Technical Information

Switching and Control

Achieving required system accuracies and precision requires selection of appropriate instruments, creativity in designing test methods, and careful attention to specifications and error terms. Most test system designs are complex enough that it is in the designer's best interest to minimize the number of uncontrolled variables. To accomplish this, the system switch performance should be tightly specified.

Special consideration should be given to tests that approach the specified limits of accuracy, resolution, or sensitivity of the measurement or sourcing instruments. These generally represent the "most critical test requirements," and switching should be selected to support these tests. A system designed to perform against the "most critical test requirements" will usually satisfy other test requirements as well.

How Do I Specify a Switch System for My Application?

Whether you are designing your own switching system or preparing to contact Keithley's applications department for assistance, you need to define certain parameters for your test system and understand how you want everything interconnected.

First, define your parameters. This includes:

- Measurements—List all the required measurement types and accuracies.
- Sources—List all the sources required.
- Quantity—List the number of terminals on the DUT and how many devices are involved.
- Signal characteristics—List signal types, levels and frequency, and impedance requirements.
- Speed—What are the speed requirements?

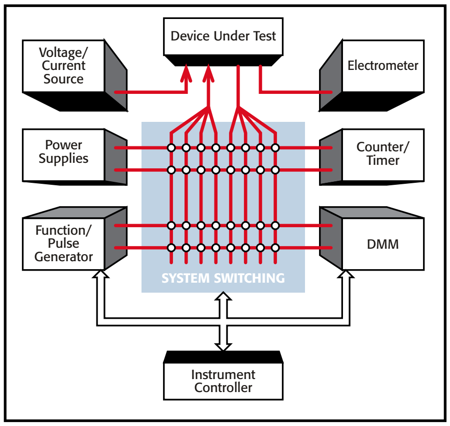

Figure 1. General Purpose Test System

- Environment—Temperature, humidity, etc.
- Communication interface—GPIB, RS-232, Ethernet, USB

Next, sketch the system. Given the number of terminals on the device and the number of instruments (source and measure), develop a picture of what type of switch and configuration will be needed. This is likely to be an iterative process as you identify what types of switching equipment are actually available.

Once you have done the groundwork, you are ready to configure the switching for your test system:

- Determine the appropriate switch and switch card configurations
- Select the appropriate switch system
- Select source and measure equipment
- Select cables and/or other accessories
- Identify need for fuses, limit resistors, diodes, etc.
- Determine the uncertainties and compare them with the required accuracies

Switching Configurations

The variety and size of switching configurations available determine the efficiency of the final switching design, including the amount and complexity of cabling and interconnect at the time of system integration. These are the basic building blocks of any switching system.

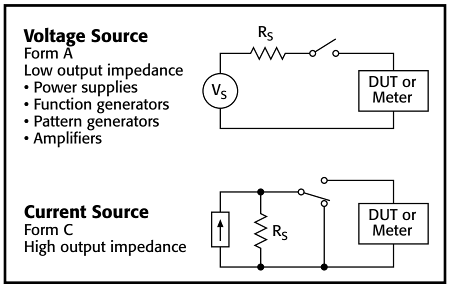

Figure 2. Example Switching Configurations

A switching configuration can be described by the electrical property being switched, its mechanical construction, or its function in the test system (**Figure 2**). These descriptions of the signal paths or electrical interconnects are necessary for laying out and wiring the test system.

A matrix switch (**Figure 3**) is the most versatile type of system switching. But first, a word on terminology here — Do not confuse a switch matrix (often called a switching mainframe) with a matrix switch. With a matrix switch, any input can be connected to any output, singly or in combination. This helps minimize the need for complex wiring and interconnect systems and can simplify the DUT interface. Although a matrix switch will work in virtually any switching application, it should not necessarily be your first choice of switch configuration.

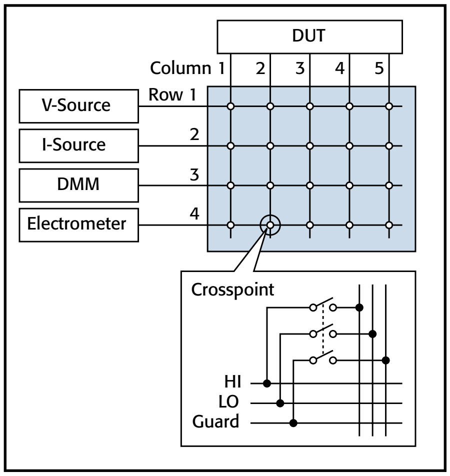

Figure 3. Matrix Switch

Consider an example where you need to connect four different instruments to ten different test points on a device-under-test. If you need to be able to connect any combination of instruments to any combination of test points at any time, then you do need a matrix switch. But, if you only need to connect one instrument to one test point at any time, then you can combine a four-to-one multiplexer with a one-to-ten multiplexer to make your connections. The multiplexer approach only uses 14 relays, while the full matrix uses 40. If you simply choose a matrix switch for the second example, you will end up paying for 26 relay channels you don't need. Careful planning can result in a more compact and economical switch system.

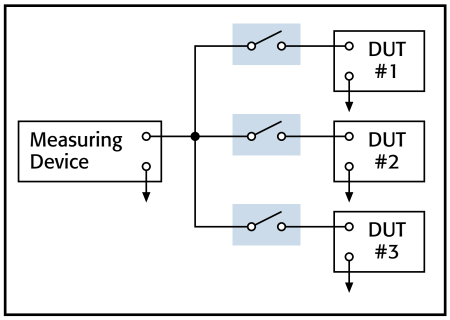

Figure 4. Multiplex Switch

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A multiplex switch (**Figure 4**) connects one instrument to multiple devices under test or multiple instruments to one device under test. The multiplex switch is useful in combination with matrix or other configurations to expand switching capacity by sharing electrical paths, to provide additional isolation and reduce crosstalk between channels, or to build special configurations.

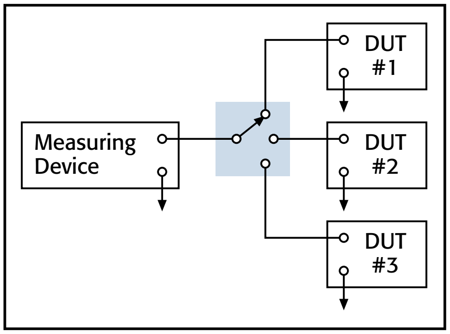

Figure 5. Scanner Switch

A scanner (**Figure 5**) is a special case of multiplex switching in which switch closures are sequential or serial, sometimes with the capability to skip channels.

The isolated switch configuration consists of individual uncommitted relays, often with multiple poles. Isolated switches are not connected to any other circuit, and are therefore free for building very flexible and unique combinations of input/output configurations with the addition of some external wiring. This type of switch can be useful for creating additional isolation between circuits, providing safety interlock, actuating other relays or circuits, or building special topologies such as binary ladders and tree structures.

Electrical Specifications

Electrical specifications of the switching cards contribute significantly to the overall performance and signal integrity in the test system. When trying to achieve high accuracy, resolution, and sensitivity or to route high frequency signals, high currents, and high voltages with minimum degradation in the test signal, the electrical performance of the switch card must be known. Match the system's critical test requirements against the specified performance of the switch. If the requirement is to measure a one-volt reference to one microvolt, be certain that the contact potential of the switch is not hundreds of microvolts. If switching of power supply voltage is required, be certain that the switch has sufficient current carrying capacity. When measuring resistances of less than one kΩ, be certain the switch will support four-wire measurements.

CHARACTERISTICS	NECESSARY FOR:
Contact potential (limits low voltage signal switching)	Precision measurement of voltage signals of less than 1V, as in reference testing, drift testing, and temperature coefficient testing.
Current offset (limits low current signal switching)	Measurement of signals of less than 1mA, as in semiconductor characterization and insulation resistance tests.
Characteristic impedance	Signal integrity in RF switching.
Thermocouple cold junction reference	Accurate measurements of thermocouple sensor devices.
Four-wire (automatic pairing of channels to facilitate switching of source and sense leads)	Precision measurement of resistance less than 1kΩ and switching of remote sensing voltage supplies.
Maximum current	Switching of power supplies and high power circuits.
Maximum voltage	Isolation and safety in high voltage systems.
Maximum power	Determining maximum current and/or maximum voltage that a relay can switch to prevent damaging the printed circuit board and relays.
Switch life	Determining maximum switch activations that can be expected under hot or cold switching.

Figure 6. Switching Performance Characteristics

The switching card specifications represent the performance of a single card. If additional cards are connected together, actual performance parameters such as offset current and insertion loss will be a function of the entire system, not just a single card. Each extra card and connecting cable adds some degradation. It may be necessary to characterize the entire system (including switching) in some applications.

Figure 6 describes a few performance characteristics and where they apply to improve system performance. There are many other characteristics to consider, depending on the type and level of signal being switched and the expected performance from the test system. The switching selector guides group switching cards according to key performance features. Many switches actually fit into multiple categories and you should look carefully at all of the switch card specifications before making a final selection. Refer to Keithley's Switching Handbook for a more in-depth discussion of switching specifications and their effect on measurement performance.

Mainframe Capabilities

A switching mainframe provides a convenient mechanical and programming environment for Keithley switching cards and can be selected to suit the size of the system. The Model 3706A offers six slots in a full rack 2U high enclosure and is compatible with a growing family of high density and high speed switching cards. For more diverse signal ranges the Models 7001 (two-slot) and 7002 (ten-slot) switch systems are compatible with the full range of more than 30 cards.

For low level semiconductor applications, the Model 707B (six slots) and 708B (one slot) mainframes are compatible with six specialized high density configurations including high speed, low leakage matrix configurations.

Switching Density

The high channel capacity Keithley mainframes provide reduces the complexity of a switch application by minimizing the number of mainframes and cards required. The Model 3706A is our highest density switching mainframe offering up to 576 two-wire multiplexer channels in a single 2U high, full rack mainframe. The half-rack 7001 has a capacity of up to 80 two-pole channels, and the ten-slot 7002 can accommodate 400 two-pole channels. The 707B can handle up to 576 channels or matrix crosspoints, while the 708B can accommodate up to 96 channels or crosspoints. The high density cards for each of these mainframes are designed for easy interconnect and wiring.

Channel Status

The Series 3700A with its LXI class B compliance offers an elaborate embedded web browser interface for intuitive point and click control and monitoring of all switch positions. The Series 7000 and 700 switch mainframes provide a visual display of each switch position on the front panel.

Expansion

The mainframe Models 3706A, 7001, 7002, and 707B each provide an analog backplane that can be used to make connections between cards when building large matrix or multiplexer configurations that require several cards. The backplane eliminates intercard wiring and increases configuration flexibility.