

Hardware-in-the-Loop (HIL) Test System

Solution Overview

Product designs are getting more complex, yet time-to-market expectations continue to apply pressure. A flexible, software-centric approach to embedded software test can help detect design issues early, while improving the ability to modify the system for future changes. Test system flexibility ensures the design meets specifications and time-to-market pressures by helping manage these (seemingly) never-ending changes. The NI HIL test system highlights the tools and technology that can help you build an HIL test rig ready to keep pace with your demanding, and changing, requirements.

Solution Architecture

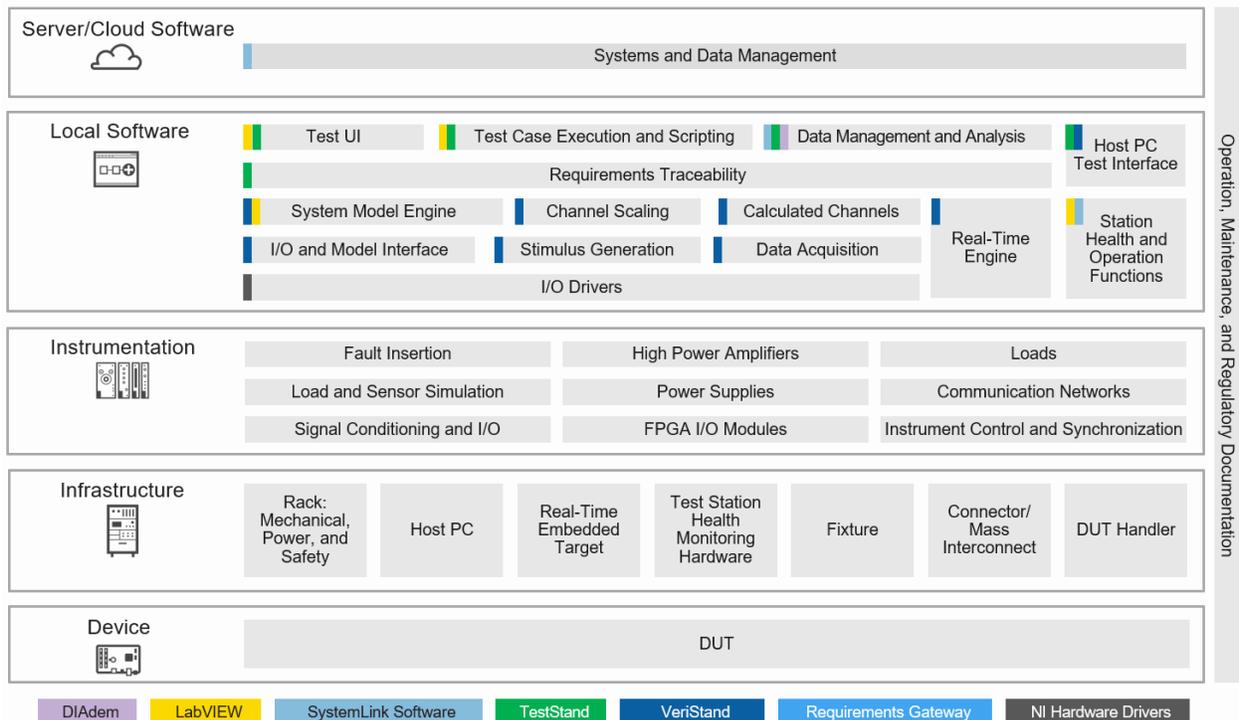


FIGURE 01

The HIL test system solution architecture includes hardware and software logical elements for a complete test system.

Key Features

- Integrate models from your environment of choice, such as MathWorks, Inc. Simulink® software, with NI VeriStand.
- PXI hardware platform for I/O performance and flexibility
- Reuse modular signal conditioning and fault insertion between test systems with NI SLSC hardware.
- Further customize signal I/O with LabVIEW programmable FPGAs.
- Build, deploy, and automate your validation test system with TestStand test management software.

Optional Features

- Custom functionality via LabVIEW, ANSI C/C++, and Python
- ASAM XIL API standard support
- Fault insertion
- Test system automation
- Communication busses

PXI System Overview

PXI is a PC-based system that combines PCIe electrical-bus features, a modular chassis, I/O synchronization technology, with user defined or application specific test software. PXI is an open industry standard governed by the PXI Systems Alliance, a group of more than 70 global test companies. NI was one of the pioneer companies in the formation of PXI and is recognized as a leader in PXI test and measurement devices.



FIGURE 02

PXI chassis (18 slot chassis shown) combine modular instrumentation, timing and synchronization technology, and test-centric software to form the core of a complete test rack

Instrumentation available in PXI form factor includes:

- Analog and digital I/O
- Digital multimeter
- Oscilloscope/digitizer
- Waveform generator
- Switch and timing/synchronization
- Source measure unit (SMU)
- Programmable DC power supply
- Electronic load
- Instrument control and synchronization
- FPGA Processing Boards

"PXI chassis are a staple of our test systems, as is LabVIEW."

Anthony Lambert, Engineer, Abbott Laboratories

NI Test Platform Benefits

- Build a universal test architecture to enable high reuse across test types and programs with NI's open and secure platform.
- Better utilize data and more efficiently manage systems with NI's enterprise-ready cloud-based tools.
- Easily integrate third-party equipment and customize software and hardware to meet unique test requirements.
- Take advantage of an ecosystem of expert hardware-in-the-loop (HIL) specialty partners.



FIGURE 03

Test systems built on PXI hardware (system on the right) are ideal for systems that need customization and the ability to keep up with change requests as opposed to traditional boxed instruments (as seen on the left) that increase the complexity of a test system as requirements grow.

Signal Input and Output Hardware

PXI I/O and Instrumentation

NI offers more than 600 PXI modules, ranging from DC to mm Wave. Because PXI is an open industry standard, nearly 1,500 products are available from more than 70 different instrument vendors. With standard processing and control functions designated to a controller, PXI instruments need contain only the actual instrumentation circuitry, achieving effective performance in a small footprint. Combined with a chassis and controller, PXI systems feature high-throughput data movement using PCI Express bus interfaces and sub nanosecond synchronization with integrated timing and triggering.



Frequency Counters

Perform counter-timer tasks such as event counting and encoder position; and make period, pulse, and frequency measurements



Custom I/O with Processing

Provide high-performance I/O and powerful FPGAs for applications that require more than standard instruments



Power Supplies and Loads

Supply programmable DC power (optional isolated channels, output disconnect functionality, and remote sense)



Data Acquisition Modules

Measure electrical or physical phenomena with a mix of analog I/O, digital I/O, counter/timer, and trigger functionality



Switches (Matrix and MUX)

Utilize a variety of relay types and row/column configurations to simplify wiring in automated test systems



GPIB, Serial, and Ethernet

Integrate non-PXI instruments into a PXI system through various instrument control Interfaces

Switch Load Signal Conditioning (SLSC)

NI SLSC is an add-on for NI data acquisition products such as PXI and CompactRIO. SLSC standardizes connectivity and provides a modular approach to signal conditioning, fault insertion, and other test needs that typically require more power or space for circuitry than allowed by the PXI standard. NI can help connect you to the right NI Alliance Partner to build a custom SLSC module that completes your test system.



FIGURE 04

The NI SLSC-12201 (left) is a 33V DIO module designed for HIL test systems. SLSC modules mount in an NI SLSC chassis and connect on the front-end of a PXI I/O module (right).

NI Software for HIL Test

VeriStand Application Software for Real-Time Test

VeriStand application software helps you configure I/O channels, data logging, stimulus generation, and host communication for NI real-time hardware. You can also import simulation models and control algorithms, respond to events with configurable alarms, and enable test automation with macro recording, TestStand, .NET, and other software. You can interact with and monitor application data, alarm states, and system execution metrics using a run-time editable user interface. Although you don't need programming knowledge, you can also use a variety of software environments such as LabVIEW, ANSI C/C++, Python, and ASAM XIL to add custom functionality to VeriStand.

Key Benefits:

- Configure real-time tasks
- Visualize data and manage test execution

- Run automated tests



FIGURE 05

VeriStand application software runs tasks such as stimulus generation, data acquisition, calculated channels, and custom scaling for real-time test applications.

“The powerful combination of the NI VeriStand platform, LabVIEW FPGA, the real-time PXI module, and years of fast prototype development and experience with NI products helped us quickly and easily design and develop the whole HIL system.”

G. Paviglianiti, Advanced Development, Whirlpool Fabric Care

TestStand Test Executive Software for Automation

TestStand ready-to-run test management software is designed to help you quickly develop and execute transaction processing system (TPS) software. You can extend TPS functionality by developing TestStand test sequences that integrate code modules written in a variety of programming languages, including G in LabVIEW, C/C++, .NET, and Python. TestStand also provides extensible plug-ins for reporting, database logging, and connectivity to other enterprise systems. You can deploy test systems to production with easy-to-use operator interfaces.

Key Benefits:

- Customize test sequences to meet every requirement
- Automate saving and reporting test data
- Increase test throughput with parallel testing
- Efficiently replicate and deploy test systems
- Troubleshoot test systems with integrated debugging tools
- Customize user interfaces to meet testing needs



FIGURE 06

Use TestStand test executive software to build and deploy automated systems faster.

LabVIEW Systems Engineering Software

LabVIEW offers a graphical programming approach that helps you visualize every aspect of your application, including hardware configuration, measurement data, and debugging. This visualization makes it simple to integrate measurement hardware from any vendor, represent complex logic on the diagram, develop data analysis algorithms, and design custom engineering user interfaces.

Key Benefits:

- Reduce system setup with access to thousands of instrument drivers, example programs, and documentation to connect to virtually any instrument.
- Use hundreds of instrument-specific example code modules and included measurement libraries to reduce development time.
- Reuse existing code libraries from languages including C/C++/C#, .NET, Python, and MathWorks MATLAB® software.
- Quickly create professional user interfaces to visualize test outcomes.
- Build proficiency with extensive online and in-person training options for both new users and certified NI tool architects.

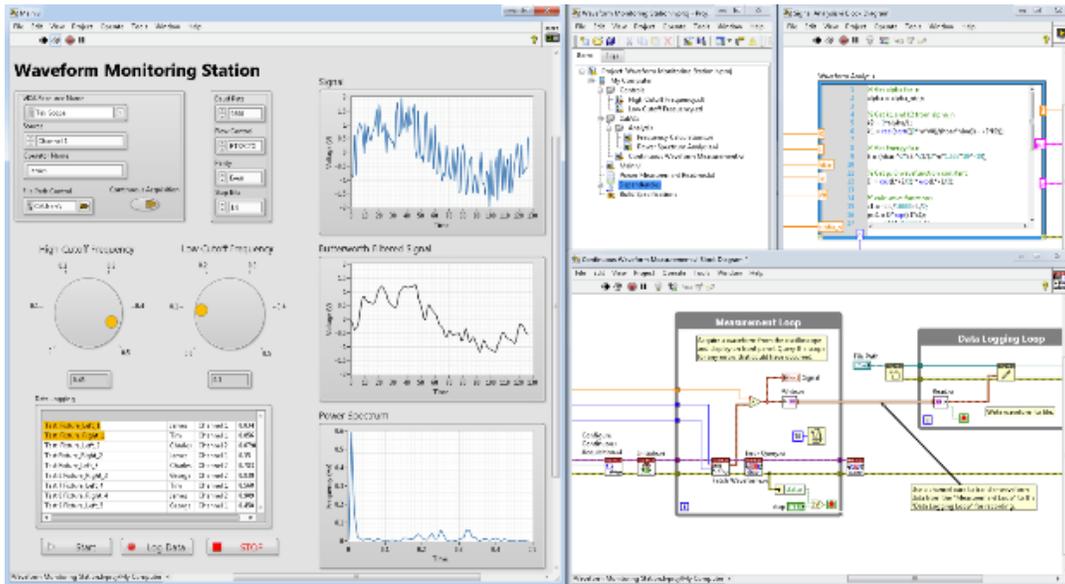


FIGURE 07
LabVIEW Software Interface

“Our team uses a common hardware platform across testing of numerous products. Reusability of common hardware configurations and utilization of common LabVIEW code simplifies development of new test systems.”

Brian Teschendorf, Software Engineer, Boston Scientific Corporation

NI Instrument-Specific Drivers and APIs

NI measurement driver software includes best-in-class APIs that work with a variety of development options, such as LabVIEW, C, C#, Python, and others. To ensure long-term interoperability of our instruments, the driver APIs are the same for all past and current instruments. The driver software also provides access to help files, documentation, and dozens of ready-to-run shipping examples you can use as a starting point for your application.

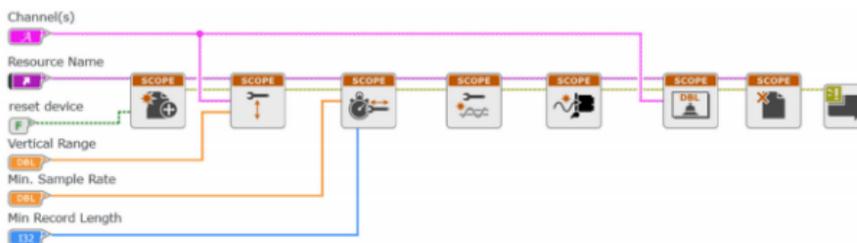


FIGURE 08

LabVIEW API Example for NI PXI Instrumentation

```
// DAQmx analog voltage channel and timing parameters
DAQmxErrChk(DAQmxCreateTask("", &taskHandle));
DAQmxErrChk(DAQmxCreateAnalogVoltageChan(taskHandle, "Dev1/ai0", "", DAQmx_Val_Cfg_Default, -10.0, 10.0, DAQmx_Val_Volts, NULL));
DAQmxErrChk(DAQmxCfgSampClkTiming(taskHandle, "", 10000.0, DAQmx_Val_Rising, DAQmx_Val_FiniteSamps, 1000));
// DAQmx Start Code
DAQmxErrChk(DAQmxStartTask(taskHandle));
// DAQmx Read Code
DAQmxErrChk(DAQmxReadAnalogF64(taskHandle, 1000, 10.0, DAQmx_Val_GroupByChannel, data, 1000, &read, NULL));
// Stop and clear task
```

FIGURE 9
C API Function Call Example for NI-DAQmx

```
import niscopes
with niscopes.Session("Dev1") as session:
    session.channels[0].configure_vertical(range=1.0, coupling=niscopes.VerticalCoupling.AC)
    session.channels[1].configure_vertical(range=10.0, coupling=niscopes.VerticalCoupling.DC)
    session.configure_horizontal_timing(min_sample_rate=50000000, min_num_pts=1000, ref_position=50.0, r
    with session.initiate():
        waveforms = session.channels[0,1].fetch(num_records=5)
        for wfm in waveforms:
            print('Channel {0}, record {1} samples acquired: {2:}\n'.format(wfm.channel, wfm.record, len(w

        # Find all channel 1 records (Note channel name is always a string even if integers used in channel)
        chan1 = [wfm for wfm in waveforms if wfm.channel == '0']

        # Find all record number 3
        rec3 = [wfm for wfm in waveforms if wfm.record == 3]
```

FIGURE 10
Code Example for NI Instrument Capture in Python

SystemLink Software

SystemLink software eliminates the manual tasks related to keeping test systems current and healthy. From automating software updates to monitoring system health, SystemLink software delivers key information that improves situational awareness and test readiness. Leveraging an automation and connectivity framework, SystemLink software aggregates test and measurement data from all test systems into a centralized data repository. Users have ready access to asset utilization, calibration forecasts, and test-result history, trends, and production metrics data to make proactive decisions on capital expense, maintenance events, and test or product modifications.

SystemLink software is comprised of four modules—Software Configuration, Asset, Test, and TDM Data Finder. These modules provide application-specific capabilities that use the SystemLink server for data communication, transmission, and movement, as well as services for managing NI and non-NI instruments, software packages, alarms and notifications, and dashboards.

Key Benefits:

- Centrally manage distribution software

- Perform remote device configuration and diagnostics
- Automatically prepare your data from multiple test systems
- Automate data analysis and report generation

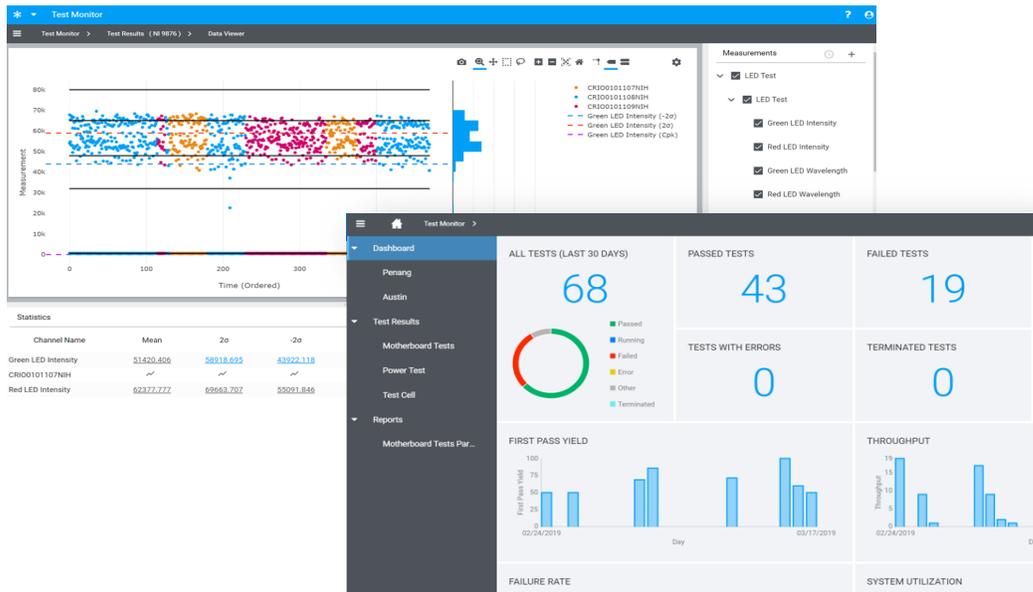


FIGURE 11. Dashboards built with SystemLink software help monitor test-station status and high-level data output.

Infrastructure Elements for HIL Test Systems

While the infrastructure around a test station isn't typically recognized in test coverage specifications, it plays a vital part in ongoing test-station operation. Carefully considering test infrastructure component quality, practicality, and functionality ensures long-term test-station success. NI provides many of the key infrastructure elements and partners with an ecosystem of trusted vendors to make recommendations on how to complete a fully operational deployed system.

PXI Chassis

A PXI chassis equates to a desktop PC mechanical enclosure and motherboard. It provides power, cooling, synchronization, a communication bus to the system, and supports multiple instrumentation modules within the same enclosure. PXI uses commercial PC-based PCI and PCI Express bus technology with rugged modular packaging (CompactPCI). Chassis range in size from four to 18 slots to fit the needs

of any application, whether its deployed as a portable, benchtop, rack-mount, or embedded system.



FIGURE 12. PXI chassis connect PXI instruments to a high-bandwidth communication and synchronization bus.

PXI Controllers

PXI controllers provide a high-performance in-chassis embedded computer. Embedded controllers have extended temperature, shock, and vibration specifications and include the latest in PC component technology and standard prereferral connectivity.

Controllers comes preconfigured with LabVIEW Real-Time or Microsoft Windows and all device drivers preinstalled. NI's embedded controllers also include managed life cycles and vendor support to ensure test system longevity and compatibility with the PXI ecosystem.



FIGURE 13. PXI controllers integrate PC elements into a PXI-based test system.

NI SLSC Chassis

The Chassis for SLSC provides power, active cooling, triggering, and a communication interface to SLSC modules. The chassis is compatible with NI SLSC modules, third-party SLSC modules, or you can create your own module using the Module Development Kit (MDK) from National Instruments.



FIGURE 14. NI SLSC chassis house NI and 3rd party designed SLSC load and signal conditioning boards for HIL test systems.

Mechanical, Power, and Safety Infrastructure

PXI systems come in a variety of options for deployment, ranging from small, 4-slot chassis that take up little space on a desk, to 18-slot systems that can stack in a rack to minimize test-system floorspace. The more automated, synchronized instruments and measurements needed, the more value PXI adds to a test system.

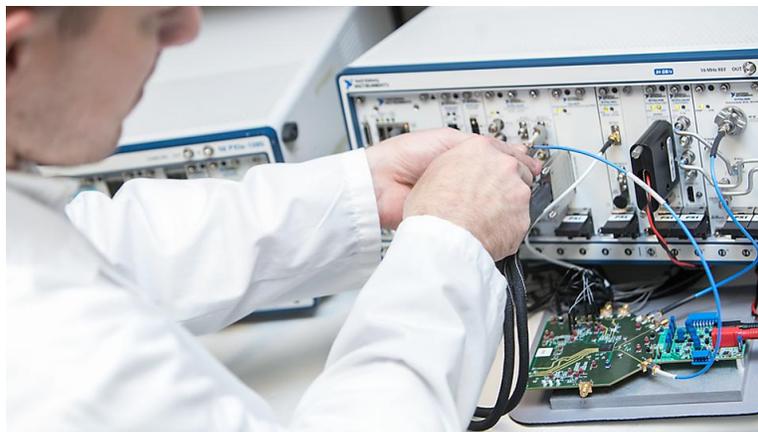


FIGURE 15. Many PXI systems are deployed on a desktop or workbench, which is ideal when you need multiple instruments but have no desire to build a full rack.

ATE Core Configurations

Not all racks are created equally: Rack vendors seeking to reduce costs can compromise accessibility, durability, mobility, and reliability. NI has standardized a mechanical, power, and safety infrastructure for deploying rack-based automated test

systems with trustworthy, high-quality components in a flexible, easy-to-maintain system.

ATE Core Configurations streamline your automated test-system procurement and control costs and timelines with single-vendor expedited preassembled, configured systems delivery. Reduce time and cost associated with multiple purchase orders by acquiring a full tester from one vendor, and having it shipped directly to your site anywhere in the world (IEC 61010-01-compliant). Each system is delivered with reusable packaging materials ideal for future redeployment.

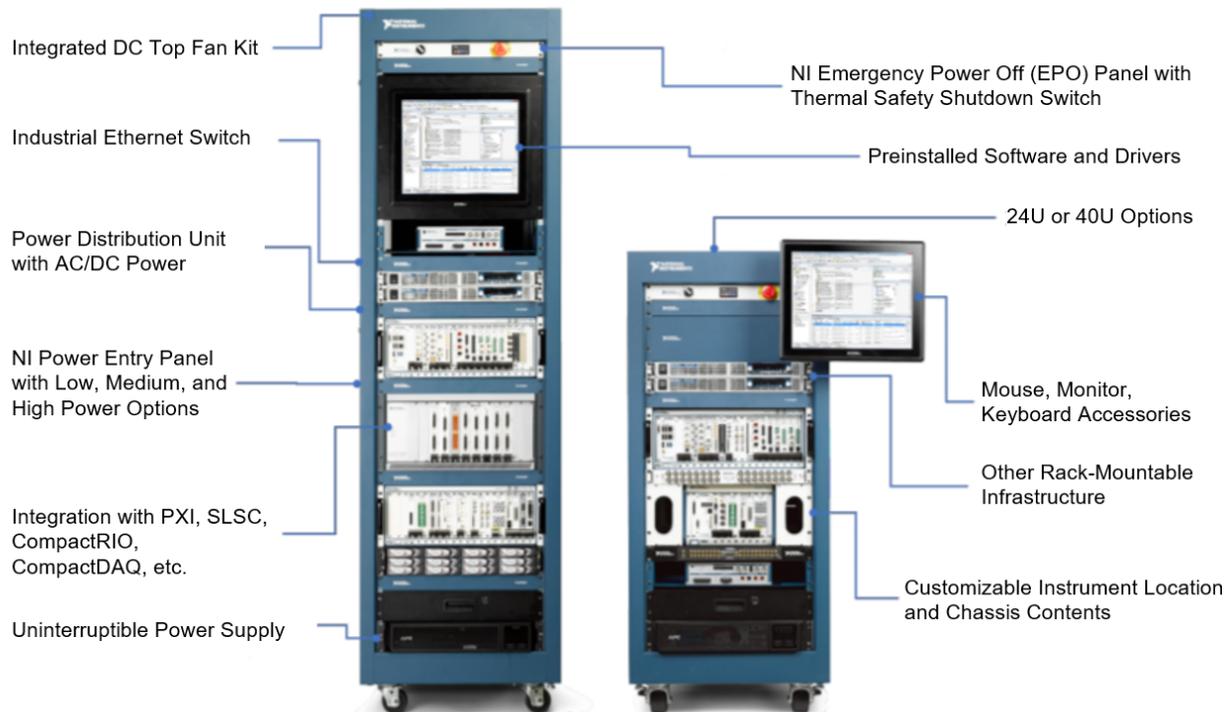


FIGURE 16. Use an ATE Core Configuration to get quality rack components, preassembled and delivered to your dock—all from a single vendor. Benefit from a single warranty covering your system, repair and replace parts from a single source, and trust NI's single service program to sustain your entire system. NI-configured systems save time and money while accelerating system deployments.

“By standardizing on NI’s ATE core configs, we were able to reduce the time it takes to build new testers by 40%.”

Chris Becher, Engineering Manager, Alstom Signaling

Mass Interconnect

Quickly swap DUTs and reuse more of your test system with a mass fixturing and interconnection solution. This modular best practice includes both the instrumentation and the test interface to:

- Allow rapid system changeover through a standardized approach
- Not compromise test coverage by supporting a full range of signals from the DUT
- Minimize downtime and reduce maintenance with reliable long-term operation

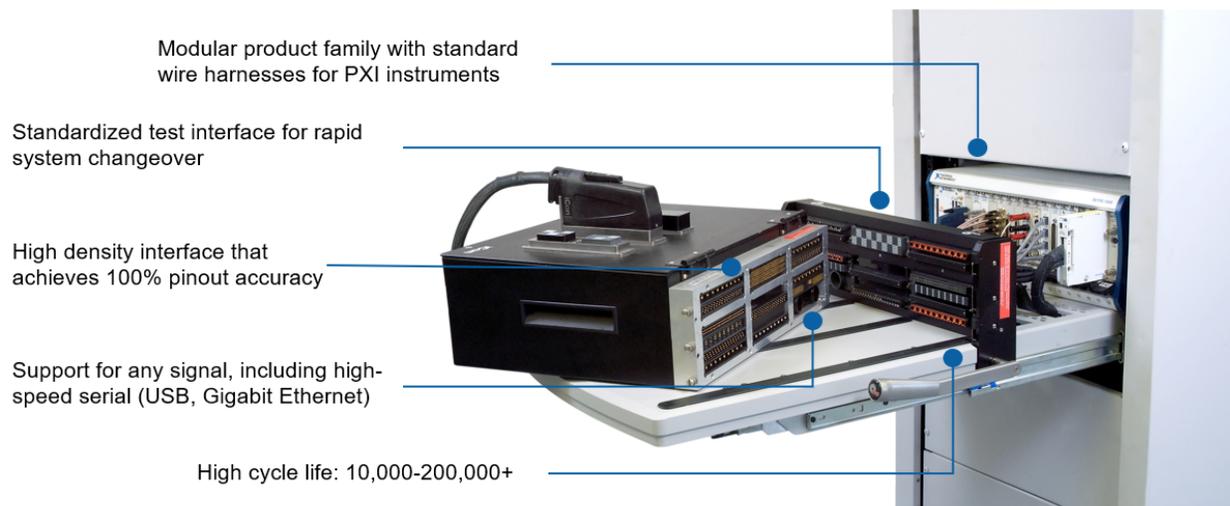


FIGURE 17. Modular Mass Interconnect

Featured Product Partner: Virginia Panel Corporation (VPC)

For almost 60 years, dedicated VPC employees have provided reliable mass interconnect solutions. VPC designs, manufactures, and markets interface connector products for commercial, consumer electronic, medical, telecommunications, aerospace, and automotive applications.

For more information, email info@vpc.com.



Hardware Services

Test station development and deployment is only half of the story. Best practice dictates that you consider station sustaining and maintenance from day one.

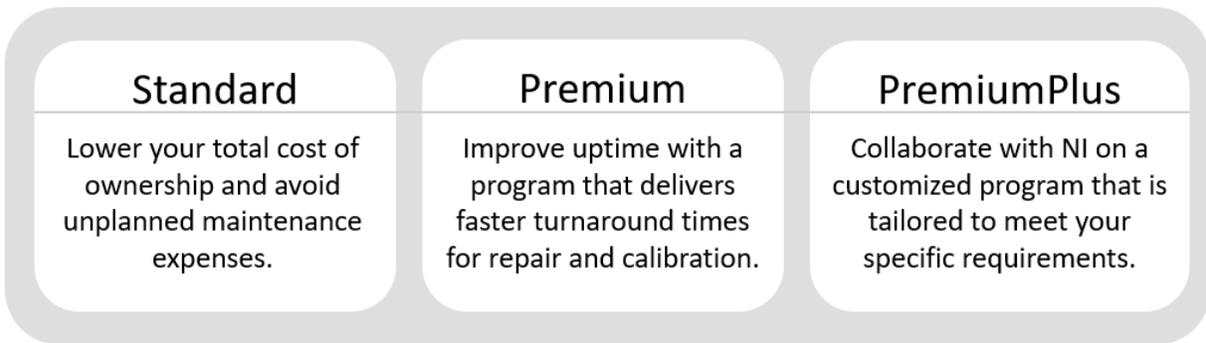


FIGURE 18. Instrumentation Hardware Service Levels

- **Budget Control:** Predict operational costs and avoid unforeseen maintenance expenses.
- **Minimize Downtime:** Get your systems back up and running within days, hours, or minutes with sparing programs, advance replacement services, and repair contracts.
- **Manage Life-Cycle Changes:** Manage technology refreshes and product obsolescence with roadmap consulting and life-cycle services programs encompassing one to twenty years.
- **Simplify Logistics:** Simplify hardware maintenance logistics and overhead with NI support.
- **Maintain Standards:** Utilize ISO 9001-traceable calibration and ISO/IEC 17025-accredited calibration services delivered on-site and through expedited shipping for confidence and convenience.
- **Speed Deployment:** Get up and running with custom installation that includes app software, custom documentation generation, individual logo/labeling, and system recovery images.
- **Quickly Troubleshoot:** Minimize development delays by consulting with experienced applications engineers based in more than 40 countries to meet your local needs in your local language.

“In the 25+ years I’ve been dealing with NI, I’ve always found their personnel to be uniformly bright, enthusiastic, and genuinely concerned with helping their customers succeed.”

Cary Long, Software Engineer

Support Services

Change initiatives are common within test teams. Whether building a new test strategy, driving a technology refresh, or extending the life cycle of an existing project, product schedules and budgets are often high-risk. Managing this risk is a tricky balance between meticulous planning and agile design choices.

Utilizing consultation, educational resources, and ongoing support programs can mean the difference between a culture of missed deadlines and budgetary strain, and a culture of on-time, on-target delivery. NI consultation, integration, and education services offer guidance and industry expertise to help build and execute a practical plan to achieve your business and operational outcomes.

Methodology Consulting Services

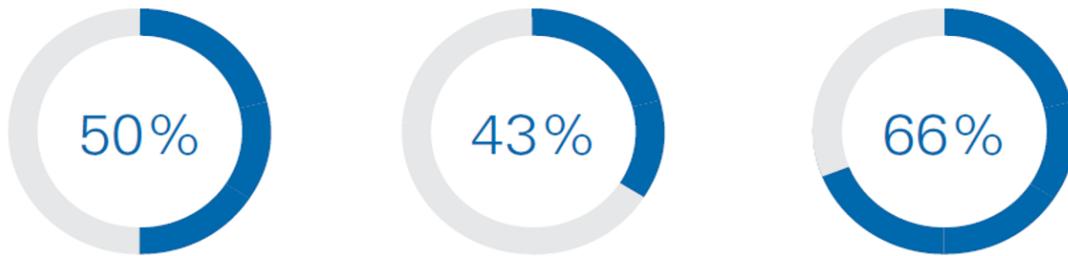
Planning and project management consulting helps build a project-execution plan that keeps teams on track to hit major development milestones. Work together with NI to establish priorities, identify the right resources, and make trade-offs to optimize cost without putting projects at risk.

Integration Engineering Services

With global solution centers and NI engineers in more than 40 countries supported by more than 900 Alliance Partner companies, NI delivers design and development assistance in every region and industry. NI engineers help you mitigate risk, develop faster, and reduce costs through project management, architecture development, and system documentation to deliver an integrated solution.

Education Services

Test teams new to NI software and seasoned veterans of the platform alike benefit from investing in their education through learning resources designed for personal and team proficiency. NI provides a comprehensive customer education program designed to increase productivity, reduce development time, and improve your team's ability to engineer robust, maintainable applications with NI products. Tailor the experience to fit any schedule with online, in-person, and flexible programs.



Shorter Development Time

Less Time on Maintenance

Faster Learning Time

FIGURE 19. Engineers who have adopted NI education services save time in development and maintenance and learn faster.

NI Alliance Partners

Best-in-class test engineering teams realize that there is seldom a simple question of in-house development versus outsourced development. Instead, they realize how complex it is to decide how to balance development teams to optimize for deployment schedule, bandwidth, domain specific expertise, proficiency development, and available budget.

NI Alliance Partners are uniquely positioned to support your business with the service that it requires, including strategic design, system integration, specialist tools, software IP, and ongoing support. More than 1,000 NI Alliance Partners, each certified and vouched for by NI and positioned globally, stand ready to consult with you on projects and provide complete solutions based on NI's productive software and modular hardware.



FIGURE 20. Alliance Partners can help ensure your success.

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