

PXI Interoperability— How to Achieve Multi-Vendor Interoperability in PXI Systems

Application Note



Achieve Interoperability in PXI Systems

Modular test systems often require a variety of hardware and software components. Confidence is key when configuring your systems to ensure compatibility between the mechanical, electrical and software aspects.

The purpose of this application note is to impart confidence through knowledge, discussions and demonstrations of smooth implementations and coexistence of PXI hardware, software and related tools. Industry standards and multiple standards organizations are also examined.

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Introduction to PXI interoperability

Test system developers generally require a large variety of components to meet system needs, and at times they are sourced from different suppliers. The system developer must have confidence that these components will work well together. Mechanical, electrical and software aspects need to be compatible to ensure successful system operation. That is one of the primary goals of standard organizations. If standards are carefully written, the resulting specification will promote compatibility between products and suppliers. In the case of PXI instruments there are multiple standards organizations that come into play. These organizations define PCI bus connectivity, HW enclosure and timing synchronization attributes.

This application note starts with a detailed look at PXI specifications and discusses its impact on interoperability. It then discusses PXI hardware and how to select modules, chassis and controllers to ensure compatibility. PXI Software, including tools such as Agilent Connection Expert (ACE) and National Instruments Measurement & Automation Explorer (NI-MAX), are also discussed because SW plays a large role in the overall compatibility of system components. With the goal of a smooth implementation of multi-vendor based solutions, hints and tips are included throughout this note.

PCI communications

PCI bus electrical and signaling attributes are developed and managed by the PCI Special Interest Group (PCI-SIG). PCI and PCIe® electrical bus structures used in PXI are based on the Personal Computer PCI bus and common chipset and signaling methods are used. Since the PCI bus is ubiquitous worldwide, a high level of interoperability is assured by the millions of engineering hours invested over the last two decades. PXI leverages these investments resulting in robust connectivity and an easy to use solution.

The engineering investments made in PCI technologies have resulted in a robust boot and messaging process. At PC boot time the PC BIOS discovers PCI hardware on the bus (including PXI modules) and the operating system will assign resources including memory and interrupt. This process is known as enumeration.

Mechanical and electrical compatibility

Upon its initial introduction 1992 the PCI bus was recognized as being a robust high speed computer interface. It performed very well in standard business applications, and it soon became apparent it also would work well in industrial applications. The PCI Industrial Computer Manufacturers Group (PICMG) leveraged the PCI bus capabilities, and in 1997 it introduced a specification for an industrial grade enclosure known as CompactPCI® (cPCI). Compact PCI was a very good mechanical platform to build from and was quickly adopted in industrial applications. The mechanical slot spacing, connector placement and pin-outs are all defined as part of the cPCI specification. Standard mechanical dimensional constraints and strict tolerances allowed smooth insertion of modules into chassis using common installation levers. These attributes combined with standard connector definitions and pin-outs allow various suppliers to begin sourcing interchangeable cPCI solutions. However, cPCI had no provisions for timing and synchronization features necessary in instrumentation applications. This is where the PXI stepped in and provided instrumentation specific features.

PXI specification ties it all together

The PXI specification is defined and managed by the PXI Systems Alliance (PXISA). This specification builds on the PCI and cPCI specifications by defining instrumentation specific attributes including timing and synchronization features. A cPCI chassis and a PXI chassis look very similar and cPCI modules can be used in PXI chassis. In this application note, we discuss how the PXI specification provides a framework for multi-vendor interoperability. Figure 1 shows the hierarchy of the PXIe specification. Notice multiple sections where CompactPCI and PCI bus attributes are adopted.

It is important to remember there are two variations of PCI bus structures—the original parallel PCI style (including both 32 and 64-bit structures), and the newer PCIe based serial structures. Both bus structures have been worked into the PXI specification. The original parallel PCI implementation is known as PXI-1 while the newer serialized PCIe style is known as PXIe. PCIe (and hence PXIe) provides a significant improvement in data bandwidth as well as other features such as point to point messaging which are important in

high-end instrumentation applications. Engineers upgrade to PXIe primarily for higher-speed communications features, in addition to improved timing and synchronization built on new high speed differential connectors

The PXIe additions also included provisions for PXI-1 backward compatibility. PXI-1 backward compatibility is critical since there are many existing PXI modules that are designed based on the older 32-bit parallel version of PXI. The intent is to allow re-use of those designs without having to modify the basic design including the PCB layout. However, a connector modification is needed, and this is discussed in the next section.

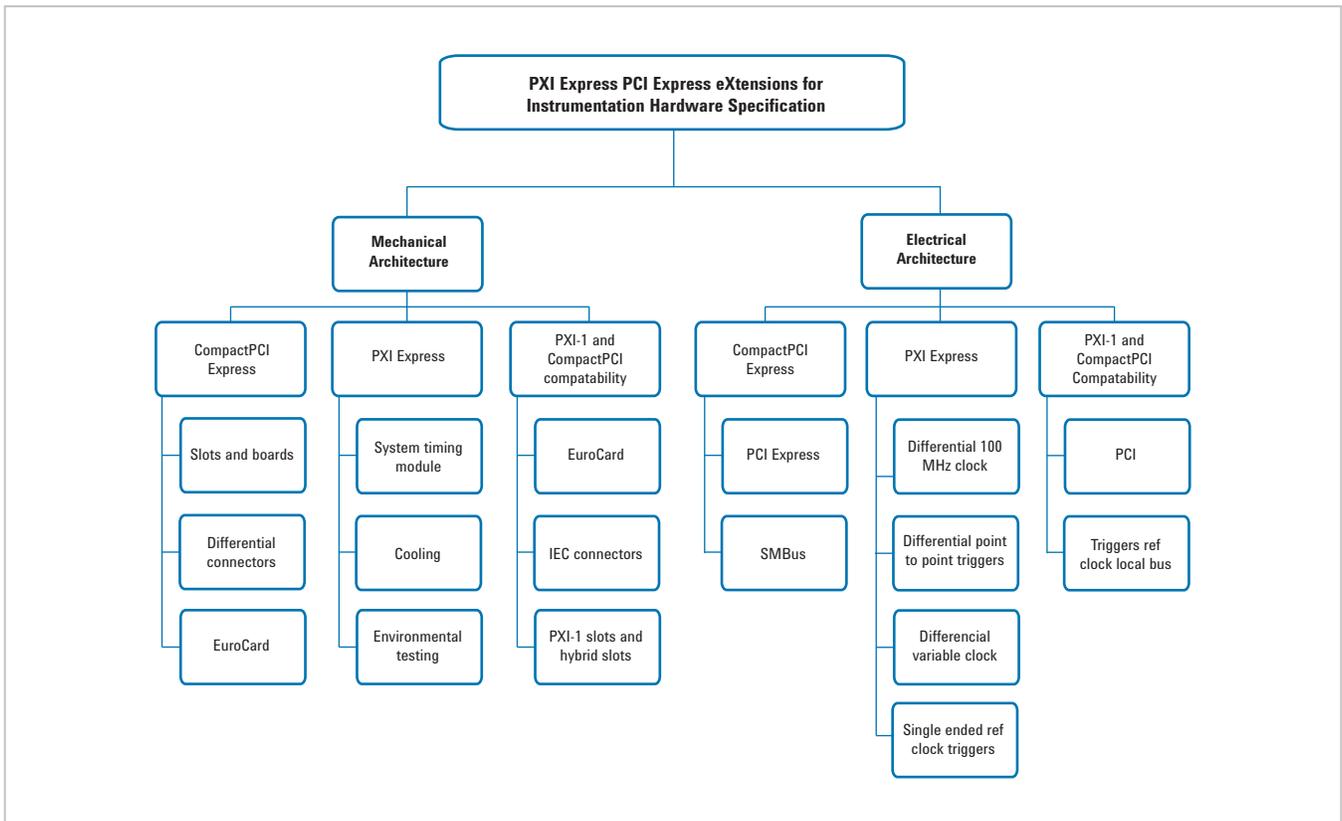


Figure 1. PXIe specification hierarchy (from PXIe specification) ¹.

PXI hardware

Module sizes

PXI modules come in two sizes - referred to as 3U and 6U. The most popular size is the 3U, which is 100 mm x 160 mm. There are over 1000 PXI modules currently available—the majority which are shipped in the 3U format and use 32-bit PCI bus for communications. Both mechanically and electrically 32-bit, 3U PXI-1 modules are well established and a large variety of modules are currently in production. We'll focus mostly on the 3U form factor for the remainder of this discussion.

Connectors

Figure 2 shows a 3U PXI-1 module. The connections for both communications and other functions are routed through connectors J1 and J2 to the chassis backplane. J1 is used for 32-bit PCI communication connections, and it provides all the signals necessary for 32-bit PXI modules to communicate to the controller. J2 contains the extra upper 32-bits in the event a 64-bit PCI version is supported, as well as additional PXI specific connections to support timing and synchronization.

PXIe uses the newer high speed PCIe serialized version of the PCI bus that provides an improvement in data bandwidth. To support the high speed PCIe signals, a newer differential style connector must be used. The standards organizations were challenged to develop a method to route the high speed PCIe connections to PXIe modules that would also be compatible

with the original PXI-1 connector footprint.

Above the red dotted line in Figure 2, critical PXI-1 signals including timing, triggering and local bus lines are routed to the J2 connector. Below the red line, connections are made for upper bits for 64-bit PXI-1 modules and little used PXI local bus connections.

The standards organization decided to reutilize the lower portion of J2 to route the high speed PCIe connections. In order to support PXIe connector J2 would be modified:

- (1) The top section would remain the same to support legacy PXI-1 triggering, and
- (2) The bottom portion of J2 would be re-assigned for use for the high speed PCIe communication signal routing.

With this re-assignment, two new styles of chassis peripheral slots were created: PXIe and Hybrid PXI slots.

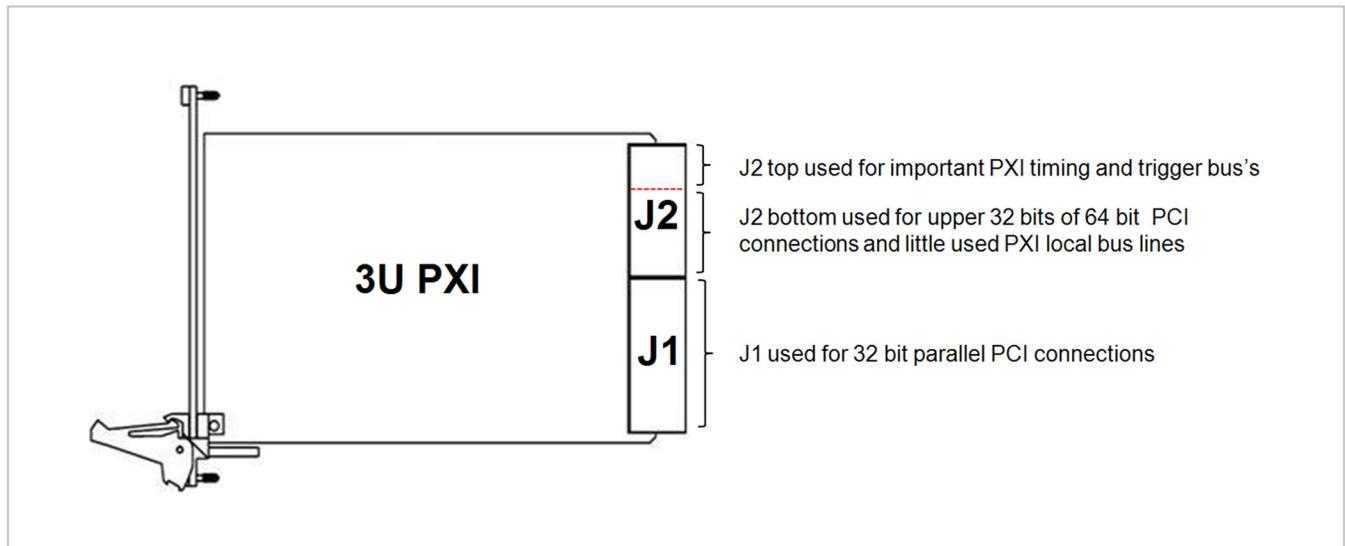


Figure 2. PXI-1 3U PXI module. Notice J1 is used for 32-bit parallel PCI connections ¹.

PXI hardware

Connectors (continued)

Figure 3 shows how an existing PXI-1 PCB layout can be redesigned or re-worked using a shorter connector to fit into a hybrid slot and how that same slot can also accommodate a PXIe module.

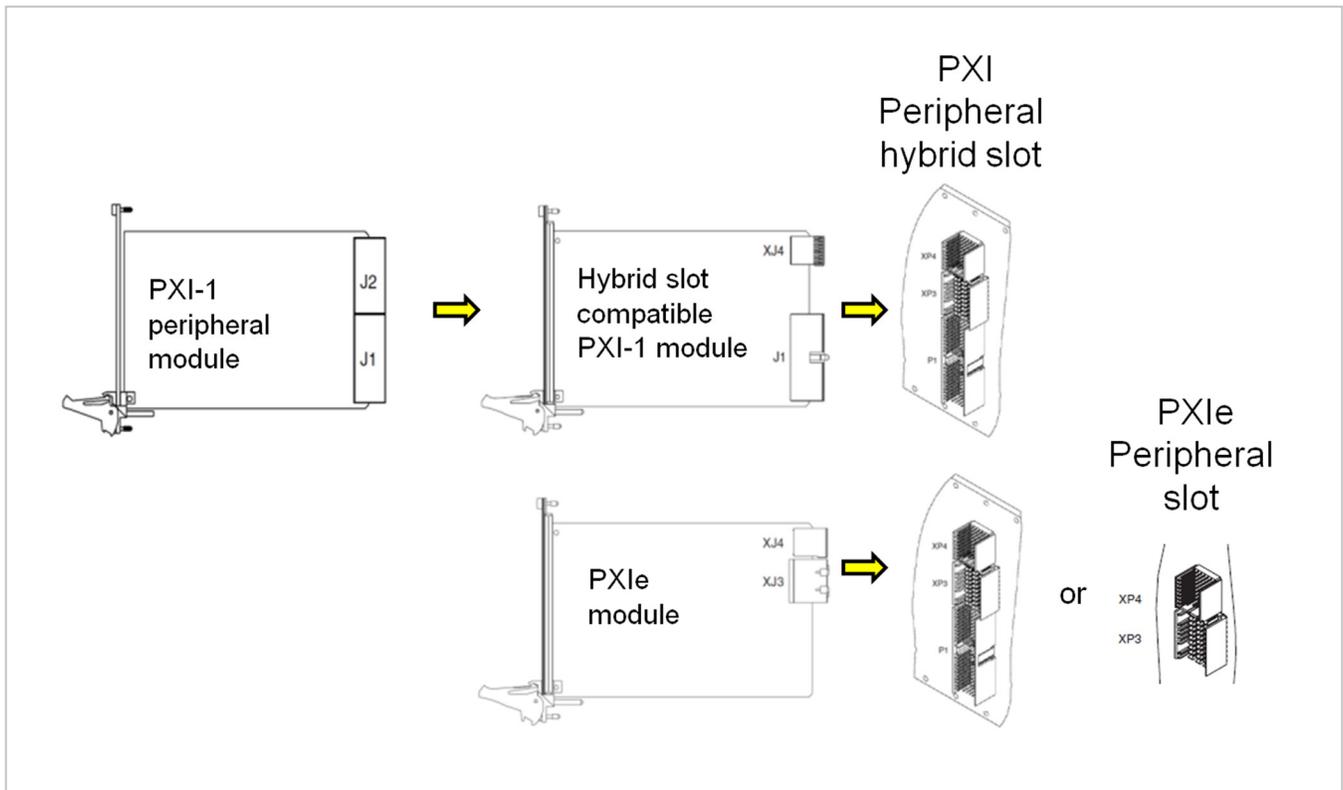


Figure 3. Legacy PXI-1 vs. hybrid and PXIe style modules and slots ¹.

PXI hardware

Connectors (continued)

Figure 4 shows views of these two styles of modules. Figure 4b shows the lower connector with differential connections. This differential connector is special to support the high speed signals required for PCIe (up to 5 Gbit/sec). The advantage of this new connector configuration is that existing PXI-1 designs can be re-configured by their manufacturer by simply replacing the larger J2 connector footprint with the shorter PXI-1 hybrid slot compatible connector (Figure 4a). This allows older product designs to be used in new PXIe chassis that contain hybrid style slots.

One aspect to be aware of—older PXI-1 modules that contain both J1 and J2 installed cannot be plugged into a PXI-1 hybrid style slot since the J2 connector will mechanically interfere with the new PCIe connector. If you have the old PXI-1 module stock on-hand, visually inspect the connectors to be sure if they are compatible. In the event they are not, some PXI module suppliers offer a modifications service to remove the J2 connector and replace with the shorter XJ4 connector. The good news is the majority of PXI-1 modules shipped today are shipped in a hybrid compatible format. To be sure, before purchasing new PXI modules verify with the module supplier that it is available in either hybrid or PXIe format.



Figure 4a. PXI-1 hybrid compatible style.



Figure 4b. PXIe connector style.

PXI chassis and controllers

Chassis

As mentioned earlier, the advantages of PXIe include significantly higher throughput, point-to-point messaging and improved triggering and synchronization. As such, in the future you will see more modules in the PXIe format. To support both the older PXI-1 and the newer PXIe style modules, it

Interoperability Hint

Select a chassis with many hybrid slots to provide slots for both PXI-1 Hybrid and PXIe style modules

is helpful to have as many hybrid compatible slots in the PXIe chassis. For maximum flexibility and interoperability, select a chassis with all hybrid slots to provide slots for both PXI-1 Hybrid and PXIe style modules. The Agilent M9018A chassis has been designed to maximize the number of hybrid slots. If you are using PXI-1 modules with the J2 connector, select a chassis with PXI-1 slots or make sure you can convert these to PXI-1 hybrid modules.

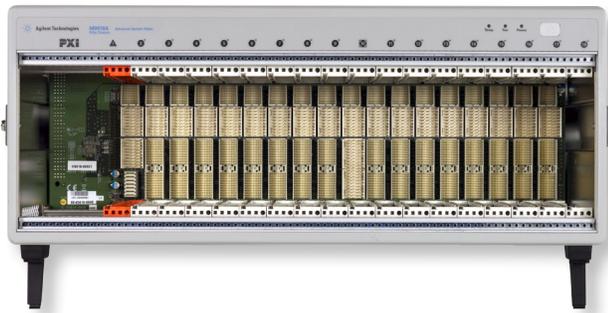


Figure 5. Agilent M9018A 18-slot chassis with 16 hybrid slots.

PXI controllers

PXI controllers can be located either outside the PXI chassis or embedded in the PXI chassis (installed into the chassis slot 1). First, let's discuss external controllers. During the early years of PXI external controllers would connect to the chassis using proprietary communications interfaces. As the PCIe communications protocol was developed, a PCIe physical layer that could extend beyond the controller was also developed. This means that the PCIe bus itself can now be extended directly between the controller and the chassis. No longer is a proprietary interface required. This is an advantage since an all PCIe based communications bus using standard COTS connectors, cables and chipsets greatly simplifies the communications bus design and use. However, there are some caveats. PCIe driver characteristics, clocking and the BIOS used in the controller are all important characteristics to note.

In tower and desktop controllers the PCIe bus is typically accessed via a PCIe connector located on the PC motherboard, and routing the bus externally using a PCIe plug-in adaptor card. Keep in mind when controlling a PXIe chassis there may be a long cable connecting the controller to the chassis. The long cable will impact signal loading and can inversely impact the eye opening for the high speed PCIe data. For optimal driver capabilities, equalization can be applied to the PCIe drivers improving the ability to drive long cables. Clock jitter can also impact PCIe communications, especially at the high PCIe Gen 2 rates. PCIe adaptor cards are available that can isolate and then re-generate a lower jitter PCIe clock to be used when decoding the PCIe message.

Interoperability Hint

If using an external controller, choose a PCIe adaptor card optimized for driving long PCIe lines and provides clock isolation with low clock/data jitter.

PXI chassis and controllers

To address PCIe signal drive and clock jitter concerns, select a proven PCIe adaptor card product. For example, the Agilent M9048A PCIe adaptor card has been engineered to provide PCIe drivers optimized to drive external PCIe cables. In addition the M9048A provides clock isolation also improving high speed PCIe data transmission. The M9048A clock isolation circuits are engineered to keep clock to data jitter extremely low, improving the timing margins at the PCIe receivers.

The enumeration process as previously described can also be impacted by the controller BIOS. To enumerate a full sized PXIe chassis, 30 or more PCI end points must be enumerated during the PC boot process. The number of PCI endpoints supported by BIOS in some business grade controllers may be limited since business applications typically only need a few PCI endpoints.

Interoperability Hint

If using an external controller select one that has been pre-tested to verify BIOS and signal characteristics are suitable for full enumeration of PXIe chassis. See www.agilent.com/find/M9018A

To reduce risk of selecting a PC that is not capable, Agilent has pre-tested popular PC controllers to verify operation. If you plan to use an external controller it is best to select one that has been pre-tested to verify BIOS are suitable for full enumeration of the PXIe chassis. For more information see the Tested Computer List (publication number [5990-7632EN](#)).

Interoperability Hint

When using a PXIe chassis with embedded controller be aware that the controller must also be a PXIe style controller.

An embedded controller, specifically designed for use in slot 1 of the PXI chassis, can also be used to control PXI instruments. If you are considering using an embedded controller it is important to note that the backplane connections for PXI-1 style controllers are different than PXIe controllers. PXI-1 controllers route the 32-bit parallel PCI bus while PXIe controllers route the high speed PCIe signals. The connectors are physically different and as such a PXI-1 controller cannot be used in a PXIe chassis. When selecting an embedded controller to use in a PXIe chassis keep in mind the controller must also be a PXIe style.



Figure 6. Agilent M9036A PXIe controller.

Software

Software is a critical component to consider when designing automated test systems. You may be concerned about mixing software, modules and chassis from different suppliers or selecting one IO library over the other. This section will address these questions and discuss software aspects of controlling your PXI system.

PCI is the primary communications path for PXI instruments. Just as the PCI electrical specifications provide a framework for electrical connectivity, the PCI device driver provides a common framework for software access. For improved usability and supportability, the driver stack usually is partitioned into multiple layers. Figure 7 shows the software stack used to communicate to Agilent PXI modules.

Application software access is always provided through the instrument driver. For Agilent products, this consists of an IVI driver, VISA driver and kernel driver. These three layers of software form a tightly coupled group that work together.

For software to successfully communicate to a PXI module the complete software driver stack must be installed and the driver needs to correctly be associated to the hardware. The driver is associated to the hardware when the PC boots up. At PC boot, the BIOS will discover PCI hardware on the bus and places information from the HW into a file location called Extended System Configuration Data (ESCD). Memory, bus addresses and IRQ's are assigned and stored into the ESCD. Next, the Microsoft Windows Plug&Play manager will process that information and create Instance ID's, associate drivers to the hardware and finally archives that information into a Windows Plug&Play manager information file.

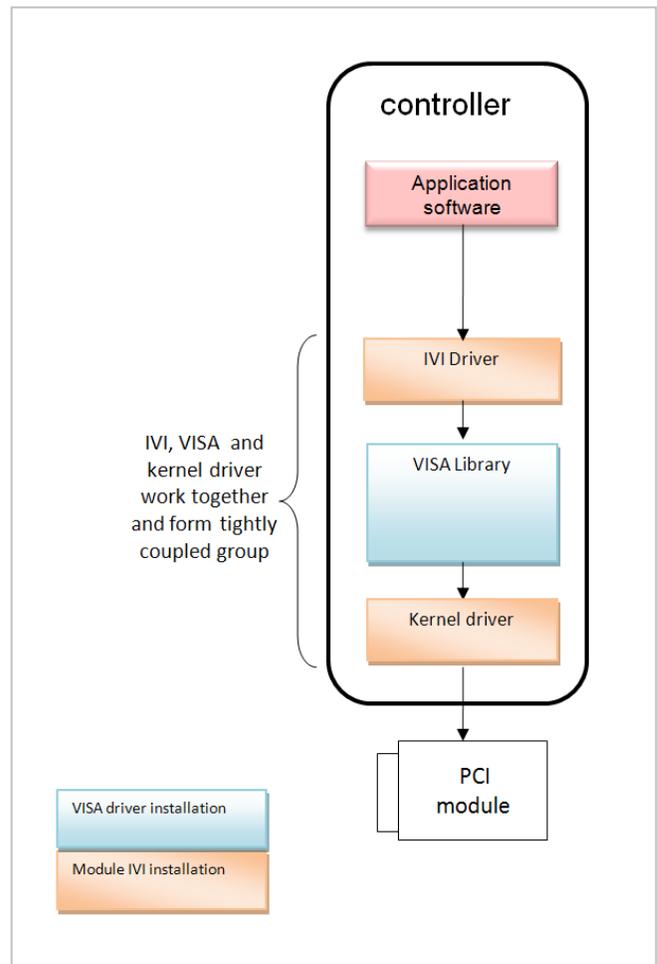


Figure 7. Software stack used to access Agilent PXI modules.

Software

The end result of this process can be observed in the Windows Device Manager. Figure 8 shows a fully enumerated M9018A chassis with Agilent Technologies, National Instruments and Pickering PXI modules present.

Viewing the PCI devices using Windows Device Manager is a good check of the status of the modules and the drivers. This view tells us the modules were successfully enumerated during boot time and the instrument kernel drivers are present and associated with the hardware. These are the first and most important steps to achieve software access to your instruments.

At this point it is always helpful to use the vendor provided soft front panel (sometimes known as test panel) to verify communications to the module. The vendor's SFP is a low level software tool that can be used to verify the health of your installation and hardware.

Interoperability Hint

Use the Windows Device Manager to determine if PXI modules are present on the PCI bus and if a driver is associated to the instrument.

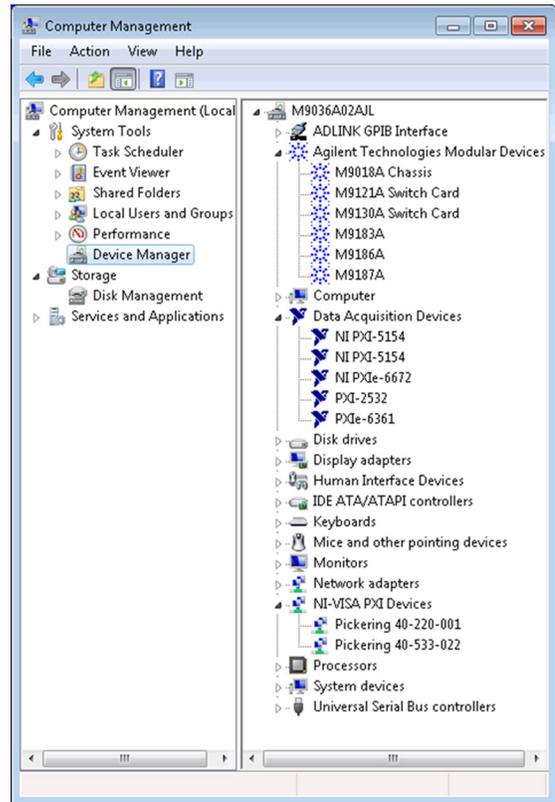


Figure 8. PXI instruments as they appear in Microsoft Windows Device Manager.

Instrument drivers, I/O libraries, ACE and NI-MAX considerations

In the previous section we discussed how critical it is to have an instrument software driver. For Agilent products the instrument driver is made up of multiple layers as we showed in Figure 7. The layers in tan are installed with the IVI driver installation, and are unique to the PXI module. The layer in blue is the VISA layer and it is installed with the Agilent I/O libraries. The VISA installation is common to all Agilent PXI modules. These software layers are separated this way for improved usability and supportability. Because of these software layers the driver installation requires both the Agilent I/O libraries and the module IVI driver. The Agilent I/O libraries can be found at www.agilent.com/find/iosuite and individual IVI drivers can be found at www.agilent.com/find/drivers. Search for the specific PXI module number.

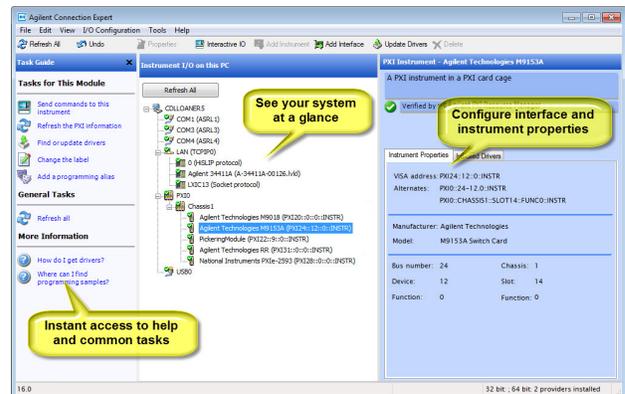


Figure 9. Agilent I/O Libraries connection expert.

With these two installations come other tools that are helpful when developing SW. For example, the Agilent Connection Expert (ACE) is installed with the Agilent I/O libraries. ACE can be used to inspect your instrument installation. It will help you visualize the contents of the chassis and inspect the driver revisions. Also, included with the instrument driver installation is a soft front panel, which helps verify initial communications and is useful when turning on the system.

Tips to improve interoperability experience

Some of the key interoperability points we've made in this application note will help you achieve a smooth implementation of multi-vendor PXI configurations. Here are a few tips:

- Select PXI modules are PXI hybrid slot compatible (older PXI-1 modules may not be).
- If using an embedded controller ensure consistent form factor:
 - PXIe chassis require PXIe controllers
 - PXI-1 chassis require PXI-1 controllers.
- To support future needs select a chassis with a large number of hybrid slots to support for both PXI-1 hybrid and PXIe style modules.
- If using an external controller select one that has been pre-tested to verify BIOS has enough bus numbers allocated to enumerate a large PXIe chassis. See: www.agilent.com/find/M9018A.
- If using an external controller, choose a PCIe adaptor card optimized for driving long PCIe lines, and provides clock isolation with low clock/data jitter.
- Insure complete driver stack is installed including both VISA software libraries and PXI module drivers.
- Use Microsoft Windows Device Manager to determine if PXI modules appear on the PCI bus and if a driver is associated to the instrument.
- Use the module Soft Front Panels as a quick check of successful hardware and software installation.
- If using VISA alias or resource descriptors, use the corresponding suppliers tools for setting: Use Agilent ACE for Agilent modules and National Instruments MAX for NI modules.

Conclusion

PXI chassis, controllers and instrumentation are based on standards maintained by the PCI-SIG, PICMG and PXISA organizations. These standards provide both the user and vendor several advantages including leveraging components and engineering investments made for high volume PC businesses. Common PCI bus inspection tools such as Microsoft Windows Device Manager give an independent verification of the PXI module driver installation and operation.

Instrument suppliers that adhere to these standards go a long way to ensuring multi-vendor interoperability. However, there are some aspects to keep in mind when configuration PXI systems. PXIe chassis with hybrid slots can accommodate older 32-bit parallel style PXI modules only if the PXI module has a hybrid compatible connector style. And when using an embedded controller in a PXIe chassis the controller must also be a PXIe form factor. Instrument drivers from different instrument suppliers are generally autonomous, and co-exist in the same system without issue. This application note has been a review of some of these characteristics to consider when using multi-vendor PXI bases solutions.

Agilent Technology is a sponsor member of the PXI Systems Alliance and closely works with other PXI SA members to ensure our customers are successful when deploying multi-vendor PXI solutions.

Related information

Software information

| | |
|--|---|
| Chassis slot compatibility: PXIe system slot | |
| Supported operating systems | Microsoft Windows XP Microsoft Windows 7 (32/64-bit) |
| Agilent IO Libraries | Includes: VISA Libraries, Agilent Connection Expert, IO Monitor |

Acknowledgements
Note 1. PXI-5 PXI Express Hardware Specification Revision 1.0, August 22, 2005.

Related information

- To find out more about the Agilent PXI products or to attend one of our on-demand or live web events visit: www.agilent.com/find/modular-education
- Agilent IO Libraries, www.agilent.com/find/iosuite
- Agilent IVI Drivers, www.agilent.com/find/drivers
- Agilent Chassis, www.agilent.com/find/M9018A
- Tested Computer List, Agilent publication number 5990-7632EN.





The modular tangram

The four-sided geometric symbol that appears in this document is called a tangram. The goal of this seven-piece puzzle is to create identifiable shapes—from simple to complex. As with a tangram, the possibilities may seem infinite as you begin to create a new test system. With a set of clearly defined elements—hardware, software—Agilent can help you create the system you need, from simple to complex.

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© Agilent Technologies, Inc. 2013
 Published in USA, November 5, 2013
 5991-0384EN



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