SURVIVING THE EV REVOLUTION // EV TECHNOLOGY AND BUSINESS TRENDS // CASE STUDIES

NI AUTOMOTIVE JOURNAL

TEST THE VEHICLES OF TOMORROW TODAY

A NATIONAL INSTRUMENTS PUBLICATION Q3 + 2019

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Q3 + 2019

Let's explore the market shifting trends that EV and other technologies are rapidly bringing to automotive, and why working with future-proof test systems is critical for today's and tomorrow's vehicles.

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Testing the Electric Vehicles of Tomorrow Today

Amidst the uncertainty surrounding the technology, timelines, and business models that will shape the future of transportation, one thing is certain: electric vehicles are the future. Government mandates for emissions reduction and hybrid electric vehicles at a minimum are driving the investment timelines for automakers, and a recent RBC report suggests that 30 to 40 percent of European consumers expect their next vehicle to be electric.

The industry is closing in on the tipping point between cost and performance, making mass-market EVs economically viable. Also, massive investments promise ongoing improvements to battery chemistry topologies, which will drive down cost and improve economies of scale in manufacturing. With this investment influencing the delivery of EVs to market, now is the time when test program investment must increase to ensure the reliability and safety of the cars.

Across the automotive supply chain, EV is a new and unprecedented area. The rapidly evolving requirements are creating new challenges for automakers to maintain a competitive advantage in getting EVs to market before their competitors.

NI is with you. We provide differentiated value for EV test groups with our software-defined platform, which includes high-performance modular systems that integrate high-accuracy power component models, power electronics, measurements, and systems and data management. By integrating our test systems, you can reduce development time, scale your test platform as requirements change, and get to market faster.

Chad Chesney, Vice President and General Manager, Transportation Business

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FEATURED ARTICLE

100 Years in a Decade: Surviving the EV Revolution

The debate these days is not really if but when and how fast the market will shift to electrified vehicles. Will it be a smooth, gradual transition with the balance of power in the industry largely intact? Or will there be a fast, massive EV adoption and one of the largest industry disruptions we've ever seen? The answers have far-reaching implications for automakers and the ecosystem built up around the internal combustion engine over the last century (supply chain, service industries, fueling infrastructure, and so forth).

Automakers are making big moves accordingly based on significantly differing beliefs and strategies, and these moves include new technology and aggressive electrified platform promises.

The Crystal Ball

An interesting way to frame the question of when and how fast EV market adoption will happen is with the Innovation S-Curve and the way it describes technology life cycles.

In this model, a technology starts in the ferment stage, then moves through the takeoff stage, and sunsets after a period of maturity. The curves of a mature technology and a new technology overlap, which creates a period of discontinuity. This disrupts the market as customers make the leap to the new technology when it's embodied in products with a sufficiently attractive mix of features versus cost. EV technology is moving through the ferment stage. Combustion engine technology is at or approaching maturity. It's been universally adopted, the market is well defined, the technology is standardized/commoditized, and all the low-hanging optimization fruit has been picked.

We are currently experiencing the messy disruption and period of discontinuity as the market makes the leap from one technology to another. The "when" and "how fast" questions will determine the shape of these technology curves. With the transition from ICE to EV, there is also the complicating factor of hybrid solutions that bridge the gap by combining the two technologies. The hybrid solution has the potential to smooth the transition and allow both technologies to coexist in the market for far longer.

Interesting and divergent graphs overlay market analyst forecast models on market timing with justifications of market factors, politics, technology inflection points, and dozens of other factors. The fact is, we simply don't know how things will shake out with the ICE to EV transition.

Gearing Up

Many industry players (OEMs, suppliers, startups, investors, and so on) see success in the EV space as a critical factor in their profitability or even survival and are making their sizable investment decisions with respect to EV technology now. They are shaping the technology s-curve as they jockey for market position by either accelerating or hindering broad market adoption of electrified vehicles with their strategies.

Design and test groups are being tasked with developing and testing EV platforms now as industry players race each other to market. Test teams must build or buy the requisite capability (technology, skill sets, supplier relationships) needed to deliver a competitive "electrified" offering to market on aggressive timelines so companies can beat out their competition and capitalize on their investments.

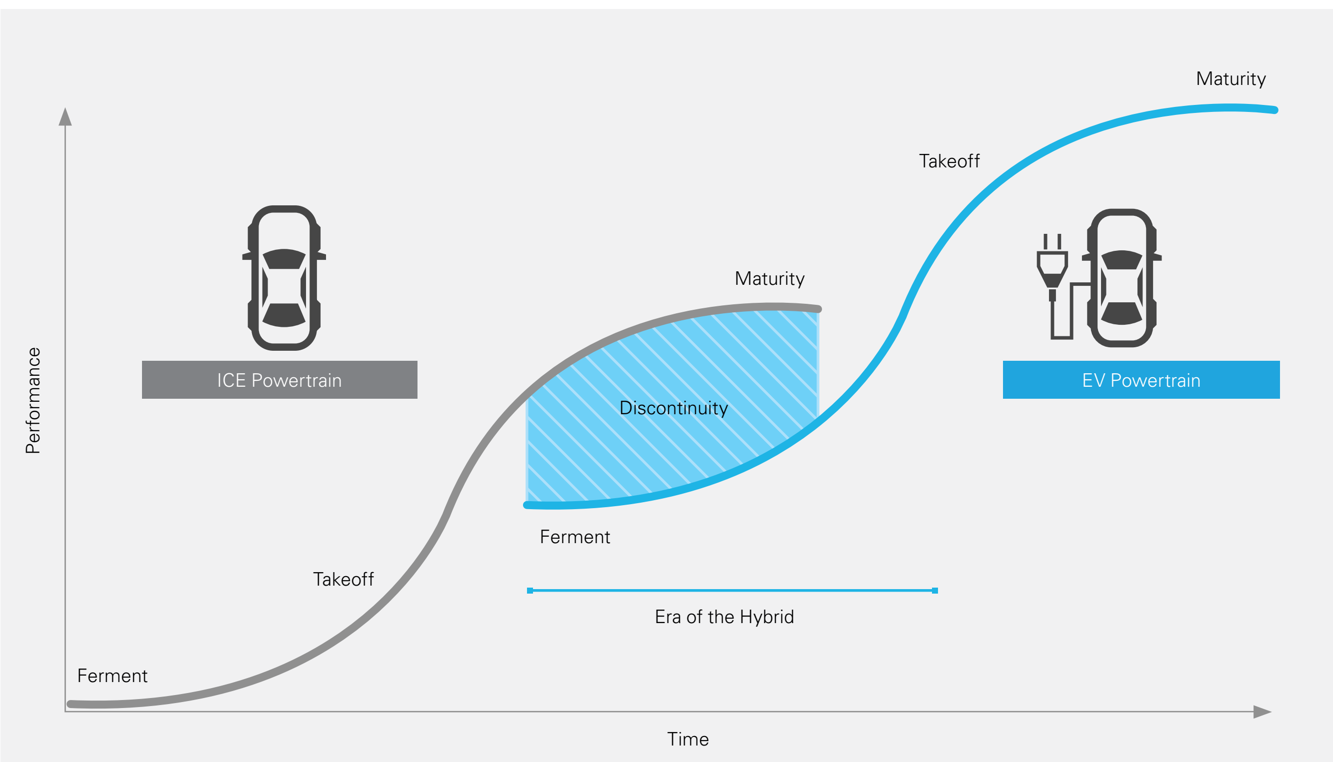
The market analysts and executives say this is easy, but what does "requisite capability" really mean when it comes to research, design, and test of EV components and systems? Your organization hands you a pile of cash and says, "We are going to be the market leader in the XYZ EV segment" or "We will have an 'all electrified' vehicle platform by 202X" or "We have $XM in funding and need to get our vehicle to market before X or we will not be here in 18 months." They can't tell you to an actionable level of detail what it means to acquire the requisite capability. As a test leader, that's up to you.

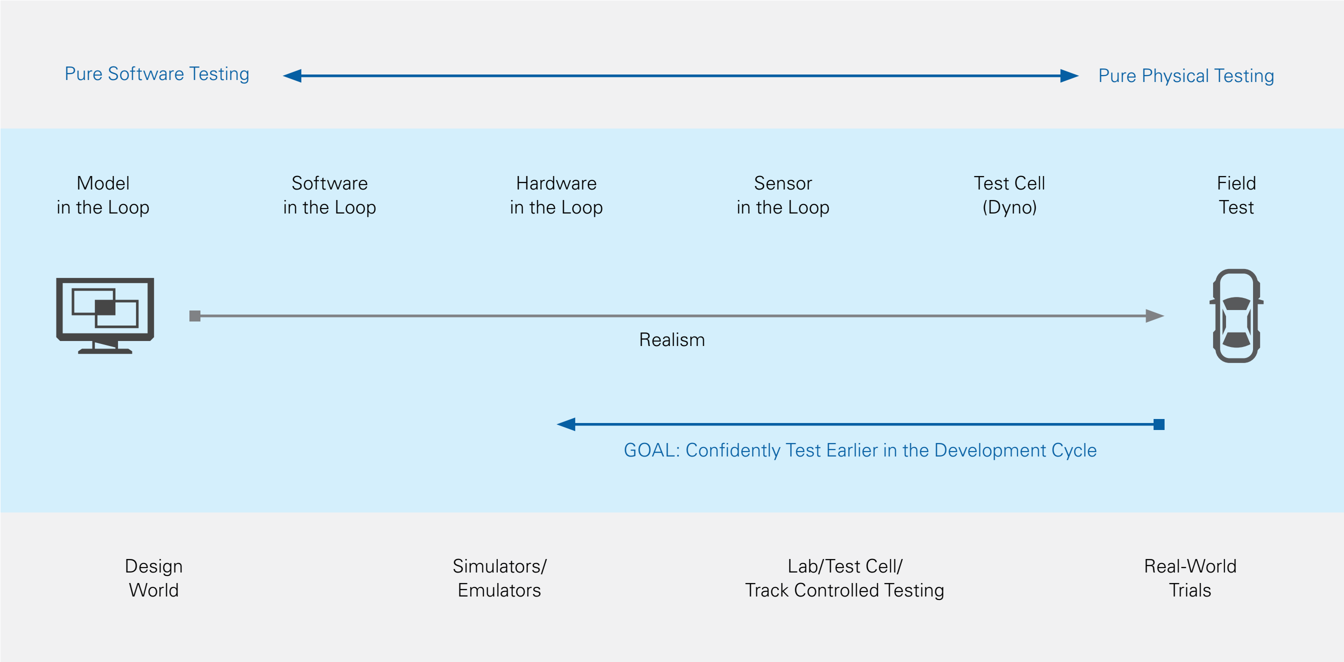
A Brave New World of Test

The requisite capability for EV test can mean a lot of things, but there are common challenges. Test requirements are evolving at the same breakneck pace as the technology and designs, while companies race to market and lay out aggressive schedules. Even as schedules are shrinking, EV test requires new capabilities and test approaches for multidomain modeling and testing dynamic electrical switching with the ultra-high-speed simulation of increasingly complex devices.

In broad terms, you will need high-power sources and loads and real-time model-based control and measurement capabilities to characterize high-power electrical switching at order of magnitude greater speeds than measuring combustion processes (hundreds of kilohertz instead of 1–2 kHz).

Similarly, you will need better systems and data management capabilities to handle globally distributed teams across new supply chains and partnerships with a proliferation of models and options and designs under test. But for what types of data and analysis? Who will need access to the data? What types of systems will have to be managed and where will they be?





Position for Success

To be a leader in EV, you must thrive in an environment of constant change and continuous learning. You must be flexible and nimble and able to adapt to changing test requirements quickly. Under intense time-to-market pressure, you must position yourself for success by adopting more efficient test approaches to either shorten the development life cycle or to increase test coverage and thus product confidence within given schedule and budget constraints.

We believe the best way to improve test efficiency is to adopt a platform-based approach to test that can be used to move test earlier in the process and more quickly traverse the iterative design cycle.

Testing earlier in the design cycle requires model-based control capabilities to simulate or emulate the components and systems surrounding the device under test. This increases test complexity, but the return on investment can be huge considering the benefits. Moving test from the field to the lab and from the lab to the desktop allows for faster iterations and reduces the cost of test.

Increased use of simulation and emulation of surrounding systems and components decouples dependencies on the groups and companies supplying those components. It also allows for increased test coverage for "malicious" tests that would normally damage the device under test or that are hard or impossible to repeat on command in a controlled physical test environment.

A platform-based test approach also facilitates developing standardized system architectures that can be used to more efficiently traverse the design cycle and fit well with the iterative and fluid nature of testing new technologies. A standardized system architecture that uses a platform of interoperable hardware and software is open to the integration of third-party equipment. You can easily reconfigure and update that equipment to promote reuse across test scenarios and applications. This approach can be used to cover common core requirements across the different devices under test in the EV powertrain, to test the same type of component but with different configurations across multiple versions of the device for different programs.

When your back is against the wall on projects, do you have the tools, expertise, flexibility, and infrastructure in place to let your teams save the project, the program, or even the company? Starting with a platform-based test approach is starting from a position of strength. Don't build on sand. Don't settle for rigid, inflexible test systems. Don't build the same things from scratch over and over. Build a better way for your organization to thrive in the transition to electric vehicles.

Nate Holmes is the Powertrain Test Lead at NI.

Signal-Level HIL Inverter Test

You can test hybrid and electric vehicle inverters for software and electrical functionality at the signal level with a closed-loop simulator. By using a simulator instead of a dynamometer, you can test sooner in the design process, test cheaper, and achieve greater test coverage because of the physical limitations of dynamometers. You need to iterate on systems quickly to manage rapidly evolving DUTs and meet time-to-market requirements.

Application Requirements

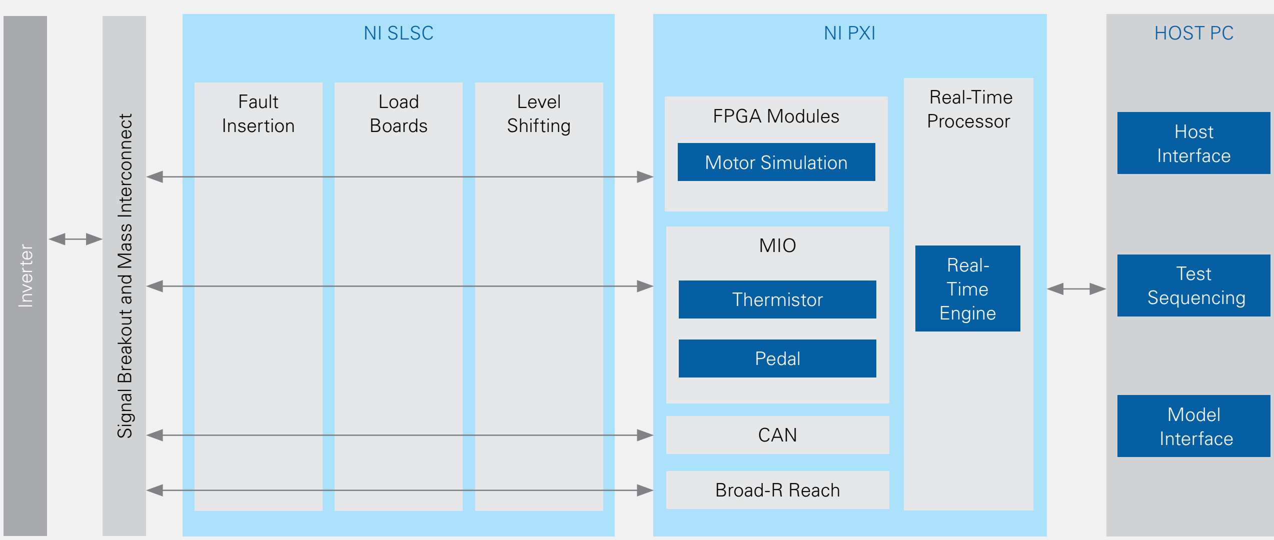
- Run motor and electrical models at 100 kHz or faster loop rates to achieve sufficient model accuracy for testing the inverter in simulation.
- Deploy quickly using existing models, tools, and workflows. Test systems need to be up and running quickly with fast delivery schedules.
- Use fault insertion in hardware for opens and shorts and software for network messages.

The NI Advantage

- NI systems can be integrated and delivered by our industry-leading partners like OPAL-RT to help you get up and running quickly.
- NI's open and flexible platform-based approach means you can own the test system IP and make changes quickly rather than solely relying on a third-party vendor.

The NI Solution

- NI PXI and CompactRIO hardware incorporates the latest commercial off-the-shelf (COTS) FPGA technology from Xilinx and provides I/O interfaces to the DUT.
- NI is collaborating with OPAL-RT to readily deploy models from a variety of electrical modeling environments like swMATH SimPowerSystems, Powersim PSIM, and NI Multisim directly to NI FPGA PXI modules.
- You can implement open, short, and ground hardware fault insertion with NI switch, load, and signal conditioning (SLSC) hardware, and you can implement software faults directly in the FPGA.



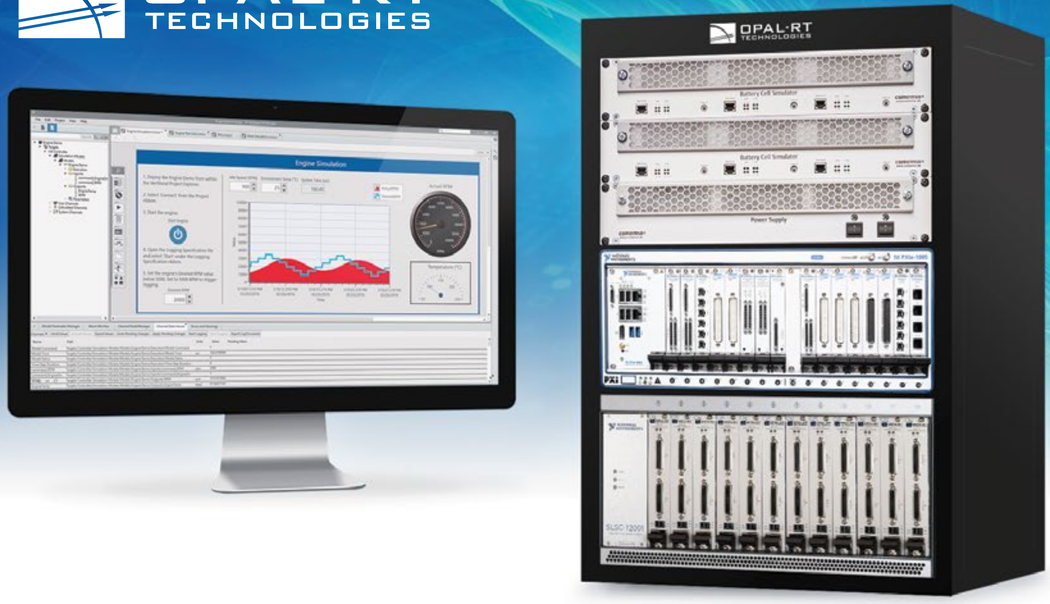
In partnership with OPAL-RT TECHNOLOGIES

“By adopting FPGA-based simulation using the NI hardware and software platforms, we achieved the simulation speed and model fidelity required for verification of an electric motor ECU. We reduced test time to 1/20 of the estimated time for equivalent testing on a dynamometer.“

Tomohiro Morita, Subaru Corporation

NI inverter test systems are built on industry-standard COTS tools like PXI, SLSC, and VeriStand, which means you can **adapt as requirements change without sacrificing integration time**.

OPAL-RT TECHNOLOGIES



PARTNER HIGHLIGHT

Expanding Possibilities for EV & BMS Testing

Disruptive trends are rapidly transforming the automotive industry. As such, two major factors are currently affecting product development for engineers: time-to-market and managing system complexity. Complete testing of electric vehicles (EV) and battery management systems (BMS), however, is the key that allows them to address these challenges in an efficient way. OPAL-RT TECHNOLOGIES is the world leader in HIL and PHIL/FPGA-based real-time simulation, delivering countless projects for major auto manufacturers over the past 20 years. Along with National Instruments (NI), they have signed a strategic agreement to accelerate the development of hardware-in-the-loop (HIL) simulation technologies for the automotive market, bringing forth innovative new applications, such as motor-wheel and redundant steering systems.

Build or Expand Automotive Testing

While electric and hybrid-electric vehicles (HEVs) deliver new levels of versatility and econ omy, interactions between electric, electronic, and mechanical components are growing more intricate. Although this creates problems that are difficult to identify or analyze using traditional test methodologies, real-time simulation can address many of these issues.

Hardware-in-the-loop (HIL) and power hardware-in-the-loop (PHIL) simulation are used to develop and test complex electric drivetrains in “EV and HEV, as well as BMS and autonomous transportation systems. They can support test scenarios that are too costly, time-consuming, or dangerous to test in the real world, and can allow developers to build a comprehensive database of test results under a well-defined combination of corner-case conditions.

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VeriStand, an open software environment, allows complete configuration of real-time test applications.

Get full support of the most recent automotive communication buses.

Backed by ASAM standards.

OPAL-RT TECHNOLOGIES

OPAL-RT provides the fastest real-time simulation for power electronics.

Face the challenges of power electronics real-time simulation with a mature solution.

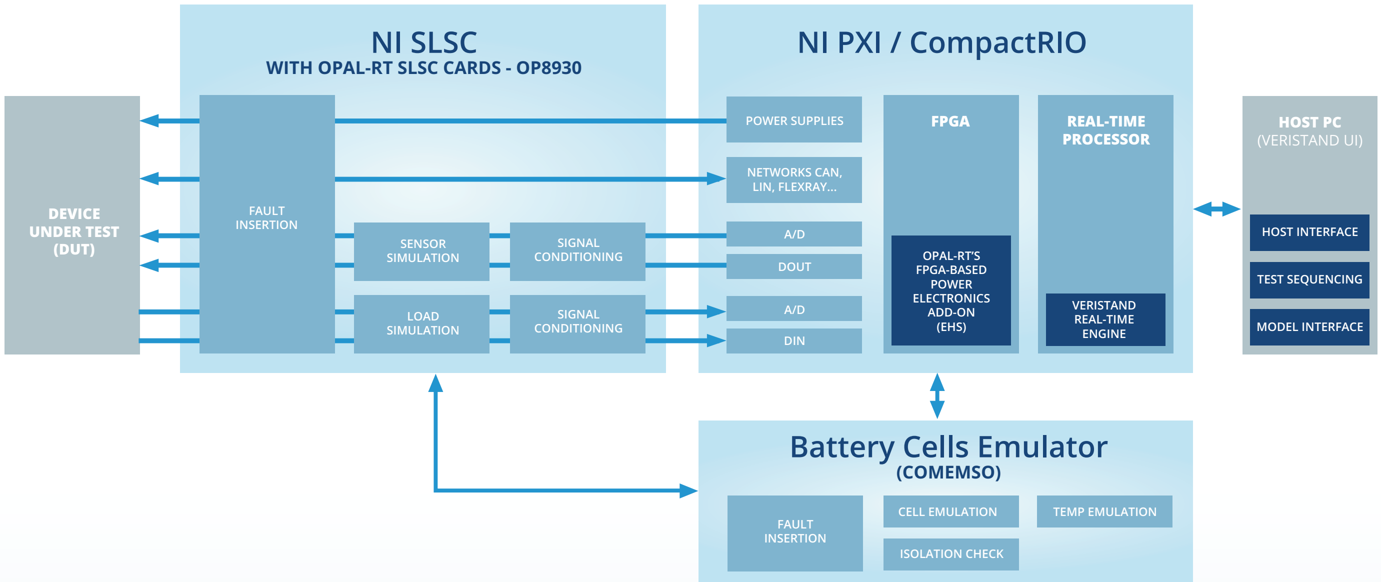
Take advantage of unique features for EV ECU real-time testing.

Download the free demo and discover our solutions at

opal-rt.com/ni

Automotive HIL Reference Architecture Integration

OPAL-RT offers complete conformity with NI Automotive HIL Testbed Reference Architecture. This allows researchers to prototype a wide variety of EV devices under test (DUTs), and provides an open, flexible solution that you can customize to adapt to changing research requirements for EV and BMS testing. By combining modular hardware and our FPGA-based simulation solver to easily import real-time models created with any modeling software, these systems help you take advantage of third-party components to reduce your setup burden and offer a common starting place for your research team members around the world. Conforming to the best practices and frameworks of automotive reference architecture will ensure all components of your open system perform optimally because they follow strict NI guidelines.



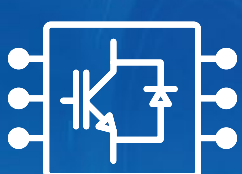
NI PXIe / CompactRIO
OPAL-RT's FPGA-based power electronics add-on (eHS) runs on a wide variety of FPGA-provided FlexRIO & R Series board.

OPAL-RT's SLSC modules
The fault injection on critical I/O signals is used to increase test coverage on the DUT by automatically inducing faults on different wires.

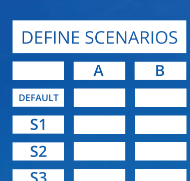
Comemso BCS unit
Test your BMS at cell-level to achieve safe, reproducible, and fully automated testing.

Unrivaled FPGA-Based Performance

Directly integrated with NI's VeriStand and LabVIEW, OPAL-RT's FPGA-based power electronics add-on (eHS) is a powerful simulation tool for hardware-in-the-loop (HIL) testing. Used with controllers for power electronics applications, it enables users to simulate an electric circuit on field-programmable gate arrays directly and, through a convenient user interface, without having to write the mathematical equations.



Schematic editing flexibility
Use the most popular schematic editors on the market, such as the Simscape Electrical, PLECS, PSIM, and Multisim.



Customized test scenarios
Perform on-the-fly parameter changes and fault generation on inverter switches without reloading or recompiling your model.

FPGA Electric Machine Library
Access different high-resolution motor models coupled with position and speed I/O (resolver, encoder, Hall effect).

EV Battery Pack/Module Test

Cycle power from a battery pack according to profiles such as drive cycles across a variety of temperatures to determine key performance and durability characteristics related to cycle life, efficiency, and safety.

Application Requirements

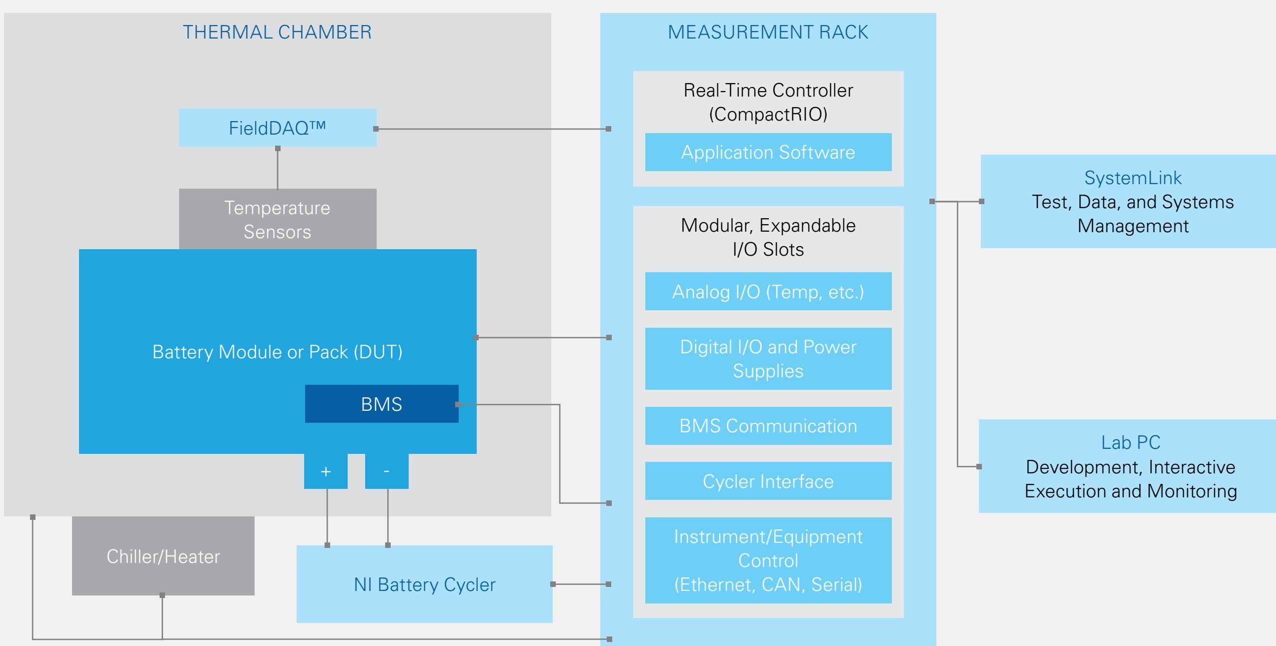
- Time-intensive tests require managing long-term tests in multiple parallel testers.
- EV power levels need a specialized source/load (battery cycler) with regeneration and safety features.
- Battery temperature dependence requires thermal chambers and heater/chiller control.

The NI Advantage

- NI data and systems management capabilities maximize the uptime of expensive test resources and ensure complete visibility and control of your globally distributed test assets.
- NI systems provide seamless integration of advanced control, measurement, and third-party equipment to help you minimize the time required to build and maintain heterogeneous test setups for a variety of components.

The NI Solution

- Battery Test Software—Manage test execution and quickly set up test sequences with pre-defined configurations and equipment drivers.
- Power Electronics—Take control with flexible power cycling for simple loading to drive cycle simulation with regeneration.
- Enterprise Test Management Software—Increase efficiency in test, date, and systems management of distributed systems from anywhere with SystemLink™ software.



Control and Sequencing

Measurements and Power Electronics

Systems and Data Management

Key Specifications	
Equipment Integration	Integration of any third-party environmental chambers or control/measurement devices and easy management of a heterogeneous fleet of equipment
Flexible Control	Sequencing, alarms, fully definable profiles, and variable/PID/custom thermal setpoints and profiles
Data and Systems Management	Scalable enterprise-ready tools for data organization and storage, interactive data exploration/visualization, custom automated reporting and analytics, software versioning and remote deployment, and so on
Charge/Discharge Mode	CC/CV/CP/Waveform
Voltage Range (Cycler)	0–1200 V
Current Range (Cycler)	±1600 A
Power Range	Up to 1.2 MW
Power Regeneration	Ability to recycle energy back to the DC bus or to the grid (utility)
High-Precision Measurements	Easy addition of any NI I/O library to scale the test system from a few to hundreds of I/O channels (temperature, thermal cameras, DIO, stress/strain, vibration, and so on) to meet test requirements now and in the future
Cell Voltage	±10 V, 24-bit, 1 kS/s/ch simultaneous, 250 V_{rms}, CAT II, channel-to-channel isolation
Cell Temperature	J, K, T, E, N, B, R, and S thermocouple types (24-bit, simultaneous sampling)
Digital Input/Output	30 V DC, 7 µs sinking DI, 500 µs sourcing DO, 60 V DC, CAT I, channel-to-earth isolation, with PWM support

Advancing Subaru Hybrid Vehicle Testing through HIL

Today, automobiles are equipped with many ECUs to manage expanded functionality and advanced controls in the vehicle. In a hybrid vehicle, the motor ECU plays an even more complicated role because it manages the interaction between the conventional engine and the electric motor, along with its power systems.

Fuji Heavy Industries, the parent company of Subaru, set out to develop its first hybrid vehicle—the Subaru XV Crosstrek Hybrid. This was our preliminary attempt to deliver a production model hybrid vehicle targeting both domestic Japanese and North American markets. Our engineers had developed a motor ECU for an earlier hybrid prototype, but the component did not meet the rigorous requirements to take a vehicle to market. For the production model vehicle, the ECU needed various control functionalities to prevent damage to the vehicle body and to ensure driver and passenger safety under various operating conditions, even scenarios that would be impossible or impractical to test on physical hardware.

A New Approach

Our engineers connected the ECU to a real-time electric motor simulation to test and verify a variety of conditions, including the extreme outliers that may otherwise break the system in traditional mechanical testing. They developed a mechanism to sufficiently confirm this software simulation approach with three primary goals for successful testing:

- Verify ECU functionality in various conditions, including extreme environments not easily created or replicated
- Map test cases to requirements to ensure complete test coverage
- Perform regression tests with ease to quickly validate design iterations

To achieve these goals, our engineering team used a V-diagram approach to launch the design and verification process. The diagram describes a phased methodology for embedded software design and deployment validation, including test points at each stage. In multiple steps of the design process, the team needed the hardwarein-the-loop (HIL) system to verify the motor ECU against a real-time motor simulation that accurately represented the actual vehicle motor. Additionally, using the HIL system, our engineers could meet traceability requirements by recording test results automatically and automating regression tests when an ECU change was made.

System Success

The new verification system built consists of a real motor ECU and the HIL system that simulates motor operations. The HIL system can represent any operating condition of the motor by setting physical parameters such as inductances or resistances. It can also set parameters of the power electronics, including fault conditions or test scenarios such as combinations of load torque and desired rotating speed. By simply changing a parameter in the middle of the test, the HIL system can easily simulate complex test scenarios like the previous loss of traction example or even a power electronics fault in the inverter that would destroy physical hardware. When the operator requests a test pattern, the HIL system responds the way a real motor would, and the overall system

The Challenge

Using automated testing to develop a new verification system that satisfies the control quality level required for the motor electronic control unit (ECU) in Subaru's first production model hybrid vehicle, Subaru XV Crosstrek Hybrid, and creating strenuous test conditions that are difficult to achieve using real machines.

The Solution

Building a verification system with NI FlexRIO hardware that makes automatic execution of all the test patterns possible and replicates the most severe testing environments to ensure the highest level of safety to the user while obtaining the required control rate and meeting critical timelines.

"All the test patterns developed can be run automatically in only **118 hours**. Performing all the tests manually would take an estimated **2,300 hours**."

response can then be cross-referenced with expectations to validate that the controller safely handles the test case.

Because the computational performance required for this process was so high, we felt NI was the only supplier that could meet these requirements. We chose core system hardware based on FlexRIO FPGA modules, which are PXI-based controllers with FPGA chips. The modules executed a model representing the simulated operation of the motors, with all deployed programs using NI LabVIEW system design software.

Benefits of Choosing the NI Platform
In the HIL system, the simulation loop rate, equivalent of the temporal resolution in simulation, was a critical factor. For the motor ECU, the loop rate needed to be 1.2 µs or less for the simulator to work. Most simulation platforms from other suppliers use CPUs for computation, resulting in a loop rate in the range of 5 µs to 50 µs.

FlexRIO used the FPGA for control and computational purposes to meet the processing requirements, which also provided a significant advantage in terms of computational processing performance. The ability to attain the required simulation rate at 1.2 µs was the decisive factor for adopting FlexRIO for this system. Additionally, because FlexRIO has a high-capacity, built-in dynamic random access memory, we could use the JMAG-RT model provided by JSOL Corp.'s JMAG software toolchain. This made it possible to represent the highly nonlinear characteristics closer to the real motor.

Moreover, our engineers could program the FPGA on the FlexRIO device graphically with the LabVIEW FPGA Module, which made it possible to develop a system with FPGA technology in a short time frame without using a text-based language such as a hardware description language.

All the test patterns developed can be run automatically in only 118 hours. Performing all the tests manually would take an estimated 2,300 hours. Automated testing also mitigates the risk and additional time associated with human errors that can occur with manual testing. The HIL system delivered additional time-saving advantages that included a significant reduction in the number of setup procedures, such as preparing a motor bench and a test vehicle, and it removed the need for test personnel to be qualified to handle high-voltage equipment.

Tomohiro Morita,
Subaru Corporation

EV Technology and Business Trends

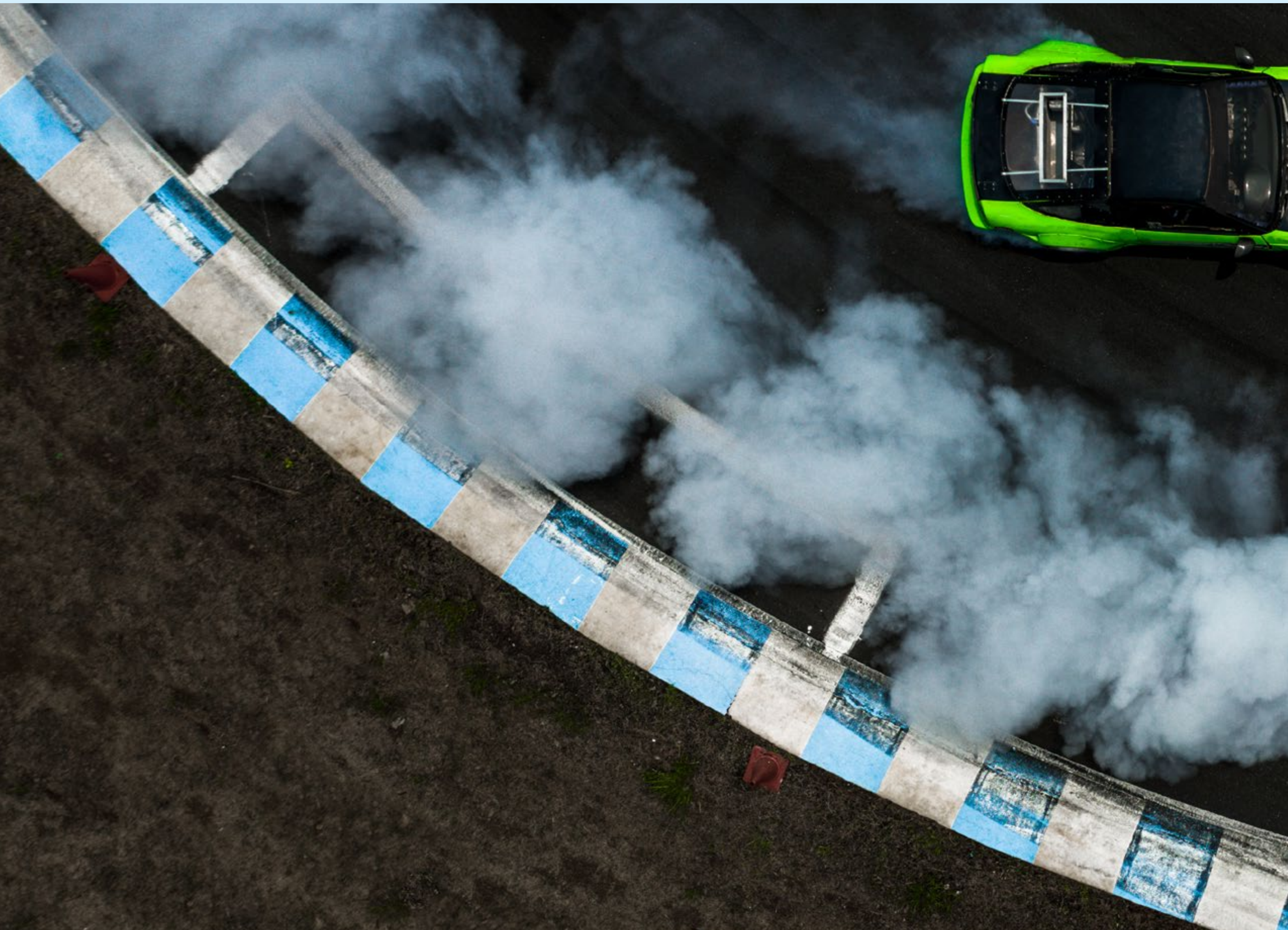
Trade shows are a good forum for keeping up to date, and it's been a busy quarter for the NI Automotive Team: ATE Stuttgart; JSAE Yokohama; The Battery Show; a variety of smaller shows, conferences, and supplier/vendor events; and, of course, our own NIWeek. Here are some takeaways and trends we pinpointed.

Business: Hybrid versus Full EV OEM Strategy

No one disagrees that the future is EV, but the shift from ICE to EV powertrain is disruptive. There are supply chain shortage concerns for certain materials. Much of the expertise and IP that OEMs have built up as competitive differentiation in ICE powertrain is no longer relevant. Effectively starting over in powertrain is a big risk for OEMs because it exposes them to the possibility for major shifts in market leadership. So many OEMs are moving pragmatically by investing in various hybrid architectures instead of full BEV powertrains. This trend is perhaps most apparent among the OEMs in Japan, but it is also observable among established OEMs in the US and Germany.

Powertrain Development Shift from OEM Internal Development to Tier 1s and Partnerships

Perhaps the investment, new technology, and supply chain risk is a major reason why we are seeing OEMs shifting powertrain responsibilities to Tier 1 suppliers or searching for partnerships to help fund development. This shift may allow/force OEMs to invest in other areas where they may see better opportunity for sustained competitive advantage such as ADAS or Transportation as a Service.



EV Technology in the Supply Chain Is Maturing and Evolving Quickly
Engineers are equipped and eager to discuss the best strategies for EV design and test. Because the technology is quickly changing, it’s more important than ever to stay informed of new developments and approaches for testing like motor simulation and FEA-based motor modeling, multi-up battery test strategies, and high-speed EV dyno control strategies.

Technology: New Battery Chemistries and Designs
Battery performance/price ratio and material availability are probably the most influential factors driving EV affordability and adoption. The focus continues on optimizing current chemistries and architectures, while promising new research on the latest chemistries and solid-state designs advances.

Higher Motor Phase Counts
Motors with six or nine phases instead of the current common three-phase design are interesting because they provide additional robustness and durability. Even if one set of phases fails, designers can implement a “limp home” mode during which the drive/motor can still provide enough power to get home or to safety. But this introduces additional control, design, and test complexity.

SiC-Based Inverter Design
Silicon carbide (SiC) IGBT switches allow for higher switching frequencies and increased efficiency/reduced mass, which, in turn, allows the use of faster, more efficient, and lighter motors. Though harder to control (faster loop rates), successful implementation may lead to improved range, decreased charging times, and reduced battery cost. It could also be used for better traction and stability control because of the higher bandwidth.

Jeff Phillips, NI Head of Automotive Marketing

PRODUCT FOCUS

NI Power Electronics for EV Test Benches

In December 2018, NI acquired Triphase, a company known for its expertise in flexible, high-performance power system design. NI is integrating Triphase into the company by designating it as the NI Leuven R&D office, which will provide power electronics solutions for test benches with an initial focus on EV powertrain test.

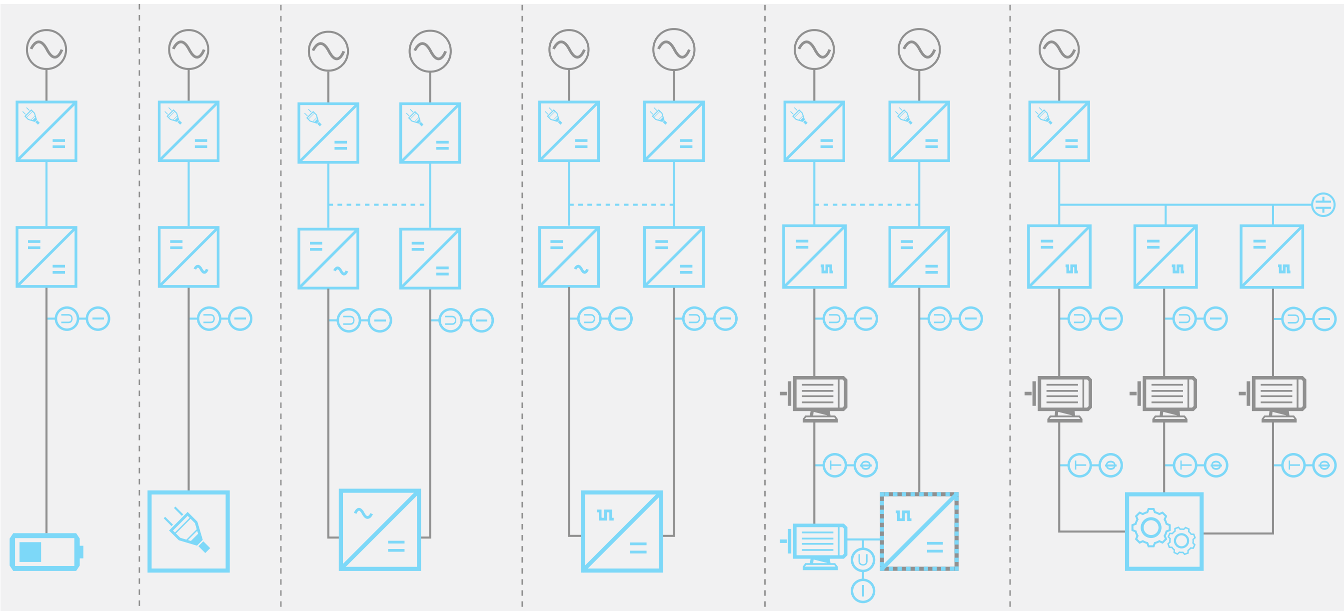
NI Leuven's expertise, experience, and key technologies will be integrated with the NI platform for automated test and automated measurements. This combination will deliver best-in-class high-power test equipment like that needed for power-level source and load emulation in EV powertrain component testing.

Designing both the power electronics and the control and measurement system allows for a seamless user experience as well as advanced high-speed control capabilities.

Key Benefits

- Integrated, turnkey solutions for testing and prototyping
- Modular and scalable converters for motion control, battery emulation, and battery testing
- System-wide, high-speed, high-bandwidth, synchronized data acquisition
- Use of PHIL and digital twin techniques to optimize test bench performance
- Open, multifunctional platform that can integrate with a wide variety of third-party and customer-specific systems
- Distributed, shared power supply across test cells for load sharing and redundancy

NI is delivering power systems to market as part of application-specific offerings for EV powertrain test. These offerings will provide higher level starting points to accelerate EV test system development while maintaining the flexibility to meet changing test requirements.



NI is developing scalable, modular power systems capable of providing synchronized high-performance model-based power-level emulation of EV powertrain components for EV test applications.

EV Power Level Test with the RM-26999

Electric vehicle battery voltages are increasing. When more than 800 V are being used to power everything from the motor to the mirrors, exhaustive testing of powertrain and power electronics components is necessary to validate their functionality and increase their efficiency. But engineers are struggling to implement new high-voltage tests with expensive, inflexible power instrumentation. The RM-26999 Power Measurements Conditioner is designed to keep test engineers nimble and keep validation teams within budget.

The RM-26999 (left) connects to a simultaneous multifunction I/O module in a PXI system (middle) and can condition up to 2000 V directly and up to 2000 A using Danisense current transducers (right).

Designed to Make Power Electronics Test Flexible and Affordable

Power electronics and powertrain validation labs are filled with box instrument power analyzers which are hefty tools designed and priced to meet any niche power measurement need. Though these work well for research, they are not worth the price for automated measurements or durability testing.

The RM-26999 breaks with convention by meeting the key needs of power electronics engineers at a fraction of the cost of box instruments. This Power Measurements Conditioner is an external rack-mounted signal conditioning device that adds high-power measurements to the PXI platform. It safely conditions ±2000 V high-voltage input paths and reads up to ±2000 A indirectly using Danisense current transducers. The RM-26999 connects to simultaneous multifunction I/O (SMIO) PXI Express devices in the NI platform, allowing for easy integration into a modular PXI test system.

These lower-cost, more flexible PXI systems enable durability tests and test cell applications, so you can better predict how components will perform with age and weather. In powertrain test applications, you can integrate and synchronize your three-phase power measurements with other critical data, like vibration, temperature, or CAN bus information.

RM-26999 Detailed View

The RM-26999 conditions ±2000 V direct connection voltage input paths safely; it is peak non-MAINs circuits UL-61010-1 certified. The rack-mount signal conditioner can also perform indirect current measurements using Danisense current transducers. A single cable powers, communicates with, and reads output signals from current transducers up to ±2000 A.

With four voltage input channels and four transducer ports for current measurements, an RM-26999 enables up to four power measurements. It connects to several NI SMIO modules and devices; you can choose your DAQ device separately from your power conditioner, so you can access a range of sample rates and resolutions. Acquire up to 14 million samples per second per channel, with up to 18-bit resolution, by choosing the right SMIO device. If an application requires more than four power channels, two RM-26999 power measurements conditioners can be connected to a 16-channel SMIO module. If you need more than eight power channels, you can easily synchronize additional SMIO modules through the PXI backplane and use channel expansion to scale measurement applications quickly.

Speed Development with Power Analysis Libraries

Power analyzers need to provide not only measurement capabilities but also the insight and analysis to understand the data being acquired. Version 19.0 of the LabVIEW Electrical Power Toolkit (EPT) introduces three-phase measurements to LabVIEW along with other power analysis libraries critical for powertrain and power electronics test.

You can use the LabVIEW EPT 19.0 release to perform IEEE Standard 1459-2010 compliant three-phase power measurements, including transformations to/from reference frames, frequency-domain power analysis, and inverter efficiency and motor efficiency libraries. It also helps you perform battery power measurements like energy and charge integration as well as real power. RM-26999 specific examples are preinstalled in the LabVIEW EPT.

Front and Back View of the RM-26999 Power Measurements Conditioner

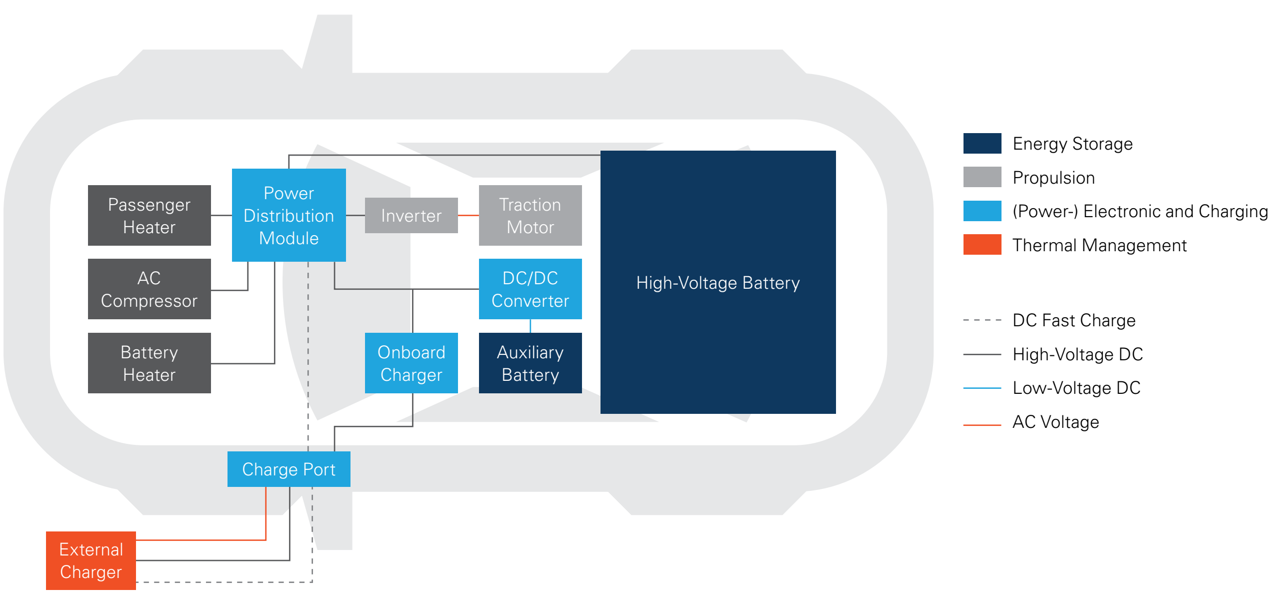
Engineers who need more from their power analysis systems can harness LabVIEW's open development environment to create custom algorithms, processing, and analysis to meet their specific needs. Test organizations that lack in-house LabVIEW development can take advantage of NI's international network of Alliance Partners to assist with the development of custom power measurement IP.

Test More with Less (Budget)

The battery of electric vehicles battery power much more than the motor alone. Battery power is transformed to three-phase alternating current, stepped down to the auxiliary battery, distributed to critical subsystems, and fed by external chargers and the charge port.

High-power measurements are no longer a niche; they are necessary to characterize numerous components and subsystems in an electric vehicle. With skyrocketing demand for high-power measurements, expensive, single-purpose box instruments that perform power analysis in a vacuum are no longer acceptable.

The RM-26999 meets the core needs of power analysis engineers, while leveraging the flexibility and modularity of the PXI platform and the customizability of LabVIEW software. Keep your test teams nimble and your budgets under control with an NI power analysis solution.



All these powertrain and power electronics components in an electric vehicle require power analysis to fully characterize performance.

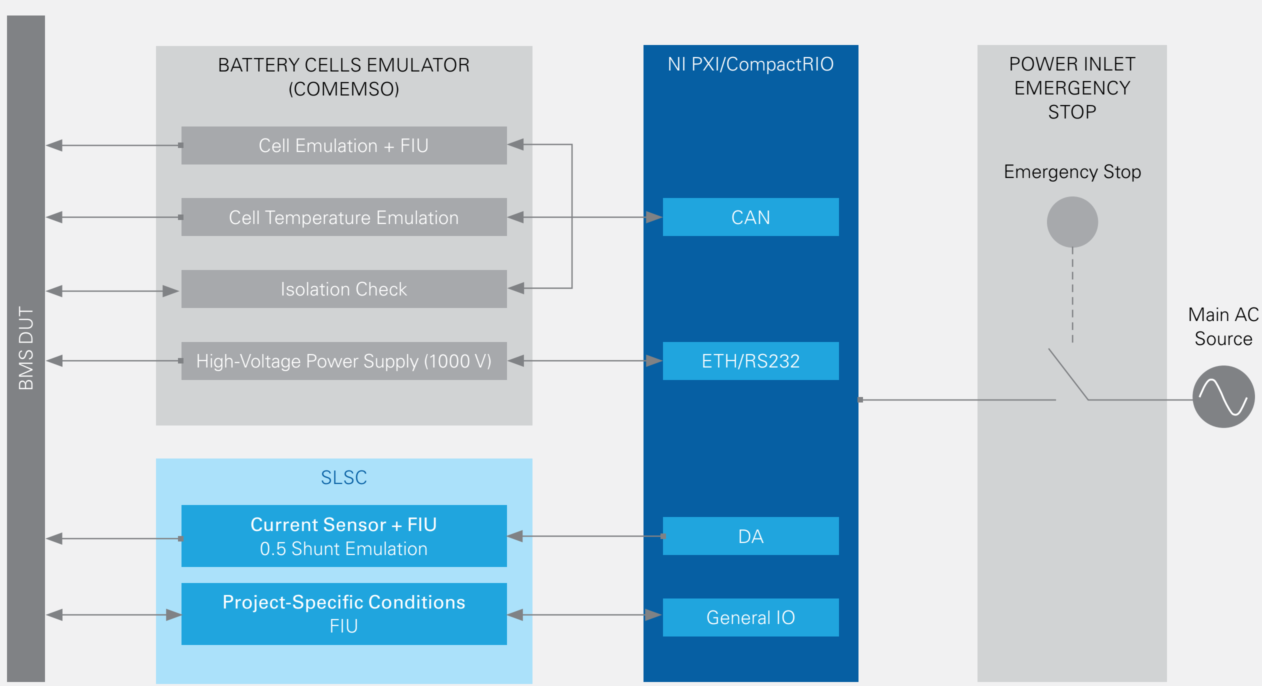
Battery Management System (BMS) Test

Verify your battery management system (BMS) function with HIL testing by emulating battery cells and simulating sensors, I/O, and communication to other ECUs. Ensure that your communication, safety functions, cell balancing, and fault monitoring algorithms are working properly.

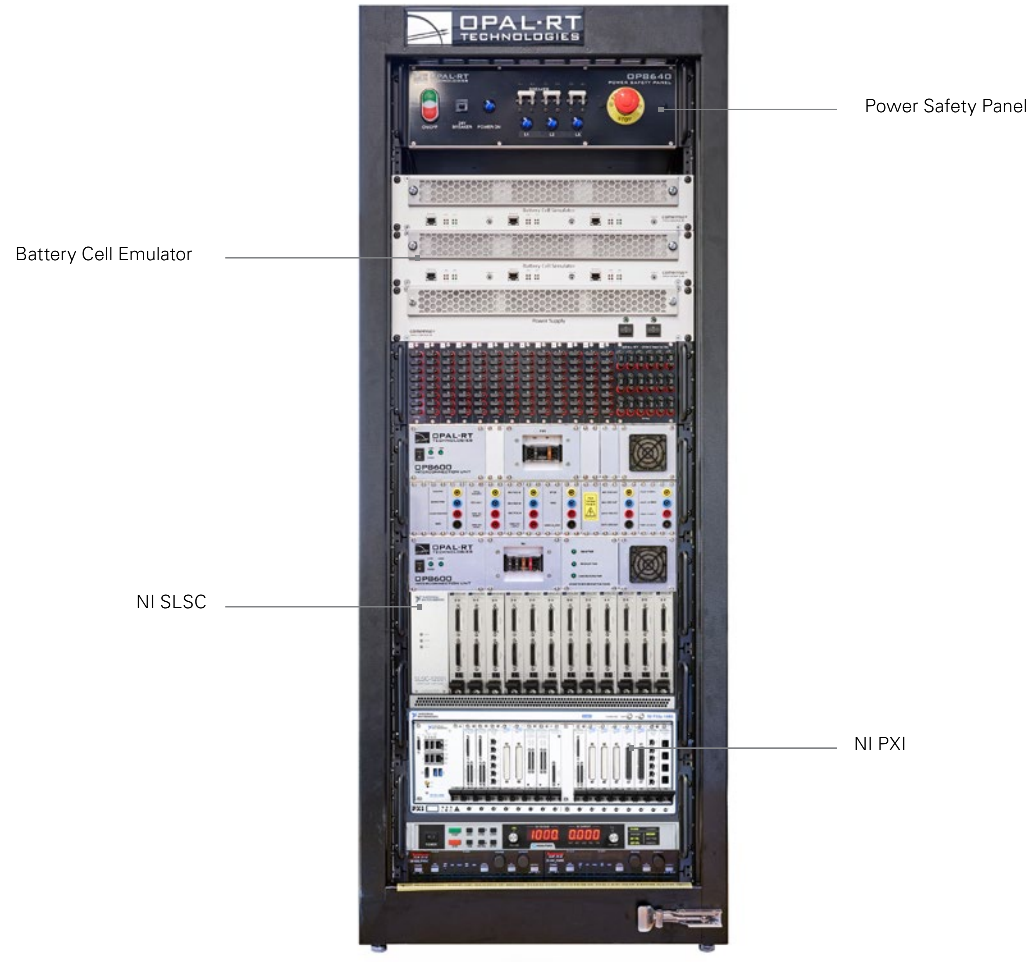
Application Requirements
- Emulate cells on battery models.
- Conduct fault insertion and signal conditioning on BMSs.
- Implement ECU communications and sensor simulation on BMSs.

The NI and OPAL-RT Advantage
- NI for hardware and VeriStand software, OPAL-RT for integration and models, and Comemso for battery emulation add up to the BMS leadership triumvirate.
- NI and OPAL-RT combined technologies help you to simulate models of batteries, high-fidelity power electronics and motors, and cooling or visual control units in real time.

The NI and OPAL-RT Solution
- Emulate 12 battery cells with a Comemso high-precision BCS unit connected to the system through a PXI CAN interface module. Easily add more channels.
- Integrate battery models configured to simulate most battery types (NiMH, LiON, and so on) with different discharge characteristics, connect to third-party equipment, and execute real-time tests with VeriStand.
- Take advantage of integration expertise and custom engineering for extra protection, shunt emulation, breakout boxes, and the incorporation of other controls and systems.



BMS test solutions on the NI platform are delivered by OPAL-RT and other NI Alliance Partners.



> “Testing a BMS in real time is not a very high technical challenge in terms of real-time simulation, but the safety and reliability, repeatability of tests, flexibility, and openness of the solution made the full difference for us.”
>
> ***Julie Darrah, Senior Engineer, IAV Automotive Engineering***

Key Specifications, Comemso Battery Emulator	
Number of Cells per Emulator	12
Voltage Range	0.01…8 V
Nominal Current	0…4.9 A
DC Accuracy	±0.5 mV
Ripple	±3 mV
Communication with NI PXI	CAN/Ethernet
Electrical Failure Simulation	Broken wire, short circuit, polarity reversal; up to 144 cells per rack, 200 cells total

Improve Operational Efficiency with Data and Systems Management Using SystemLink

Managing distributed test systems effectively and making the best possible use of the increasing amount of data they generate are essential for test teams looking to optimize their operations. Standardizing on a solution like SystemLink can dramatically improve system and test management efficiency and data utilization.

Improve the way you handle distributed test assets, test teams, and client (design) team reporting with SystemLink system and test management features.

Managing Systems

Owning expensive test assets requires better planning for downtime activities like calibration and software upgrades to maximize asset use and avoid expensive retests due to incorrect test configurations. The SystemLink Asset Module provides information on how many assets are currently connected and the percentage of all assets that are available over time as well as asset details including alarms and notifications. It can also be used to monitor calibration status and see a calendar of when assets are due for calibration to better plan system maintenance. This functionality works out of the box with NI hardware but can also be used to integrate third-party equipment.

Managing Automated Tests

One of the primary business drivers for improving test asset management is to facilitate the efficient and accurate running of automated tests. The SystemLink Test Module minimizes test downtime and accelerates test insights with dynamic tracking views, configurable dashboards, and powerful trend analysis to monitor KPIs. This works automatically with NI's test executive TestStand and APIs are available to integrate with custom test executives built with LabVIEW, Python, or .NET. The Test module provides the status of historical test runs and a report of test yields or pass rates, as well as the ability to generate reports such as a Failure Pareto to better understand bottlenecks in your testing. You can drill into details of each test and see all results of a particular test performed across all deployed systems with the capability to run that test. You can view information on individual test steps and look at trends over time to help with failure analysis and access all test files generated with the ability to further filter results.

"SystemLink allows teams to focus on their domain expertise, developing tests and generating insight, rather than low-value tasks such as copying files and running installers. We see this software suite as a disruptive technology for test and measurement and data management applications."

Steven Dusing, Project Engineer, DMC Inc.

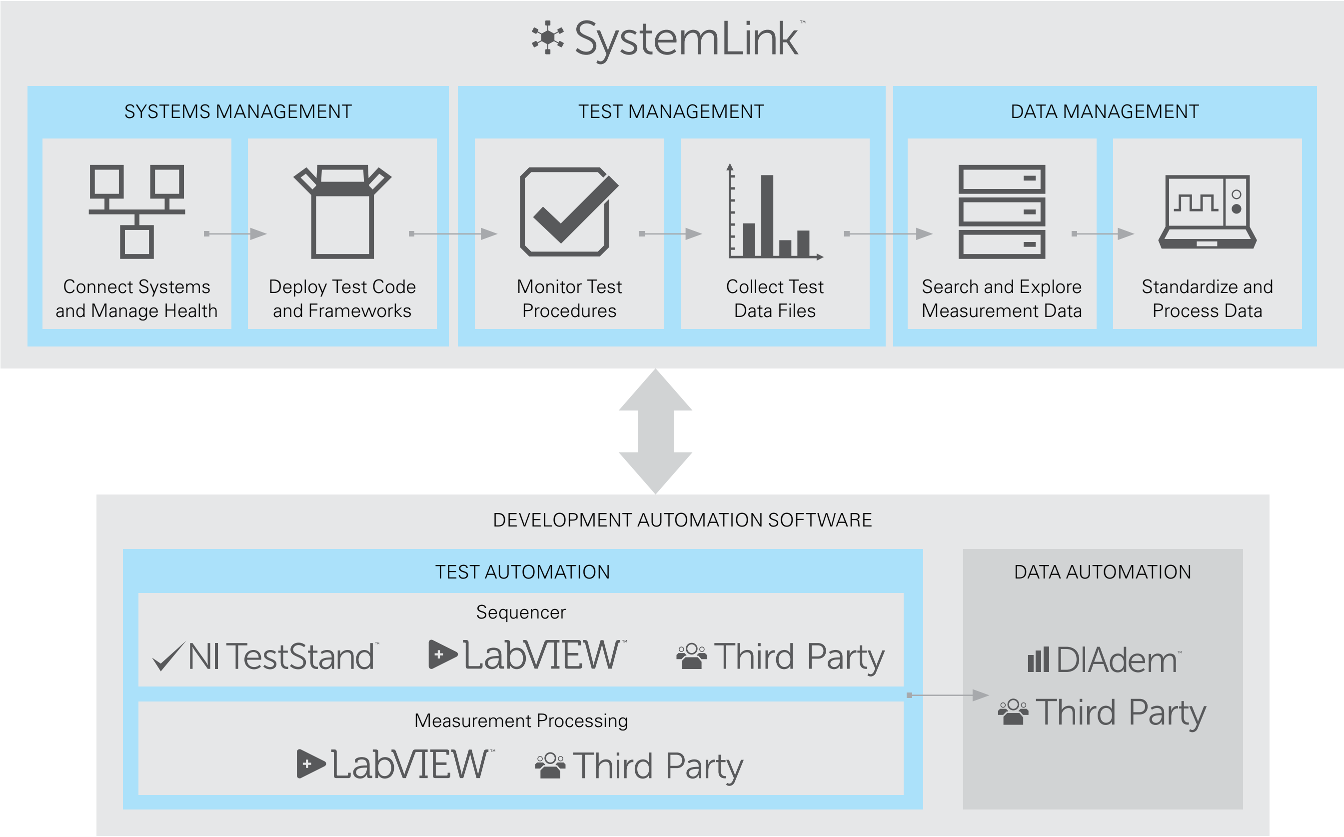
Managing Data
SystemLink includes our DataFinder Server technology in the new TDM DataFinder Module. This functionality can be used to mine measurement data by creating queries to search for data that match multiple conditions. The system indexes all data according to meta data and data headers to quickly return search results. You can look at properties of each file, preview waveform data from within SystemLink, and add it to the data cart for further analysis. SystemLink also includes custom analysis script support for files in your data cart. Once complete, you have access to resulting PDF reports needed for root cause analysis or test optimization. These analysis tasks can also be scheduled to automatically generate reports as new test results are logged or certain conditions are met.

This is just scratching the surface of what SystemLink can do and looking ahead NI is pursuing new capabilities in leading-edge technologies that enable advanced analytics and machine learning. We designed SystemLink to be at the core of all your automated test and measurement systems.

Experts Ready to Help
The SystemLink Specialty Partner Program recognizes NI Alliance Partners such as DMC, Inc. that offer expertise with SystemLink to develop powerful distributed solutions to increase the value of your existing test systems. DMC's expertise integrating NI systems combined with the new capabilities of SystemLink are allowing them to provide a competitive advantage to our automotive customers.

Identifying the right solution partner is particularly valuable to help you navigate today's dynamic technology environment, and DMC and other Specialty Partners offer expertise and best practices to translate your needs into high-value solutions.

Find a specialty partner near you at ni.com/findapartner.



Durability Test Stations for New P0 HEV Motor Generator Devices

Breaking Down Barriers with New Technology in the HEV Industry

The HEV market has grown because of increased consumer demand, fuel efficiency improvements, environmental impact, and stricter vehicle emission policies worldwide. The customer is a multinational, Tier 1 automotive supplier that developed a new motor generator product for P0 HEVs and needed accelerated life-cycle testers designed and built. These new motor generators created multiple new technology challenges for the supplier, which the Ball Systems team addressed.

Functionality of New Test Stations

The HEV motor generator durability test system is designed to be scalable to address new models across a wide array of testing requirements and future HEV rotating electric devices. The source code and other source design documents and files are delivered with the systems, so the customer's team can modify the test system functionality and sequences in the future as needed.

In addition to implementing an open, scalable software architecture using LabVIEW and LabVIEW Real-Time, we designed, built, and validated a structurally rigid frame and custom fixturing system for the device under test (DUT). The system has a high-performance drive train that supports four-quadrant motoring and generating in both rotational directions and consistently operates at multiple extreme conditions including maximum torque, maximum acceleration/deceleration, high RPM, high temperature, low temperature, electronic loads, and so on.

This drive train has a unique multibearing spindle shaft system positioned between the DUT and the load motor. It not only couples shaft rotation and torque from the drive motor to the DUT and vice versa but also serves as a sacrificial wear component to minimize costly drive motor rebuild events due to the severe DUT durability test cycles implemented by the test system.

Facing Technical and Mechanical Challenges in a Large Tester Head-On

This test system addresses the following engineering challenges:

- Four-quadrant (torque/speed) dynamometer operation in the 80–100 horsepower range
- Simulation of extreme automotive engine compartment thermal and electrical conditions
- Configurable test profile (recipe) generation capability with robust data collection and reporting
- Automated belt tensioning system with hub load measurement capability
- Commercially supported standard software environment
- The use of as many COTS components as possible
- Interchangeable fixturing system for multiple DUT mechanical designs
- Structurally rigid frame to maintain drive pulley, drive belt, and DUT pulley alignment
- Adherence to customer-specified safety and installation requirements

During the test, the DUT is fixtured in a thermal chamber. A belt is then attached between the DUT motor pulley and the drive train pulley via a structurally robust but programmatically automated belt tensioning system. The rotation of the connected shafts is established by electrically powering the DUT motor from the DUT inverter or the drive motor via the drive motor inverter. Power is transferred from the DUT motor to the drive motor via the drive belt or vice versa. Concurrently, the drive motor absorbs power via the drive belt and transfers it back to the power grid via the drive motor inverter or, in the case of the DUT motor absorbing power, via the DUT inverter back to the power grid through the battery simulator. The NI CompactRIO-based control system

The Challenge

A Tier 1 automotive supplier required the design and delivery of multiple dynamometer-based durability test stations for newly designed motor generators targeting the P0 hybrid electric vehicle (HEV) market.

The Solution

Ball Systems designed, built, and validated six independent and universal belt-driven dynamometer-based durability test stations for motor generators using commercial off-the-shelf (COTS) subsystems, custom mechanical fixturing, industrial mechatronics/electronics, and a network-based, open architecture featuring LabVIEW, the LabVIEW Real-Time Module, and CompactRIO hardware. This solution saves test time, adapts to future test needs, and is more cost-effective than the competitor's approach.

manages all the system-level device operations and collects DUT and system data during test sequence execution.

Software Recipes Are Key to Durability Test Stations

Creating an easy-to-use recipe generation system that is application specific yet extensible to new product classifications was essential to our customer's success.

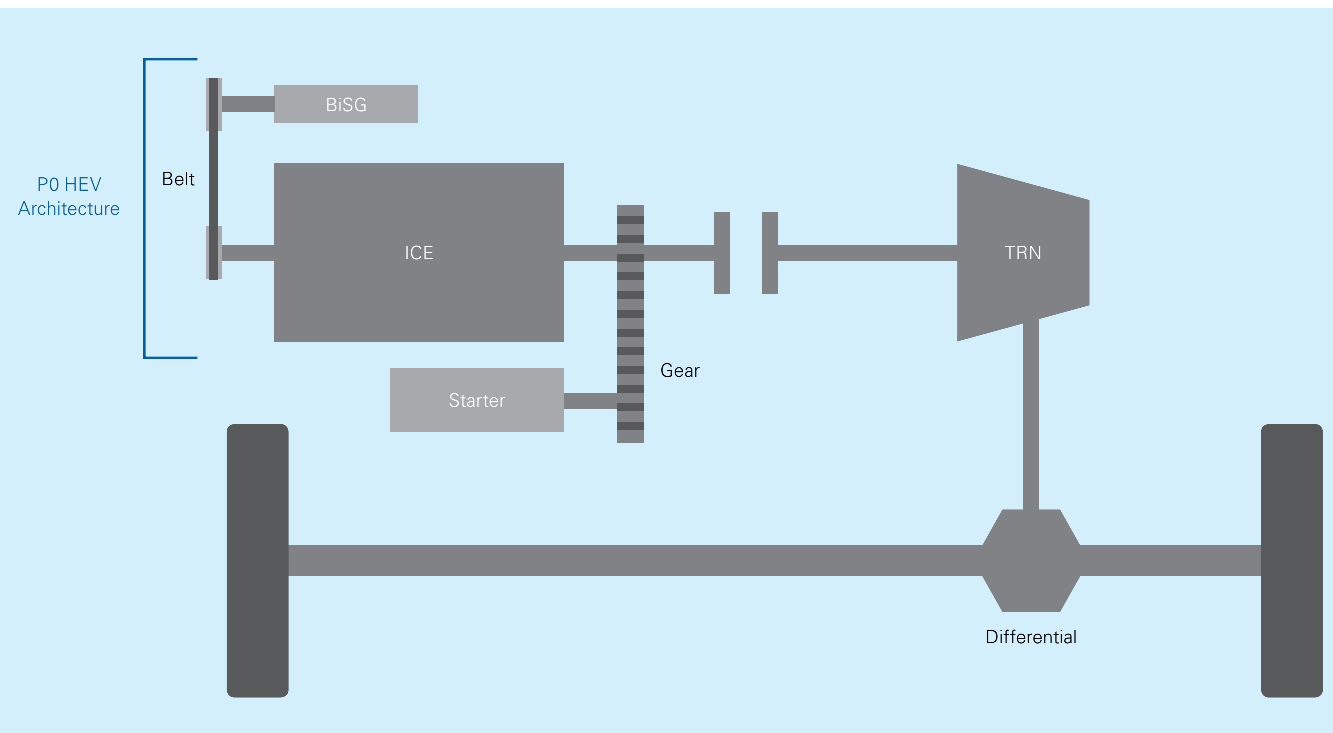
Most of our LabVIEW-based systems include test step sequencing functionality. This allows the end user to create test sequences by compiling a list of actions with defined parameters at each step.

In this instance, the customer intends to create tests that can run for weeks at a time, so their sequences consist of thousands of steps if implemented discretely. To modularize sections of these lengthy test sequences, we added the ability to call subsequences within a test sequence and the ability to iterate these subsequences any number of times. This is a common technique in software engineering, but it is not widely available in a test system programming environment.

Instead of thousands of separate action steps, our software engineers implemented a recipe approach that allows the user to accomplish the same test sequence in fewer steps. This modular feature saves the end user time when creating and modifying test sequences. These recipes can then be saved for future use or for modification and easy creation of new recipes.

Brock Benefiel, Ball Systems, Inc.

*To learn more about durability test stations based on the NI platform, contact **info@ballsystems.com**.*



Illustrates the HEV P0 architecture, where the electric machine or the BiSG is connected to the internal combustion engine (ICE) through a belt, on the front-end accessory drive (FEAD).

Visit with NI at an Event Near You

NI Automotive Industry Forums

August 14, Mexico
September 26, Detroit

October 3, India
October 11, Japan

October 30, Korea
November 7, Sweden

Trade Shows

Americas

September 10–12
The Battery Show
North America
Novi, MI

October 22–24
Automotive Testing Expo
Novi, MI

Asia

July 17–19
JSAE Automotive
Engineering Exposition
Nagoya, Japan

September 24–26
Automotive Testing Expo
Shanghai, China

Europe

September 4–5
Cenex-LCV
Bedfordshire, UK

October 16–17
Electronics in Vehicles (ELIV)
Bonn, Germany

December 10–11
ASAM International Conference
Dresden, Germany

NIDays Asia

Shanghai, China
中国上海

Shanghai International Convention Center
上海国际会议中心

November 14–15
11月14–15日

NIDays Europe

Munich, Germany
München, Deutschland

International Congress Center—Munich
Internationales Congress Center München

November 20–21
20. und 21. November

Register at ni.com/nidays