

Testing Devices with High Voltage and High Current

Introduction

Some test applications require the use of both high current and high voltage in the same test system, such as when components require multiple tests for verification. The performance verification may involve measuring high or low resistance or even testing the device at its operating levels of voltage or current. Typically, when a component requires a combination of these measurements, multiple instruments are required to supply the ranges of voltage and current. Keithley's SourceMeter® line is extremely adaptable for component testing applications of this type.

Testing a component's isolation or high resistance is best done with high voltage, while continuity or operating current is often verified with higher currents. The Model 2410 SourceMeter can source up to 1100V for the isolation or leakage current tests. The Model 2430's pulse mode allows testing components with 1kW pulses by supplying up to 10A@100V or, while in the DC (continuous) mode, the 2430 can output up to 3A@20V or 100V@1A.

Splitting high current and high voltage into two separate instruments maintains versatility, while minimizing cost. For applications that require only one of the instruments, many switching cards are available for multi-pin testing. The switching cards are designed to fit the dynamic range of usually one or a few similar instruments. It would be difficult and expensive to design a switch card to cover the entire dynamic range of a family of instruments as versatile as the 2400 Series. Designing such a switching system would require very large contactor-type relays, which are cumbersome and inappropriate for sensitive measurements. Therefore, this note describes how to configure a Model 2410 and a Model 2430 with switching hardware into a cost effective system to test a wide range of devices that have both high voltage and current requirements.

Test Description

Switching for the high voltage and current capabilities of both the 2410 and 2430 becomes a challenge when the application demands integrating the two into one system. *Figure 1* illustrates a configuration to test a diode with a high reverse breakdown voltage and a high forward carry current. This setup is also useful for applications such as testing connectors, which involve determining the insulation resistance (under high voltage) between pins of the connector and the continuity (under high current) of the pins.

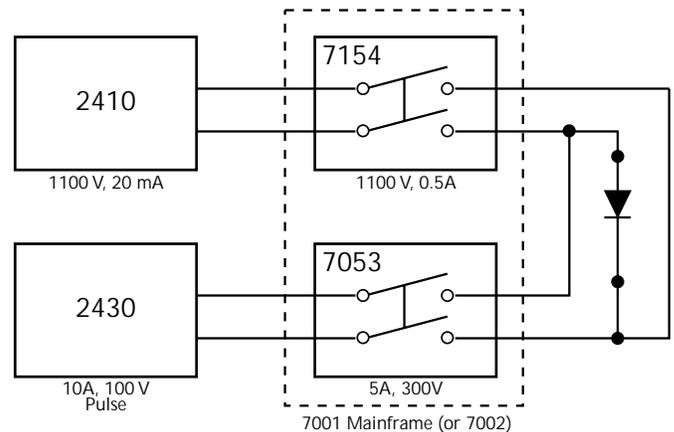


Figure 1. High voltage and high current test with switching

Safety Considerations

The requirements of this test are rigorous due to the demands placed on the switch cards. When performing the high voltage portion of the test, a relay on the Model 7154 High Voltage Scanner Card is closed to connect the 2410 to the device under test (DUT). If the DUT were isolated from other components in the test system, the high voltage would not be a problem, but as seen in *Figure 1*, the relay on the Model 7053 High Current Scanner card is also connected to the DUT. When performing the high voltage test, the relays on the Model 7053 remain open to isolate the Model 2430 from the high voltage that could potentially damage the instrument. This implies that the 7053 relay must be able to withstand the voltage supplied by the 2410 in order to protect the 2430. The same is true for the Model 7154 relay and 2410 when performing the high current test.

Once proper timing of the switching can be established, the level of current or voltage they can withstand when the contacts are open must be addressed. The card's ability to withstand high voltage depends mainly on the dielectric strength of the open relay contacts, which is typically specified as the isolation voltage of the relay.

The Model 7154 can withstand the 100V that the 2430 can deliver when the channels on the card are open. The same is true for the 7053 and the 2410. The 7053 can withstand the full 1100V from the 2410 but *only* at 15mA compliance to maintain safety ratings of the switch card and mainframe.

A key issue with this application is that the high voltage and the high current are never applied to the DUT at the same time. In addition to damaging the part, trying to apply the high voltage and current simultaneously would exceed the rated input capacity of both instruments, likely resulting in catastrophic damage to the sources and switching.

Figure 2. High Current and High Voltage Test System

Take great care in regard to switch timing to avoid applying the high current and voltage at the same time. When applying high current with the 2430, all of the relays on the 7154 card must be kept open in order to isolate the 2410 from the circuit. The same is true for the 2410 and the 7053. Performing the switch timing correctly ensures the instruments' protection limits and input ratings are not exceeded.

Test System and Configuration

Figure 2 illustrates proper connections between each piece of the test system and the DUT.

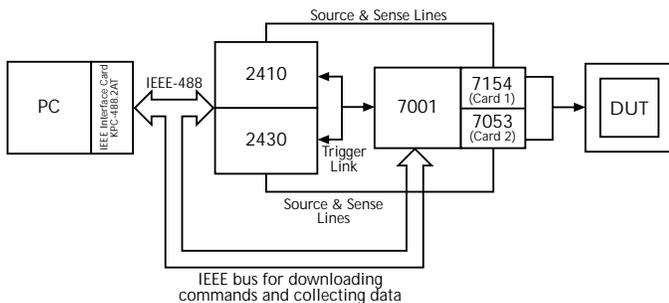


Figure 2. High Current and High Voltage Test System

Timing and Relay Life

It is equally important to ensure the system does not "hot switch" the relays while performing this test. Hot switching implies there is a current flowing through or a potential across the relay contacts while it is being actuated. "Cold switching," ensuring the relay does not make or break the current or voltage, is desirable because it can extend relay life by 10–1000 times over switching at maximum signal levels.

NOTE: The system outlined here demands cold switching in order to isolate the sources from each other.

Another issue involved in trying to open or close the relays when high voltage is applied is that voltage transients can be created within the mainframe. The switch mainframe is digitally controlled, so a large enough voltage transient could produce glitches within the mainframe. The presence of a glitch may skew timing of the switch sequence.

The best way to avoid hot switching the scanner relays is to enable the Auto Output Off Mode in both of the SourceMeter instruments. This mode ensures that the source is disabled after the source-delay-measure cycle but before either instrument triggers the switch mainframe to move to the next channel pattern. Enabling the output auto off feature in both the 2430 and 2410 eliminates the possibility that both sources would be shorted

together when the entire system is configured properly.

Turning the output auto off mode on can be done over the bus by sending the command: `SOURce1:CLEAr:AUTO ON`, or over the front panel with the following sequence: `CONFIG → ON/OFF OUTPUT → AUTO-OFF → ENABLE → ENTER`.

Switching and Triggering Sequence

The following example sequence illustrates applying first 1100V, then 10A to a device once. This process can be expanded to include more source values or repeated for multiple devices.

- Close channel 1 on 7053 card
- Apply 10A pulse from 2430 to DUT
- Turn output of 2430 off
- Open channel 1 on 7053 card
- Close channel 1 on 7154 card
- Apply 1100V from 2410 to DUT
- Turn output of 2410 off
- Open channel 1 on 7154 card

Figure 3 illustrates how the Trigger Models of each instrument in the system are configured using the Trigger Link function. The Trigger Link is a hardware handshake bus used by the instruments to ensure proper test sequencing and comes standard on all newer Keithley products

The Trigger Models of the three instruments are shown in Figure 3. The Trigger Model consists of three layers in the 7001 (only two are used for this application) and two in the 2400 to allow for complex triggering schemes. Programmable counters allow operations to be repeated, and various input and output operations are available to provide source-measure synchronization between the SourceMeter instruments and the switch mainframe. Each instrument allows sequence flow control via Trigger Link. The thick black lines indicate trigger lines feeding into the respective parts of each Trigger Model. Once the instrumentation is configured properly, the test sequence will run automatically with each of the instruments triggering each other until all of the devices are tested.

After the Trigger Model of each instrument is initialized, trigger signals must be supplied and sent in the correct order to satisfy the Trigger Model flow diagrams and execute the test properly. Each segment of the flow diagram is a discrete operation and must be completed before the instrument will proceed to the next step. The "Event Detector" portions of each trigger model wait for the necessary trigger input signal before proceeding to the next section of the trigger model. Between the Initialization and Event Detection steps, no triggers are generated from the Trigger Model. All triggers are typically generated

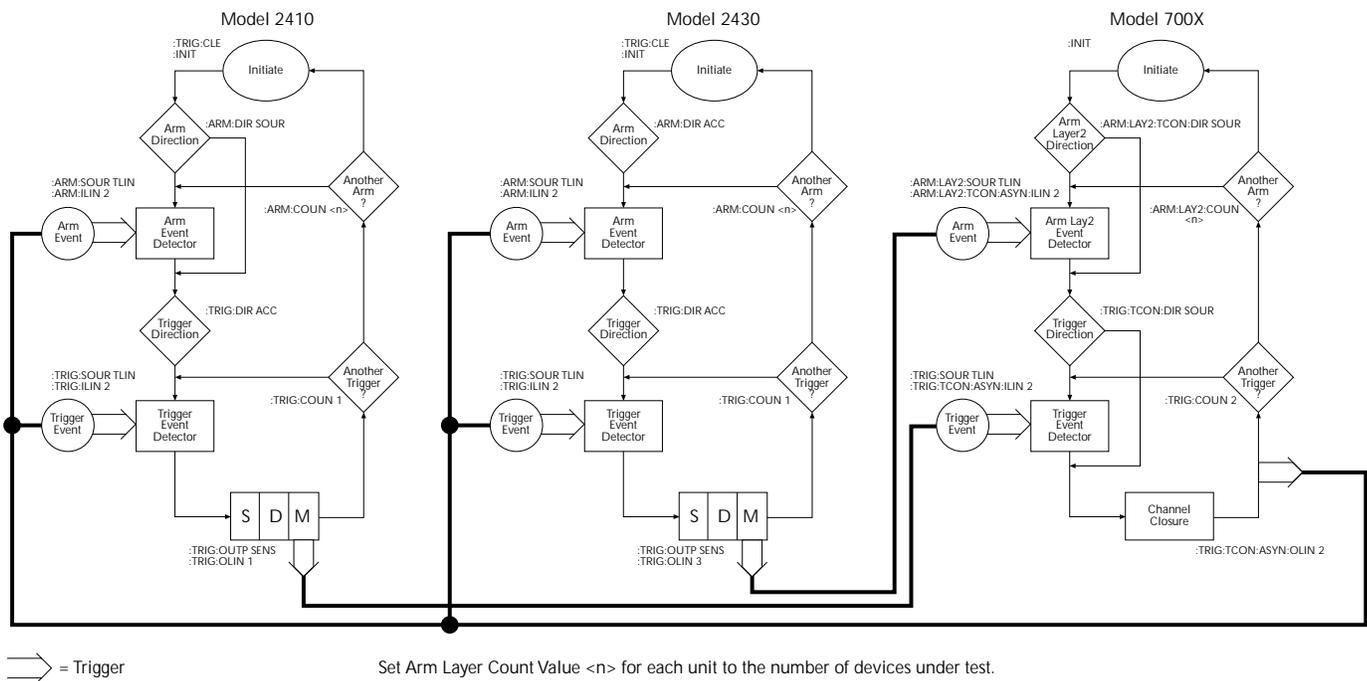


Figure 3. Synchronization of test system trigger models

after the measurement or channel closure. Without any triggers available, the instruments will wait at the Event Detection portion of the flowchart forever. With Arm or trigger Layer Direction configured as Source (as opposed to Acceptor, which is the default setting), the need for an initial trigger before closing the first channel is eliminated. Bypassing the initial trigger allows the 7001 to close the first channel and output a trigger afterward. Once the initial trigger from the Model 7001 is received by each SourceMeter, the rest of the test sequence progresses until completion.

NOTE: Bypassing the Event Detection in the Trigger Model only occurs the first time after initialization.

For this application, the 2410 is configured to bypass the Event Detection in the Arm Layer while the 2430 is set to wait for a trigger in the Arm Layer. After the instruments are initialized, the 2410 is waiting for a trigger input to the Trigger Layer Event and the 2430 is waiting at the Arm Layer. The Model 7001 has the event bypass enabled for both layers of the trigger model; therefore, it skips each event the first time, closes the first channel pattern, and then outputs a trigger. Each SourceMeter receives the Model 7001 output trigger and the 2410 begins by performing the high voltage test on the first device and the 2430 moves to the next layer of the trigger model and waits. After the high voltage measurement is completed, the 2410 will output a trigger to the 7001 and then proceed to the Arm Layer and wait for another input trigger. Once the 7001 has received the trigger from the 2410, it will switch to the high current memory location for the first device and output a second trigger to each SourceMeter. This second trigger from the 7001 enables the 2430 to go ahead with its measurement and the 2410 moves from the Arm Layer to the Trigger Layer and waits. The 2430 will then output a trigger back to the 7001, indicating that it should move to the first memory location for the second

device to be tested. This trigger pattern continues until all triggers and counters are exhausted.

The SourceMeter family of instruments will latch input triggers. By latching input triggers, the 2410 and 2430 will hold triggers between test cycles and process them if they receive another initialization command. For the test sequence to function properly, the first trigger must be generated by the Model 7001. If an "extra" trigger is latched in the system, the trigger sequencing will be thrown off track, potentially damaging the system. The sequencing algorithm presented in Figure 3 will result in "extra" triggers buffered within each SourceMeter instrument after a test cycle in completed. The extra trigger occurs once the 2410 has completed its testing and receives the last trigger to the 2430 from the 7001. *The buffered triggers must be cleared before the next test cycle can commence.* With each SourceMeter using Firmware revision C13 or higher, the SCPI command, :TRIGger:CLear, must be sent before each initialization command.

Programming over the Bus

To accomplish the switching sequence described previously, the following SCPI commands must be sent over the IEEE-488 bus to the instruments. If a setting is not stated, assume factory default. Refer to the operator manual for each model for specific instrument instruction information and operating information.

Commands to set up Model 7001 (or 7002)

NOTE: <n> represents the device number in the test sequence

1. *RST
 - ‘ Reset instrument
2. :ABORt
 - ‘ Abort any operation
3. :ROUte:OPEN ALL
 - ‘ all channels are open
4. :ROUte:CLOSe (@1!<n>)
 - ‘ Close desired channel on 7154 Card
5. :ROUte:MEMory:SAVE <n>
 - ‘ Save channel pattern into memory
6. :ROUte:OPEN ALL
 - ‘ Open all channels
7. :ROUte:CLOSe (@2!<n>)
 - ‘ Close desired channel on 7053 Card
8. :ROUte:MEMory:SAVE <n+1>
 - ‘ Save pattern in incremental mem location
9. :ROUte:OPEN ALL
 - ‘ Open all channels
10. :ARM:LAYer2:COUnT <number of devices>
 - ‘ Define number of devices to test
11. :ARM:LAYer2:SOURce TLINK
 - ‘ Set input trigger source for Arm Layer2
12. :ARM:LAYer2:TCONtrol:DIRection SOURce
 - ‘ Bypass first arm event
13. :ARM:LAYer2:DELay 0.01
 - ‘ Define short trigger delay
14. :ARM:LAYer2:TCONtrol:ASYNchronous:ILINe 3
 - ‘ Define Arm Layer2 input trigger line
15. :ARM:LAYer2:TCONtrol:ASYNchronous:OLINe 6
 - ‘ Define Arm Layer2 output trigger line
16. :TRIGger:COUnT 2
 - ‘ Set to run two tests per device
17. :TRIGger:SOURce TLINK
 - ‘ Set input trigger source for Trigger Layer
18. :TRIGger:TCONtrol:PROTection ASYNchronous
 - ‘ Set to asynchronous trigger mode
19. :TRIGger:TCONfigure:DIRection SOURce
 - ‘ Bypass first trigger event
20. :TRIGger:TCONfigure:ASYNchronous:ILINe 1
 - ‘ Define Trigger Layer input line

21. :TRIGger:TCONfigure:ASYNchronous:OLINe 2

- ‘ Define Trigger Layer output line

The Model 7001 (or 7002) has two different methods for scanning. The first and most basic method is to scan individual relays, which is typically done in numerical order. The 7001 also allows the user to scan through memory locations that are configured internally before testing begins. Within each memory location defined by the user, unique relay patterns can be downloaded and saved. This method provides the most flexibility for the user since multiple relays can be saved under each memory location. Once multiple memory locations are set up, the memory locations can be scanned sequentially. Since the first method requires jumping back and forth between each card to test one device, the second scanning method is more desirable.

The number of memory locations that are scanned in this system is twice the number of devices that are to be tested since each device requires two tests. Each channel on the 7154 card is paired with the same channel on the 7053 card. If the two channels required for each device on each card are saved in different memory locations and this process is continued for each DUT, all of the memory location can be scanned in order. The following is a sample scanning sequence for a sample of three devices:

| | | |
|-----------|--------------------|----------------------|
| Device #1 | Memory location #1 | Model 7154 Channel 1 |
| Device #1 | Memory location #2 | Model 7053 Channel 1 |
| Device #2 | Memory location #3 | Model 7154 Channel 2 |
| Device #2 | Memory location #4 | Model 7053 Channel 2 |
| Device #3 | Memory location #5 | Model 7154 Channel 3 |
| Device #3 | Memory location #6 | Model 7053 Channel 3 |

Commands to set up Model 2410:

1. *RST
 - ‘ Reset the instrument
2. :TRIGger:CLEAr
 - ‘ Clear any impending trigger
3. :OUTPut:STATe OFF
 - ‘ Turn the output off
4. :ROUte:TERMinals REAR
 - ‘ Select input terminals (may also use front inputs)
5. :SOURce:FUNCTion VOLTage
 - ‘ Configure to output voltage
6. :SOURce:VOLTage 1100
 - ‘ Set to output 1100V
7. :SOURce:DELay 0.02
 - ‘ Delay for a short time before taking measurement to allow voltage source to settle
8. :SOURce:CLEAr:AUTO ON
 - ‘ Automatically disable output after measurement

9. :SENSe:FUNcTION:CONCurent ON
‘ Enable V-source read-back
10. :SENSe:FUNcTION ‘CURRENT’
‘ Measure current from V-source
11. :SENSe:CURRent:NPLC 1
‘ Set A/D converter integration time
12. :SENSe:CURRent:RANGe 0.02
‘ Measure current on 20 mA range
13. :SENSe:CURRent:PROTection 0.015
‘ Set compliance value for V-source
14. :FORMat:ELEMents CURRent,VOLTage
‘ Send current and voltage values to PC
15. :ARM:COUNT <number of devices>
‘ Define number of devices to test
16. :ARM:DIRection SOURce
‘ Bypass first arm event (high voltage test first)
17. :ARM:SOURce TLINK
‘ Set input trigger source for Arm Layer
18. :ARM:ILINe 2
‘ Define Arm Layer input trigger line
19. :ARM:OUTPut NONE
‘ Do not output any trigger from Arm Layer
20. :TRIGger:COUNT 1
‘ Perform only 1 high voltage test
21. :TRIGger:DIRection ACCeptor
‘ Wait for first input trigger event
22. :TRIGger:SOURce TLINK
‘ Set input trigger source for Trigger Layer
23. :TRIGger:OUTPut SENSe
‘ Output trigger after measurement
24. :TRIGger:ILINe 2
‘ Define Trigger Layer input trigger line
25. :TRIGger:OLINe 1
‘ Define Trigger Layer output trigger line
- 4 :ROUte:TERMinals REAR
‘ Select input terminals (may also use front terminals)
- 5 :SOURce:FUNcTION:SHAPE PULSe
‘ Place unit in Pulse Mode
- 6 :SOURce:FUNcTION CURRent
‘ Configure to output current
- 7 :SOURce:CURRent 10
‘ Set to output a 10 Amp pulse
- 8 :SOURce:PULSe:WIDTh 0.002
‘ Set width of current output pulse
- 9 :SOURce:PULSe:DELay 0.02
‘ Define delay between subsequent pulses
- 10 :SOURce:CLEar:AUTO ON
‘ Automatically disable output after measurement
- 11 :SENSe:FUNcTION ‘VOLTage’
‘ Measure voltage from I-source
- 12 :SENSe:VOLTage:NPLC 0.01
‘ Set A/D converter integration time
- 13 :SENSe:VOLTage:RANGe 100
‘ Measure voltage on 100V range
- 14 :SENSe:VOLTage:PROTection 100
‘ Set compliance value for I-source
15. :FORMat:ELEMents CURRent,VOLTage
‘ Send current and voltage values to PC
- 16 :ARM:COUNT <number of devices>
‘ Define number of devices to test
- 17 :ARM:DIRection ACCeptor
‘ Wait for first arm event (high current test second)
- 18 :ARM:SOURce TLINK
‘ Set input trigger source for Arm Layer
- 19 :ARM:OUTPut NONE
‘ Do not output any trigger from Arm Layer
- 20 :ARM:ILINe 2
‘ Define Arm Layer input trigger line
- 21 :TRIGger:COUNT 1
‘ Perform only 1 high current test
- 22 :TRIGger:DIRection ACCeptor
‘ Wait for first input trigger event
- 23 :TRIGger:SOURce TLINK
‘ Set input trigger source for Trigger Layer
- 24 :TRIGger:OUTPut SENSe
‘ Output trigger after measurement

Commands to set up Model 2430:

- 1 *RST
‘ Reset the instrument
- 2 :TRIGger:CLEar
‘ Clear any impending trigger
- 3 :OUTPut:STATe OFF
‘ Turn the output off

25 :TRIGger:ILINe 2

‘ Define Trigger Layer input trigger line

26 :TRIGger:OLINe 3

‘ Define Trigger Layer output trigger line

- Keithley Model 7154 High Voltage Scanner Card
- Keithley Model 8501-1 Trigger-Link Cable (2)
- Keithley Model 7007-1 Shielded GPIB Cables (3)
- Banana Plugs (4)
- Test Leads

Example Program

Keithley Instruments has developed an example program that performs the tests on the diode with the system shown in *Figure 1* and described previously. While the program may require some modification to meet specific application requirements, choice of computer controller, etc., it provides a good starting point for developing an application-specific program.

To obtain a copy of the Example Program as a digital file, access the Keithley Instruments World Wide Web server at (<http://www.keithley.com>). It is a Visual Basic program: HiHiv.bas

NOTE: *The example program assumes the Model 7154 High Voltage Scanner Card is installed in Slot #1 of the Model 7001 Switch Mainframe, while the Model 7053 High Current Scanner Card is installed in Slot #2.*

Equipment List

The following equipment can be used to create a test system that will test ten devices with a 2-wire connection to each DUT. The high voltage and high current test system will only function safely and properly with the equipment outlined.

- Keithley Model 2410 1100V SourceMeter
- Keithley Model 2430 1kW Pulse SourceMeter
- Keithley Model 7001 Switch Mainframe
- Keithley Model 7053 High Current Scanner Card

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WARNING

To ensure the safety of the user and the equipment when using the Model 2410 SourceMeter in the test system, the compliance value of the 2410 source must not be set higher than 15mA when attempting to source more than 300V.

Alternative Solutions

Any instrument in the Series 2400 SourceMeter product line could be used to implement this test system. The Model 2400 allows testing up to 200V or 1A with 20W of total output. The Model 2420 offers up to 3A or 60V with a 60W output. The Model 2425 offers up to 3A or 100V with a 100W output. All the instruments in this product line are programmed similarly, differing only in their output capabilities.

If a higher channel count is needed to test up to 50 devices, the ten-slot Model 7002 Switching Mainframe could be substituted for the two-slot Model 7001. The 7002 is programmed identically to the 7001.

For More Information

Refer to Keithley's *Switching Handbook* for in-depth information on the Model 7001, Models 7053 and 7154 switch cards, and other switching solutions.

