PXI
The Industry Standard Platform For Manufacturing Test

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Introduction

Test engineers face many challenges. In the forefront of these challenges are increasing test requirements and fewer resources to meet those requirements. The most important requirements considered include matching specifications to your device under test (DUT), lowering costs, rapid test system development, increasing throughput and reliability, all in a smaller footprint. Today, choosing the appropriate platform for your test system is a complicated decision. There are many options and standards available, making this process challenging to those who do not fully analyze all aspects of their application and its needs in advance. Originally automated test equipment (ATE) customers did not have such a rich selection of platforms and products.

Historically, ATE has been built with proprietary hardware and software for specific applications and required many months to development and build. Despite high cost, lack of scalability, and certain limitations, many applications have continued to require dedicated ATE to achieve the throughput and coverage requirements.

As technology has continued to evolve, however, commercial technologies have developed that now parallel and often eclipse the capabilities of dedicated, proprietary systems. Comprehensive hardware and software architectures are available that bring capabilities once confined to very expensive, proprietary systems, to applications from design verification test through highly automated manufacturing. Just as computers that once filled entire rooms have shrunk while steadily increasing capability, sophisticated ATE is now available for desktop use, with the cost, flexibility, and performance demanded by a large number of engineers in research, design, and manufacturing.

In 1998, PXI (**P**CI e**X**tensions for **I**nstrumentation) was introduced. PXI combined the latest commercial hardware and software technologies with concepts and technologies derived from ATE, including sophisticated timing and triggering for high-performance measurements. By leveraging these commercial PC and digitizer technologies, PXI provides the advanced performance of proprietary ATE, but at a much lower cost.

A platform that features complete hardware and software interoperability, such as PXI, is able to meet all test system needs. The open PXI specification resulted in a modular approach to test systems, allowing for easy integration of multi-vendor systems as well as flexibility across other platforms.

PXI offers functionality in nearly every area of automated test including the following typical test system components: controlling PC, signal generator, switching, digitizer, boundary-scan, power supply, and mass interconnect. The following sections will discuss each of these components more in depth, including the benefits of their PXI offerings. To learn more about the PXI Specification or for a complete list of PXI vendors visit www.pxisa.org

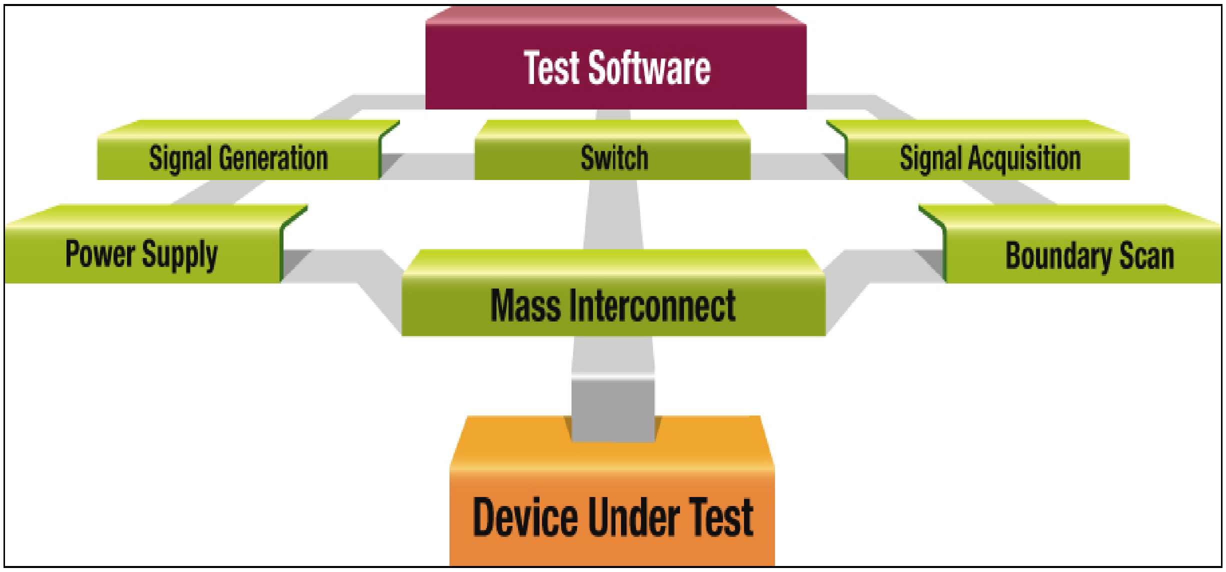

Figure 1. Test System Architecture

Controlling PC

Test management software resides on a system controlling computer. The computer must be high performance with standard software that eases development, integration, and execution. The system controller must be rugged to withstand the manufacturing environment. Cost effectiveness is also a primary concern for most test engineers and their budgets. A constant desire to decrease test time and ease maintenance mandates that the system controller is easily upgradeable. The controlling PC hosts the test code, which is developed in the chosen test executive software, application development environment (ADE), and the measurement services software. The test executive manages the execution of a series of tests developed in the ADE. Measurement services software consists of the driver and configuration utilities that accompany your hardware products. These software components allow for easy development, integration, and execution when the proper controlling computer is selected.

The PXI Specification defines slot one of the chassis as the system controller, managing all modules across the PCI-derived PXI backplane. Manufacturers utilize the latest commercial PC technologies to produce high performance controllers. These controllers feature many typical inputs and outputs that you would find on a desktop PC, in a rugged modular form. Popular operating systems, such as Windows XP, are standard on most PXI controllers, which eliminates any learning curve for these industrial PCs.

There are two basic types of PXI Controllers, embedded and remote controllers. In addition to standard operating systems, real-time operating systems are also offered on PXI Controllers. Windows-based controllers function identically to desktop PCs. These controllers, such as the NI PXI-8176, feature high performance Pentium processors, integrated peripherals for keyboard, mouse, Ethernet, USB, serial, and parallel ports. The PXI system controller embeds this functionality into the first slot of the chassis. Real-Time-based PXI controllers are intended for applications requiring deterministic and/or stable performance for headless measurement and control applications.

Remote PXI system controllers give developers the freedom to utilize the latest commercial PCs and their processors. With MXI-3 (which stands for Measurement Extensions for Instrumentation) from National Instruments, users can remotely control PXI instrument systems from either a desktop PC, or a master PXI chassis with an embedded controller. MXI-3 remote controllers give users the flexibility to integrate their high performance desktop PC with their PXI system whether it’s two feet away, for design and validation, or 650 feet away, on the manufacturing floor.

PXI system controllers offer many solutions to meet most any ATE and manufacturing test need with the features and software to allow for easy development, integration, and execution. To learn more about National Instruments embedded and remote controllers visit www.ni.com/info and enter pximv

Signal Generators

Signal sources form the foundation of a measurement system and are used from the early design stages on through manufacturing test. The task of the signal source is to provide a stimulus or excitation to the device under test so that the device's behavior can be characterized or validated. There are three common uses for a signal source in manufacturing test: ideal "golden" signal stimulus, "real-world" signal generation, and component or subsystem emulation. To validate the proper operation of a device, the signal source will need to provide an ideal "golden" stimulus signal. Once the device is debugged, it must be tested under "real-world" operating conditions, where noise, interference, and distortion will be present in the input signals. The design or test engineer will decide whether it is appropriate to test the device using the ideal or real-world signals during manufacturing test. Using a signal source to emulate a component or subsystem allows you to test sections of a device before the subsystems are assembled. When devices are highly complex, emulation aides in isolating defects earlier in the manufacturing process before more work is done on a defective device.

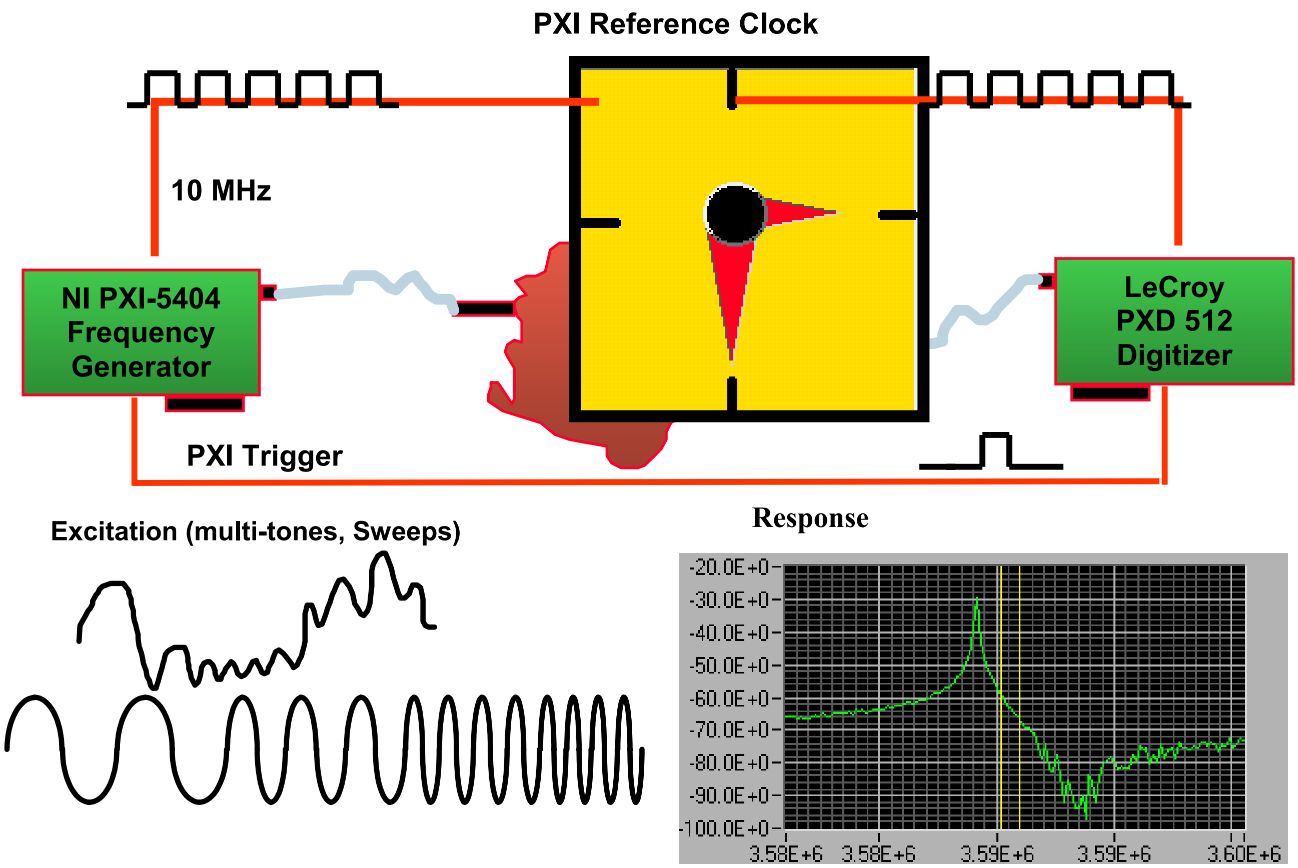

Figure 2. PXI as a Signal Source Platform

The physics of the signal typically dictate the amount of time it takes to “play” the output waveform. The largest gains in test throughput can be made by minimizing the amount of time necessary to setup the instrument for the test. Using the 132 MB/s PCI-based PXI backplane, data can be downloaded to a signal source almost 300 times faster than traditional GPIB based instrumentation, resulting in a substantial improvement in test throughput. Since it is very rare to find a signal source without an acquisition instrument, the built-in PXI Trigger Bus and 10 MHz reference clock improve both the accuracy and speed of a stimulus-response type measurement. For example, using the NI PXI-5411 arbitrary waveform generator and a high-speed digitizer, a frequency response sweep tester or “Bode plotter” can be made. In this case, a list of the desired frequencies is created in software and downloaded to the PXI-5411’s onboard memory. When the high-speed digitizer is finished acquiring a set of data at a given frequency, it triggers the PXI-5411 to generate the next frequency in the list. The next set of data is then acquired and the process repeats itself. Using hardware triggering, the instruments execute the test over ten times faster than traditional GPIB-based instruments. For more information on National Instruments Signal Sources visit www.ni.com/info and enter *pximv*

Switching

Nearly every ATE test system today uses some aspect of switching. In short, switching delivers the ability to connect a high number of channels to a few test instruments, therefore reducing the amount of money required to build an automated test system. For example, with switching, you can connect one oscilloscope to 20 test channels or one digital multimeter (DMM) to more than 200 resistance temperature detectors (RTDs).

Switching also adds measurement flexibility for accommodating a variety of test fixtures at a significantly reduced cost compared to building a test system without switching. To use switching in your test systems, it is important to understand the different types of available switching topologies. You can categorize switches into three areas - general purpose, multiplexer, and matrix.

Modular switch hardware empowers you to define exactly what you need in your system, while at the same time allowing for future expansion and integration with existing hardware and software. This allows for significantly reduced costs because you pay for only the function that you need while gaining increased switching performance and capabilities. Modular switch hardware also provides tight integration with other modular hardware components in your system and delivers unparalleled timing and synchronization capabilities. Ultimately, the key features of modular switching hardware include: reduced system cost, greater flexibility, a smaller footprint, and increased development productivity.

There are a wide variety of high-quality switching products, including general-purpose relays, multiplexers, and matrices for the PXI platform. There are PXI switch modules for almost every application, from high-power applications requiring up to 1000 VDC and 30 A to satisfying high density and high frequency requirements up to 65 GHz.

In addition, the PXI trigger bus facilitates hardware scanning by simplifying the trigger routing and removing the need for ambiguous software delays. Hardware scanning improves throughput by downloading a list of connections to the switch modules and cycling through the list using an event (trigger) without any interruption from the host processor. In order to implement hardware scanning, a PXI switch module must have a scanlist architecture.

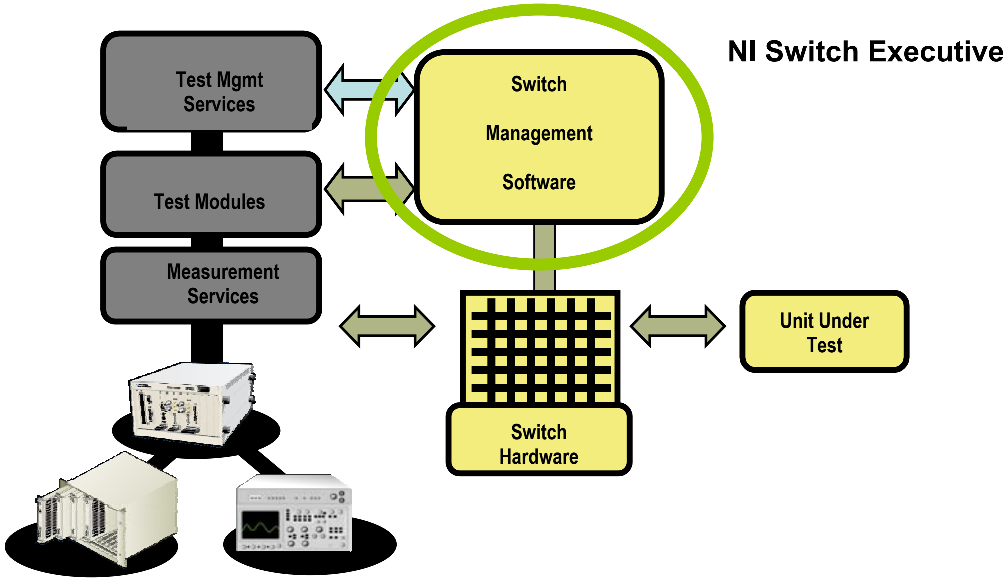

Figure 3. NI Switch Executive Software

For additional assistance in configuring, programming, and managing higher channel count switching systems, NI Switch Executive software offers an easy-to-use intelligent switch management and visual routing environment. This off-the-shelf switch configuration and management software delivers the crucial software integration between the switch hardware and the actual electronic tests by providing the openness and flexibility for configuring and managing switch systems using any interchangeable virtual instrument (IVI)-based switch hardware available from a wide variety of switch vendors. To learn more about NI Switch Executive software visit www.ni.com/info and enter *switchexecutive*

Digitizers

A high-speed digitizer is a very general-purpose product. All LeCroy modular digitizers conform to the industry standard PXI format and have 3U height. Some are targeted to automotive and other applications where higher voltage signals are present (the model 222 has 200 MHz bandwidth, 1 Mohm impedance and is rated for 300 volt CAT II signals). Others are targeted to testing typical analog and digital signals from a broad array of products. Figure 4 lists the basic specifications of several high-speed PXI digitizers. You can also view a variety of National Instruments digitizers at the ni.com website. There is a very wide variety of performance and price range. LeCroy PXI digitizers are two channel or four channel units with a range of bandwidths starting at 200 MHz. Note that each of them incorporates an analog to digital converter (ADC), which samples the incoming signal in real time (up to 2.5 GS/s sampling rate). But since typical test systems apply a test signal repeatedly to the DUT, these digitizers can also use the additional information available from a repetitive signal to acquire a much more accurate signal shape using 50 GS/s equivalent time sampling. This type of acquisition mode is common in digital oscilloscopes but is not included in many modular digitizers. As a rule of thumb, to make a precision measurement the ratio of sample rate to signal bandwidth should be 10:1, if possible.

MODEL VENDOR	2 LeCro	PXD1021 LeCro	PXD522 LeCroy	PXD514 LeCroy	PXD512 LeCroy	PXD214 LeCroy	PXD212 LeCroy	PXD114 LeCroy	PXD222 LeCroy
Bandwidth	1 GHz	1 GHz	500 MHz	500 MHz	500 MHz	250 MHz	250 MHz	150 MHz	200 MHz
Maximum Single-Shot Sample Rate	2 GS/s	2 GS/s	2 GS/s	1 GS/s	1 GS/s	1 GS/s	1 GS/s	1 GS/s	2.5 GS/s
Maximum Repetitive Sample Rate	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s	2.5GS/s
Channels	2	1	2	4	2	4	2	4	2
3U PXI Slots	3	2	3	3	2	3	2	3	2
Acquisition Memory Standard	256k	256k	256k	256k	256k	256k	256k	256k	27.5k
Acquisition Memory Option L	4M	4M	4M	4M	4M	4M	4M	4M	
Acquisition Memory Option XL	8M	8M	8M						
Single-Shot Capture Window	10 ns-10,000s	10 ns-10,000s	10 ns-10,000s	10 ns-10,000s	10 ns-10,000s	10 ns-10,000s	10 ns-10,000s	10 ns-10,000s	50 ns-50s
Repetitive Capture Window	2 ns-10 us	2 ns-10 us	2 ns-10 us	5 ns-10 us	5 ns-10 us	5 ns-10 us	5 ns-10 us	5 ns-10 us	N/A
Sequential Mode Max Segments	8192	8192	8192	4096	4096	4096	4096	4096	N/A
Power Consumption	58W	36W	58W	70W	41W	70W	41W	70W	8W

Figure 4. A table of PXI digitizers from LeCroy. The model PXD 222 is designed for a different set of applications. It has CAT II safety rating and allows inputs up to 300 Volts. The other digitizers are targeted toward use with lower voltage digital and analog signals.

Triggering the System

Once you have set up a test system, the next step is to send signals into the DUT and look at the output. Typically this requires a trigger. An important provision of the PXI standard is the Star Trigger. As shown in Figure 5, multiple instruments in the system can be triggered by the system controller (using the PXI Trigger Bus) or by the module in slot 2 (using the PXI Star Trigger). Having multiple levels of trigger control makes it much easier to trigger a variety of instruments that may be resident in a test system. On a digitizer such as the ones shown in Figure 4, the digitizers can trigger automatically, in normal mode or via several other modes. All of the digitizers in Figure 4 can have 0 to 100 % of their memory assigned for pre-trigger recording. Another important factor is that there may be a master trigger signal that is controlling the system. In cases like this, it is important to have an external trigger input for the digitizers in addition to the signal inputs.

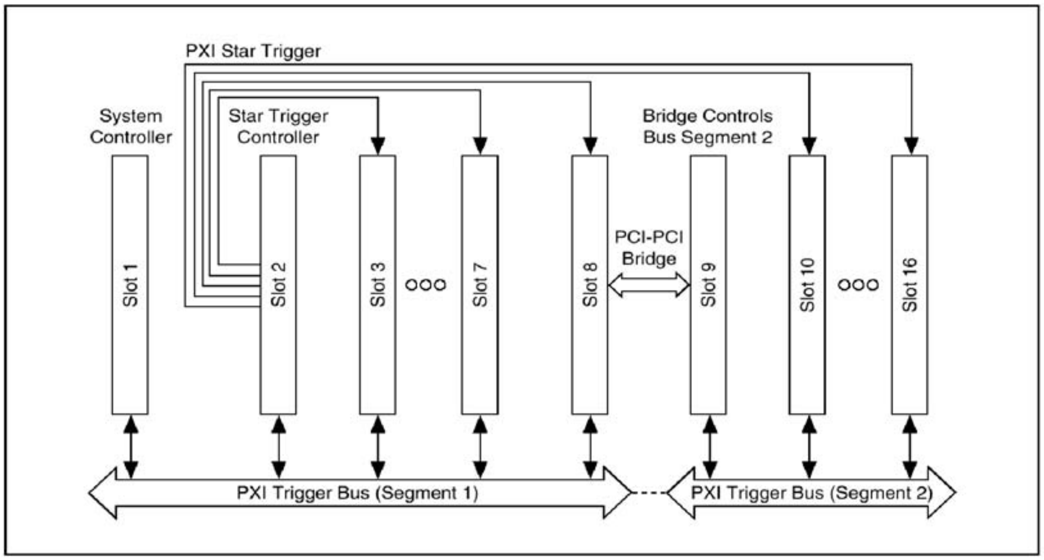

Figure 5. This block diagram from the PXI standard shows the implementation of the PXI Trigger Bus and of the PXI Star Trigger. The trigger bus has eight bidirectional lines to each slot. The Star trigger has a dedicated line between slot two and each of the other slots in a chassis. Special slot two modules have the ability to bridge the trigger lines to an additional chassis

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Digitizer Summary

The digitizers need to have the number of channels, dynamic range and bandwidth needed to capture the signal—and it is preferable for it to have a repetitive mode in addition to single shot. After all, the more information you capture from your DUT, the more accurate the answer will be concerning its performance. Of course it is a good idea to have test instruments with the best general-purpose capabilities, such as the ability to be part of a flexible triggering scheme. The PXI standard provides an excellent industry wide standard under which a variety of vendors are building high quality digitizers. To learn more about digitizers from LeCroy visit www.lecroy.com To learn more about digitizers from National Instruments visit www.ni.com/info and enter *pximv*

Boundary-Scan

Testing of electronic assemblies in the manufacturing facility has been greatly impacted by two unrelenting trends:

1) The use of VLSI components in advanced fine-pitch packages (e.g. BGA), in which hundreds or even thousands of electrical contacts are incorporated on the underside of the devices
2) Increasingly complex PCB designs utilizing double-sided surface-mount technology, multiple inner layers and smaller track dimensions.

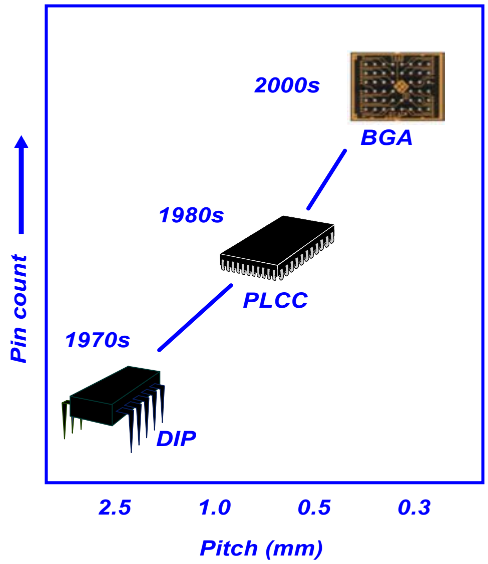

Figure 6. Trend in IC device complexity

As a consequence of these trends, conventional in-circuit test methods relying on physical contact to a large number of test points are becoming limited in their fault coverage and effectiveness. Manufacturers must either deploy other means of verifying the structural integrity of their printed circuit assemblies or allow faults to "escape" to the functional test stage, where diagnosis and repair can be lengthy and expensive.

One of the most widely adopted structural test methods for advanced PCBs are boundary-scan, which provides high-density test access via a simple, inexpensive interface defined in IEEE Standard 1149.1. Boundary-scan testing restores high test coverage for structural faults while overcoming the restrictions of bed-of-nails access to the board nets. By improving test coverage, fewer boards with structural faults escape undetected to functional testing. As a result, boundary-scan reduces the "bone-pile" of mystery boards, those that fail functional test but are difficult to repair.

As the significant benefits have become apparent, a large number of companies (in the thousands) around the world are using boundary-scan. PXI technology provides a highly efficient means of implementing boundary-scan for testing and in-system programming on the factory floor, by incorporating a PXI-based boundary-scan test instrument (the controller) within a functional test system. This integration allows the two complementary test methods to share the same user interface and footprint. PXI's robust structure and compactness allow users to build their boundary-scan system within a comprehensive test platform that includes a wide range of other test and measurement instruments.

In the integrated test, a predetermined sequence of test steps is performed, beginning with structural verification using boundary-scan. The latest PXI controller from JTAG Technologies is capable of driving four scan chains independently or in parallel at a sustained test clock rate of 40 MHz. A front-end pod provides high signal integrity and extended range to the target. In most cases, detected faults are identified with precision, allowing them to be quickly found and repaired.

Figure 7. Functional test system, including PXI-based boundary-scan controller for structural Testing

Often the structural test is followed by in-system programming of flash memories and logic devices, also under control of the boundary-scan instrument. Special hardware and software features in the JTAG Technologies PXI controller accelerate flash programming to support high beat-rate production lines.

At this point, after the board's structure has been verified and configured via boundary-scan, the test executive conducts the scripted sequence of functional tests using the great variety of PXI instruments that are available. In this way, even highly complex mixed-signal boards can be tested comprehensively and programmed in one integrated station. Total test system cost is minimized, floor space and user training are reduced, and process logistics are greatly simplified. To learn more about JTAG Boundary Scan products visit www.jtag.com

Power Supply

Expectations for Power Supplies
In year 2000, a small power outage in Taiwan caused 3 million US dollars worth of damage in semiconductor production stoppage, but damages to silicon wafers was several times higher. The manufacturing market demands more than just reliable supplies. Power supplies should tolerate abuses from a few defective parts or a minor accident. Supplies should execute proper on/off sequencing to minimize damages to DUT. A PXI solution with UPS, and smart power supplies could have saved a lot of money in this case.

Power Supply in Product Testing
In product testing, the power supply simulates power conditions the DUT may face in the real world. A TV should be tested to work on different AC line conditions. A cell phone should be tested to work on different battery conditions. In some cases, the power supply is part of the input stimulus in order to test other power supplies or chargers.

To stay flexible and agile, power supplies should be programmable. The supply should measure current and voltage so you know if there are hidden problems before physical failure such as cold solder joints, or to test power saving functions for Energy Star compliance. The supply should be an integral part of the test system.

PXI-Based Power Supply

Modular supplies of up to 300 watts can be fitted into a PXI 3U, single slot form factor. PXI supply compactness comes from the minimization of overheads. The mechanical chassis, cooling fan, display, and control interface are shared with other PXI modules. This form factor minimizes the system footprint and eliminates troublesome cables and connectors.

PXI power supplies are rugged due to the time tested Eurocard mechanical packaging. Front access brings mean time to repair (MTTR), to within minutes. Some PXI power supplies can operate in parallel to increase the current drive, or to operate in series to increase voltage output. This level of flexibility streamlines the power supply inventory and ultimately brings down the total cost of ownership (TCO).

External Power Supply Integration

Chassis cooling capability limits the output power of PXI power supplies. External power supplies with GPIB interface can also be integrated. PXI implements Virtual Instrument Software Architecture (VISA) makes such integration fast and painless.

The PXI specification requires internal and external power supplies hardware device drivers to be written. This facilitates hardware and software interoperability and eases production integration and maintenance.

Example: ATE for PCB

A projection display PCB test system designed by Chroma is shown in Figure 8. Six PXI dual-channel programmable supplies were used: Five modules were used to power the DUT, and one set is used to control a high voltage linear supply via analog channels. This system with 192-pin capability is housed in a standard PXI chassis, and the development required only two months. It includes a virtual instrument interface where system operation can be conducted over the web. This system enables problem detection right at the board level before assembly in order to minimize test cost.

PXI components are like pieces in a LEGO^{TM} set, with precision interconnection schemes in hardware, software, and mechanical dimensions. It enabled Chroma to quickly assemble a complex test system in record time. To find out more about Chroma Power Supplies visit www.chromaate.com/pxi

Figure 8. PCB Automatic Test System

Mass Interconnect

Today's manufacturing test environment is dynamic, fast-paced, budget-sensitive and extremely competitive. A successful test program requires a strategy that optimizes your test system investment by providing both flexibility and reliability at the lowest total cost of ownership.

A mass interconnect system helps leverage your PXI investment by providing the following:

- **Standard Interface Platform-** A company-wide standard interface and wiring platform for test programs.
- **Flexibility-** Ability to accommodate any ATE configuration, allowing quick fixture or Device Under Test (DUT) changeover.
- **Reliability-** Supporting thousands of connections and connector mating cycles over the lifetime of the test system.
- **Lowest Total Cost of Ownership-** Lower cost of ownership interconnection alternative over the life of the ATE system.

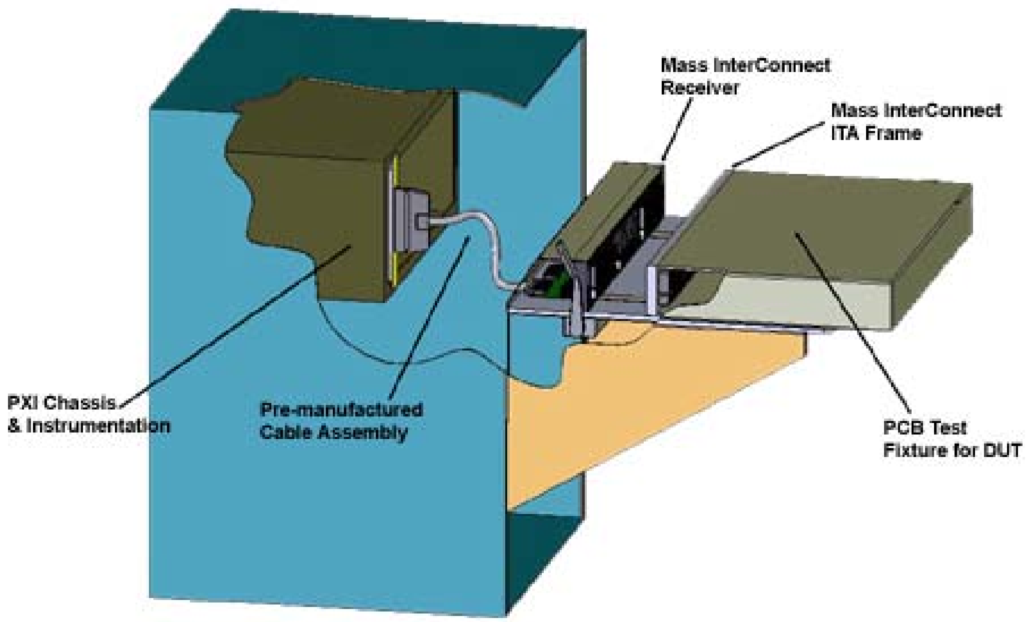

Figure 9. Typical PXI-based mass interconnect system for testing printed circuit boards in a manufacturing test environment.

In today's electronics manufacturing environment, it is possible for a test system to be designed at one location, integrated at a different location, installed, and then supported at many other locations throughout the world. A PXI test platform with a common mass interconnect interface and wiring standard reduces costs associated with company-wide redundancies in test system development, wiring design, integration and support at multiple locations. Standard documentation, troubleshooting and maintenance reduce test program administration and support costs while realizing economic purchasing benefits associated with company-wide standardization.

A modular PXI test platform with a standard interface and wiring approach also improves your ability to respond to the intense demands created by quick time-to-market requirements and short product lifecycles. A mass interconnect system provides the flexibility required to quickly change from one test fixture or DUT to another. Any downtime associated with rewiring or troubleshooting when setting-up a new test program is minimized.

Mass interconnect systems accommodate a wide range of analog, digital, RF, fiber optic, power, thermocouple and pneumatic requirements while allowing for future expansion as test requirements evolve. With next generation, high density interconnect technology, a single mass interconnect system can consolidate from 100 to over 17,000 connection points in a single interface, eliminating the multitude of cables and connections required by many test system configurations. Design, integration, troubleshooting and documentation time are minimized with the availability of cable assemblies pre-configured for instrument cards to match your PXI applications. Online configuration tools make cable assembly selection quick and easy.

Mass interconnect systems are designed for the repeated mechanical cycling and rigors of the typical test environment and are warranted for tens of thousands of repeated mating cycles. This reduces costs associated with repair of worn or damaged connectors and downtime that adversely affects manufacturing throughput and can lead to thousands of dollars in lost revenue.

Your investment in instrumentation hardware is significant. A mass interconnect system protects this investment by providing a repeatable and reliable interface between your instrument and the fixture or DUT, allowing you to get longer life out of your instruments.

With support costs approaching as much as five times the initial cost of a system, it is important to be sensitive to the true costs associated with supporting your test program. A successful test program requires a strategy that optimizes your test system investment by providing flexibility and reliability at the lowest total cost of ownership. A core test platform strategy utilizing PXI modular instrumentation with a mass interconnect system allows you to get the most from your test system investment.

To find-out more about how a mass interconnect solution will help optimize your test investment, contact Virginia Panel Corporation at www.vpc.com/mi.

Conclusion

Manufacturing test applications mandate that test platforms address many requirements. Integrated well-defined hardware and software specifications are critical to ensure platforms are able to meet present and future needs for test systems. The selected platform must also be able to meet changing needs by continuing to release new and innovative products while supporting integration of existing legacy hardware. The PXI platform is suited for most test systems because it continues to offer high value products that consistently meet necessary test requirements while remaining flexible. In addition, PXI is cost-effective, reliable, and has a small footprint, which is crucial for manufacturing test applications.

The specification that PXI is built on provides unparalleled interoperability. PXI continues to offer a wide range of products. With over 880 PXI-compatible products available from more than 60 vendors, PXI can meet the needs of nearly any manufacturing test application. You can find more information about PXI and the many vendors that supply PXI compatible products by visiting pxisa.org. For information from the companies or products mentioned in this white paper, see the contact information below:

Chroma	www.chromaate.com/pxi
JTAG Technologies	www.jtag.com
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