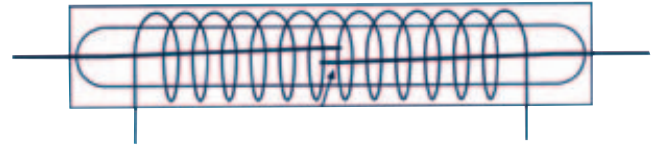A. Side (cutaway) view showing lines of
   electromagnetic force

B. Side View

Automated Signal Switching Primer

Introduction

Routing electrical and even optical signals from one source to another requires an overall understanding of the application, signals being switched and finally an understanding of how to select a switching solution that helps maintain signal integrity at a reasonable cost. Some of the main Issues to consider are:

- **Types of relays**
- **Types of relay topologies**
- **Selecting appropriate switching configurations to minimize size and cost while maintaining signal integrity**
- **Communicating with the switching system to maximize overall system throughput**
- **Cabling and wiring to/from one source to another**
- **The ability to easily configure and expand the switching system for several applications**

The intent of this switching primer is to provide our customers with a step-by-step guide to help configure a switching system for their application, without being tied to the constraints of typical switching systems on the market. Although the focus is for test and measurement, the same principles also apply for any automated switching task. Configuring a switching system is application-specific. Help in configuring an optimum solution to your application is available by contacting our applications department.

Types of Relays used in Test and Measurement

Dry Reed Relays

Contacts are made from ferromagnetic material (reeds). These contacts are encapsulated in glass. An energizing coil is wrapped around the glass and an EMF brings the two reeds together, closing the contacts.

Main Advantages

- Hermetically sealed, reduces oxidation build-up
- High Isolation (about 10^{14} Ω)

Main Disadvantages

- EMFs effect adjacent relays – requires shielding of relays in high-density applications.
- Inconsistent contact resistances

Mercury Wetted Reed Relays

Similar in construction and operation to dry reed relays except that a small amount of mercury is added inside the glass tube to provide more consistent contact resistances.

Main Advantages

- More power handling than a dry reed
- Consistent and low contact resistances

Main Disadvantages

- Position sensitive
- Mercury is a sensitive material
- Expensive relays

Solid State Relays

In a solid state relay an opto isolator is typically used to control FETs, SCRs or triac types of solid state devices.

Main Advantages

- Offers long mean time between failures (MTBFs)
- Very fast switching times (typically in microseconds)
- Allows for high density signal switching

Main Disadvantages

- Degrades signal integrity
- Typically not bi-directional
- Not useful for high voltage swings
- Typically application specific

SPST

SPDT

Form A

Form C

DPDT

DPST
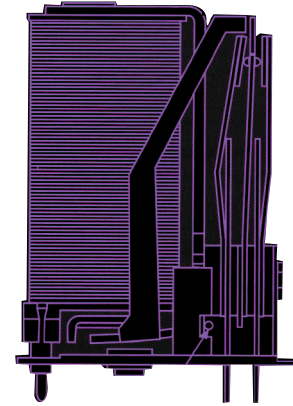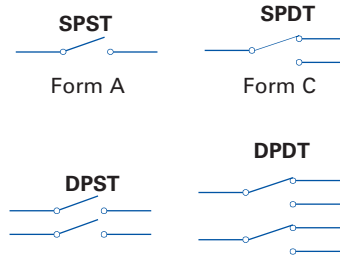
Technical Note

Automated Signal Switching Primer

Electromechanical Relays

An electromechanical relay uses an armature to bring two electrical contacts (i.e., gold over silver) together. This method provides consistent contact resistances. There are many different types of armature controlled electro-mechanical relays such as contactor for high power, bifurcated contacts for better general purpose switching, coaxial switches for microwave applications.

Main Advantages

- Ideal for general purpose switching
- Good consistent contact resistance
- Many variations available
- Allow switching of high power
- Allows for RF/microwave switching

Main Disadvantages

- Not ideal for low thermal, very low voltage switching.

Switch Card Types

The types of relays used determines the application of the switch card. The types of switch cards can be divided into the following categories:

Power switching cards that use high power electro-mechanical relays that can handle switching signals above 2 A - the SMP2000 series

General purpose switching cards designed for low-level and low-frequency applications (less than 2 A, and typically less than 20 MHz) - the SMP3000, SMP4000, SMP5000 series

RF switching cards that are controlled impedance (typically 50 Ω or 75 Ω). These modules are typically designed to handle RF signals under 1 GHz - the SMP6000 series

Microwave switching cards designed for switching frequencies between 1 GHz and up to 40 GHz - the SMP7000 series

Optical switching cards designed to switch fiber optic signals - the SMP8000 series

Relay Topologies

Each switch card provided by a switching system manufacturer will typically consist of relays that have one of the following topologies:

A SPST relay simply opens or closes a signal path. This relay is typically normally open when power is removed, and the relay needs to be energized in order to close the signal path. A normally open relay is sometimes also referred to as a Form A relay. A normally closed SPST (i.e., closed when no power is applied) is referred to as a Form B relay. A DPST relay is in essence two SPST relays, but energized from the same coil. A SPDT relay has one normally open and one normally closed path, and a DPDT relay is in essence two SPDT relays which are energized from the same coil. A SPDT relay is also referred to as a Form C relay.
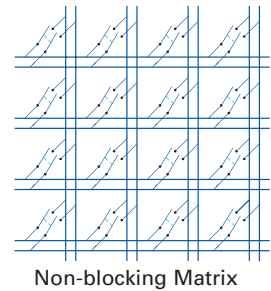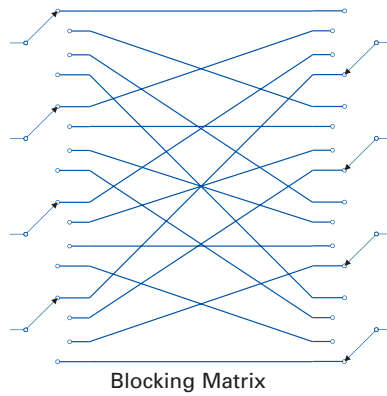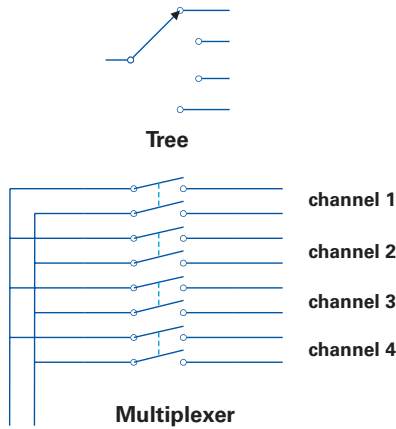
Switching Configurations

A typical automated switching system consists of several switch cards/configurations combined together to achieve the final result. The flexibility, modularity and mixture of different switch cards/configurations from a manufacturer play an important role in selecting the correct switching system for a particular application. Care needs to be applied to how these building blocks are used and combined since a bad configuration can effect the size, cost and signal integrity of the system. The main types of switch configurations are tree, multiplexer. and matrix.

The tree only allows one channel to be selected at a time, whereas the multiplexer can allow all channels to be selected simultaneously. The multiplexer configuration, however, has limited bandwidths due to unterminated stubs hanging onto the selected channel. The tree configuration is typically used in RF applications, whereas the multiplexer is used for general purpose switching.

The matrix is the most flexible type of switch topology, since any input can be connected to any output. However, it is also the most expensive, and effects overall signal integrity more than other configurations.

A low frequency matrix has large unterminated stubs, where as a matrix designed for RF applications has no unterminated stub effects. Although the matrix is the

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Tree

channel 1

channel 2

channel 3

channel 4

Multiplexer

Blocking Matrix

Non-blocking Matrix

Automated Signal Switching Primer

easiest topology to specify for a complete switching solution, it is best to break the switch solution into smaller building blocks that consist of each of the switching topologies dscribed. This will considerably improve the size, cost and integrity of the overall solution.

VXI Technology has years of experience in helping configure switching systems, optimizing performance and cost.

Programming

Since signal switching is a very key part of overall system throughput (i.e., scanning channels and changing points to measure on the UUT quickly), commands need to be sent and processed quickly by the switching system. Until the advent of VXI over a decade ago, the majority of programmable switching systems were programmed using the IEEE-488 bus or RS-232. With the introduction of the VXIbus, several alternative methods of programming switching systems became available (see technical note: "Application Programs, Instrument Drivers and VXI*plug&play* Overview") allowing test times to be considerably improved.

There are two types of switching systems available on the VXI platform. Message-based and register based. A message-based switching system is programmed using message-based strings, similar to programming an IEEE-488 switch, and up until the introduction of the SMIP*II*™ family from VXI Technology, this was the only way to obtain an intelligent switching system. A register based switching system is programmed by directly accessing registers (see technical note: "Message-based or Register-based Programming").

Message-based switching is considerably slower than register-based switching and can add significant time to overall test throughput. For example, even if relays typically take 2 ms to 5ms to close/open, it takes approximately 1ms to send and process a character on a message-based switch (Racal series 1260). To send a command to close three relays (Cl. 1.00,02,04) on a message-based switch takes approximately 13 ms (13 characters). In comparison, writing data to a register takes approximately 1 µs.

The SMIP*II*™ family switching system is designed to optimize overall system throughput. Relays can be commanded to open and close within microseconds, making it the fastest switching system on the market. In addition to simple open and close instructions, several other programming features exist that allow the SMIP*II*™ family to be combined with other instruments to enhance system throughput even more.

All SMIP*II*™ switch modules come with a GUI, and both IVI and VXI*plug&play* drivers. Complete system GUIs can also be provided by request.

Cabling Wiring to/from the Switching System

A switching system is merely an extension of the cabling/wiring from one point to the next. The choice of cable used is as important in the overall system integrity as the method of cabling/wiring to the switching system. For example, if twisted pair shielded cabling is to be used to wire between the unit-under-test (UUT) and an instrument via the switching system, the switching card employed needs to be an extension of the twisted shielded pair cable. In such a case a switch module with a balanced line pair (2 lines/ channel) should be used. This same switch module should have isolated shielding that would be an extension of the shield on the twisted pair cable (eg. SMP3001).

A universal switching system also needs to provide the user with the capability to wire up to the switching system in a variety of methods, allowing the user to determine the simplest approach for cabling/wiring the switch to the rest of the system. If the switching system is to be used in an application where the switch cards will be wired and re-wired several times (i.e. in R&D, engineering or scientific applications), the user should consider wiring to/from the switch card using a screw-down terminal block approach. If the switching system is to be used in an ATE application and wired once for a long period of time, crimp type pins and connectors are recommended.

The connector kits available on the SMIP*II*™ family give the user several options for cabling and wiring to the switching system.

AMETEK®
PROGRAMMABLE POWER

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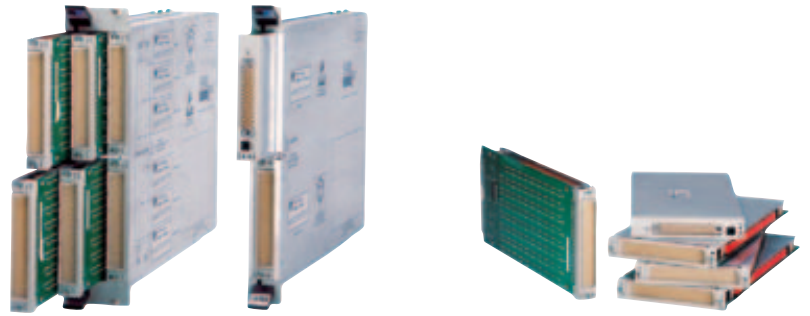
Specifications to Consider and What They Mean

The following is a brief definition of specifications found for switching cards. The specifications defined by a manufacturer are normally only for a switch card and not the complete switch system, since this would consist of several switch cards combined with the appropriate cabling and wiring.

- **Maximum Switching Voltage** is the maximum open circuit voltage which can safely be switched by the contacts. AC and dc voltage maximums will differ in most cases.

- **Maximum Switching Current** is the maximum current which can safely be switched by the contacts. AC and dc current maximums may differ.

- **Maximum Switching Power** is the upper limit of power which can be switched by the contacts. Care should be taken not to exceed this value.

- **Maximum Carrying Current** is the maximum current that can safely pass after closing or prior to opening the contacts.

- **Path Resistance** is the resistance of the worst-case signal path and includes relay contact resistance, trace resistance, and connector resistance.

- **Breakdown Voltage** is the maximum voltage that can be tolerated by the relay without damage for a specified period of time.

- **Relay Settling Time** is the time it takes the relay to close or open and settle from all bounce.

- **Mechanical Life** is the minimum number of times the relay can be operated under normal conditions with no load on the contacts.

- **Electrical Life** is the minimum number of times the relay can be operated under nominal conditions with a specific load being switched by the contacts.

- **Isolation** : High frequency signals leak through the stray capacitance across contacts. This is called isolation and is specified in dB to express the magnitude of the leak signal. The larger the dB the better the isolation.

Isolation will typically be expressed from input to output of the worst case channel, with the relay open. The isolation specification is important to consider since it determines the amount of noise that is induced to the output of a channel from the input of that channel when the channel is open.

- **Crosstalk** is used to express the stay capacitance between adjacent channels on a switch card and is specified in dB. The larger the dB, the better. The crosstalk specification is important to consider since it determines the amount of noise that is induced to the signal switched from an adjacent channel.

- **Insertion Loss.** At high frequencies signal disturbance occurs from self-induction, path resistance, dielectric loss, as well as from reflection due to impedance mispatch in circuits.

This type of loss is called insertion loss is expressed in dB, and refers to the magnitude of the loss of the input signal on the output. The lower the magnitude of the insertion loss, the better the signal path.

- **VSWR (Voltage Standing Wave Ratio):** At high frequencies resonance is generated from the interference between the input signal and the reflected signal. VSWR is specified as the ratio of the maximum value to the minimum value of the waveform. The lower the VSWR, the less the reflected wave.

Conclusion

When selecting a switching system, it is strongly recommended that the user understand the application and test philosophy before configuring the system in order to optimize the solution. However, since test stations today are sometimes designed concurrently with the product to be tested, it is not always easy to determine the exact configuration. Selecting a switching system, therefore, that is modular and easily expandable should be key, putting particular focus on the selection of the correct building blocks.

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