Choosing the Right Platform for Switching: PXI, USB or LXI?

By

Keith Moore, CEO Pickering Interfaces

Bob Stasonis, Sales & Marketing Director, Pickering Interfaces

When an engineer is designing a functional test system, it is normally the goal to design and integrate the best system in terms of measurement accuracy, throughput, and budget. Too often switching is the last section to be added. How switching is implemented in your test strategy can affect accuracy and repeatability.

It is important to note that you do not need to keep all instrumentation and switching in the same platform. In this article, we will show an overview of the three most popular platforms used for switching today, the advantages of each in various switching applications, and provide some basic questions to ask as you integrate any test system.

Our goals today are simple – we want to make you “dangerous” in terms of switching. By that we mean that we can’t make you an expert by reading our article, but we will arm you with enough knowledge to research for more details.

Back to Basics

In developing a better understanding of Signal Switching in Test, you need to know the types of switching configurations available, how relay types selected can influence your test strategy, and how the connectivity of the instruments and switching can be crucial. Once you have this knowledge there are questions to ask of your selected switching vendor.

Finally, you need to know that one test platform does not fit all switching applications. The various platforms we will discuss – PXI, LXI, and USB – all have specific advantages in various applications. So, let’s move on!

To begin, we must first understand why we need switching or, as we also call it, “Signal Management”. I think that most of you know that testing is a cost center. No additional benefit to increase the bottom line, or so many managers believe. But without testing, quality may suffer, especially in early production runs. Nothing hurts a company’s reputation more than a purchased product out of the box that does not work. And if this product is safety related – say, anti-lock brakes – failure can be very expensive! So clearly, we need to think about test. And in virtually all applications, your test system will require switching. So, let’s delve into the how and why of Signal Switching.

There are multiple reasons why you need to utilize Signal Switching. The first and most obvious reason is to share resources. Generally speaking, you do not make just one voltage measurement or one waveform measurement in a test program. There are multiple measurements to be made to ensure that a DUT is fully operational. And if you do not share one DMM or digitizer using switching, the solution is to have an operator move a probe around the DUT. This can be time consuming and also be error prone. Of course, you can have multiple DMMs in your test system, but that can be costly and make the test system overly large.

If you are testing multiple DUTs, switching is even more important. We have seen complex switching systems used to create an asynchronous test strategy, where the operator can replace a DUT in the test fixture when testing is complete while other DUTs are still being tested. This allows the test system to be more efficient, lowering the cost of test and potentially reducing the number of test systems needed.

For Portable Applications, switching can shrink a test system footprint by more tightly integrating instruments. The sharing I mentioned earlier allows the tester to potentially have fewer instruments.

When dealing with HALT/HASS Applications - HALT is Highly Accelerated Life Testing and HASS is Highly Accelerated Stress Screening – switching is usually required to access multiple DUTs in an environmental chamber. As these tests can take weeks and months, Solid State switching may be used as they technically never wear out.

Finally, let’s consider Hardware in the Loop Systems (HILS). HILS testing often involves both soft and hard failures. Soft failures may be something like bad serial data of errors in firmware. Switching is used to inject hard faults like shorted pins or connection to VCC or GND and monitor responses.

Now that we need to aware of is the switching configurations available to use in your test system. The simplest is individual relays that are not configured to work together. So these relays can be used to connect power, loads, or simulate switches on the DUT’s control panel. The switch types are generally SPST, DPST, SPDT, DPDT. They can be purchased in normally open and normally closed configurations. Finally, many types or relays are available in either Shielded or Unshielded for different electrical noise levels.

A multiplexer is probably best compared to a single test engineer. When making measurements, they move from test point to test point; they can only make one measurement at a time. Multiplexers work like that as well. Programmatically, they can move an instrument from test point to test point, one at a time. They are relatively simple to program and are available at a moderate cost. When selecting a multiplexer, you need to consider the number of Poles (Simultaneous connections), the number of channels (connections), and the amplitude and frequency of the signals.

The Cross Point matrix is probably the most versatile switch configuration available. Essentially, it is virtually access from any test point to any instrument. The diagram here shows a series of vertical and horizontal lines. The vertical lines are the Y Axis and the horizontal lines are the X Axis. Where an X line and Y Line intersect, or "Cross", a relay is there to connect these two lines together.

There are two ways to connect a matrix into the test. You can connect all of the instruments to the X Axis and the test points to the Y Axis. However, we recommend that all connections be on the Y Axis. The reason is that the X Axis could limit the number of instruments available if you use the first method. Using the second method, you can have more instruments available. The limitation is that the Y axis will limit the maximum number of *simultaneous or Concurrent* connections.

Like anything else in life, there are good sides and bad sides to the cross point matrix. The first to consider is "stub length". If you make a connection between two X points that are close to each other, you potentially have a rather long Y axis connection attached as well. This added signal length acts like an antenna and can pick up noise that will be added to your test signal. This is especially prevalent at higher frequencies. If this is a concern, make sure your matrix selection has isolation relays at multiple points along each Y Axis. Opening these relays at the appropriate time can reduce the stub length and make for cleaner signal paths.

Another issue with matrices is the added cost. As I said each X & Y cross point has a relay attached. If you have say a 512X8 matrix, that is 4,096 relays! As a rule of thumb, each Crosspoint relay costs about $10. So, your matrix could cost upwards of $40,000!

Finally keep in mind that programming a matrix requires a higher degree of care. As I said earlier, a matrix is any instrument to any cross point. If you are not careful in opening and closing the appropriate relays, you could technically short two or more test points together, creating unwanted parallel connections. At the worst case, you might connect power to the wrong test point, and destroy the DUT and maybe the matrix as well. You may want to consider purchasing switching path software that will keep track of this before it becomes a danger.

Choices, choices

Now that we understand the available switching configurations, we now need to specify what kind of signals we will switch. As there is no one relay that can switch from a few millivolts to a thousand volts at a range of DC to 40 GHz, you need to tell your switching vendor what the switch will be subject to. So, the amplitude, power level, and frequency of the signal are important.

One parameter that is often overlooked is cold versus hot switching. Cold switching is making a connection and THEN connecting power. The relay contact is never stressed. Hot switching as it implies makes the connection with power applied – the circuit is hot. Depending on the voltage and power applied, any arcing between the contacts can severely reduce the useable life of the relay. All switching manufacturers note their hot versus cold switching specs. So please pay close attention to this spec.

In very low-level signals, Contact Resistance may affect the repeatability of a test. You should look at the contact resistance and the projected variation over time.

Armed with this knowledge, you can now select the appropriate cross point matrix, multiplexer, or a simple switch.

Lastly, let's look at certain DUT Parameters – What is the number of test points, do you have access and so on. In high frequency applications (e.g, testing USB, Ethernet, etc.), Impedance Controlled Switching is important. In RF and microwave applications, parameters like bandwidth, VSWR, and insertion loss are crucial. It is important to keep in mind cable lengths, connector types and number of connectors in a signal path as all of these items add loss to the signal path.

Finally, in Optical applications, issues like Fiber Type & Connectors specified all add their own losses to the signal path.

When selecting a switching module, most test engineers are restricted by a budget for the test system. You know how many relays or channels you need. But depending on your vendor of choice, their choice may be too large or too small for your requirements. For example, if you need 30 individual relays and you vendor of choice only offers a module with 100 relays, you are spending too much. If you look at the graphic, you see a PXI switching module that is available with either 50, 75, or 100 relays installed. So choose a switching vendor that can provide solutions closer to your needs in order to save money.

Now let's talk about Relay Types. There are generally three different relay types – Reed, Electromechanical, and Solid State. Each has their advantages depending on the application.

Reed Relays are designed for long life and repeatability. They have the most consistent contact resistance of the three. But they are the highest cost on average (About 30% more expensive than comparable Electromechanical) and their hot switch specifications are lower than Electromechanical.

EMRs, or Electro-Mechanical Relays are designed for more general-purpose test applications. They are what is called an "open frame" construction, meaning that they are not hermetically sealed like reed relays. So, they are not recommended in environments that have flammable vapors in the area. They have higher current and hot switch specs when compared to reed relays, and they are the lowest cost switching solution.

On the down side, they have a shorter life that reed relays and exhibit less consistent contact resistance. They are physically larger than reeds, which equate to fewer relays per module.

Solid State relays have the advantage of virtually unlimited life and exhibit no switch bounce, which can minimize intermittent test results. In high current applications, MOS-FETs provide 300% more switching per module than relays, which saves slot count where many high current switches are required

On the downside, they do have bandwidth and voltage limitations, so using them within their rated specifications is important. Linearity in terms of their performance over a frequency range can limit solid state in certain switching applications unless the test engineer can calibrate out the linearity of the module. Therefore, we recommended that you match any available solid state switching to the application. They should not be considered general purpose switching.

What is often forgotten in signal switching design is the potential complexity of cabling, connectors, and wiring. It is important to specify adequate wire size and type for the application. In order to minimize capacitance and the potential errors and the damage it can cause, keep you cable lengths as short as possible. This also helps to preserve signal integrity.

As we mentioned earlier, try to minimize the number of Interconnects. In RF applications, every connector has some insertion loss. In high power applications, each connector adds resistance and the potential for unacceptable signal losses and heat buildup in the test systems. It is important to understand not just the switch modules selected, but you need to understand the ENTIRE signal path.

Which Platform is Best?

So now that we understand the questions to ask about switch types, and interconnects, you need to determine the best platform for the switching in your test system. Remember that thanks to advances in software and test system architecture, many different platform types play well together. So, you can select the best platform for your switching, power supplies, and instrumentation without regard to whether they will work together. So, select the best platform based on performance, budget, and availability.

Your first questions to ask on the platform type depend on how you are structuring your test system. Questions include;

- Switching Only? Is a chassis with just switching advantageous to your design?
- Interface to Test Controller – How do you anticipate connecting all the test elements together? Is latency an issue for your test program?
- Voltage Isolation – If you are dealing with high voltage, do you need a level of isolation between the switching and the instrumentation?

- Remote/Distance Control – how close to the host CPU will the switching be located?
- Product Availability – Do you have vendors available that can support you with COTS products? How long will they provide support?
- Vendor Support – Do you feel that your switching vendor of choice has the products and the support infrastructure to make you successful?
- Single Vendor Solution – Are you OK with dealing with a vendor solution that is only available from that vendor?

PXI. In this platform, several companies are committed to PXI switching. At this time, Pickering is the market leader, with more than a thousand choices. Other companies with switching include NI, Geotest, Adlink, and Chroma.

As there are multiple companies selling switching, there are regular new product introductions, giving you more choice. The amount of choices meant that new systems and upgrades are easily replicated with minimal effort.

Switching density has progressed greatly in recent years. It is now possible to get up to 528 crosspoints in a single width module, potentially saving chassis slot count for other instruments.

PXI is highly dependent on Windows and the PC. This has its good side and its bad side. In terms of switching in large applications requiring multiple PXI chassis, power sequencing is an issue. If you do not power these chassis in the correct order, the PC May not be able to enumerate the busses – this has the potential to lock up your PC or not discover modules correctly,

LXI. Similar to PXI, LXI Ethernet has several LXI switching vendors, making for a great many choices.

It should also be noted that both PXI and VXI Switching Platforms can also be LXI compliant, which allows you to separate your switching from the instruments. The transformer coupling of Ethernet provides voltage isolation from the rest of the test system.

Generally, many LXI switching systems are ideal for solutions needing diverse and highly integrated switching. This includes large I/O counts and higher power. The mechanical freedom of LXI switching allows for a wide variety of solutions that would not easily fit in other modular platforms.

LXI's Ethernet interface is simple to use and maintain. Localized intelligence provides freedom from the power sequencing issues I mentioned in the last slide. Built in software drivers speed initial starting and install process of a test system integration.

If the application requires switching remote from a host PC, LXI and Ethernet assures control of your switching in the next room or around the world.

<u>USB.</u> This platform is being seen more and more in test. First, USB is as Universal as Ethernet in PCs. The latest specification, USB 3.0, is more robust than previous versions and is much faster. The downside is there are few choices in USB Switching at this time. But we anticipate this will change in the coming years.

Like LXI, USB can be used for remote data acquisition, although not as distant at LXI. We find that USB switching is seen as complimentary to USB Data Acquisition in many applications.

The downside to USB is that most USB switching platforms lack a locking connector, so any strain relief needed must be addressed by the test engineer.

In small benchtop applications, USB switching is simple to install and utilize

So How do I Choose?

As we stated earlier, no one platform fits all applications easily. In general terms, LXI excels at

- High Power, Current or Voltage Switching. This is because of the physically large relays and connectors that do not fit well in PXI
- Microwave Switching, again because of the size of large microwave switches with coaxial interconnection
- Switching Is Remote from Controller. Ethernet control reaches a long way, across a building or around the world
- LXI' local intelligence allows for simple recovery from power interruptions
- For applications requiring a variety of switching types, there are standalone LXI chassis with PXI modules installed.
- If your company has made a corporate mandate to using LXI for all test applications, there are solutions to meet most switching needs.
- Finally, in very complex applications, the internal processor of an LXI device relieves host CPU overhead, which cane reduce the test times.

In PXI, there are also advantages:

- For compactness, PXI makes it easier to include switching and instrumentation in a single chassis
- The high interface speed of PXI makes the instrumentation portion of your test system much more efficient.
- As PXI is Windows based, you normally deal with a single software environment.

- For compactness and portability, the PXI chassis can have the application controller and switching in a single chassis.
- Finally, PXI switching is best implemented with a diverse mix of different switching functions, mostly small to medium I/O count.

USB. Similar to LXI, remote testing with USB is easily implemented. Also, the internal processor relieves host CPU overhead for very complex applications, much the same as LXI.

Because USB is ubiquitous and has a very reasonable integration cost, low cost test systems are easily implemented in USB. For Industrial PC applications, USB Switching saves the limited slot count in the PC for instrumentation. It can also move electrical switching noise outside of the PC, making it easier to make measurements,

So, Who Uses What Platform?

Now let's look at a few applications where one of these platforms worked well and why. There are of course, many more ways to use PXI, LXI, or USB in switching and test. Perhaps some of these solutions will give you inspiration for your test requirements

Video Displays A manufacturer of televisions wanted to be able to transmit many different patterns to multiple televisions in an environmental chamber. Up to 24 televisions needed to be connected to one of 8 signals. A 24 X 8 Video matrix in PXI would be cumbersome. Because of a PXI Module's small size, it would take multiple modules and a fair amount of cabling to create the matrix – the added cabling made access for maintenance difficult and would also deteriorate the signals. An LXI 24x8 video coaxial matrix was selected. Because LXI has no physical size limitations, the manufacturer could build a small 1U high chassis to house the matrix.

Military Communications A manufacturer of Software Defined Radios, or SDF, for military and local government applications was defining a next generation test station. The previous generation tester was too slow and could only test one radio at a time. With the rapid increase in sales, just building more test stations as they would require more floor space than they could allocate, more operators, and greatly increase the cost of test.

The design goals wanted a test system that could test five radios *asynchronously*. In other words, when the test of one radio was complete, the operator could disconnect the finished radio and connect a new one without interrupting the tests of the other radios. Such a design would require a lot of switching as the instrumentation (RF & Audio) would have to be shared across five radios at any one time. In addition, the tester would have to connect power and USB devices at various times.

The final systems design was created using PXI. PXI had most of the available instruments, and unlike the previous example, there were a variety of different switching requirements that would fit well in a PXI chassis.

RF Amplifier

A calibration lab was using decade boxes to manually determine the resistor values needed for an amplifier in order to get the amplitude within specification. Doing this manually was very slow and was prone to possible errors. Test times needed to be shortened in order to lower their costs for their end customer. Automation was seen as the best way to move forward.

As the instruments used in the calibration were not modular, a two-slot USB chassis was fitted with programmable resistor module and an RF multiplexer for making multiple measurements was chosen. Once the code was written for the test, the test times were greatly decreased and repeatability was improved.

FADEC (Full Authority Digital Engine Control) A manufacturer of Engine controls on Jet Engines was looking to improve the verification of the product in final test. Specifically, testing was added to verify the FADEC's firmware to ensure that not only that it worked correctly in normal operation, but that it would do its best to keep functioning when things went wrong. This type of testing is called HILS, or Hardware In The Loop. Basically, the concept is to inject a hardware fault, such as a shorted cable to ground or a failed sensor, and measure the FADEC's response.

The test system already being used was based on PXI instrumentation for ARINC and MIL-STD 1553 signals, so the preference was to continue with this platform. Fortunately, there are several PXI vendors who make switching modules for fault injection. The test system needed an additional PXI Chassis to house the Fault Insertion modules, but there was adequate room in the test rack. Interfacing another PXI chassis is quite simple, again making the upgrade fairly easy.

The "Grey" Area There are certain occasions where you only need to be concerned about switching only and no other instrumentation. In this instance, virtually any platform may suffice. But here are a couple of suggestions;

- PC Interface – Will the switching be close to the controller? In that case, any of the platforms we have pointed out will work well. However, if controlling the switching system remotely is important, then LXI is the most logical choice.
- Switching Configuration If you have a variety of switching requirements – say a mix of low power, RF, and high voltage – a modular format where all of the necessary switching is available will probably be the most economical and compact.
- Real Time OS – Real time applications generally do not favour LXI because of the latency inherent in Ethernet. There have been efforts by the LXI Consortium to improve the performance of LXI in real time applications. Go to www.lxistandard.org to learn more. In USB, we would suggest that USB3 will be more robust in a real time environment than USB2. Finally, PXI vendors have solutions that work with real time OS'.

The bottom line here is that your test strategy has to be balanced between specifications, test times, budget, software environment, and Vendor support after the sale.

In summary, to paraphrase the adage "One platform does not fit all applications. The PXI, LXI, and USB platforms are well suited to switching applications. But each one has particular features that are right for your particular test strategy. True, there are grey areas where no platform has an edge. What is important for you is to make sure you understand each platforms strengths and weaknesses and ask the right questions to your switching vendor of choice.