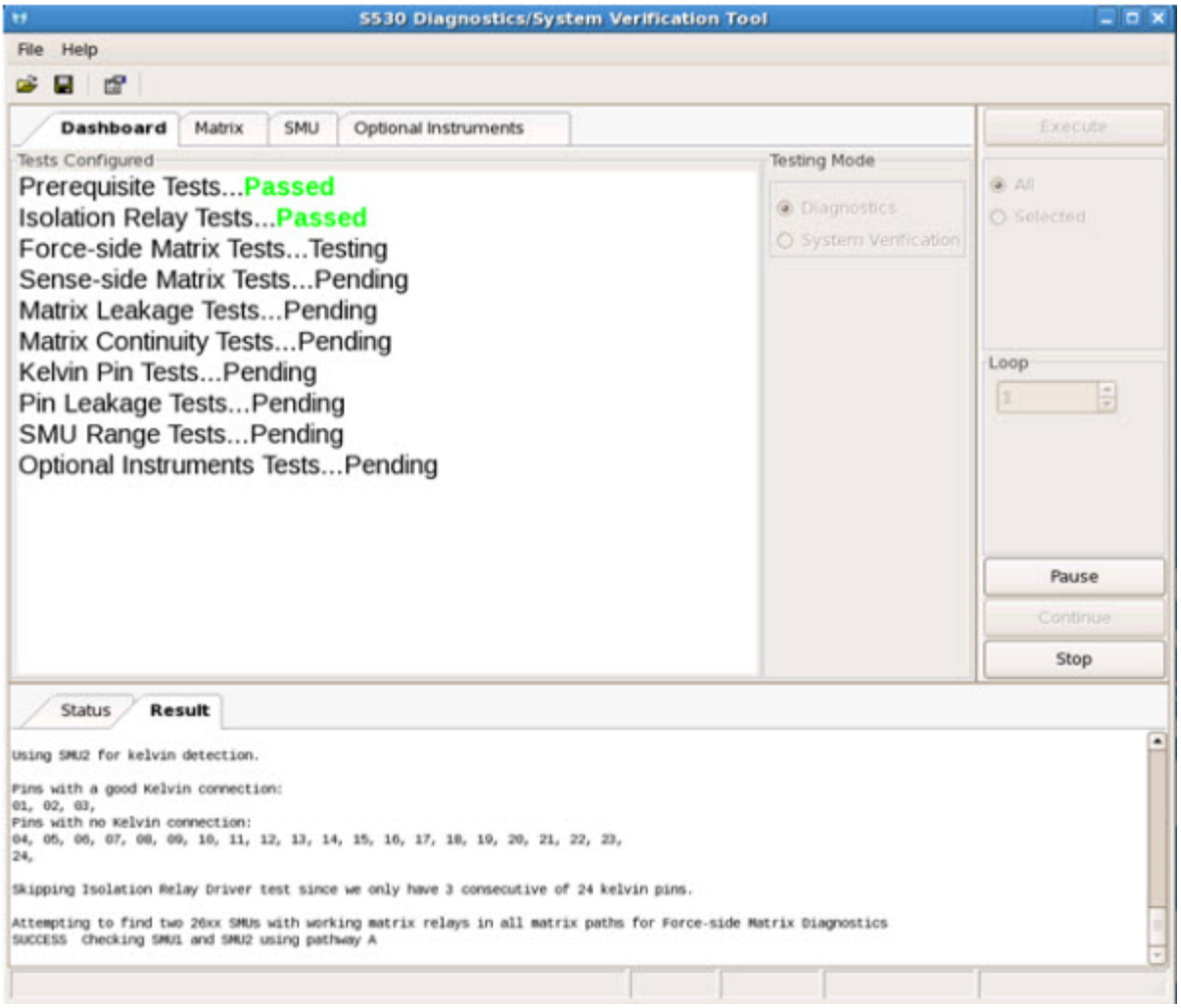
Dashboard tab

The Dashboard tab, shown in the following figure, provides an overview of the test selection and configuration. The **Tests Configured** section is a read-only list of the diagnostic tests selected. When selected, the **All** radio button shows all of the diagnostics tests, or you can choose specific tests when **Selected** is selected.

This list is updated during test execution to provide a high-level summary of the diagnostics testing state.

The **Testing Mode** section allows you to choose between executing only the diagnostics tests, or system verification tests. The system verification tests will take more time to execute and will verify that the instrumentation is operating within the proper specifications.

Figure 2: S530 Diagnostics Dashboard tab



Matrix tab

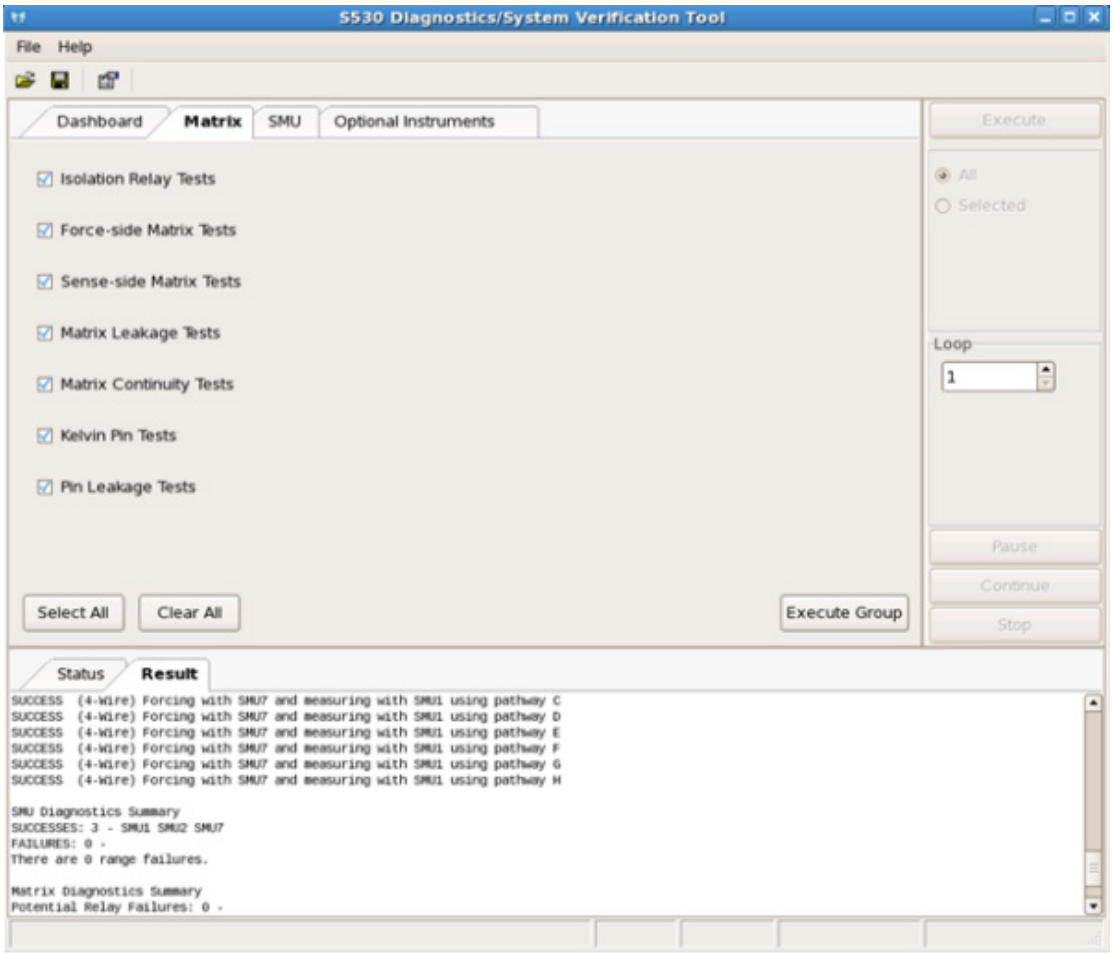
The Matrix tab, shown in the following figure, allows you to select and execute the following tests:

- Isolation Relay
- Force-side Matrix
- Sense-side Matrix
- Matrix Leakage
- Matrix Continuity
- Kelvin Pin
- Pin Leakage

You can select the desired test or tests individually, or use the **Select All** or **Clear All** buttons. The **Execute** button enables the selected tests to execute.

The **Execute** button is disabled, along with the **All** and **Selected** radio buttons when the Matrix tab is selected. However, the other controls are still enabled allowing you to **Pause**, **Continue**, or **Stop** the test sequence.

Figure 3: S530 Diagnostics Matrix tab



SMU tab

The SMU tab, shown in the following figure, allows you to select and execute the SMU diagnostics tests.

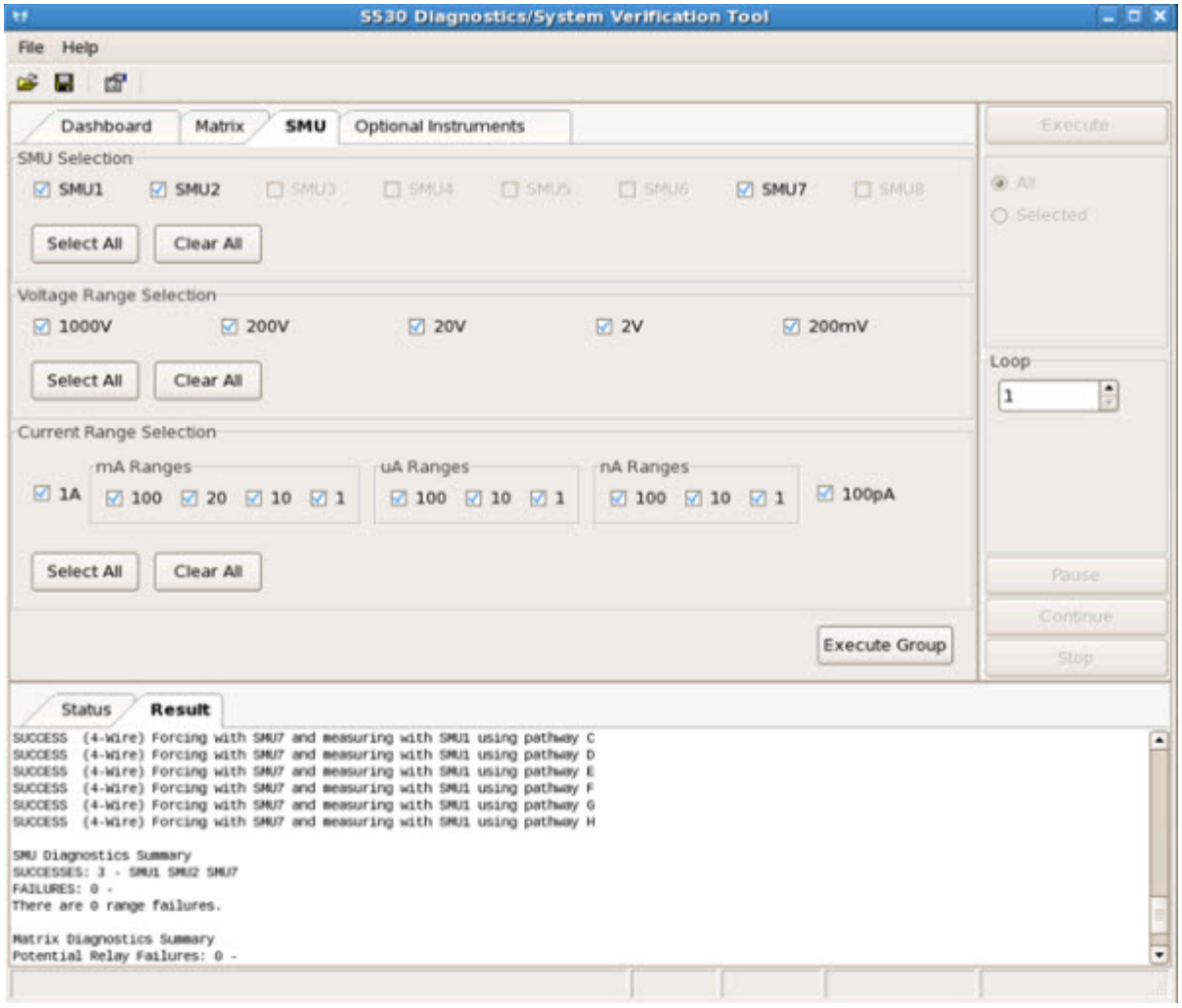
You can select all or specific SMUs for testing. In addition, you can select all SMU ranges, specific voltage ranges, or specific current ranges to test.

NOTE

The voltage and current range(s) selected are tested on all of the SMUs selected.

The **Execute** button enables the selected tests to execute. When you have the SMU tab open, the **Execute** button, plus the **All** and **Selected** radio buttons are disabled. However, the other controls are still enabled allowing you to **Pause**, **Continue**, or **Stop** the test sequence.

Figure 4: S530 Diagnostics SMUs tab



Optional Instruments tab

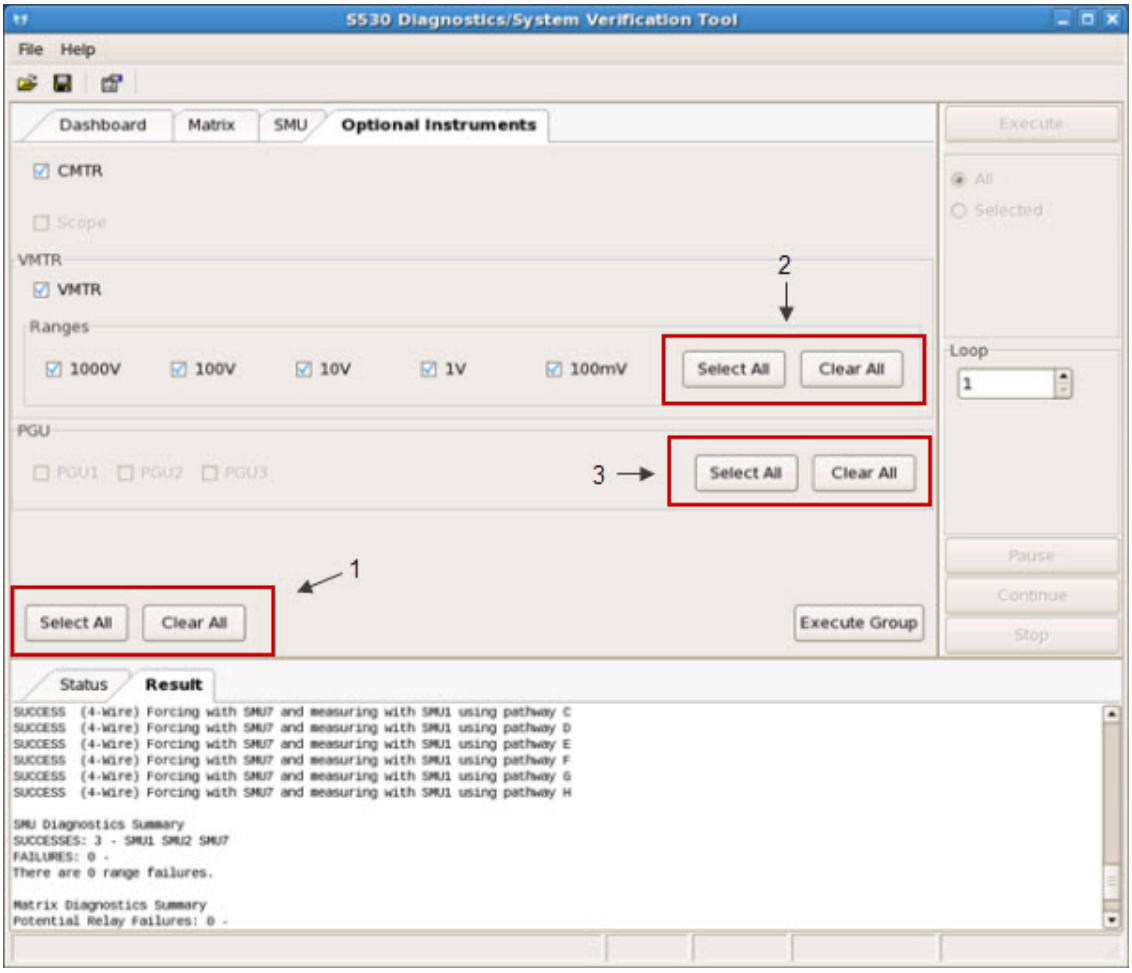
The Optional Instruments tab, shown in the following figure, allows you to select and execute only the diagnostics tests available for the Optional Instruments:

- Capacitance meter (CMTR)
- Oscilloscope (SCP)
- Digital multimeter (VMTR)
- Pulse generator (PGU)

You can select the desired instruments individually or by using the **Select All** and **Clear All** buttons (see number 1 in the next figure). All of the available voltage ranges for the VMTR can be selected or cleared by selecting the **Select All** or **Clear All** buttons (see number 2 in the next figure). Also, all of the available PGUs (up to 3) can be selected or cleared by selecting the **Select All** or **Clear All** buttons (see number 3 in the next figure).

The **Execute** button enables the selected tests to execute. On the Dashboard tab, the **Execute** button, plus the **All** and **Selected** radio buttons are disabled when the Optional Instruments tab is selected. However, the other controls are still enabled allowing you to **Pause**, **Continue**, or **Stop** the test sequence.

Figure 5: S530 Optional Instruments test selection



Configuration

The instrument controller configuration file (`$KIHOME/IC/icconfig_<QMO>.ini`) contains a list of instruments to test. This list is in the "DIAG" item of the [INSTRUMENTATION] section of the software. The matrix diagnostics reads the instruments from this list and performs tests only on the matrix columns used by these instruments.

NOTE

A probe card must be installed in the PCA and probes must be in the "up" position before running diagnostics. There must be at least three pins configured and connected to the matrix/probe card.

Section 2

Diagnostic Tests

In this section:

Introduction

The following information describes the various diagnostics tests used in the S530 diagnostics suite.

Test sequence

- Pre-requisites
  - Instrument communications
  - Matrix configuration
  - Minimum of two SMU channels
  - Minimum of two Kelvin pins (three Kelvin pins for systems with 7072-HV cards)
- Matrix row isolation relay test
  - Force-side row isolation relays
  - Sense-side row isolation relays
- Matrix column isolation relay tests (7072-HV only)
  - ♦ Force-side column isolation relays
  - ♦ Sense-side column isolation relays
- Matrix force-side relay test
- Matrix sense-side relay test
- Matrix leakage test
  - Pathway-to-pathway current leakage
  - Pathway-to-pathway guard capacitance
- Matrix continuity test
- Kelvin pin
- Pin leakage
  - Pin-to-pin current leakage
  - Pin-to-pin guard capacitance
- SMU range tests

- Optional instrument tests
  - Execute capacitance meter (CMTR) test
  - Execute oscilloscope (SCP) test
  - Execute pulse (PGU) test
  - Execute volt meter (VMTR) test

Prerequisite tests

NOTE

A probe card must be installed in the PCA and probes must be in the "up" position, not contacting the wafer, before running diagnostics. There must be at least two Kelvin pins connected from the matrix to the probe card through the PCA.

A series of tests need to be completed successfully before the entire diagnostics test suite can be executed. These prerequisite tests will determine if the instruments are working properly and if a minimum number of SMUs and the matrix are functioning. These preliminary tests are simply "go, no-go" tests and are not intended to verify full functionality.

Communication tests

Each instrument will be queried for identification using the equivalent *IDN (for example, `*idn?)` command. The response will be logged and used as part of the diagnostics report. If the response does not appear, then the instrument is declared bad and will not be included in later tests.

SMU two-wire prerequisite test

Put SMUs in two-wire mode and connect a forcing SMU to a measuring SMU using a matrix pathway.

Repeat for each SMU combination:

1. Force voltage on the forcing SMU and measure voltage with the measuring SMU.
   - Force/measure the following voltages: ±1.4 V, ±12.3 V, and ±32.7 V.
2. Repeat step 1, except force and measure current instead of voltage.
   - Set a limit of 5.0 V and force ±1.4 mA and ±1.4 µA.
3. Swap the forcing and measuring SMUs and repeat the test.

The force/measure test for the SMU combination must pass for all matrix pathways before the SMU is considered good.

If at least two SMUs pass this test, then the two-wire SMU prerequisite test is successful.

Kelvin tests (four-wire systems only)

The purpose of this prerequisite test is to scan the pins with the two good SMU instruments (determined in the previous SMU 2-wire prerequisite test) and find a minimum number of pins with valid Kevlin connections. For a low current system (a system using 7530 or 7174 matrix cards), the minimum number is two. For a high voltage system (a system using 7072-HV series matrix cards), the minimum number is three. If less than this minimum number of pins have a valid Kelvin connection, the test fails and further testing cannot continue.

The Model 2636A/B SMUs have a built-in contact test feature that is used to determine if this Kelvin connection is present. The diagnostics software will connect the first SMU with the first pin using matrix pathway 'A.' If a valid Kelvin connection exists, the same SMU pin pair is connected again using the next matrix pathway. This loop is repeated for each pathway. If all pathways can supply a valid Kelvin connection, then this SMU/pin pair is good.

SMU four-wire (four-wire systems only)

The SMU four-wire test follows the same sequence as the two-wire test except that the SMUs are placed into four-wire mode. The two SMUs are connected together using one of the Kelvin pins detected above. The force/measure test for the SMU combination must pass for all of the matrix pathways before the test is considered good. The acceptance window for the resulting measurements is ±2.5%.

At minimum, two SMUs must pass this test before the four-wire SMU pre-requisite test is considered successful.

If any of the prerequisite tests fail, the diagnostics session will terminate. You, or a Keithley Instruments field-service engineer (FSE) will need to correct the problem(s) before diagnostics can run to completion.

Matrix tests

Isolation relay tests

The relay cards used for the S530 KTE systems all contain isolation relays for row connections and the Model 7072HV cards also containing pathway isolation. The Model 707B mainframe cannot directly control the isolation relays. The following tests were created to indirectly use and validate that these relays function correctly.

Requirements: One working SMU and 2 Kelvin pins for the low-current (7530 and 7174-based) systems, and three Kelvin pins for the High-voltage (7072-HV-based) systems. Note that during testing the SMU is placed in 2-wire mode.

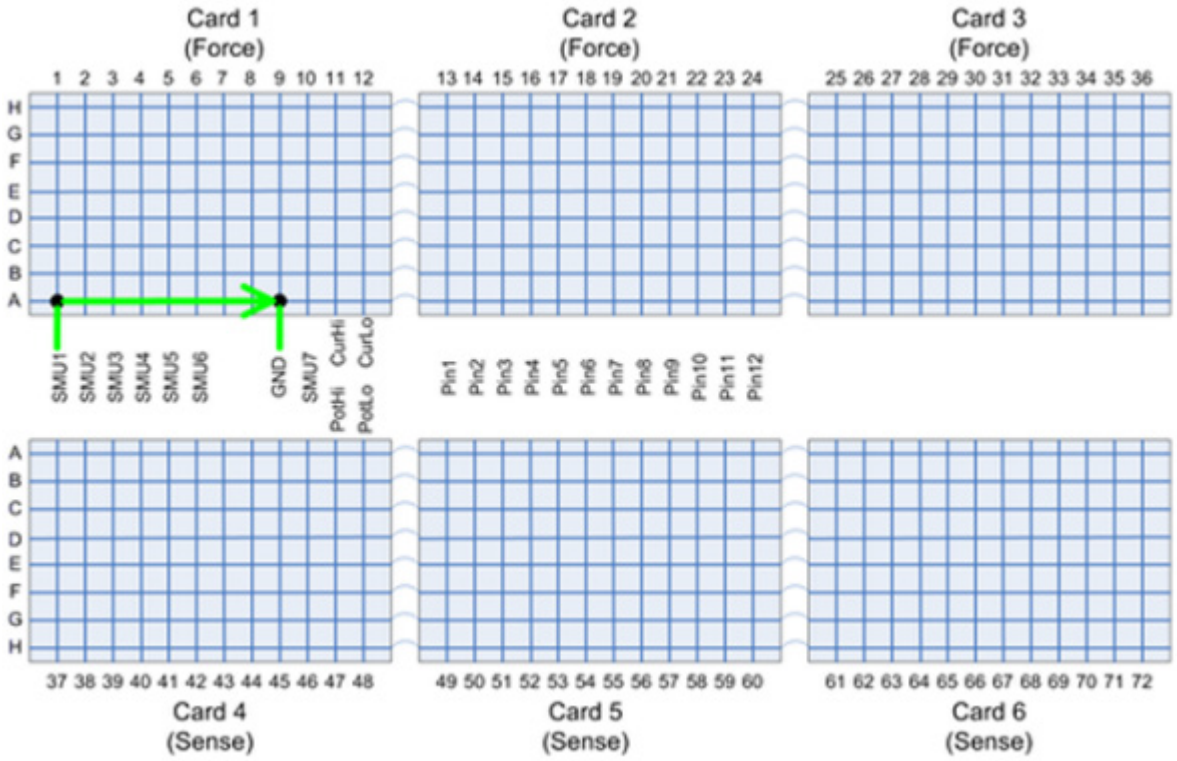
Force-side row isolation relays

Test the force-side of the matrix first. The test first validates that the working SMU (SMU1 in this case) can force current into GND for all eight pathways on card 1.

The next figure shows the matrix connection for testing pathway A. SMU1 is configured with a voltage limit of 5 V and forces 1 mA of current. Current flowing out of SMU1 is measured and compared with 1 mA. If the current measurement is correct, the next pathway is checked until all eight have been verified.

Details of the test method are shown in the next figure. Note that the relay is tested in both open and closed states twice to increase the chances of detecting a relay that may be intermittently stuck in one state.

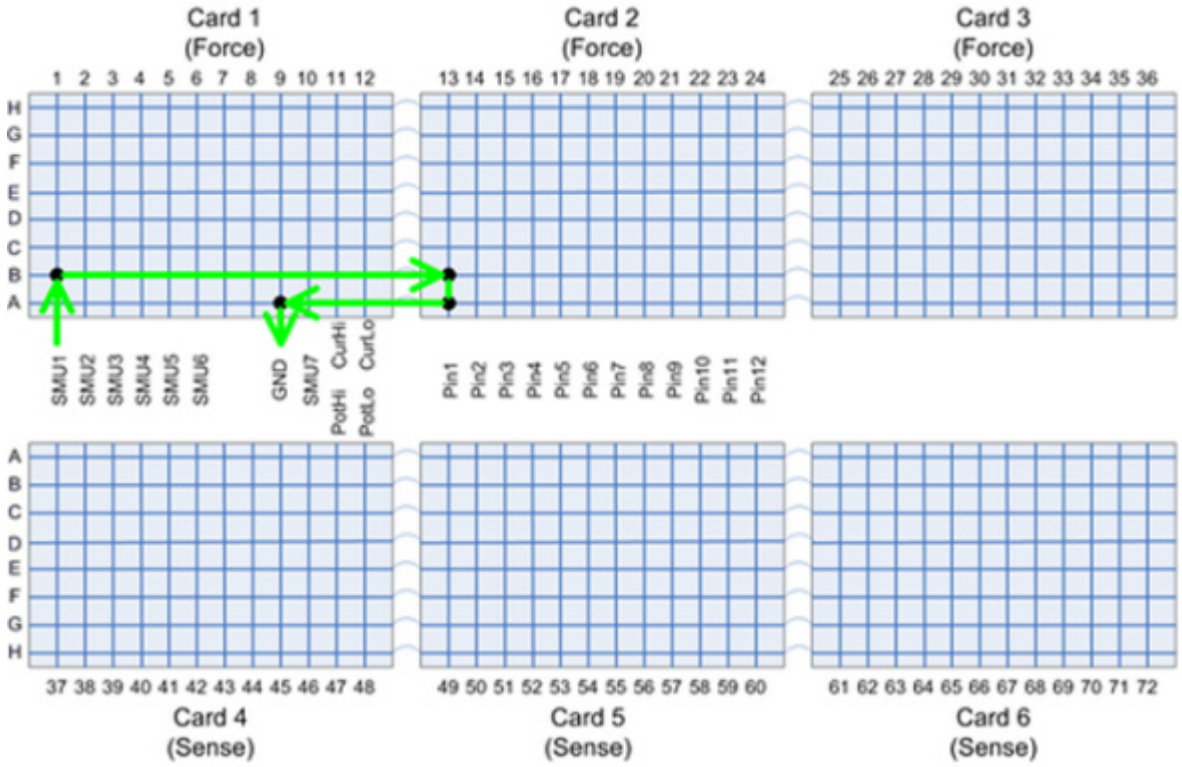
Figure 6: Validate all pathways for Card 1



Now that you know that card 1 pathways are good, you can test the card 1 and card 2 connections, and then the card 1 to card 3 connections. You will need to test both combinations in order to determine if card 1, card 2, or card 3 has any failures since we cannot test card 1 directly.

Connect card 1 and card 2 together to verify the row isolation relays. The next figure shows the matrix connections to verify pathway A and B.

Figure 7: Check Card 1 and Card 2 isolation relays



Test sequence measurement details

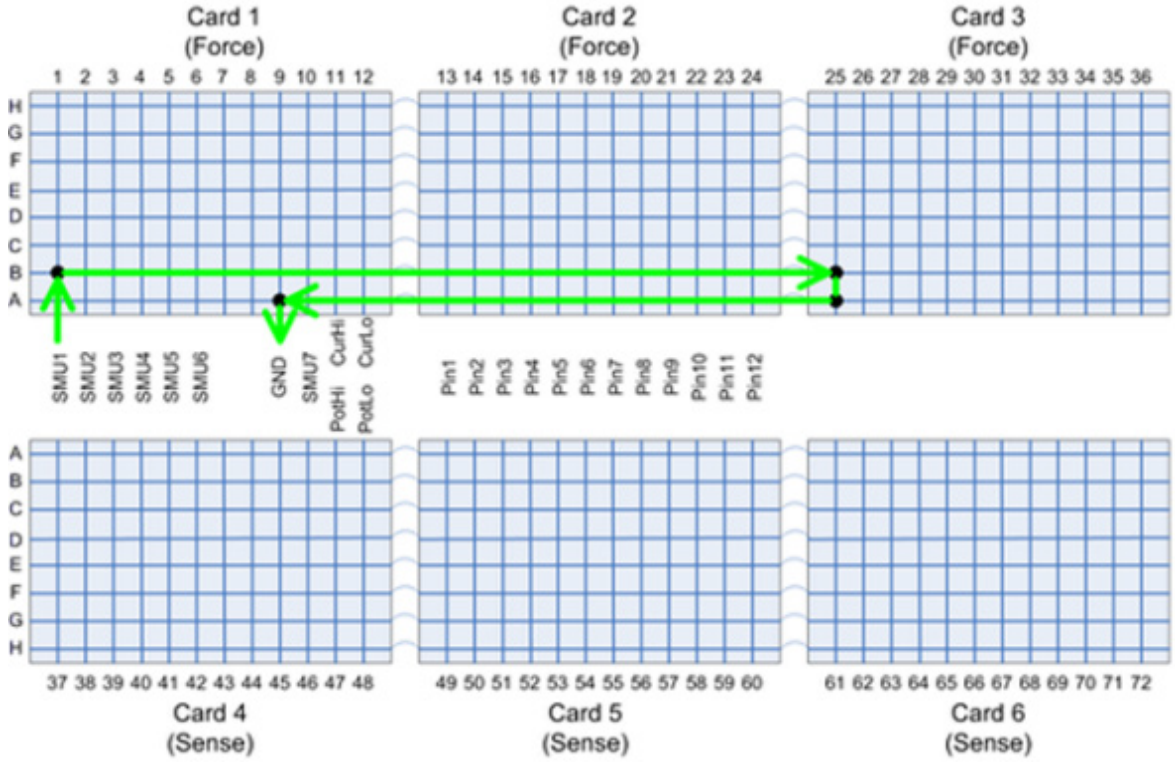
During the test, current is forced and measured with SMU1 and if current flow is successful, you know that the row isolators for card1 and card2 are closing. Also, you need to verify that these isolation relays will open correctly. The complete test sequence, shown in pseudo code, is as follows:

```
close relay 2A01 and 2B01
forcei/measi   Should measure 1mA
devclr()
open relay 2A01
forcei/measi  should fail current flow
devclr()
close relay 2A01
forcei/measi  should pass again
devclr()
open relay 2B01
forcei/measi  should fail current flow
devclr()
close relay 2B01
forcei/measi   should pass again
devclr()
open relays 2A01 and 2B01 since this test is complete.
devint()
```

If all of the above tests pass and fail at the appropriate times, you know that the row isolation relays for pathway A and B between card 1 and card 2 are operational. If the tests fail, you know that either the row isolation relays on card 1 or card 2 are bad. However, you do not know which card.

The tests are repeated for pathways C to D, E to G, and F to H. The pathways for E to G and F to H are staggered due to the Model 7072HV card pathway differences. If any pathway group fails, the test has failed.

Figure 8: Check Card 1 and Card 3 isolation relays



Once testing has completed for card 3 you can determine if the row isolation relays are good. If both card 2 and card 3 tests are good, then card 1 is also good.

If the card 1 to card 2 tests fail and the card 1 to card 3 tests are good, then card 2 should be replaced.

If the card 1 to card 2 tests are good and the card 1 to card 3 tests fail, then card 3 should be replaced.

If the card 1 to card 2 tests fail and the card 1 to card 3 tests fail, then card 1 should be replaced.

Sense-side row isolation relays

NOTE

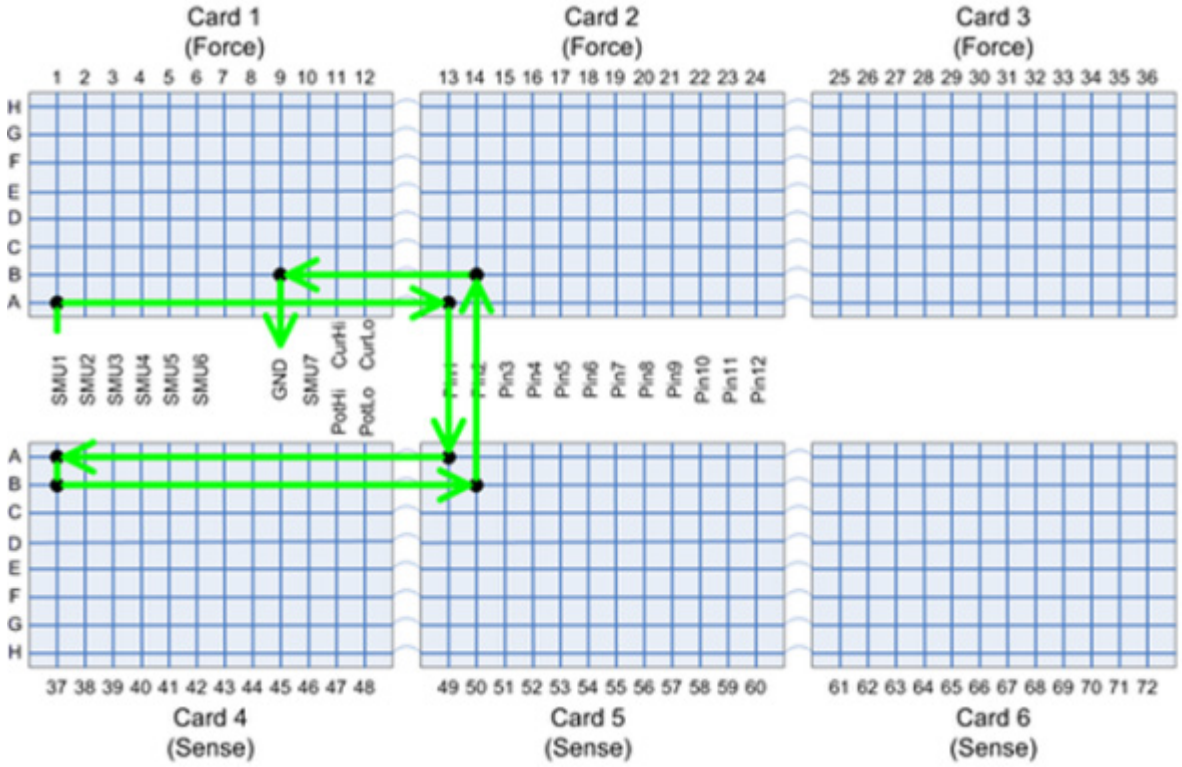
This test does not apply to the Model 7530 matrix card.

Now you will test the sense-side of the matrix. You will use two Kelvin pins to bridge the connection between the two halves of the matrix. A similar test sequence used for the force-side isolation relays of the matrix will be used on the sense-side isolation relays. The next figure shows the matrix connections used to validate the row isolation relays for pathway A and B between matrix cards 5 and 4.

Repeat the tests for pathways C to D, E to G, and F to H. The pathways for E to G and F to H are staggered due to the Model 7072HV card pathway differences. If any pathway group fails, the test has failed.

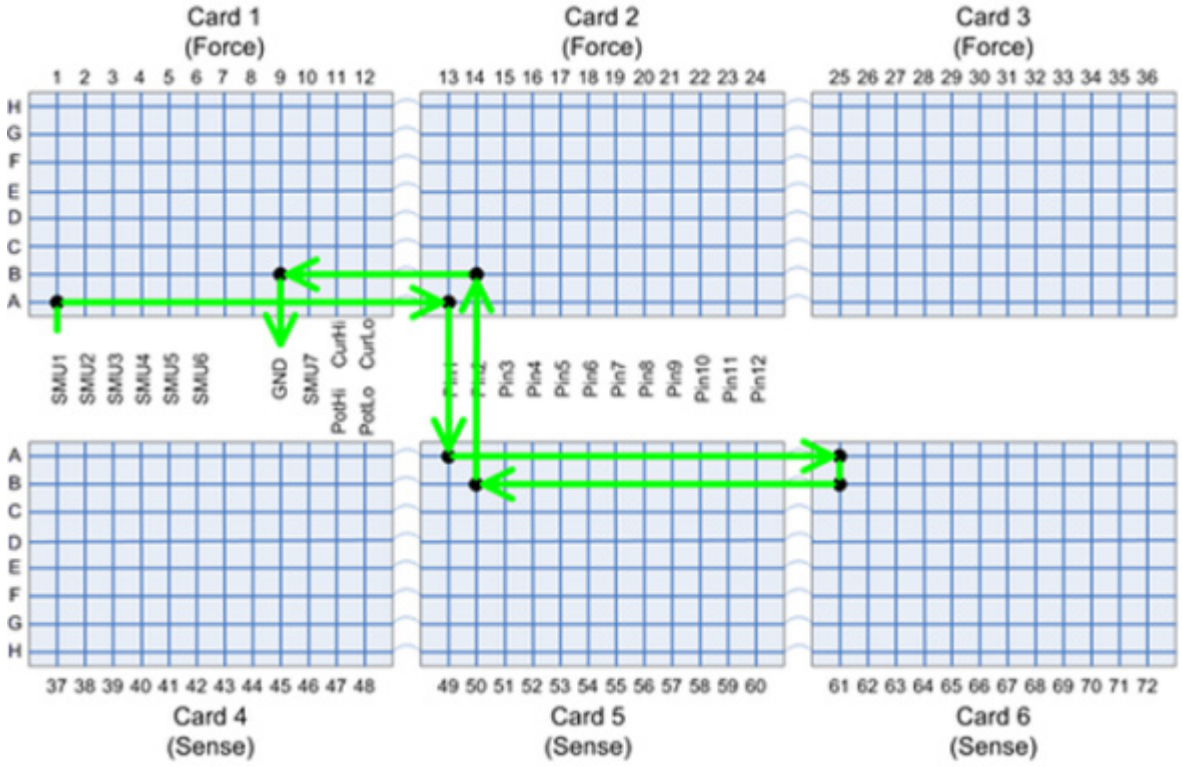
The Test sequence measurement details shows the measurement and evaluation details of the test.

Figure 9: Sense Card 5 and Card 4 isolation relays



The matrix connections used to validate the isolation relays for pathway A and B between cards 5 and 6 are shown in the next figure.

Figure 10: Sense Card 5 and Card 6 isolation relays



Once testing has completed for card 6 you can determine if the row isolation relays are good. If both card 4 and card 6 tests are good, then card 5 is also good.

If the card 5 to card 4 tests fail and the card 5 to card 6 tests are good, then card 4 should be replaced.

If the card 5 to card 4 tests are good and the card 5 to card 6 tests fail, then card 6 should be replaced.

If the card 5 to card 4 tests fails and the card 5 to card 6 tests fails, then card 5 should be replaced.

Force-side column isolation relays

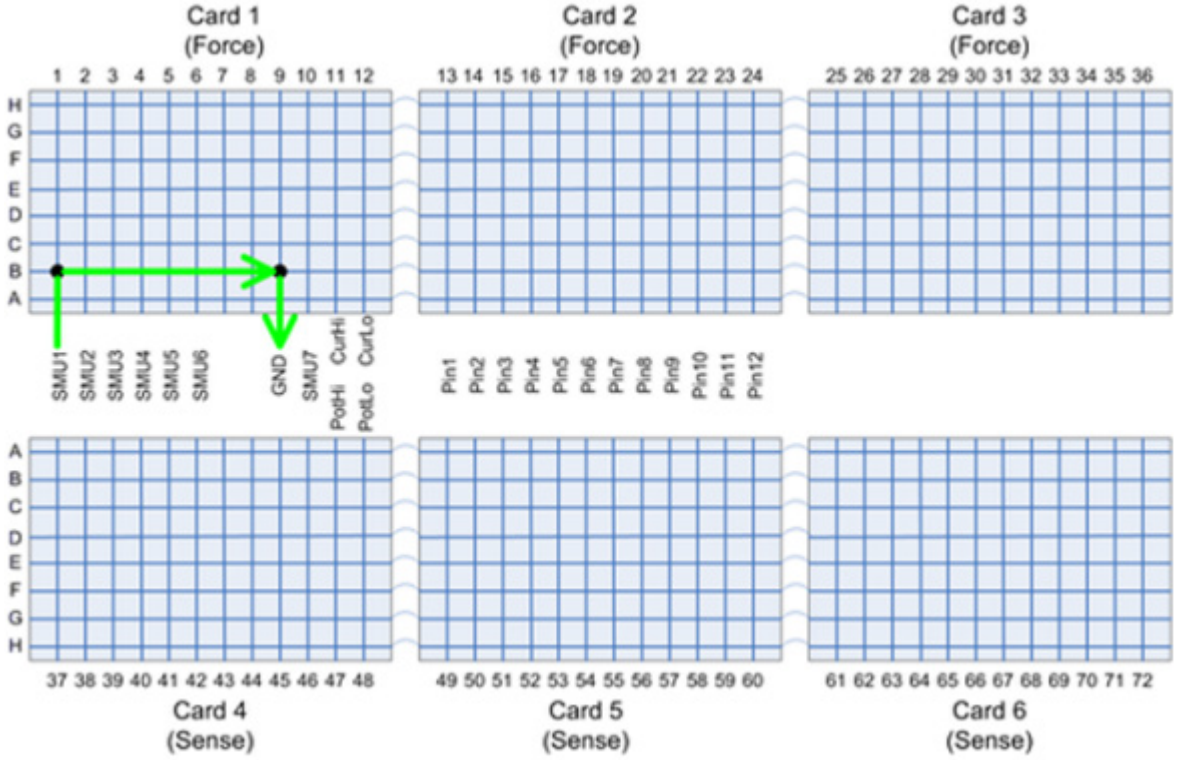
NOTE

This test is for the Model 7072-HV cards only.

This test measures and validates that the column isolation relays are operating correctly. At the start of the test, the minimum number of Kelvin connections is detected and the SMU used is tested to ensure it can force current into the GND connection. This test checks for proper isolation relay operation by using a SMU to force current through various pathways into the GND connection.

The next figure shows the matrix connection for testing pathway B. SMU1 is configured with a voltage limit of 5 V and forces 1 mA of current. Current flowing out of SMU1 is measured and compared with 1mA. If the current measurement is correct, pathway C is tested using the same procedure.

Figure 11: S530 Diagnostics Force-side column isolation relay (pre-test)



Test sequence measurement details

The next figure shows the matrix connection for testing pathway C. SMU1 is configured with a voltage limit of 5 V and forces 1 mA of current. Current flowing out of SMU1 is measured and compared with 1 mA. If the current measurement fails, the column isolation tests cannot execute because both pathways (B and C) are not verified. Once both pathways are verified, the actual column isolation relay tests can begin.

The column isolation relays are tested by configuring a circuit in the matrix to have current flow through a column across pathways B and C.

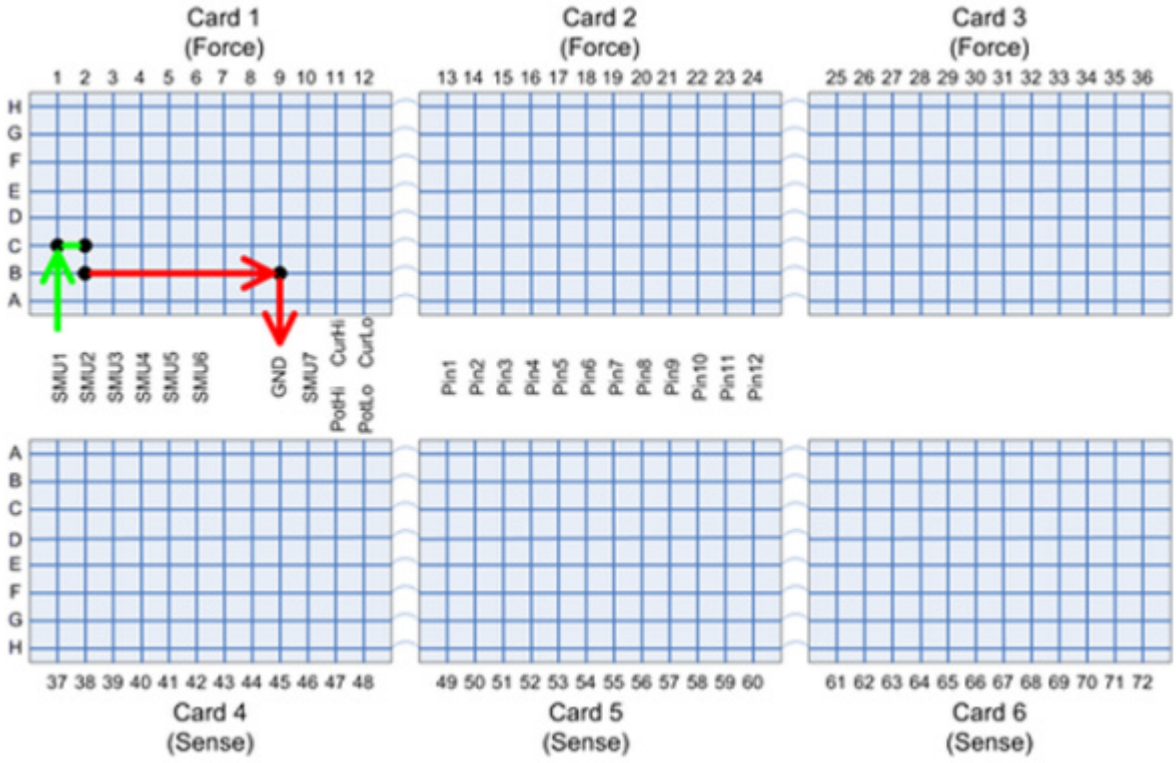
The test sequence used is as follows:

```
Close relay(s)
limitv(SMU1, 5.0)
forcei(SMU1, 1e-3)
delay(25)
measi(SMU1, current)
measv(SMU1, voltage)
ohms = voltage/current
If ((current > leakageLimit) || (voltage > voltageLimit))
   We have an error
devint()
```

The previous test sequence is repeated for all of the columns in the matrix cards 1, 2, and 3.

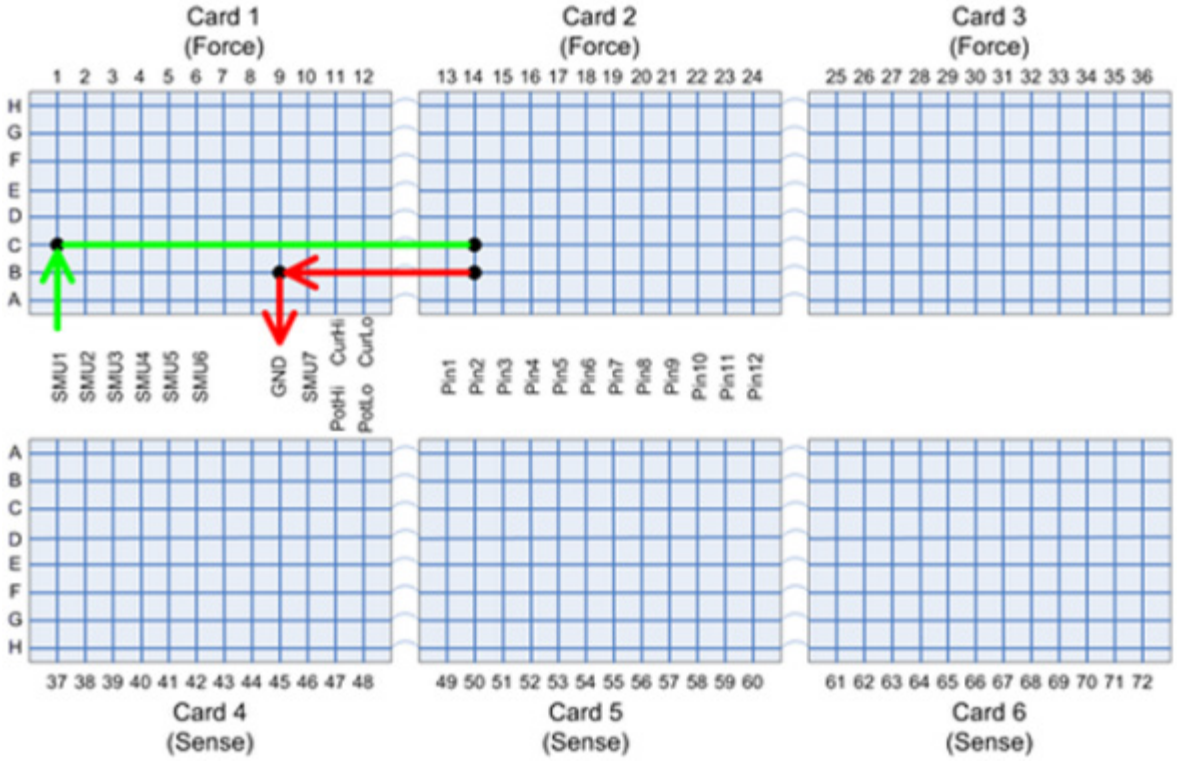
The next figure shows the matrix connection used to validate the column isolation relay for column 2. The red path shows where current should not flow due to the isolation relay being open. This is expected behavior.

Figure 12: Force-side column 2 isolation relay test



The next figure shows the matrix connections used to validate the column isolation relay for column 2 on card 2.

Figure 13: Force-side column 2 on Card 2 isolation relay test



Sense-side column isolation relays

NOTE

This test is for the Model 7072-HV cards only.

This test measures and validates that the column isolation relays are operating correctly. At the start of the test, the test validates that the minimum number of Kelvin connections are available and that Card 4 pathways B and C are functional.

The next figures show the matrix connections used to validate that pathways B and C are functioning correctly. Note that these tests are performed with the SMU in 4-wire mode and the pathway shown in blue in the figures is to provide a valid Kelvin-to-ground connection within the low-patch panel.

Please note that SMU2 is used to test column 1 on card 4. This is necessary to avoid interaction with the SMU1 sense input.

Figure 14: Sense-side column isolation relay (pre-test pathway B)

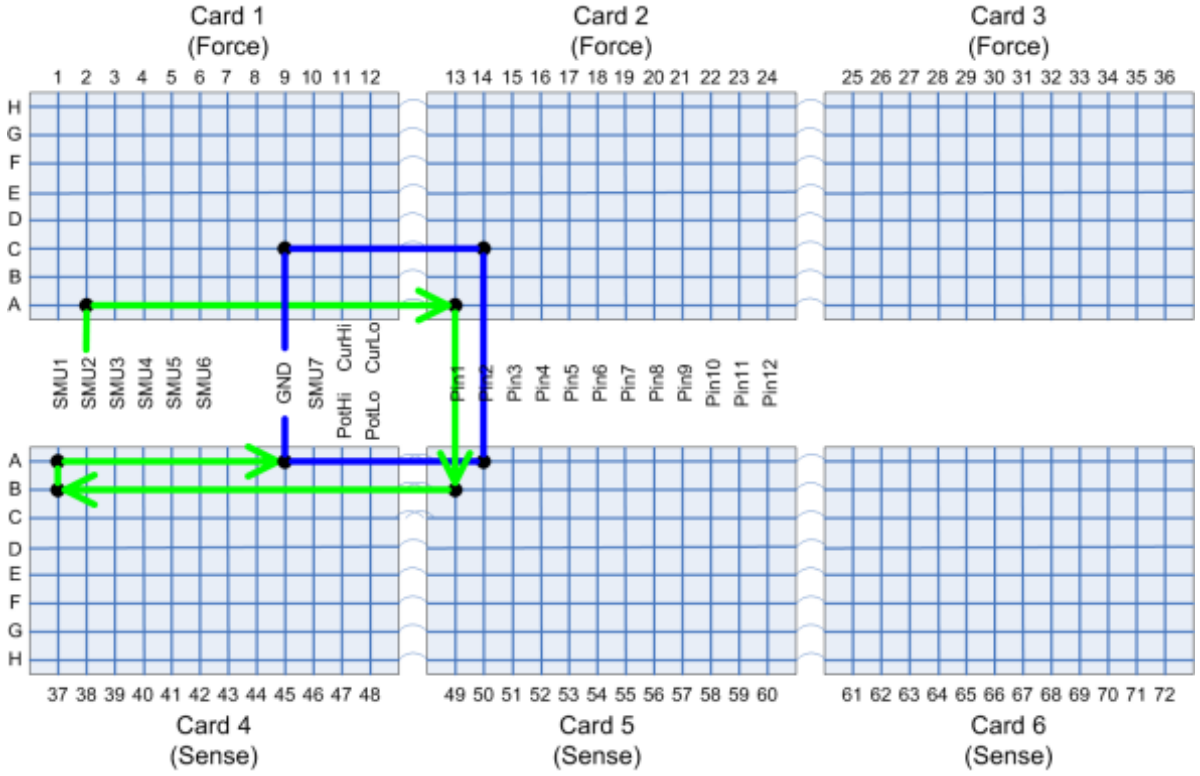
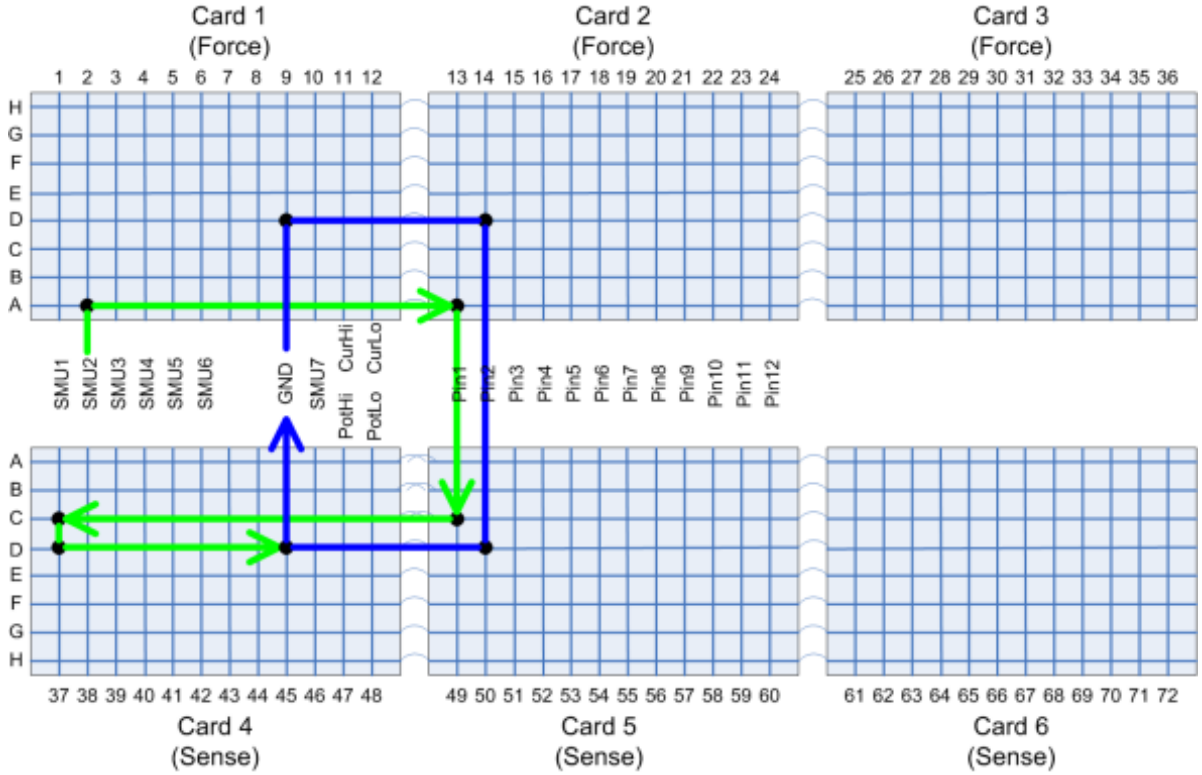


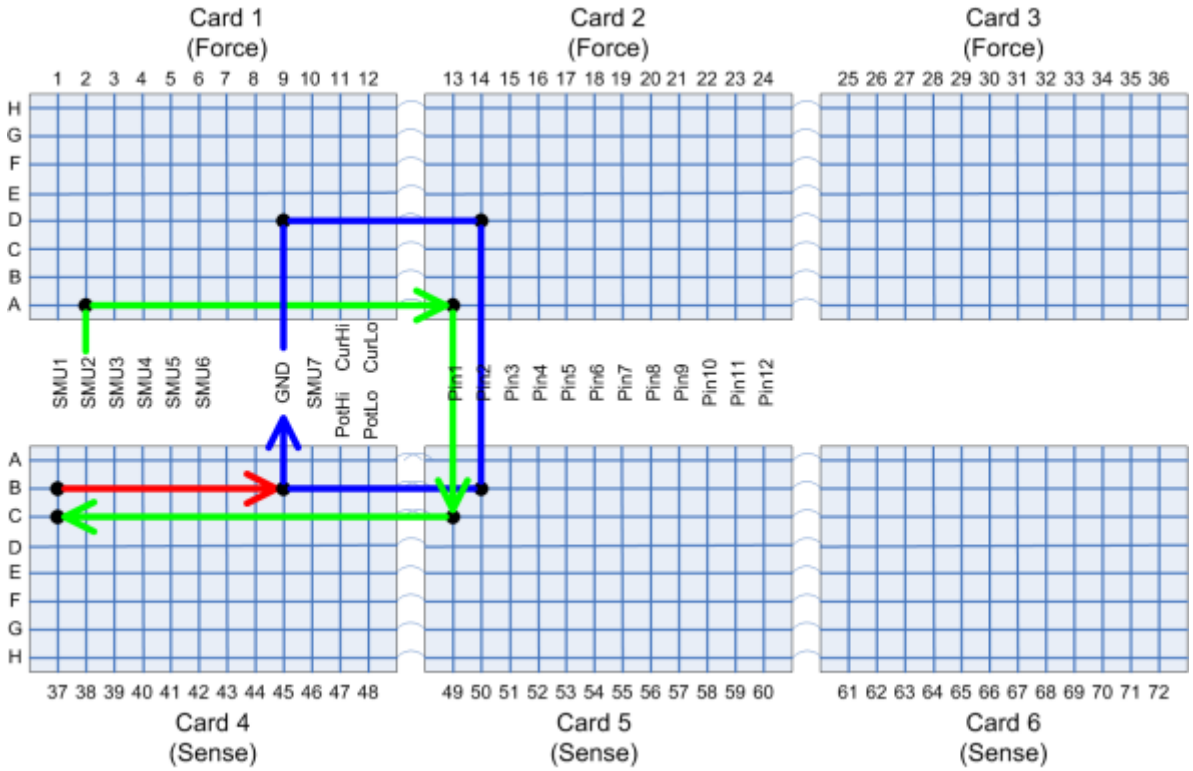
Figure 15: Sense-side column isolation relay (pre-test pathway C)



Once valid pathways are confirmed, the column isolation relay test may be run.

The next figure shows the matrix connection used to test the isolation relay for column 1 on matrix card 4.

Figure 16: Sense-side column isolation relay test



The previous test sequence is repeated for all columns in matrix cards 4, 5 and 6.

Column isolation relay driver test

NOTE

This test is for the Model 7072-HV cards only.

The twelve columns on a card are divided into four groups of three for control. If all three of the relays in the group need to be engaged at one time and the control circuitry is damaged, some or all of the relays in the group will not close properly. This test will detect if any relay is not closed.

The 7072-HV matrix card contains isolation relays for each column between pathways B and C. This column isolation relay will open if the relay on pathway A or pathway B is closed in order to protect the low-voltage part of the matrix card. This column isolation relay will open if any relay on pathways C through H is closed.

The driver circuitry for these isolation relays can sometimes be damaged, which will cause intermittent behavior of the matrix card. The following test was created to help you identify if the driver circuit has been damaged.

NOTE

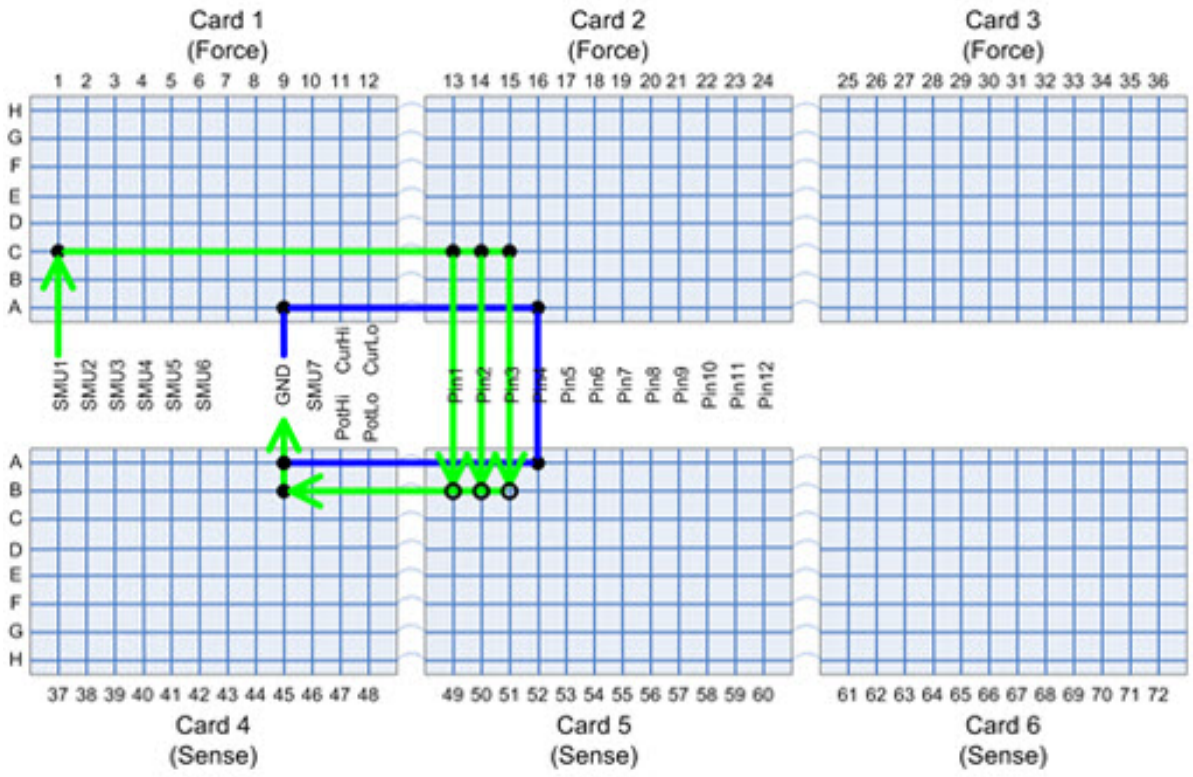
All of the configured pins in the system must have a valid Kelvin connection. If the system does not have a valid connection, the column isolation relay test will not execute.

Force-side isolation relay driver test

In the next figure, pin 4 is used to make a Kelvin connection for the GND unit. SMU1 is used to connect to pins 1, 2, and 3 using pathway C. These connections should cause the isolation relays to close for the pin columns. Pathway B on the sense-side card is used as the return-path for the current that will be forced from the SMU.

The next figure shows the connections for pins 1, 2, and 3.

Figure 17: S530 Force-side relay driver test A

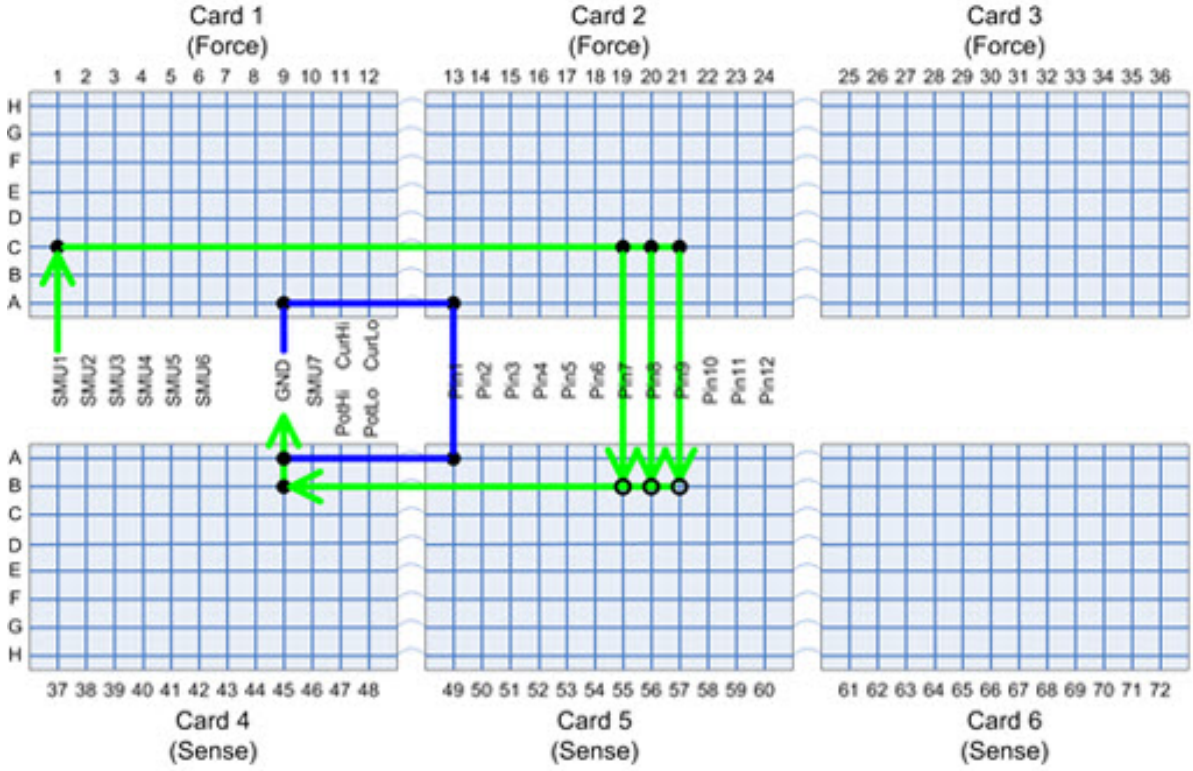


The relays on pathway B on card 5 will be closed and opened, one at a time, and current flow will be measured by the SMU.

For example, the relay on column 49 will be closed, and SMU1 will force 1mA of current. If the isolation relay driver circuitry is working correctly, current will flow from the SMU to GND. The SMU will be turned off, the relay opened, and the next relay (column 50) will be closed. The process will be repeated for all three relays in each set.

The GND Kelvin connection will be moved to pin 1 after the first test set has completed, as shown in the next figure (this figure shows the connections used for testing pins 7 through 9).

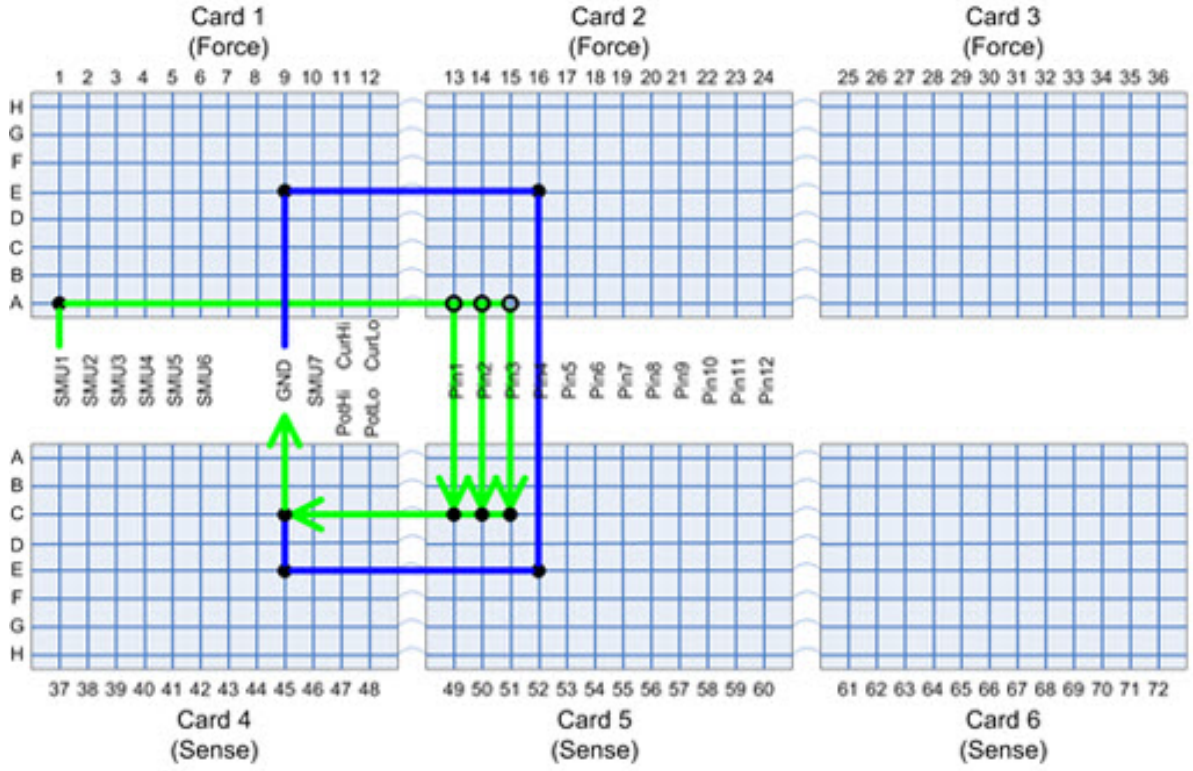
Figure 18: S530 Force-side relay driver test B



Sense-side isolation relay driver test

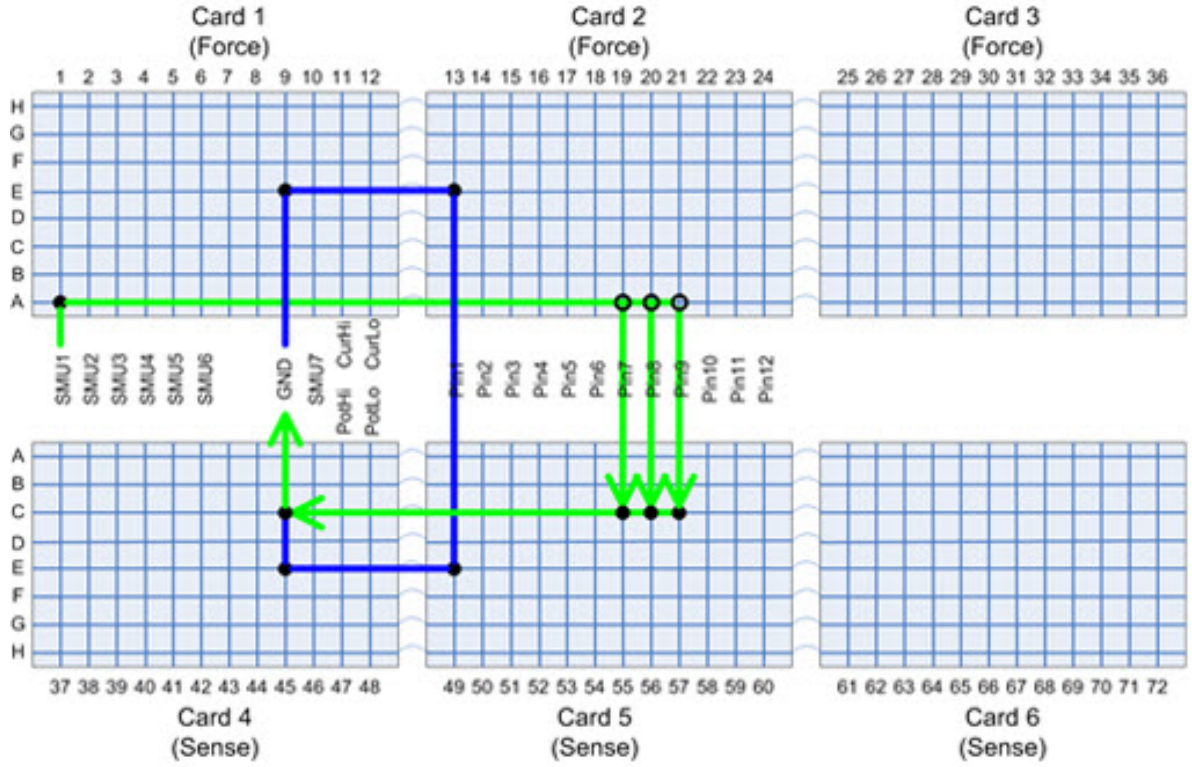
The sense-side isolation relay driver test of the matrix will be tested next. A similar scheme will be used, except the connections will be slightly different, as shown in the next figures:

Figure 19: S530 Sense-side relay driver test A



Pins 1 through 3 on the sense card are tested with pin 4 being used for the GND connection. Each of the three relays on columns 13, 14, and 15 will be closed and opened, one at a time, to test the isolation relays on the sense card.

Figure 20: S530 Sense-side relay driver test B



Pin 1 will be used for the GND connection for the remaining pins on the sense cards.

Force-side relay tests

Connect and test various pathways to validate the force-side of the matrix.

- The eight rows of the matrix are processed as four groups of two: A to B, C to D, E to G, and F to H. These are split to compensate for the Model 7072HV isolation relays and CV pathways.
- Two relays from a column are tested at one time; one relay from each row of the current group

NOTE

Prior to testing the relays, the routine will determine that two 2636 SMUs operate correctly and connect to all matrix pathways.

- The SMUs are placed into 2-wire test mode for this matrix test.
- Connect a circuit from a forcing SMU to GND.
- Force 1 mA and measure voltage/current with the SMU (voltage limit set to 5 V).

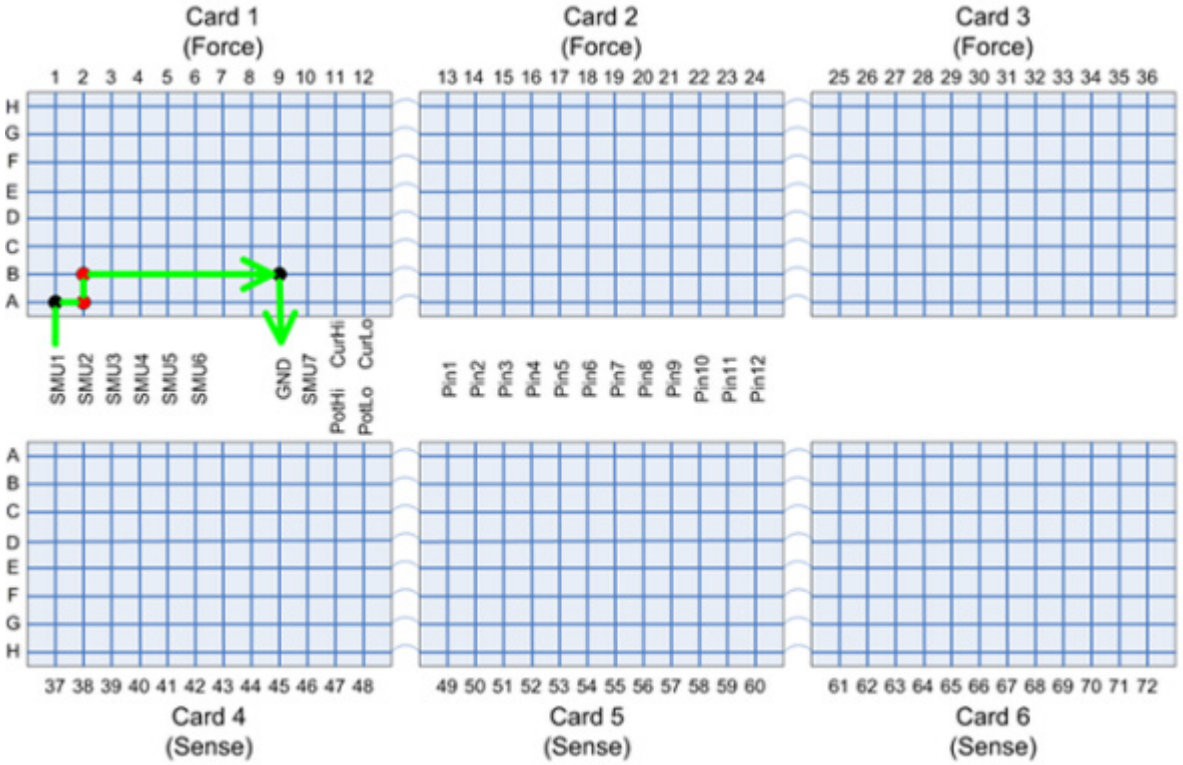
Force-side relay test details

- Two relays from a column are tested at one time, with an open-test or close-test approach similar to the force-side row isolation tests:
  - Close both relay 1 and relay 2 and measure (should pass).
  - Open relay 1 and measure (should fail).
  - Close relay 1 and measure again (should pass).
  - Open relay 2 and measure (should fail).
  - Close relay 2 and measure again (should pass).
  - Open relay 1 and relay 2. The tests for this relay pair are complete.

The next figure shows the two relays in red that are being tested with the open and close process described in the steps above. In both, the Status and Result logs, each relay closure is described by a set of numbers and letters to show the card, row, and column. For example, 1A01 is Card 1, Row (or path) A and Column 1. Note that the column numbers in the results log are card-based, not system-based. The figure shows the connections:

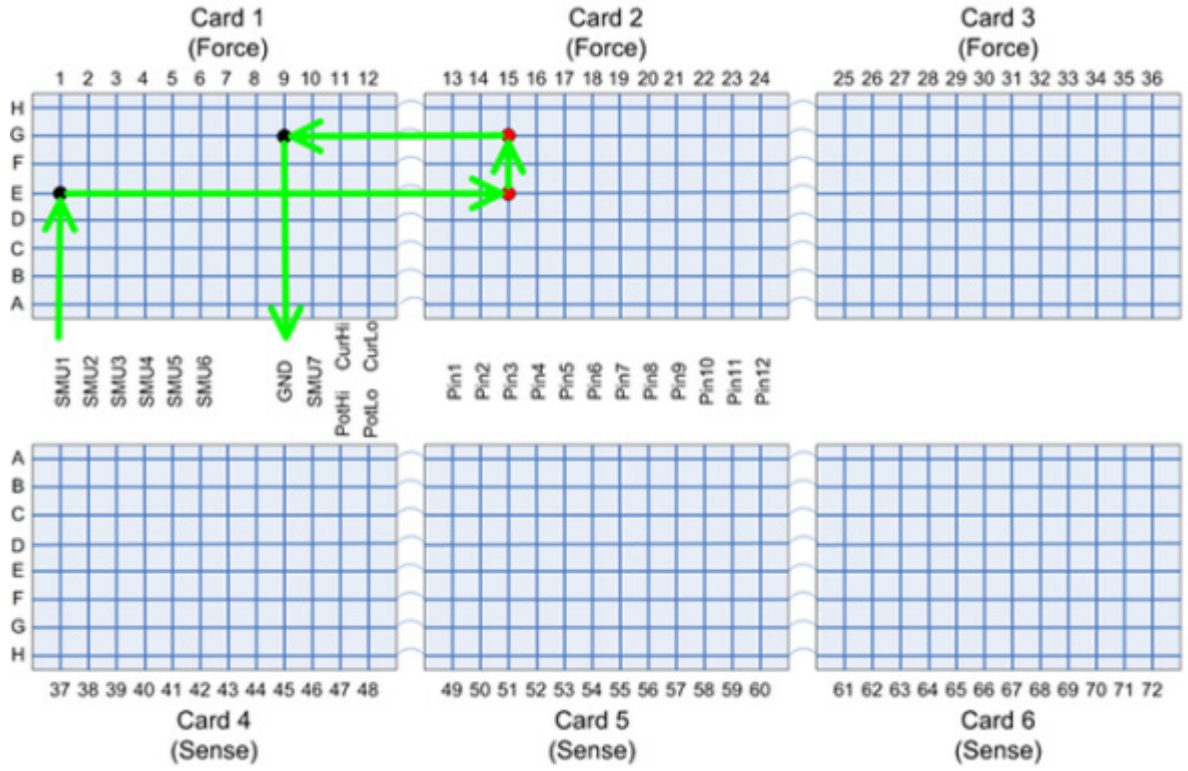
SMU1 1A01,1B09, 1A02,1B02

Figure 21: Testing force-side relays on Card 1



The next figure shows a later step in the 2-wire relay test.

Figure 22: Testing force-side relays on Card 2



Model 7072-HVD matrix card discharge circuit test

NOTE

This test is for the Model 7072-HVD cards only.

A SMU is connected to a pin and a special routine is executed on the SMU to force 5 volts and take a series of background measurements. While these measurements are being taken, a relay is toggled on the matrix card, causing the discharge circuit to engage. Another special routine is executed on the SMU to analyze the measured data. The data results should be at 5 volts and then go down to 0 volts while the discharge circuit is engaged. Once the discharge circuit turns off, the voltage level should go back to 5 volts. The test is repeated for -5 volts. This completes the test for the pin.

All pins are checked, both on the force-side of the matrix as well as the sense-side of the matrix, to provide coverage for all matrix cards used for pin connections.

The 7072-HVD matrix card provides a hardware mechanism to discharge any stored energy in the cables or DUTs connected to the card. Whenever a relay changes state on the card, a special circuit is engaged to discharge the path before the relay will open or close. This will prevent any hot-switching from occurring and prevent damage to the relay.

Sense-side relay tests

NOTE

This test does not apply to the Model 7530 matrix card.

These tests will connect various pathways to validate the relays on the sense-side of the matrix (cards 4-6).

- Similar to the connection/test scheme used for 2-wire mode except that the sense-side of the matrix is tested.
- Requires the use of the Kelvin pin(s) used earlier in testing.
  - Kelvin Pin 1 is used to allow current to flow from the SMU into the sense-side matrix
  - Kelvin Pin 2 is used to allow for a valid ground connection in the low-patch panel.

Before the sense-side testing begins, the routine checks for the type of protection module that determines the methods used to perform the sense-side relay testing. The next figures show examples of matrix connections for the sense-side relay testing.

Figure 23: Sense-side relay testing example 1

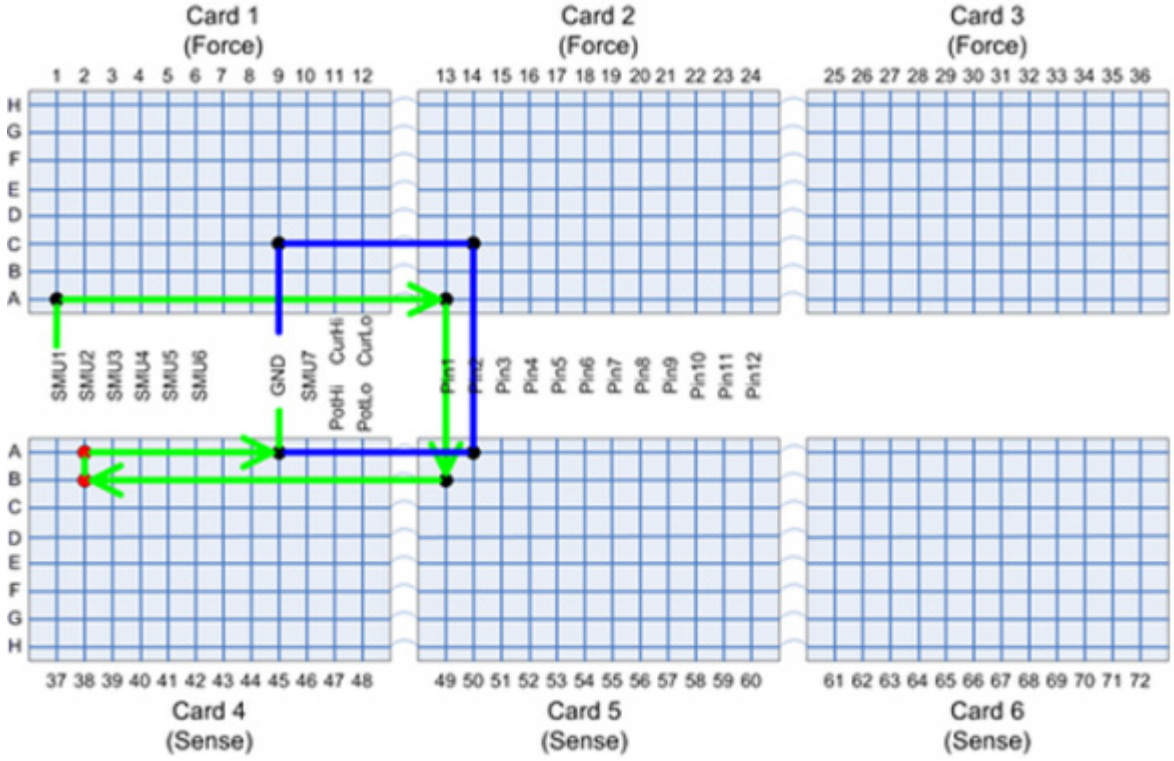
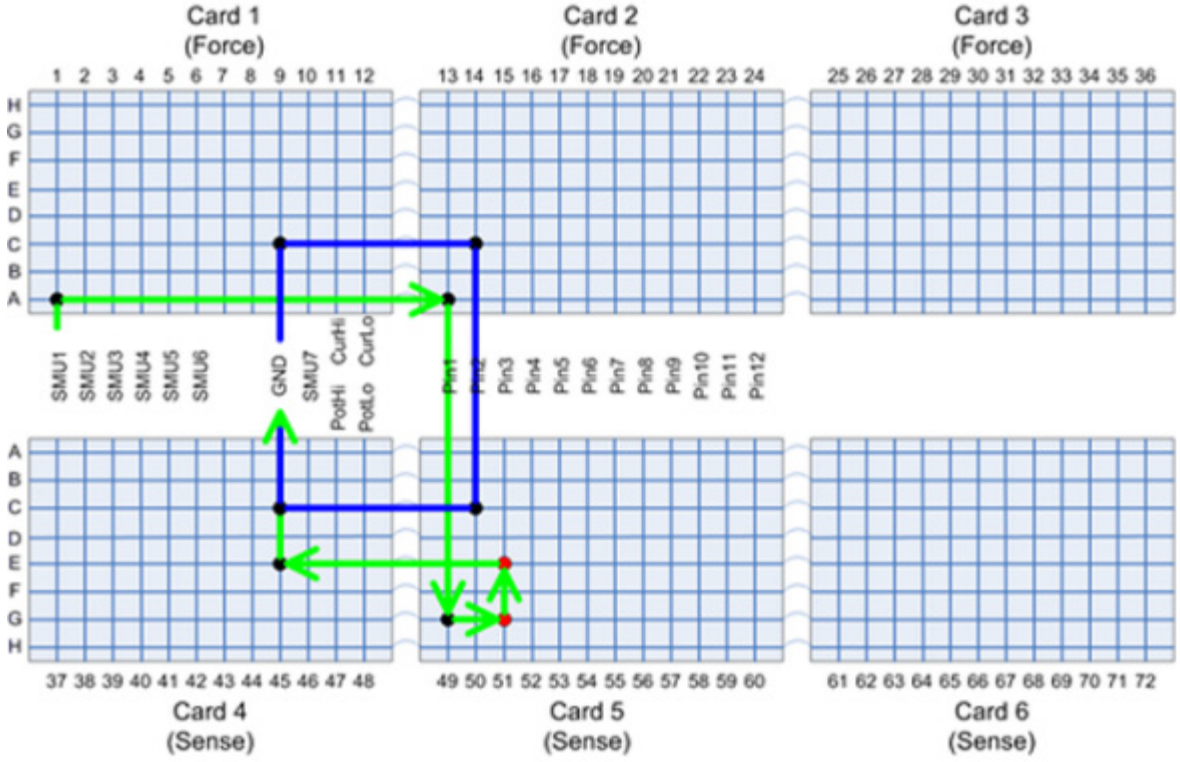


Figure 24: Sense-side relay testing example 2



NOTE

The discharge circuit test occurs after both the force-side and sense-side matrix tests have completed. The discharge circuit test will only execute if the 7072-HVD cards are installed and used for pin connections

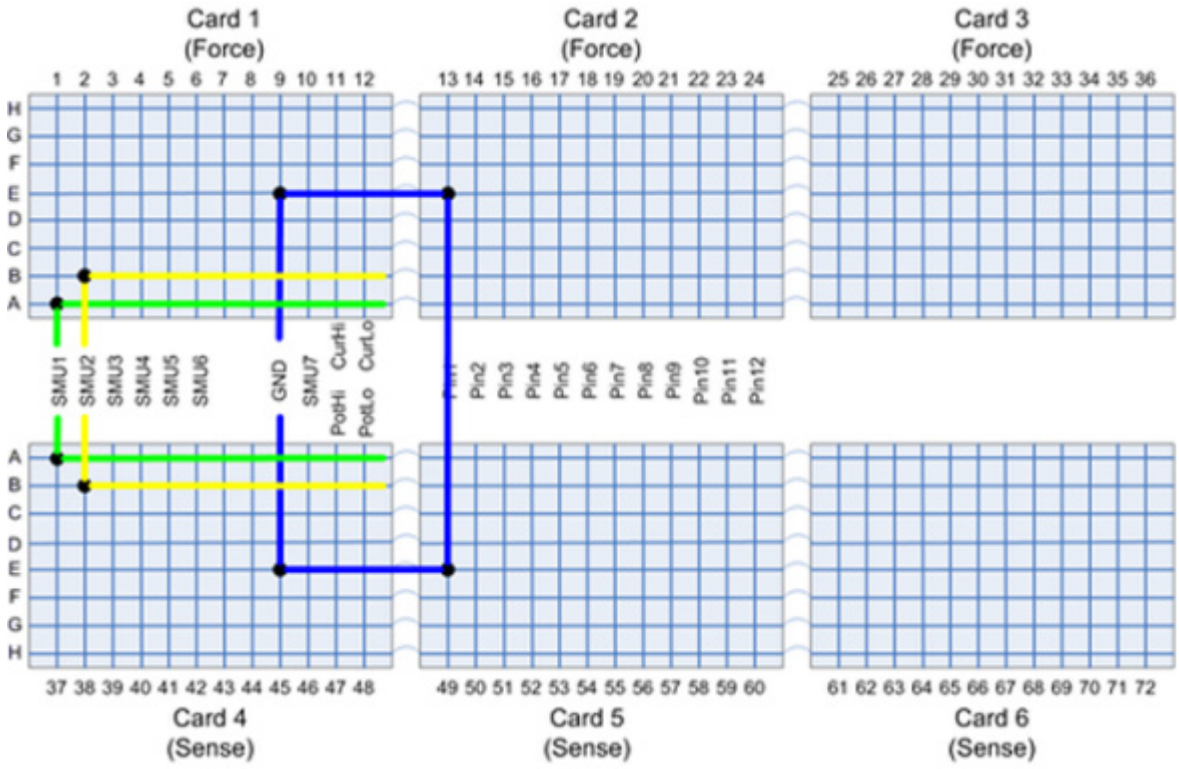
Matrix leakage test

There are two parts to the matrix leakage test. The first part looks for leakage or shorts between adjacent pathways. The second part looks for leakage or shorts on the guard signal of the pathways.

The first matrix leakage test will detect if there is a short between adjacent matrix pathways. Two SMUs are used: a forcing SMU and a measuring SMU. The SMUs are connected to the matrix in 4-wire mode and the forcing SMU will force 180 V on the low current systems (systems with 7530 or 7174 matrix cards). For high voltage systems (systems with 7072-HV or 7072-HVD matrix cards), either 180 V or 900 V will be applied. The measuring SMU will measure the current on the adjacent pathway. A measurement higher than the leakage threshold, which varies by system type (see Results information for specific leakage limits) is a failure. The force and measure SMUs are swapped and the force/measure sequence is repeated. Pathway F to G and F to H are used as adjacent pathways on the Model 7072HV cards.

The next figure shows the matrix connections for testing pathway A and B with SMU1 and SMU2. The green path shows the forcing SMU and the yellow path shows the measuring SMU. The blue pathway is the ground connection needed for a valid Kelvin 4-wire configuration.

Figure 25: Pathway shorts test for Pathway A to B



For the second part of the matrix leakage test, a quasi-static capacitance measurement, requiring one SMU, is used to test for potential shorts to the guard signal.

- Force 1nA current into a matrix pathway
- Delay 10 milliseconds
- Measure voltage and calculate the capacitance (1 nA * .010) / fabs(volts)

For the 7530 matrix, capacitance more than 50 pF is a failure for Card 1 and capacitance more than 80 pF is a failure for Cards 2 through 6.

For the 7072-HV matrix, capacitance values vary based on pathway and whether the tested pathway is within Card 1 parameters or across cards. For pathways A and B, the capacitance values are the same as the 7530/7174 capacitance failure. For the other pathways, the values are three times larger.

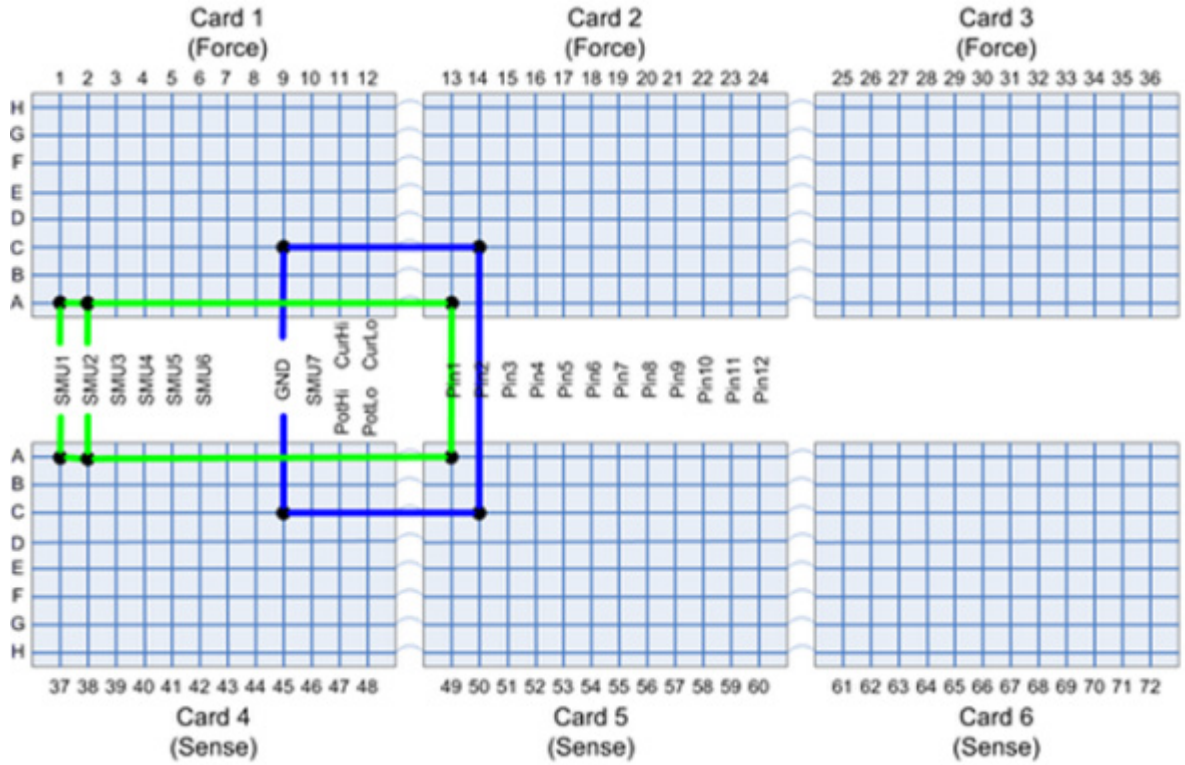
Matrix continuity test

This test measures the resistance of the pathways to make sure that relay contacts are working properly. It repeats the following sequence for each pathway:

- Use two SMUs connected together on a pathway
- SMU1 forces 1 mA (20 V compliance), SMU2 forces 0 V
- Measure current and voltage on SMU1 and calculate resistance

Results: Any resistance greater than 2 Ohms is a failure.

Figure 26: Pathway A continuity test connection



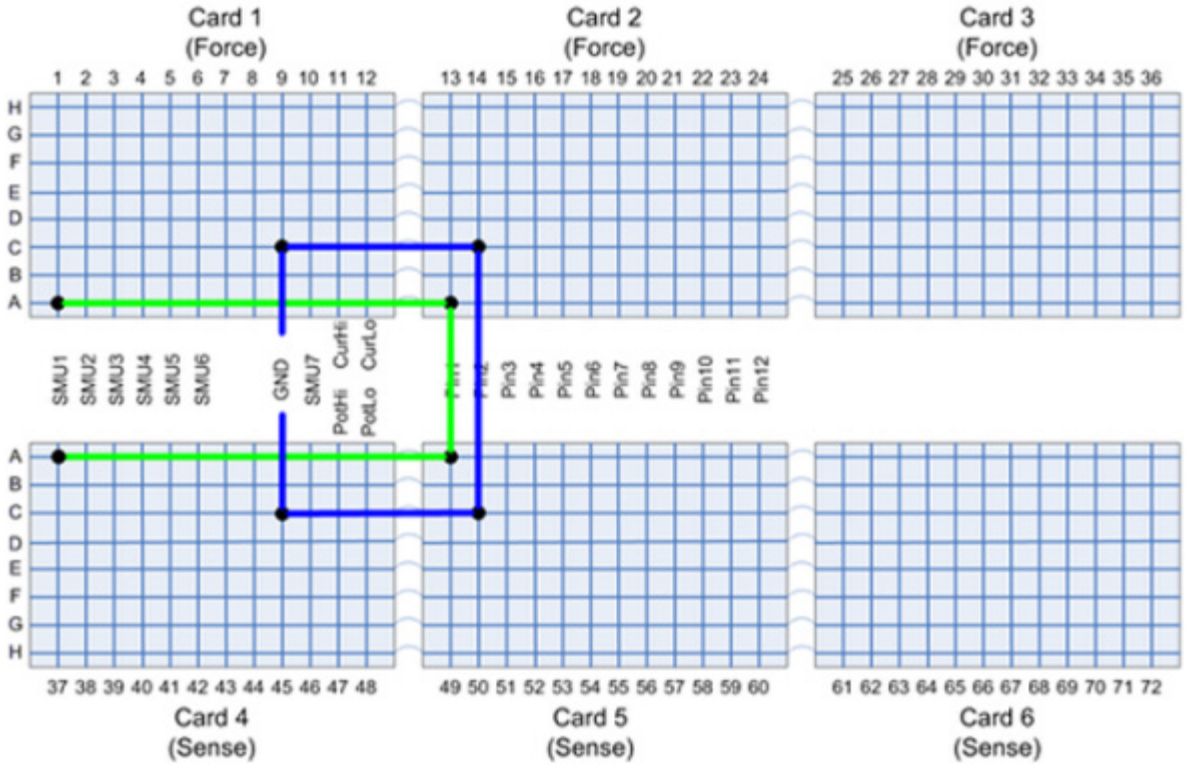
Kelvin pin tests (four-wire systems only)

The diagnostic test determines which pins have and which pins do not have a valid Kelvin connection. The Model 2636A/B SMUs have a built-in contact test feature that is used to determine if a Kelvin connection is present. The diagnostics software will connect the first SMU with the first pin using matrix pathway 'A.' If a valid Kelvin connection exists, the same SMU/pin pair is connected again using the next matrix pathway. This loop is repeated for each pathway. If all of the pathways can supply a valid Kelvin connection, then this SMU/pin pair is good. This process is repeated for all of the configured pins. Once all of the pins have been tested for the first SMU, the remaining SMUs are tested using only Pin1 with all of the pathways since the other pin combinations were previously tested with the first SMU.

If any of the configured pins do not have a valid Kelvin connection, the test will fail. However, as long as there are two good Kelvin pins, the remaining diagnostic tests will continue even with other Kelvin pin failures, since only two pins are needed for the later tests.

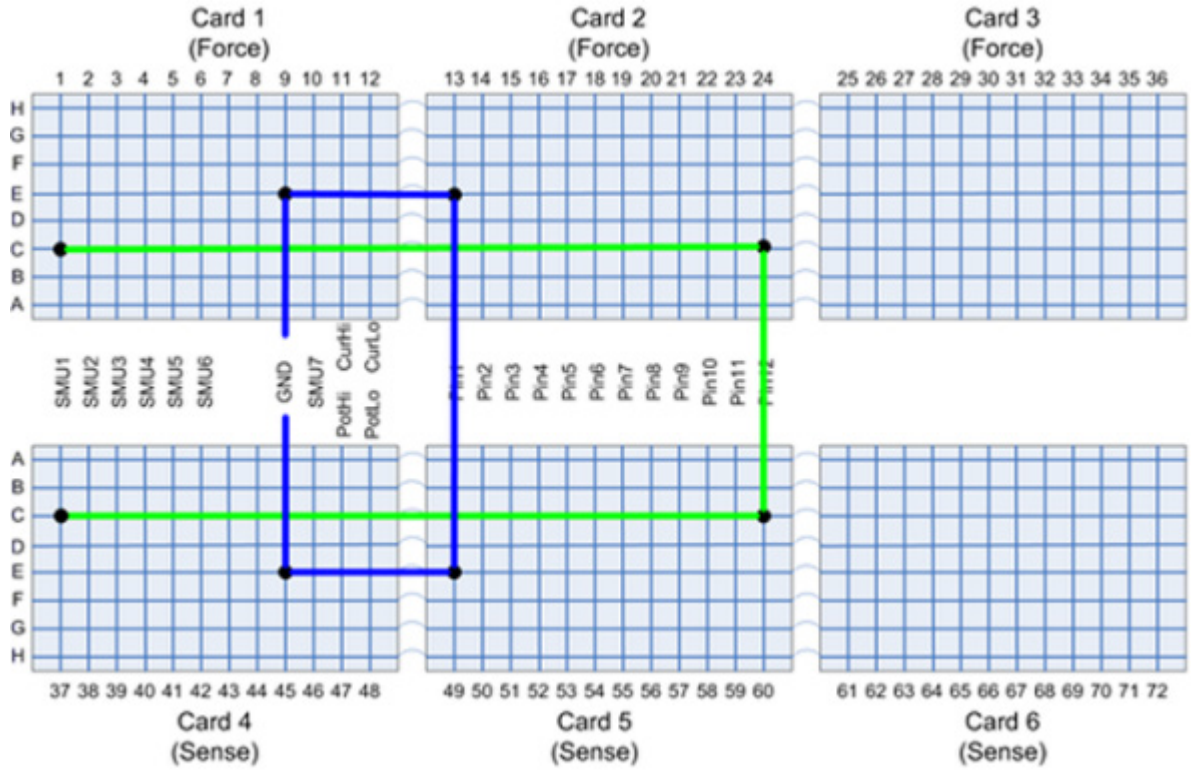
The next figure shows SMU1 and Pin1 connected together during the Kelvin-pin detection. The blue pathway shows Pin2 connected to GND to complete the lo/sense-lo portion of the Kelvin connection. Matrix pathway 'C' is used for this GND connection, unless the SMU/pin connection conflicts. If so, then the matrix pathway 'E' is used.

Figure 27: S530 SMU1 and Pin1 connected



The next figure shows SMU1 and Pin12 connected together during the Kelvin-pin detection. The blue pathway shows Pin1 connected to GND to complete the lo/sense-lo portion of the Kelvin connection. In this example, matrix pathway ‘C’ is being tested for Kelvin operation and matrix pathway ‘E' is used for the GND connection.

Figure 28: S530 SMU1 and Pin12 connected



This Kelvin pin-connection test can be individually run to validate connections from the system to the probe card, which is useful after a probe card change or re-cabling. See the Matrix tab for information on how to configure the diagnostics software to run this test.

Pin leakage test

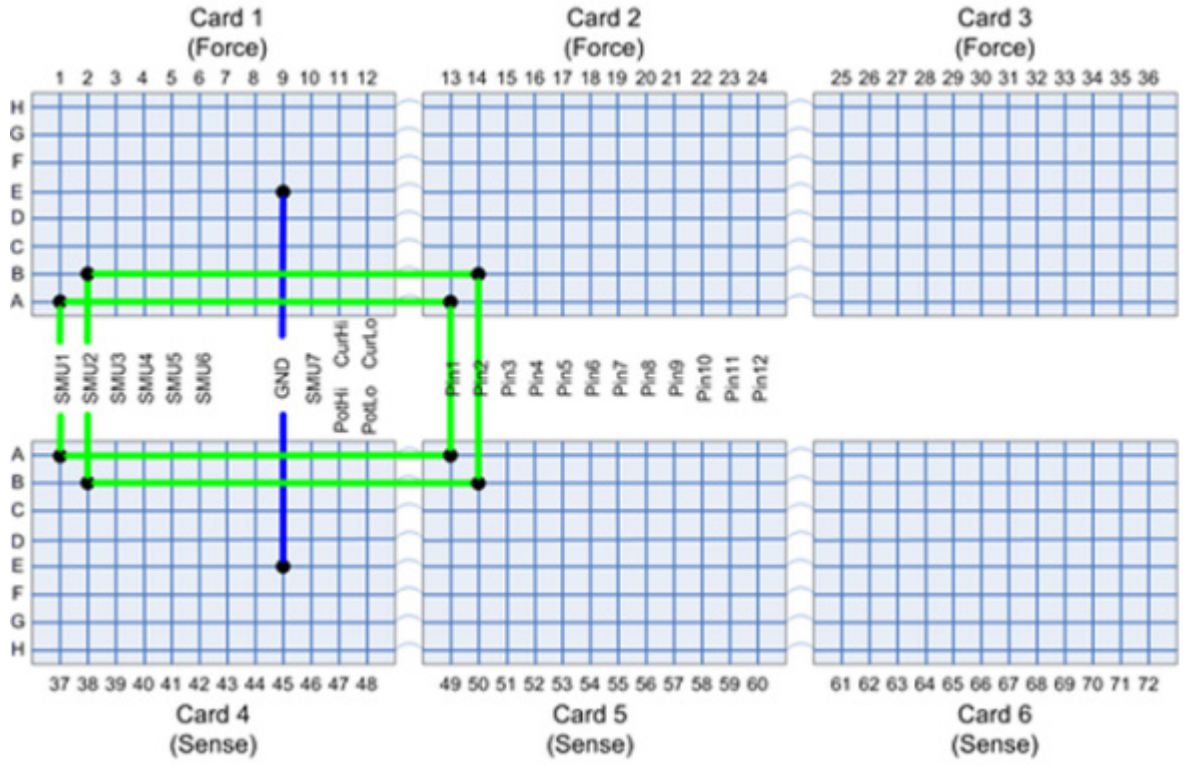
Similar to the matrix leakage pathway tests, there are two parts to the pin leakage tests. The first part looks for leakage, or shorts, between adjacent pathways. The second part looks for leakage, or shorts, on the guard signal of the pathways. Using the first two good pathways, in the 'good pathway' list, created from the previous matrix leakage and continuity test; perform the following test on the adjacent Kelvin pins, shown below in pseudo-code:

```
conpth(goodPath1, forcingSMU, pinA, 0)
conpth(goodPath2, measSMU, pinB, 0 )
conpth(altPathway, GND, 0 )

forcev(measSMU, 0.0)
forcev(forceSMU, 50.0)
rangei(measSMU, 10e-9)
setmode(KI_SYSTEM, KI_INTGPLC, 5.0)
delay(8000)
intgi(measSMU, leakage)
```

Results: If the leakage is greater than 10 nA, this is considered a failure.

Figure 29: Pin 1-2 leakage test connection



Note that the pin-guard test is similar to the pathway shorts test where a quasi-static, SMU-based capacitance measurement is used to test for guard-to-ground shorts. The maximum capacitance value is 150 pF.

SMU tests

Voltage and current range

The SMU range tests are used to verify that each SMU can force and measure properly on each of the available voltage and current ranges.

The $KIDAT/diag_limits.ini file contains a list of SMU models supported and their voltage and current ranges. Each current and voltage range will be tested at ±90% and ±10% of range.

NOTE

The KI2410 SMU will only force +/-190V for the 1000V 90% value.

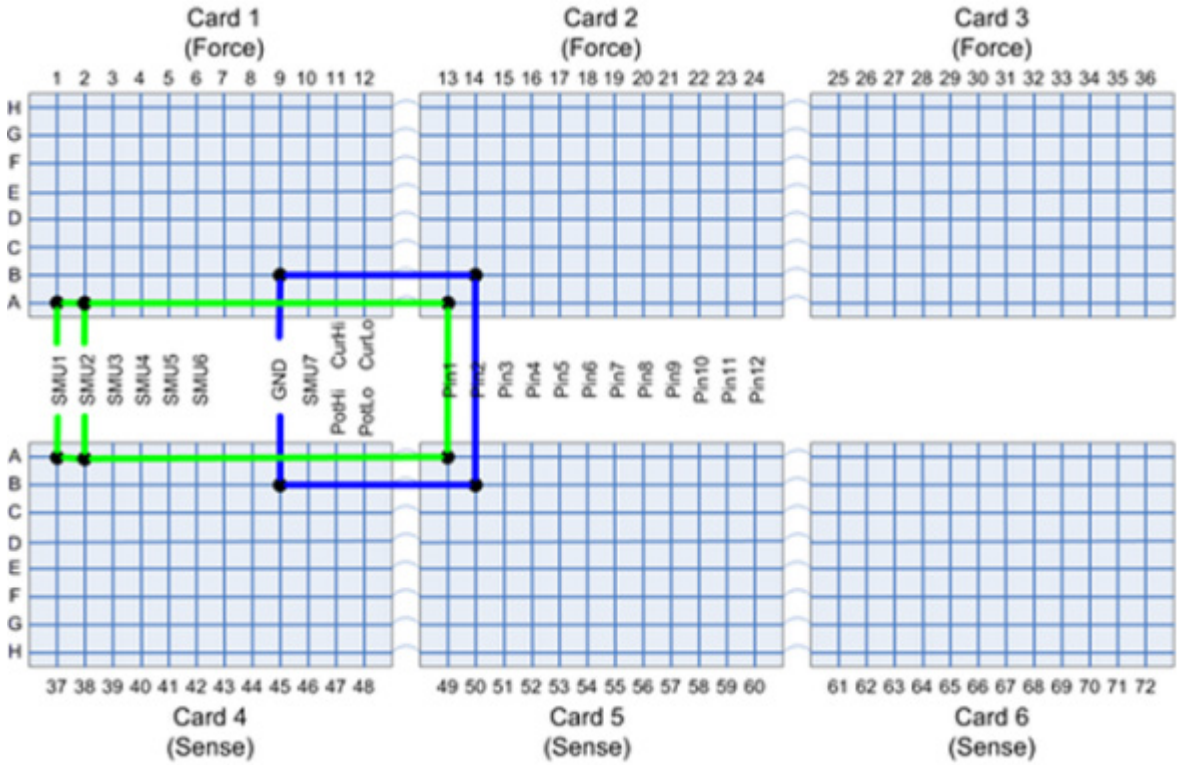
The range test will use two SMUs: the forcing SMU (SMU under test) and the supporting SMU.

Each SMU will be set to the appropriate range (200 V max for the Model 2636A/B measure SMU), and the forcing SMU will both force the appropriate value and then measure itself. The supporting SMU will also measure the value and the two measurements will be compared against the limits specified in the $KIDAT/diag_limits.ini file for the range. If the readings are within the limits, the test will pass, otherwise the test fails.

The test order for a range is a follows: +10%, +90%, -10% -90%.

The next figure shows the matrix connection used to test the ranges for SMU1. And SMU2 is used as the measuring SMU for this test.

Figure 30: SMU range test connection



Other instruments (pulse, capacitance, digital meter, scope)

Capacitance meter (CMTR)

Perform the following test on the CMTR:

1. Take impedance measurement across an open and a short. If the ratio of these measurements < 1000, the test fails.
2. Test of the CVU biasing capability. Force 28.3V and measure with a good SMU. If the measured value is within 2% of the forced voltage, the test passes; otherwise, the test fails. Force -5.6 V and repeat test.

Oscilloscope (SCP)

The scope test uses the built-in self-test of the Model 4200-SCP2HR card.

Pulse Generator (PGU)

Perform the following test on the PGU:

1. Create a 4V pulse and measure with a SMU.
2. Create a -4V pulse and measure with a SMU.
3. If the measured value is within plus or minus 1% of pulse height, the test will pass, otherwise the test fails.

Digital Multimeter (VMTR)

This test will force voltage on a known good SMU and measure the voltage with the VMTR. If the measured voltage is within plus or minus 2% of the forced value, the test passes; otherwise, the test fails. The test is repeated with the SMU forcing negative voltage.

Section 3

System Verification

In this section:

Introduction

The system verification routine(s) will test and measure the instruments against the specifications for the system. Whereas diagnostics will ensure that the instrumentation is operating, system verification will ensure that the instrumentation is operating within the system specifications.

Diagnostics must be executed before the system verification tests can execute. You will need to verify that the system is operational before you try to validate the specifications.

The result of the system verification test is a pass or fail. If the test fails you can use the diagnostics test results to troubleshoot the system.

NOTE

It is possible that the diagnostics test will pass and the system verification fails. This is because the system verification routine uses tighter acceptance limits for the tests. For the verification process to be valid, all instruments in the system must be within their calibration cycle, and not overdue for calibration.

The S530 system is tested during manufacturing and Keithley Instruments makes sure it conforms to its warranted specifications based on its data specification sheet. Each system is calibrated using measurement standards traceable to the International System of Units (SI) through the National Institute of Standards and Technology (NIST), or other National Metrology Institutes (such as NPL, PTB, etc.), and meets the requirements of standard ANSI/NCSL Z540-1-1994: Requirements for the Calibration of Measuring and Test Equipment.

The system verification procedure compares each SMU in the system to every other SMU using appropriate measurement practices. Assessment of the accuracy procedure is carried out through measurement uncertainty evaluations taking into account known major contributors ensuring failing decision risks are minimized.

An S530 that passes the system verification procedure conforms to its warranted specifications as stated on its data specification sheet provided its individual instruments are calibrated within the recommended annual calibration interval.

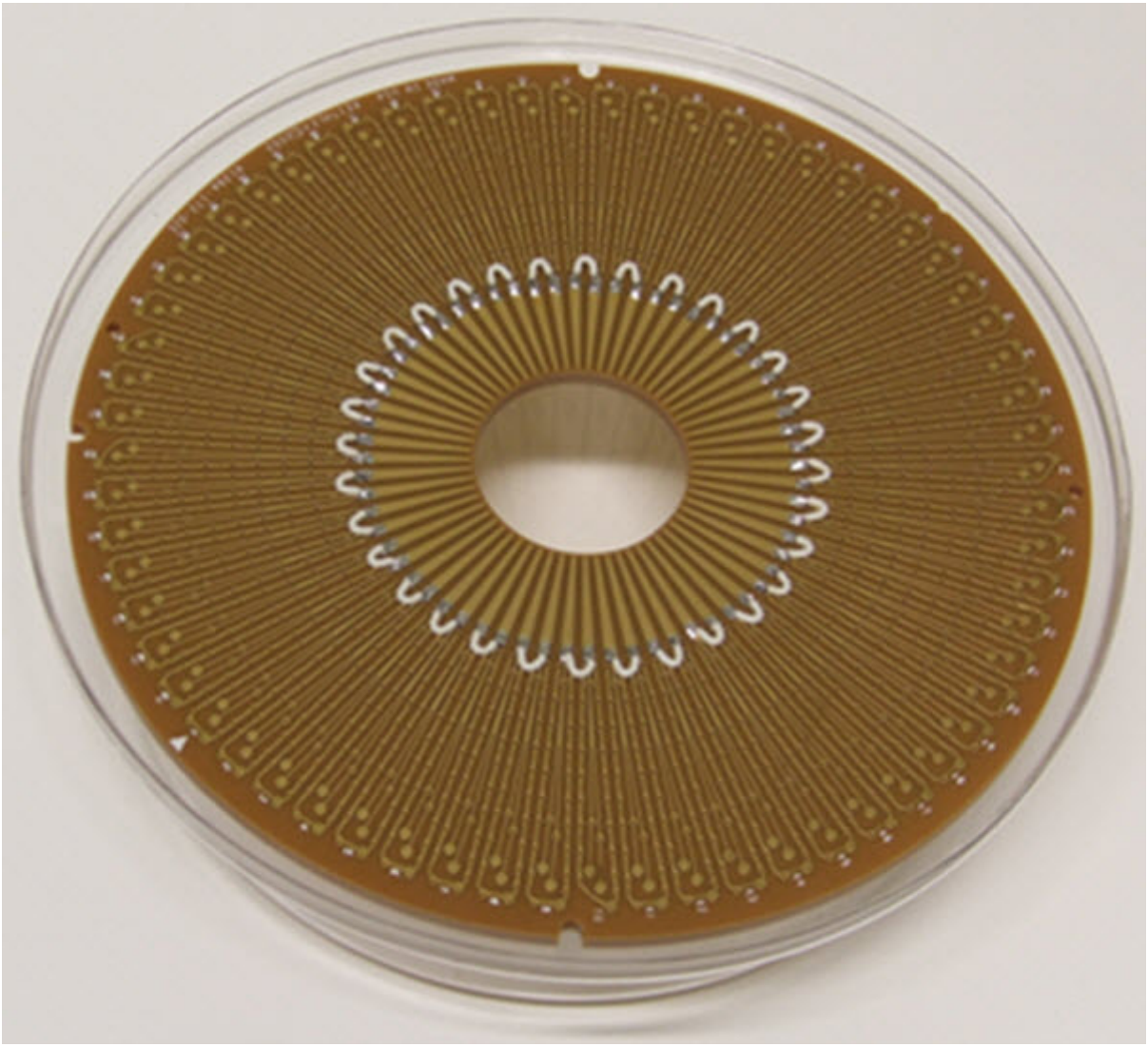
Keithley recommends annual calibration of the individual instruments and offers on-site calibration services.

Verification probe card

The system verification routines require the use of a special probe card that is included when ordering the 9139-PCA-xx with the S530 system. This probe card has pins shorted together to create pathways from the tester to the probe card and back to the tester. These pathways are used to verify tester performance against the system specifications.

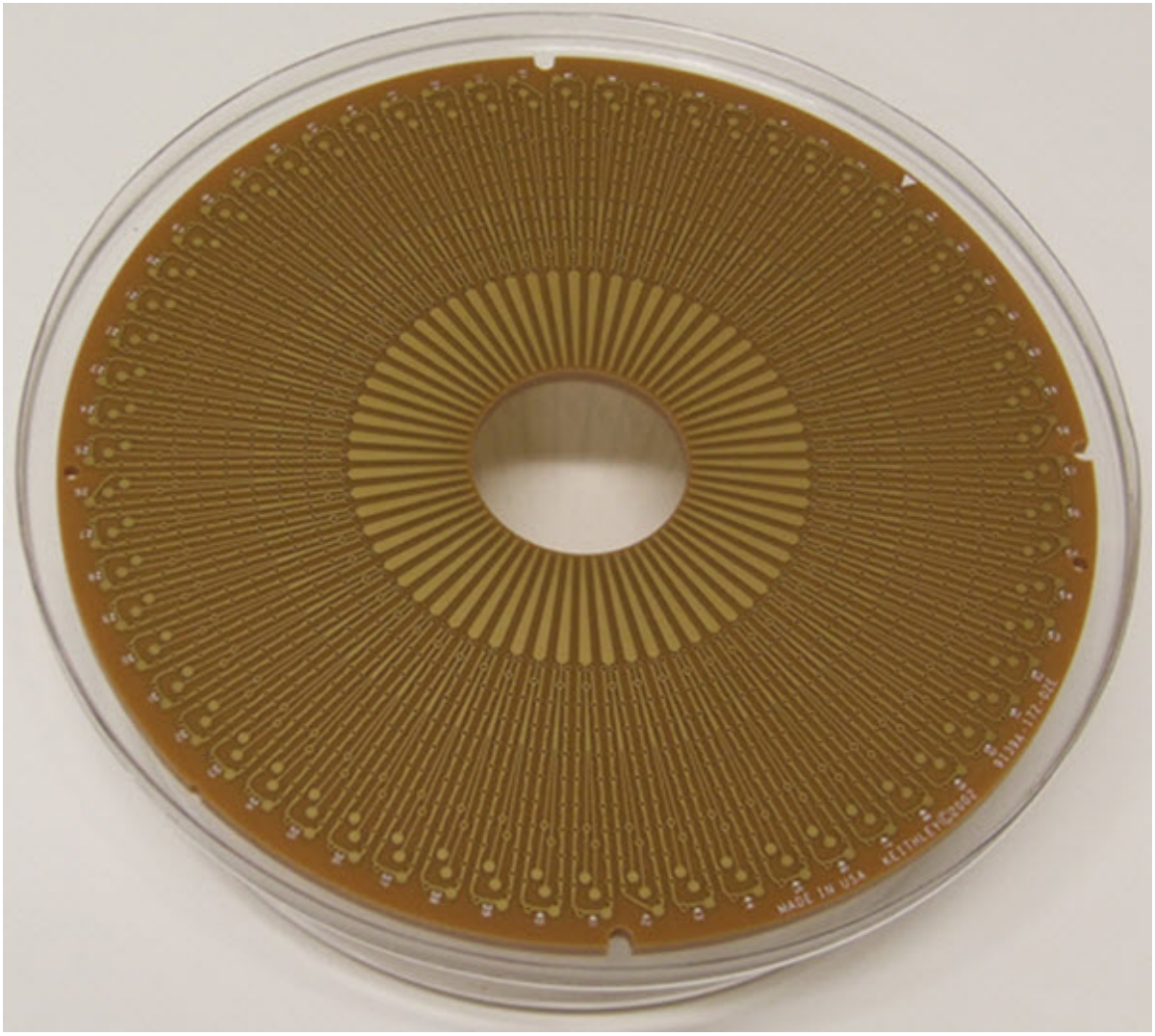
The verification probe card (see next figure) will short pin 1 to pin 2, pin 3 to pin 4, pin 5 to pin 6, up to the number of pins available in the system. This will allow the system verification routines to connect various instruments to the appropriate pins for the test sequence. The system verification software will verify that this card is installed before starting the test sequence.

Figure 31: S530 Verification probe card



The following blank probe card figure is included so that you can easily see the difference between this card and the verification probe card. Note that the number and configuration of jumpers (white wires in previous figure) on the verification probe card are determined by the system configuration.

Figure 32: S530 Blank probe card



Verification tests to execute

The tests used to verify the system specifications are similar to what are used for diagnostics. The main differences are that the pathways used include a round-trip to and from the probe card through the shorted pins and the measurement data from the verification test(s) are compared against a different set of limits than what was used for the diagnostics tests.

Matrix leakage tests

In system verify, the matrix leakage tests are similar to the diagnostics test, but only the pathway-to-pathway leakage portion, which is the first part of the test. No quasi-static capacitance measurements are taken. See the Matrix tests topic for more information.

SMU verification

Connect the force SMU to pin A and measure SMU to pin B (where pin A and pin B are shorted together). Execute the diagnostics SMU range tests against tighter limits compared to the limits used for diagnostic testing.

One SMU pair will be used to test all of the pin-pair combinations. Once this test is completed, a known good pin-pair is used to test all of the other SMU pairs.

Section 4

Troubleshooting

In this section:

Introduction

⚠ WARNING

Hazardous voltages may be present within the S530 cabinet that can cause personal injury or death due to electric shock. Only personnel who are qualified to perform troubleshooting on electrical systems and instrumentation should use this information and perform troubleshooting on the S530 system.

This section provides important information on how to troubleshoot the hardware under failure conditions. The content is provided in order to guide you towards a resolution to any issues you may encounter during prerequisite and diagnostics testing. If you do not see the specific failure under the test categories, please contact your local Keithley Instruments field service engineer (FSE).

The troubleshooting information is based on the tests offered and executed during prerequisite and diagnostics testing. Test messages, as well as any errors or failures, are displayed in the diagnostic's Status and Result tabs (see the Graphical user interface (GUI) topic for more information). For your records, you may want to save these results in a log text file. This is done by right-clicking inside the window and selecting Save.

NOTE

In the Status and Result tabs, failures are shown in red text, but the text color will not transfer to the saved text file.

During execution of a test, these tabs will provide information pertaining to executed tests. Any time you want to interrupt the automatic scrolling during an active run, click in the window and scroll. If you want the automatic scrolling to resume, press **Ctrl** and **End** on your keyboard.

Troubleshooting overview

Diagnostics testing provides you information to determine if the system is working properly. When there is a problem, the Result and Status tabs will usually tag specific test(s) or summary with the word "FAILURE." However, the S530 consists of many instruments connected together in a system, which means that a failure in a test cannot always be directly related to a problem with a specific instrument, nor will it indicate which instrument is the cause of a particular failure. That is why the tests generally repeat the same conditions, but on different combinations of instruments or matrix pathways, which provide a variety of results to determine an overall behavior or pattern. In other words, single test failures are not provided as simple error numbers or codes, but the result of a measurement or condition that does not meet the pass criteria.

For example, testing a SMU range is done with two SMUs, one that is sourcing (the SMU being tested, SMUA) and another that is measuring (SMUB). If the test result is outside the expected limits, this test fails. But in this case, with a single test result, it is not clear which SMU has the problem. So, the test continues by using other SMUs in the system. In this way, a suspect SMU can be identified.

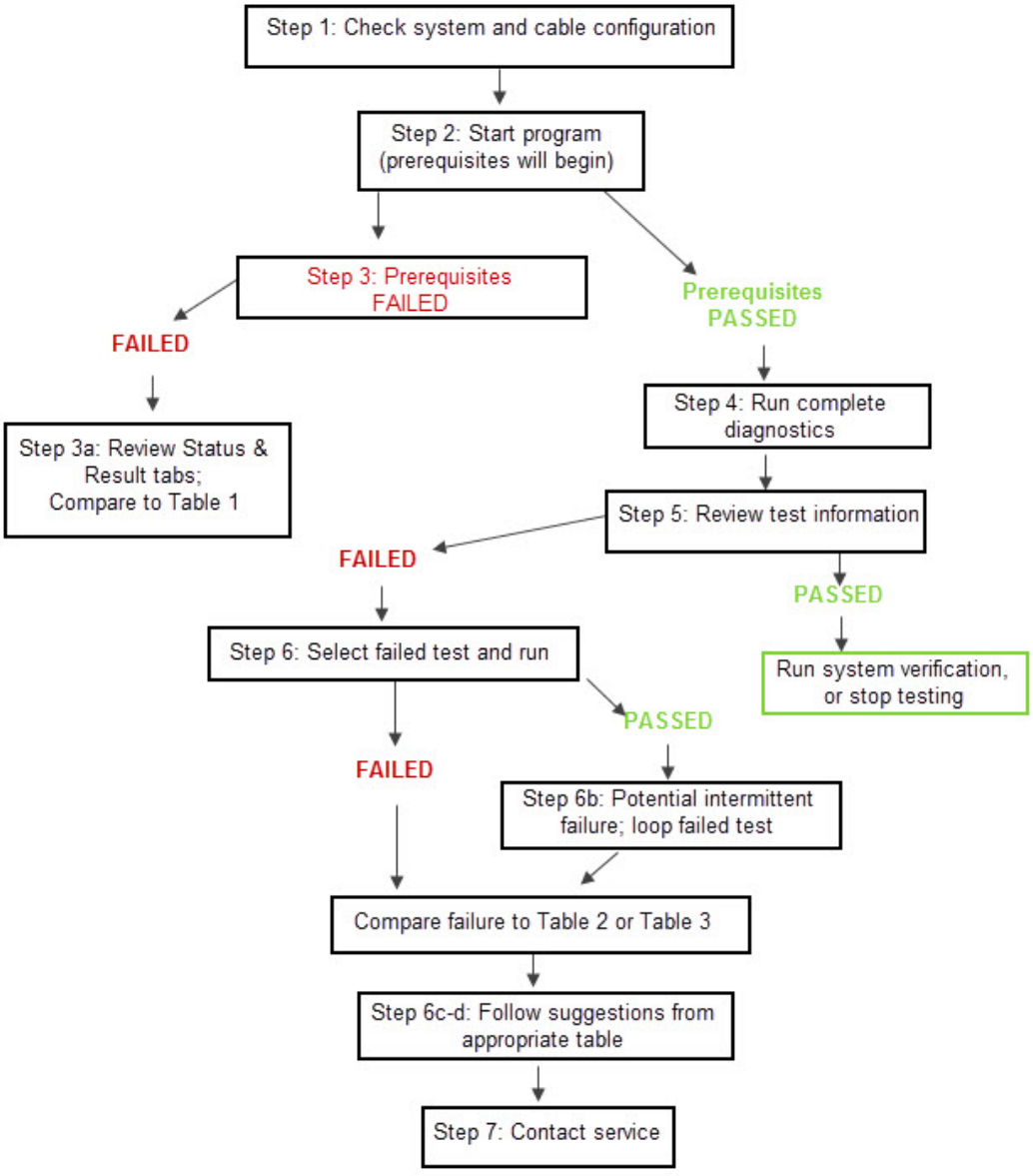
To continue this example, assume SMUA has a problem. During the test, SMUA is used both as a source and as a measure SMU. But other SMUs are also used to measure SMUA. If two or more SMUs only have failures when sourcing or measuring with SMUA, then SMUA is confirmed as a suspect SMU. By reviewing the results involving SMUA interacting with other SMUs in the system, it is possible to determine if SMUA is the common instrument in the various failures. If multiple SMUs show failures only when interacting with SMUA, then SMUA is confirmed as not working correctly.

This means that the troubleshooting situation requires the system user to review the Status and Result information and match the pattern of test results to the problem situations provided in the tables below. This type of pattern matching, or deduction, is key to effectively troubleshooting the S530 system.

Troubleshooting flow chart

The troubleshooting flow chart represents the procedures that you should use. Refer to the Troubleshooting procedure steps, that are found directly after this flow chart, for detailed step-by-step information.

Figure 33: S530 Troubleshooting flow chart



Troubleshooting procedure steps

1. Ensure that the system and cabling are properly configured.

   Separate the probe card from the wafer. For a Kelvin (4-wire) system, each force-measure pair should be connected. No force pins should be connected to other force pins.

2. Start the diagnostics program (see the Diagnostic Tests topic for more information).

   The diagnostics program will automatically run a set of prerequisite tests (see the Diagnostic Tests topic for more information).

3. If the Prerequisite tests FAIL (did not pass):
   a. Review the Status and Result tab information and compare to Table 1: Troubleshooting prerequisite tests to determine possible causes.
   b. Right-click the Status and Result tab and save the log information into separate files.
   c. If specific causes can be determined, review cabling and connection information in the S530 Administrative Guide to ensure proper configuration.
   d. Continue to step 7.
      - Contact your local Keithley Instruments FSE to explain the prerequisite failure details.
      - Provide the Status and Result log files.
      - If directed by a Keithley FSE, review the Shadow log file topic for more information.
4. If the prerequisite tests PASS, run the complete diagnostics test (see the Diagnostic Tests topic for more information).
5. Review the test information results.

NOTE

Generally, failures are listed in the summary section at the end of each test. Scrolling through the Status or Result tabs will also show individual test failures, usually in RED text. It is recommended that you run the complete diagnostics test when troubleshooting an issue for the first time.

   a. Review the Status and Result tabs for test result information.
   b. Find the specific test which results in the failure. If there is more than one failure, address the first failure that appears in the Status or Result log.
   c. Right-click the Status and Result tab and save the log information to separate files for each. It is recommended that you include the test date and time in the filename so that you can compare any future files.
   d. It is recommended that you clear the Status and Result tab information. This will allow you to better troubleshoot the next test results, if necessary.
6. Find and enable the test that had the error. Execute only the selected test.
   a. Review the Status and Result tabs for test result information. Determine if the same error occurred by comparing this most recent test with the earlier complete diagnostics test.
   b. If the error does not recur, the failure condition may be intermittent.
      - Use the loop feature to repeat one or more tests to obtain additional results about the failure
   c. If the error is the same, then review the appropriate tables for additional information.
      - For Matrix-related failures, see Table 2: Troubleshooting matrix diagnostic tests information for specific conditions.
      - For SMU, CMTR, Scope, VMTR or PGU failures, see Table 3: Troubleshooting SMU and other instruments diagnostic tests information for specific conditions.
   d. After following the suggestions in the appropriate table, re-run the appropriate diagnostics test.
7. If the failure persists, contact your local Keithley FSE for additional guidance. Provide the failure information, failure frequency, as well as any saved test logs.

Troubleshooting Prerequisites

The next three tables are presented in chronological test order and represent the tests that are done during the diagnostic tests. The following table provides you some guidance on the failures that may occur during the prerequisite diagnostic tests. If you can not find a comparable solution to your issue, contact your local Keithley Instruments FSE.

Table 1: Troubleshooting prerequisite tests

Prerequisite tests	Potential test failures	Possible solutions

Force-side (2-wire)	A failing 2636A/B SMU:
	
	LPT Error with code E0020 or E0029 (shown in Result tab)
	
	`>>>> Tester LPT Error: 2013/08/14 12:24:01 - E0020 (unknown) Command not executed because a previous error was encountered.`
	`>>>> Tester LPT Error: 2013/08/14 12:24:01 - E0029 (unknown) An error generated by instrument = 4102, code = 1211, message = Node 2 is inaccessible.`
		1. Check power to instruments:
		a.Open front door of system
		b. Check front panel of SMU
		c. If front panel is dark:
		• Check power button
		• Check power plug cable connection to SMU back panel (see --- in the S530 Admin Guide)
		
		2. Check TSP connection on master 2636A/B SMU:
		a. Ping master SMU
		Use the system IP address and adding ".2" to end of IP#. This IP is hardcoded and not the customer IP.
		PC: 192.186.1.**1**
		Master SMU: 192.168.1.**2**
		707B: 192.186.1.**5**
		4200-SCS: 192.168.1.**12**
		Example: At a Windows command prompt or Linux® terminal ping 192.168.1.2
		b. If no connection is found, visually check the TSP connection on back panel of 2636A/B SMU
		c. If cable is connected, perform the following steps:
		
		1. Exit GUI.
		
		2. Reset router located in back of system.
		
		3. Reset all SMUs.
		
		4. For KTE (Linux systems only).
		• If terminal shows prompt:
		stop_ic.pl
		then run_ic.pl
		• Else:
		Ctrl C
		run above .pl calls
		
		5. Run Diagnostic GUI.

Force-side (2-wire)	A failing 2636A/B SMU
	
	Failure on SMU for all pathways while as a Forcing SMU and a Measuring SMU
	
	Example: SMU2 Failed
	`FAILURE (2-Wire) Forcing with SMU1 and measuring with SMU2 using pathway A`
	…
	`FAILURE (2-Wire) Forcing with SMU2 and measuring with SMUs using pathway B`
		1. Check Result tab for LPT Error code E0020 or E0029. If this error occurred, see the troubleshooting information in the above section.
		
		2. Check failing SMU's HI Sense and HI Force cable connections from back panel of SMU, verify cables are correctly connected to the appropriate terminals.
		
		3. Check failing SMU's LO Sense connection and to Low Patch Panel.
		
		To check these items, open the back door of the system. The cables are labeled with the SMU# and function.

Force-side (2-wire)	A failing matrix card pathway
	
	Failure seen for same pathway on most 2636A/B SMU combinations:
	
	Example: Pathway E
	
	`FAILURE (2-Wire) Forcing SMU1 and measuring with SMU4 using pathway E`
	…
	`FAILURE (2-Wire) Forcing SMU3 and measuring with SMU7 using pathway E`
		1. A closed relay in the pathway. If intermittent then you may pass this test then fail the next time.
		
		• To check for this, close GUI and restart. Perform this a few times to determine if intermittent or stuck

Kelvin	Failure with all SMUs on same pin and matrix path for Kelvin detection. Result is not enough Kelvin connections found.
	
	Example: Relay 3C02 stuck open on Sensitive System
	
	`Using SMU1 for kelvin detection.`
	`FAILURE!! SMU1: Pin 02 (ForceCol=26 [Slot=3 Col=2] SenseCol=26 [Slot=3 Col=2]) Matrix Path: C Hi,Lo=9.91000e+37`
	…
	`Using SMU8 for kelvin detection.`
	`FAILURE!! SMU8: Pin 02 (ForceCol=26 [Slot=3 Col=2] SenseCol=26 [Slot=3 Col=2]) Matrix Path: C Hi,Lo=9.91000e+37`
	`ERROR! We need at least two pins to be non-adjacent.`
	
	NOTE: For 7072HV Matrix Cards, the minimum Kelvin Pins required is 3. For 7530 and 7174 Matrix cards the minimum is 2.Recommend minimum to configure for is 3.Card type will be provided in the Results Tab as part of Prerequisite testing information.
		Issue with relay on Matrix Card.
		
		Contact your local Keithley Instruments FSE for guidance with this issue.
		
		If directed by the FSE, power down the system, using the Removing System Power procedure in the S530 Administrative Guide. If directed by the FSE, remove the suspect card from the matrix using the General replacement procedure in the S530 Administrative Guide, along with any additional information provided by the FSE.

Kelvin	Not enough Kelvin connections found.
	`ERROR! We did not find two valid pins...`
	…
	`ERROR! We need at least two pins to be non-adjacent.`
		1. Verify that there is at least the minimum amount of Kelvin pin connections on the probe card.
		
		2. Check ground cable connections (GND Sense and GND Force) from Lo patch box to matrix card.
		
		NOTE: For 7072HV Matrix Card, the minimum Kelvin Pins required is three. For 7530 and 7174 matrix cards the minimum is two.Recommend at minimum to configure for three.Card type will be provided in the Result tab as part of prerequisite testing information.

Sense-side (4-wire)	All SMUs Fail two adjoining pathways
	`FAILURE (4-Wire) Forcing with SMU1 and measuring with SMU2 using pathway D`
	`FAILURE (4-Wire) Forcing with SMU1 and measuring with SMU2 using pathway E`
	…
	`FAILURE (4-Wire) Forcing with SMU4 and measuring with SMU1 using pathway D`
	`FAILURE (4-Wire) Forcing with SMU4 and measuring with SMU1 using pathway E`
		1. Potential short between matrix card pathways.
		
		a. Power down system (refer to the procedure Removing System Power in the S530 Administrative Guide, if needed).
		
		b. Open top hatch of matrix system chassis that exposes matrix card jumpers. Perform a visual check of jumpers which failed.

Sense-side (4-wire)	All SMUs fail the same pathway
	`FAILURE (4-Wire) Forcing with SMU1 and measuring with SMU2 using pathway E`
	…
	`FAILURE (4-Wire) Forcing with SMU4 and measuring with SMU1 using pathway E`
		1. Potential short between matrix card pathway to ground/chassis.
		a. Power down system (refer to the procedure Removing System Power in the S530 Administrative Guide, if needed).
		b. Open top hatch of matrix system chassis that exposes matrix card jumpers. Perform a visual check of jumpers which failed.
		
		2. A closed relay. If intermittent, this test may pass, then fail the next time.
		a. To check for this, close GUI and restart. Perform this a few times to determine if intermittent or consistent.

Troubleshooting matrix diagnostic tests

The following table provides you some guidance on the failures that may occur during the matrix diagnostic tests. If you can not find a comparable solution to your issue, contact your local Keithley Instruments FSE.

Table 2: Troubleshooting matrix diagnostic tests

Matrix diagnostic tests	Potential test failures	Possible solutions

Isolation relay	Force side row isolation failure
	
	Example 1: Relay stuck open
	
	`FAILURE SMU1 1D01,1C09, 2D01, 2C01 Relay 2D01 and/or 2C01 failed to close`
	`RETEST: Relay 2D01 and/or 2C01 failed to close Relay 2D01 failed to close`
	`RETEST: Relay 2D01 failed to close Relay 2C01 failed to close`
	`RETEST: Relay 2C01 failed to close`
	
	Example 2: Relay stuck closed
	
	`Checking card 1 to card 3 relays.`
	`FAILURE SMU1 1B01,1A09, 3B01,3A01 Relay 3A01 failed to open`
	`RETEST: Relay 3A01 failed to open`
	
	Sense-side row isolation failure
	
	Example: Relay stuck open
	
	`Checking card 1 to card 3 relays.`
	`FAILURE SMU1 1B01,1A09, 3B01,3A01 Relay 3B01 and/or 3A01 failed to close`
	`RETEST: Relay 3B01 and/or 3A01 failed to close Relay 3B01 failed to close`
	`RETEST: Relay 3B01 failed to close Relay 3A01 failed to close`
	`RETEST: Relay 3A01 failed to close`
		A faulty relay-
		1. If intermittent, this test may pass, then fail the next time.
		a. To check for this, update the loop count field, select only this test from the Matrix Tab and run selected test.
		
		2. Could be stuck open or closed as shown by the failures. Card will need to be replaced.
		
		An Inspection of card should be done by qualified service representative.

Force-side relay	Force-side failure on a second card
	`FAILURE SMU1 1A01,1B09, 3A02,3B02 Relay 3A02 and/or 3B02 failed to close`
	`RETEST: Relay 3A02 and/or 3B02 failed to close Relay 3A02 failed to close`
	`RETEST: Relay 3A02 failed to close Relay 3B02 failed to close`
	`RETEST: Relay 3B02 failed to close`
		A faulty relay-
		1. If intermittent, this test may pass, then fail the next time.
		a. To check for this, update the loop count field, select only this test from the matrix tab and run selected test.
		
		2. Could be stuck open or closed as shown by the failures. Card will need to be replaced.
		
		An Inspection of card should be done by qualified service representative.

Sense-side relay	FAILURE SMU1 1C01,2C01 4E09,5E01 Relay 4E09 failed to open RETEST: Relay 4E09 failed to open Relay 5E01 failed to open RETEST: Relay 5E01 failed to open FAILURE SMU1 1C01,2C01 4F09,5F01 Relay 5F01 failed to open RETEST: Relay 5F01 failed to open	A faulty relay- 1. If intermittent, this test may pass, then fail the next time. a. To check for this, update the loop count field, select only this test from the matrix tab and run selected test. 2. Could be stuck open or closed as shown by the failures. Card will need to be replaced. An Inspection of card should be done by qualified service representative.
Matrix leakage	Failing 2636A/B SMU1 when measuring capacitance. It is on the edge of failing. **Example: Showing Failure when Guard is lost on SMU1 Force Hi and Sense Hi** FAILURE Using SMU1 and path B: Measured capacitance of 5.0331e-11 Limit=5e-11 %Limit=100.663 Card 1 only … SUCCESS Using SMU1 and path E: Measured capacitance of 4.9881e-11 Limit=5e-11 %Limit=99.7623 Card 1 only … FAILURE Using SMU1 and path F: Measured capacitance of 5.0346e-11 Limit=5e-11 %Limit=100.693 Card 1 only	1. Verify SMU1 cable connections are valid from back panel of SMU to Matrix. 2. If okay, may be a bad cable or adapters/connectors. a. Replace SMU1Cables (Sense HI, Force HI, and Sense LO) b. Move SMU1 Cable
Matrix leakage	Failing SMU1 measured capacitance for all pathways **Example: Showing failure when SMU1 sense Hi is disconnected** FAILURE Using SMU1 and path A: Measured capacitance of 1.8512e-09 Limit=5e-11 %Limit=3702.44 Card 1 only FAILURE Using SMU1 and path A: Measured capacitance of 1.8844e-09 Limit=8e-11 %Limit=2355.5 Cards 1 and 2 FAILURE Using SMU1 and path A: Measured capacitance of 1.7612e-09 Limit=8e-11 %Limit=2201.5 Cards 1 and 3	1. Verify SMU1 cable connections are valid from back panel of SMU to Matrix. 2. If okay, may be a bad cable or adapters/connectors. a. Replace SMU1Cables (Sense HI, Force HI, and Sense LO) b. Move SMU1 Cable
Matrix continuity	Failing on all Pathways **Example: Showing failure when SMU1 Sense Hi is disconnected** FAILURE Forcing with SMU1: SMU2 measured 10.8346 ohms on path A. Limit=2 %Limit=541.73 Card 1 only FAILURE Forcing with SMU1: SMU2 measured 10.7649 ohms on path A. Limit=2 %Limit=538.246 Cards 1 and 2 FAILURE Forcing with SMU1: SMU2 measured 10.779 ohms on path A. Limit=2 %Limit=538.948 Cards 1 and 3	1. Verify SMU1 cable connections are valid from back panel of SMU to Matrix. 2. If okay, may be a bad cable or adapters/connectors. a. Replace SMU1Cables (Sense HI, Force HI, and Sense LO) b. Move SMU1 Cables

Kelvin Connection		
Pin leakage	FAILURE Testing Pins: 1, 2. Forcing with SMU1 on path A: SMU2 measured -7.73668e-14 on path B. Limit=1e-08 %Limit=0.000773668 SMU1 using path A is not forcing voltage of 50!(Possible short to GND?) Measured=0.0967503 Error limit=0.05 SUCCESS Testing Pins: 1, 2. Forcing with SMU1 on path B: SMU2 measured 9.99991e-10 on path A. Limit=1e-08 %Limit=9.99991 FAILURE Testing Pins: 2, 3. Forcing with SMU1 on path A: SMU2 measured -2.0597e-12 on path B. Limit=1e-08 %Limit=0.020597 SMU1 using path A is not forcing voltage of 50!(Possible short to GND?) Measured=0.0967741 Error limit=0.05 SUCCESS Testing Pins: 2, 3. Forcing with SMU1 on path B: SMU2 measured 9.99997e-10 on path A. Limit=1e-08 %Limit=9.99997 … Running Pin Guard Tests FAILURE Using SMU1 to test pin 1. Measured capacitance of 2.46724e-06. Limit=1.5e-10 %limit=1.64483e+06 FAILURE Using SMU1 to test pin 2. Measured capacitance of 9.02001e-08. Limit=1.5e-10 %limit=60133.4 FAILURE Using SMU1 to test pin 3. Measured capacitance of 7.06112e-08. Limit=1.5e-10 %limit=47074.1 FAILURE Using SMU1 to test pin 4. Measured capacitance of 1.82361e-06. Limit=1.5e-10 %limit=1.21574e+06 FAILURE Using SMU1 to test pin 5. Measured capacitance of 8.9051e-08 . Limit=1.5e-10 %limit=59367.3 FAILURE Using SMU1 to test pin 6. Measured capacitance of 2.16424e-08. Limit=1.5e-10 %limit=14428.3	A faulty Relay – 1. If intermittent then you may pass this test then fail the next time. a. To check for this, update the loop count field, select only this test from the Matrix Tab and run selected test. 2. Could be stuck closed as shown by the failures. Card would need to be replaced. **NOTE**: An Inspection of the card should be done by a qualified service representative.

Troubleshooting SMU and other instrument diagnostic tests

The following table provides you some guidance on the failures that may occur during the SMU and other instrument's diagnostic tests. If you can not find a comparable solution to your issue, contact your local Keithley Instruments FSE.

Table 3: Troubleshooting SMU and other instruments diagnostic tests

SMU & other instruments diagnostics tests	Potential test failures	Possible solutions

SMU voltage ranges	This failure along with low current range failures
	
	`SUCCESS Paths: A & B Range 200V: SMU1 forced 20 measured 20.0006 SMU2 measured 20.0005 Error=0.00053 Limit=0.2675 %Limit=0.0991`
	`ERROR: SMU1 measurement out of range: low=179.593 high=180.407`
	`ERROR: SMU2 measurement out of range: low=179.593 high=180.407`
	`FAILURE Paths: A & B Range 200V: SMU1 forced 180 measured 79.9742 SMU2 measured 79.2031 Error=-100.8 Limit=0.4075 %Limit=-1.24e+0`
		A faulty Relay –
		1. If intermittent then you may pass this test then fail the next time.
		a. To check for this, update the loop count field, select only this test from the Matrix Tab and run selected test.
		
		2. Could be stuck closed as shown by the failures. Card would need to be replaced.
		
		NOTE: An Inspection of the card should be done by a qualified service representative.

SMU current ranges	SMU measurement out of range due to additional low resistance in series
	
	Example: Additional resistance on SMU1 force
	`ERROR: SMU2 measurement out of range: low=0.3819 high=0.4181`
	`ERROR: SMU1 measurement out of range: low=0.3819 high=0.4181`
	`FAILURE Range 1A: SMU2 forced 0.4 measured 0.166343 SMU1 measured 0.166614 Error=-0.2334 Limit=0.0181 %Limit=-645`
		1. Verify SMU1 cable connections are valid from back panel of SMU to Matrix.
		
		2. If okay, may be a bad cable or adapters/connectors.
		a. Replace SMU1Cables (Sense HI, Force HI, and Sense LO)
		
		b. Move SMU1 Cables.

CMTR	Bias Test Failure on all Path Pairs (A&B, C&D, etc) due to Swapped Hi and Lo signal connections.	Check CMTR Hi Pot/Cur with Lo Pot/Cur cables. Verify that the connections to CMTR and CMTR Protection Module (4200-PM-40) are correct.

Pulse card	SMU Measurement Error
	
	`FAILURE PGU1B Pulsed 4 and SMU1 measured -4.21634`
	`FAILURE PGU1B Pulsed -4 and SMU1 measured -4.27092`
	OR
	`FAILURE PGU1B Pulsed 4 and SMU1 measured -0.3397`
	`FAILURE PGU1B Pulsed -4 and SMU1 measured -0.335039`
	OR
	`FAILURE PGU1A Pulsed 4 and SMU1 measured 1.98491`
	`FAILURE PGU1A Pulsed -4 and SMU1 measured -1.98648`
		1. Check Failed PGU Channel Output Connection from back of S4200 PGU to Matrix Card connection.
		a. ex PGU1B = Card 1 Channel 2
		
		2. May have some resistive load on the Failed PGU Channel Output.

Advanced information

Force-side isolation card tests

When you test the force-side of the matrix to verify the row isolation relays (see the Force-side row isolation relays topic for more information):

- If card 1 to card 2 tests fail and the card 1 to card 3 tests are good, then card 2 should be replaced.
- If card 1 to card 2 tests are good and the card 1 to card 3 tests fail, then card 3 should be replaced.
- If card 1 to card 2 tests fail and the card 1 to card 3 tests fail, then card 1 should be replaced.

Sense-side isolation card tests

When you test the sense-side of the matrix to verify the row isolation relays (see the Sense-side row isolation relays topic for more information):

- If card 5 to card 4 tests fail and the card 5 to card 6 tests are good, then card 4 should be replaced.
- If card 5 to card 4 tests are good and the card 5 to card 6 tests fail, then card 6 should be replaced.
- If card 5 to card 4 tests fail and the card 5 to card 6 tests fail, then card 5 should be replaced.

Intermittent failures

Some failures may be intermittent. The looping feature (see the Control area topic for more information) of the diagnostics software is useful to repeat all or some diagnostic tests to look for occasional failures.

Shadow log file

The shadow log file is created by the diagnostics software. This file contains more information than you find in the Status or Result tab sections. If the Status or Report content does not provide enough information for your needs, you can refer to the shadow log file.

The file name is `shadow.log`. This file always contains the latest information. When this file size reaches 1.5 megabytes (MB), the content is rolled into a backup shadow log file (for example, `shadow1.log`) and a clean shadow.log file is used. There are up to 5 backup log files before the information is removed.

The location of this file:

- On a Windows system using ACS V5.1 is C:\ACS\Diagnostics\Report\.
- On a Linux system using KTE V5.5 is $KILOG directory (default = /opt/kiS530/log)

IC log file

In addition, for the Linux KTE systems, there is a log file for the instrument control (IC) server process, which may be useful for certain troubleshooting situations. The ic process log file is `ic.log` and is located in the $KILOG directory (default = /opt/kiS530/log).

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