



E-Mobility: Innovative Design and Test Solutions

For battery test labs and the EV charging ecosystem

Keysight's Global Automotive and Energy Footprint

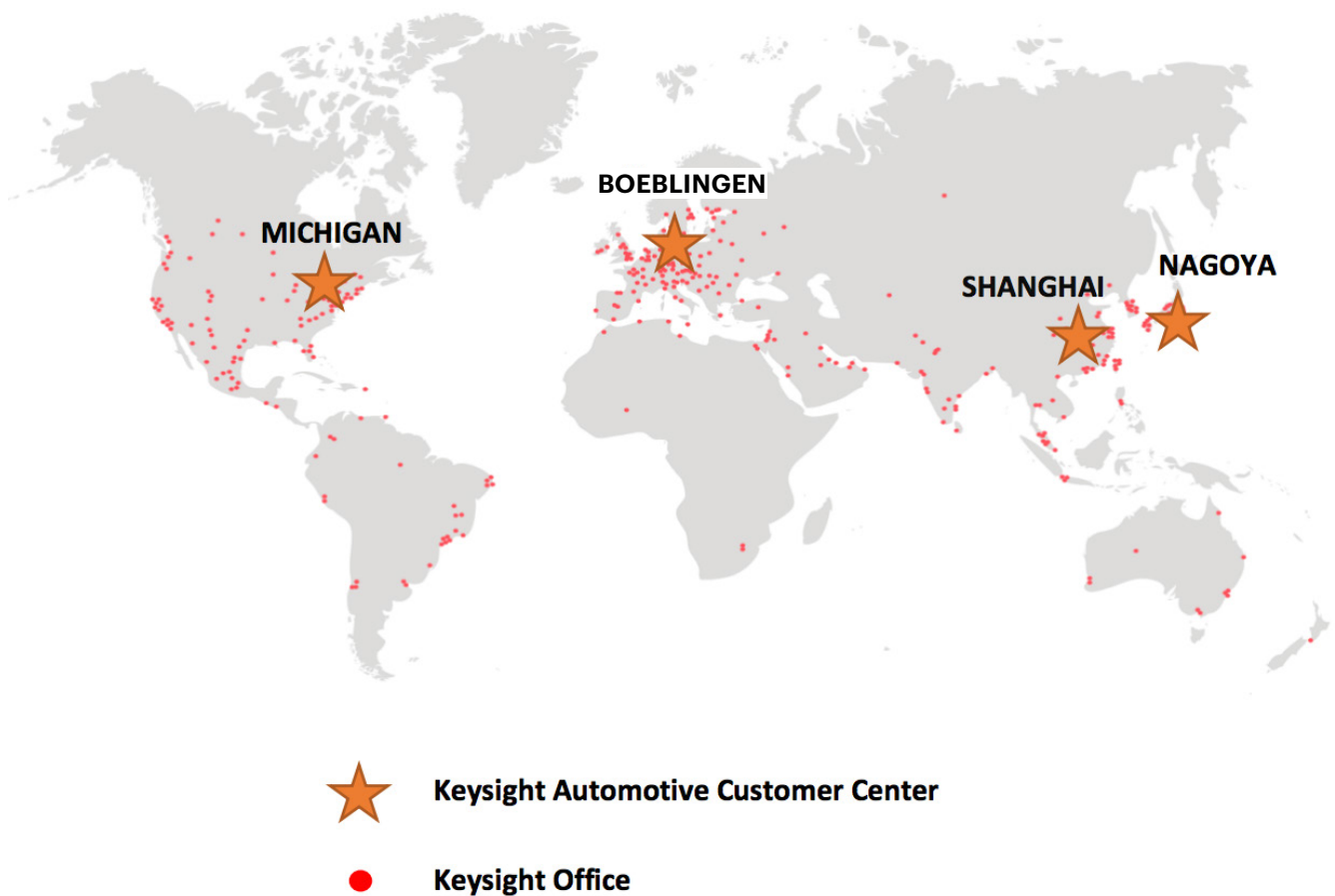
Keysight's global footprint ensures we deliver solutions where you need them.

We have established automotive customer centers in Michigan, United States; Boeblingen, Germany; Nagoya, Japan; and Shanghai, China.

These centers underscore our commitment to working with and serving customers in local proximity to support innovative technology projects that drive the automotive and energy industries.

We maintain partnerships with international organizations that help set the standards for electromobility (e-mobility).

All of this translates into future-ready solutions for your automotive design and testing requirements.





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What Is Fueling the E-Mobility Ecosystem?

The number of pure electric vehicles (EVs) and hybrid electric vehicles (HEVs) on the world's roads will hit 240 million by 2030, the International Energy Agency forecasts. ¹

That is a big leap from the 30 million such vehicles the agency reported for 2022. Advances in technologies for power trains, power electronics, cells and batteries, and charging infrastructure (Figure 1) match the growth in EVs and HEVs.

Manufacturers must ensure that their EV fleets comply with CO₂ emission regulations. They also need to improve energy efficiency and range.

It typically takes more than one design cycle before new powertrain technology turns a profit. The cost pressure on EV powertrain components (traction motors, converters, power converters, and batteries) continues to drive new fundamental technologies. These technologies increase demand for design and test solutions that provide better emulation and test coverage to comply with safety and performance standards.

Growth in the plug-in vehicle market is also fueling new technologies in the adjacent renewable energy ecosystem. These include photovoltaic (PV) inverter and smart grid technologies.

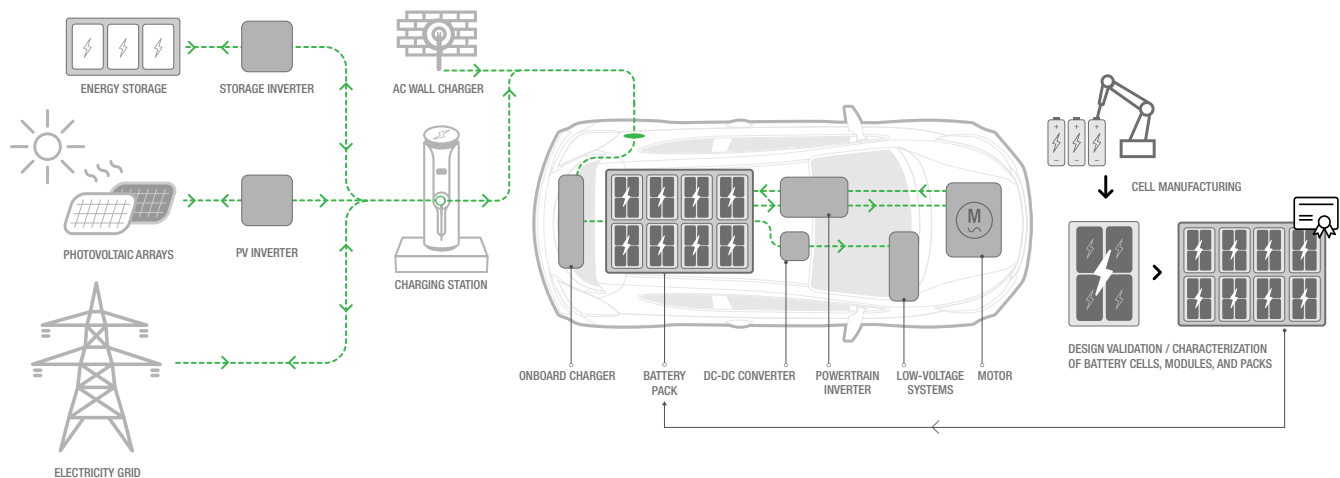


Figure 1. The e-mobility energy ecosystem

1. Global EV Outlook 2023. International Energy Agency, 2023. <https://www.iea.org/reports/global-ev-outlook-2023/prospects-for-electric-vehicle-deployment>.

Testing in the High-Power E-Mobility Environment



Bidirectional test: Testing bidirectional power flow demands equipment that can source and sink power seamlessly. Conventional test methods use external circuits and multiple instruments. These methods typically do not allow for smooth signal transitions between sourcing and sinking power, resulting in inaccurate simulations of operating conditions. They also lead to heat build-up in the test environment, requiring costly cooling measures.



New power semiconductor technology: Designers are starting to use wide-bandgap (WBG) devices. These offer better power efficiency and the ability to handle higher voltages and temperatures than conventional silicon devices. However, their use complicates the simulation and design of DC-to-DC converters. Traditional simulation tools used in the design of power converters do not accurately capture the behavior of WBG devices and cannot support the optimal design of converters using these devices. Designing today's converters requires new simulation and test technologies.



Safety and reliability concerns: Using new semiconductors requires extra validation and reliability testing to ensure that the converters will last under harsh operating conditions. Given the power levels used with converters, designers must be careful when testing them. These tests require special safety mechanisms in manufacturing, including redundant systems that do not expose personnel and equipment to high voltages if a failure occurs.



Maximizing efficiency: To improve a device's efficiency, measurements must be repeatable and made in real-world conditions. Keysight understands the importance and processes involved in creating higher-efficiency products, as our latest pack test system is more than 96% efficient.

Test Solutions for Electric Vehicles and Power

To address these emerging design and test issues, Keysight has created and introduced innovative approaches to help developers and manufacturers accelerate their programs. This e-mobility brochure will provide you with an overview of the design and test solutions and services that Keysight offers in this ecosystem.

Electric powertrain testing: Ensure energy efficiency at the power semiconductor level through inverter and DC-to-DC converter testing for onboard systems. Characterize cells and test and battery modules and packs for power efficiency while addressing safety, time, and cost concerns.

Charging technology and infrastructure testing: Test the EV and electric vehicle supply equipment (EVSE) charging interfaces in the field or laboratory, from mobile use to comprehensive applications.

Energy ecosystem testing: Use leading-edge emulation technology and software, spanning solar cell testing to PV inverter efficiency testing, to help meet stringent industry standards for safety and performance.

Do not hesitate to reach out to us to address specific design and test needs for your products and solutions. www.keysight.com/find/e-mobility



Battery Test Laboratory

Keysight offers comprehensive cell, module, and pack test solutions. We provide complete solutions starting at the battery terminals, including fixtures, cabling, environmental chambers, sophisticated electronics, and software. You can upgrade our scalable solutions to keep pace with the dynamic battery market.

As battery labs grow, our solutions offer operational and electrical efficiency that lowers operational costs. Our solutions provide advanced analysis, including electrochemical impedance spectroscopy (EIS). Keysight's global footprint enables on-site installation and service in most locations.



Figure 2. Battery Test Lab

Battery test lab software

Keysight supplies a complete software solution for battery test labs. The software supports all Keysight cell, module, and pack testers, allowing labs to support testing of one or more types of batteries. PathWave Lab Operations for Battery Test helps track batteries through the test process and provides data across organizations. Keysight Energy Storage Discover (ESD) is the software solution for developing tests, performing tests, and reporting results from battery test systems. Quickly create simple test procedures or combine multiple tests into a comprehensive procedure.



Energy storage software

ESD is a purpose-built application that controls all Keysight battery testers and peripherals. Start making measurements today. Each “program” is a step-by-step instruction list that mirrors a manual process. Use subroutines, variables, and battery models to split more complex tasks into simpler pieces.

- Learn once with software that supports all Keysight cell, module, and pack testers.
- Connect quickly to the battery test systems via Ethernet.
- Gain insights quickly and export results with standard formats.
- Install a simple single license per workstation and receive regular updates.

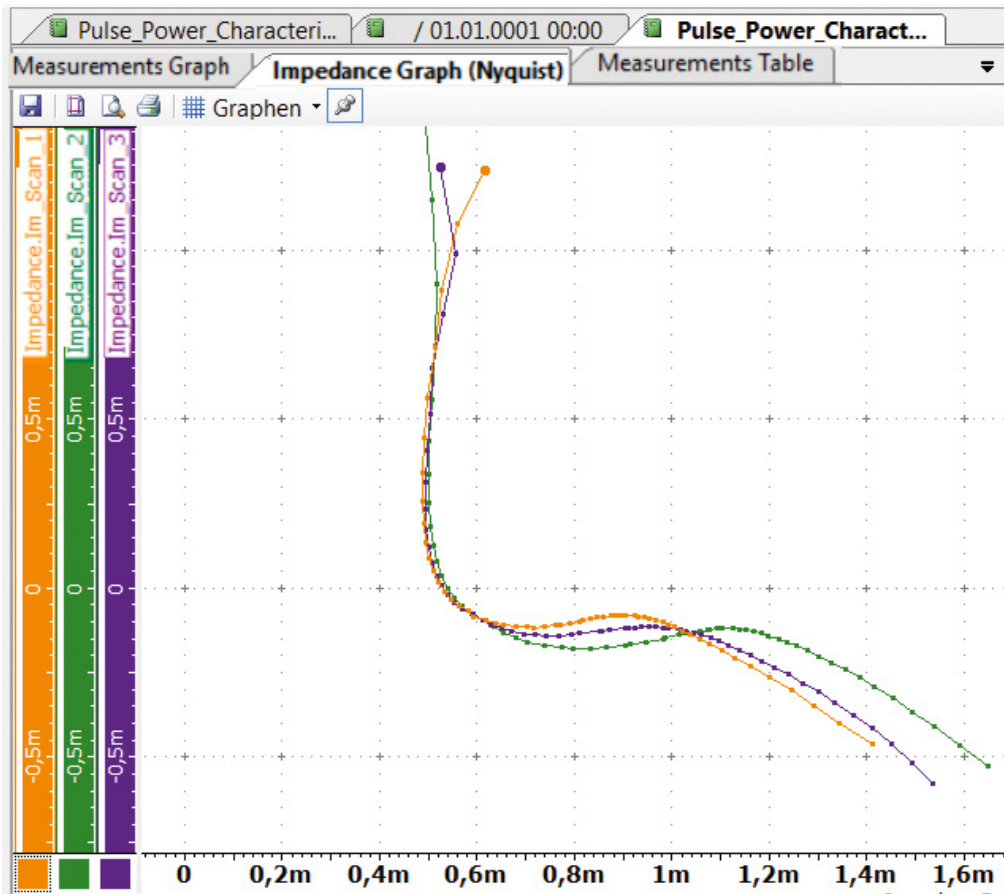


Figure 3. Impedance graph visualized in ESD software

PathWave Lab Operations for Battery Test

PathWave Lab Operations for Battery Test enables efficient planning and coordination of your entire battery test laboratory. It manages all resources, including test facilities, test systems, and devices under test. It provides an integrated, browser-based lab management platform that helps you modernize test workflows, eliminating legacy paper-based processes and increasing data integrity and traceability.

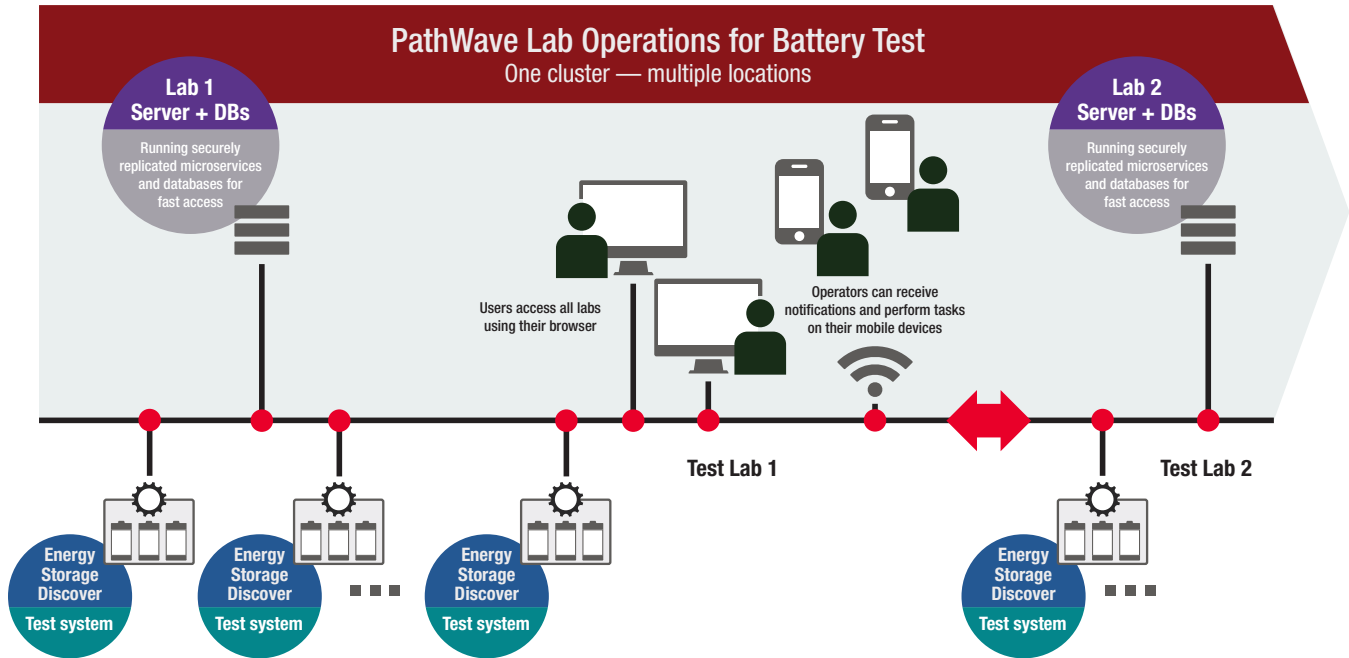


Figure 4. PathWave Lab Operations for Battery Test

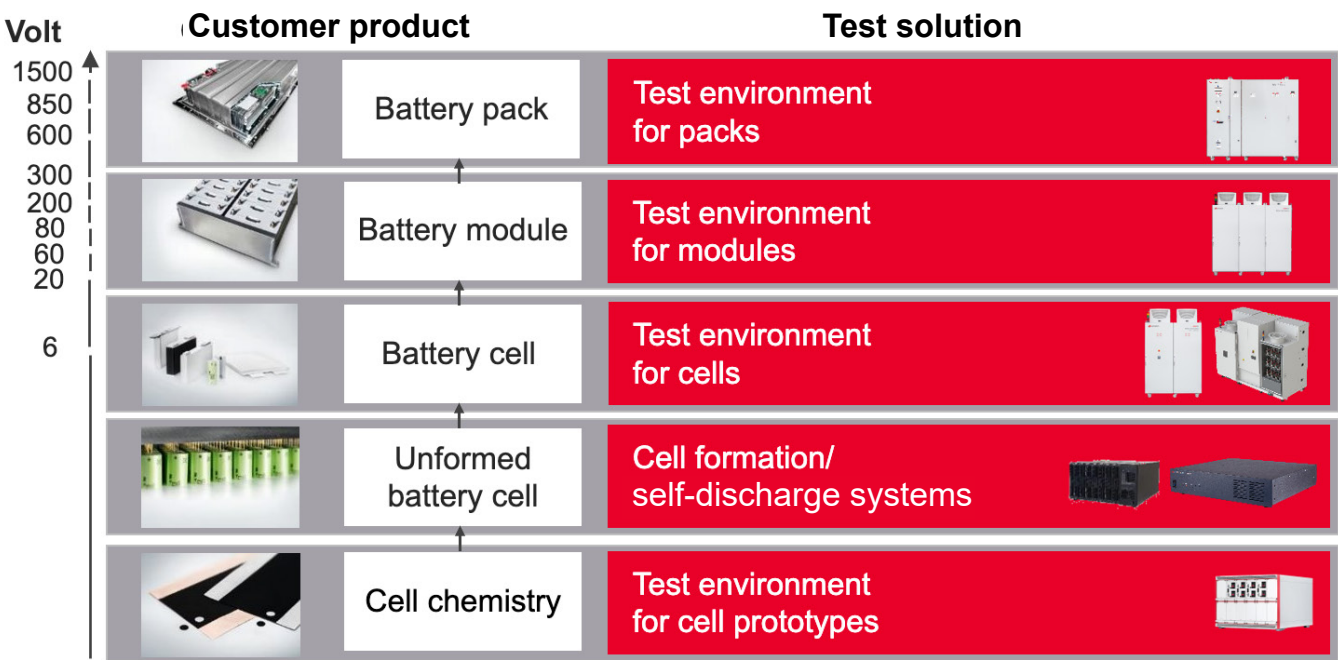
This toolset boosts throughput for cell and battery testing so you can meet project requirements, stay on schedule, and optimize asset utilization. The tools are automated, networked, and scalable for any lab size — up to thousands of channels. You can share and control test plans, results, data, and other documents for simple and productive collaboration and discussion among lab staff.

- Easily register and track test objects in your lab.
- Quickly analyze your data and statistics.
- Organize your test lab workflow, documents, lab orders, and tasks.
- Plan and optimize your test capacities and sequences.
- Remotely control your lab and its devices anywhere, anytime.
- Manage and route notifications to your preferred device or email service.

Cell, module, and pack testers

A single software solution enables the testing of any combination of cells, modules, or battery packs. Our solutions can scale to meet your additional volume or battery innovation challenges. Keysight test systems offer high efficiencies to reduce operating costs and ambient noise. EIS is also available.

Battery test solutions from cell chemistry to packs



Learn more:

Cell self-discharge analysis

32-channel self-discharge analyzer

The Keysight Self-Discharge Analyzer directly measures self-discharge current on large numbers of Li-ion cells. Using a potentiostatic measurement technique reduces the time required to discern good versus bad cell self-discharge performance from days or weeks to minutes or hours. For cell manufacturers, it provides dramatic reductions in work-in-process inventory, working capital costs, and facility costs. For cell designers and evaluators, this provides faster cell analysis, which drives shorter design cycles and faster time to market (Figure 5). The Keysight BT2152B, along with the BT2155A software, enables the following key features:

- Up to 32 channels of self-discharge current measurement available in four-channel increments.
- Current measurement accuracy: $\pm (0.30\% + 250 \text{ nA})$.
- Voltage measurement accuracy: $\pm (0.04\% + 0.1 \text{ mV})$.

High levels of Li-ion cell self-discharge are indicative of latent failures. The new Keysight potentiostatic solution addresses cell self-discharge measurement challenges, enabling users to realize a significant reduction in time and cost savings and accelerated time to market.

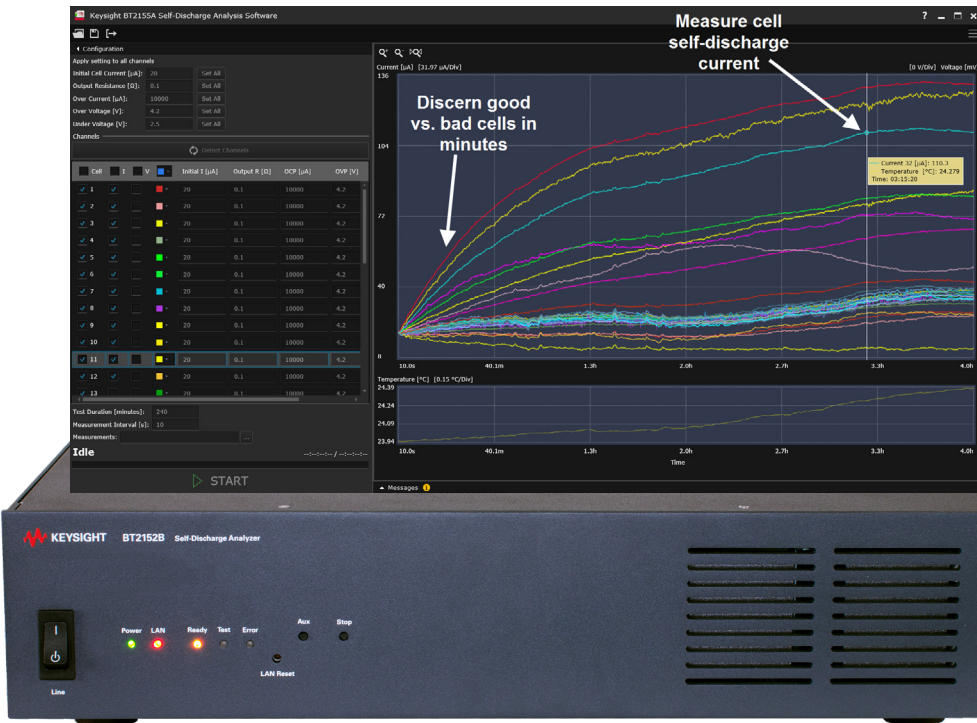


Figure 5. The Keysight potentiostatic measurement technique cuts the amount of time needed to discern good versus bad cell self-discharge performance

Cell charge-discharge platform

Keysight charge-discharge platform

The Keysight charge-discharge platform is cost-effective and easily reconfigurable for Li-ion cell formation. Modular configurations support cells requiring maximum currents ranging from 6 to 200 A, with 8 to 256 cells or user channels per chassis. Benefits of this platform include the following:

- Modular configurations from 6 to 200 A, 8 to 256 channels; up to eight modules per chassis, 32 channels per module.
- ± 6.25 A per physical channel, and up to 32 channels paralleled to increase range up to ± 200 A per user channel, with 1 s sampling intervals.

Easily configurable for new or additional capacity ratings, the charge-discharge platform helps manufacturers respond quickly to requirements for different cell types at a low cost.



Charging Technology and Infrastructure Test

A crucial factor in the breakthrough of electromobility is enabling all drivers to charge their EVs / HEVs conveniently and safely. Reliable charging puts high demands on the charging interfaces at both sides of the charging adapter — on the EVSE and within the vehicle. Alongside the power itself, fault-free communication between EV and EVSE guarantees reliable charging. This communication requires electromagnetic compatibility-compliant components, norm-compliant procedures, and compatible technologies. Other factors to consider include local mains supplies, regional climatic conditions, and compatibility with different EVs and EVSEs.

Learn more:



Charging Discovery System

For comprehensive testing of all EV and EVSE charging interfaces, Keysight offers an all-in-one test solution. The Keysight Charging Discovery System (CDS) Series is a breakthrough solution for holistic testing of all AC and DC charging interfaces of EVs and EVSEs. Its modular and innovative design enables customers to configure it to their specific needs and replace multiple real EVs / EVSEs with one test solution to ensure an optimal price-performance ratio.

Highlights of the CDS include the following:

- Automated functional, conformance, interoperability, and quality testing for R&D, end-of-line, and electromagnetic compatibility (EMC) applications.
- Time synchronous measurement and decoding of communication and power signals.
- Scalable and future-proof hardware design according to CharIN e.V. CCS Test System.
- Extensive test case library for automated conformance testing of CCS, CHAdeMO, and GB/T standards.



Charging Discovery System — High-Power Series

The Charging Discovery System — High-Power Series (HP CDS) enables testing for charging interfaces of EVs and EVSEs during high-power charging up to 1,500 V DC and ± 600 A DC.

The solution exists in two variants and can test up to 1,500 V DC or up to 1,000 V DC. An upgrade from 1,000 V DC to 1,500 V DC is possible at any time as an additional option. With CDS, customers can perform all necessary conformance and interoperability tests according to worldwide charging standards. The solution, which features a separate cooling unit with interchangeable liquid-cooled charging adapters, also enables a high-power upgrade of the Keysight SL1040A Charging Discovery System — Portable Series.

Highlights of the HP CDS include the following:

- Automated functional, conformance, interoperability, and quality testing for R&D and end-of-line applications.
- Time-synchronous measurement and decoding of communication and power signals.
- Scalable and future-proof hardware design according to CharIN e.V. CCS Test System.
- Extensive test case library for automated conformance testing of CCS, CHAdeMO, and GB/T standards.

EV-ESE charging communication interface tester

This device enables component-level tests of electric vehicle communication controllers (EVCC) and supply equipment communication controllers (SECC). It supports combined charging system (CCS) communication. The com tester supports the following use cases:

- Good case emulation for development testing of EVCC and SECC.
- Conformance test cases for type approval testing of EVCC and SECC.
- Scenario-driven tests for manufacturing testing of EVCC and SECC.
- Hardware-in-the-loop (HiL) integration tests on component level.



CCS charging protocol tracer

This device enables seamless observation of the CCS communication channel between an EVSE and an EV. In combination with the SL1487A CCS charging protocol trace viewer, it enables you to analyze over-the-wire communication traffic. The charging protocol tracer features the following:

- Easy analysis of CCS charging communication.
- Compact size for use directly on the EV or EVSE.



Charging Discover test software

The software enables you to operate the system, visualize measured values, record test sequences, and generate reports. It includes the following features:

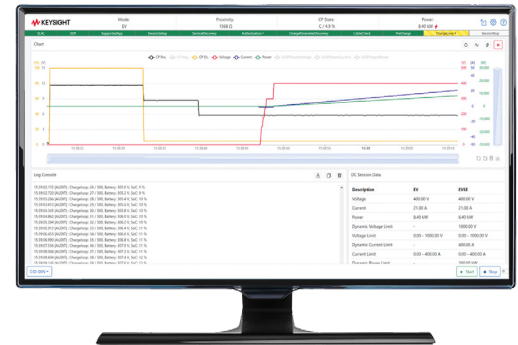
- Live and synchronized views of recorded measurements.
- Test editor for creating individual test cases.
- Powerful graph view for analyzing recorded traces.
- Remote functionality for HiL test benches.



EV – EVSE Smart Charging Emulation software

The software provides emulation of EVs / EVCCs or EVSEs / SECCs according to the standards addressed by the CCS specification. It enables you to do the following:

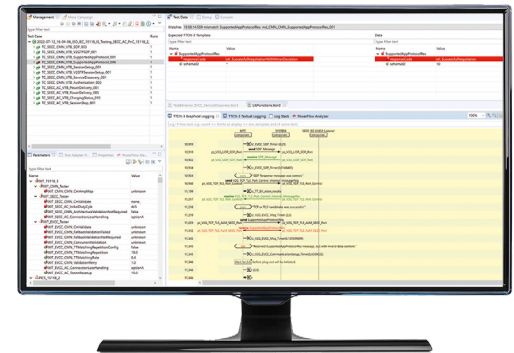
- Accelerate functional testing for CCS with EV and EVSE emulation packages.
- Perform AC and DC charging emulation.
- Get a holistic view with a graphical user interface for parameter configuration, monitoring, and smart charging control.



Charging Communication Test Automation software

This software provides test case packages for conformance and interoperability testing based on the test implementation language TTCN-3 (Testing and Test Control Notation). It features the following:

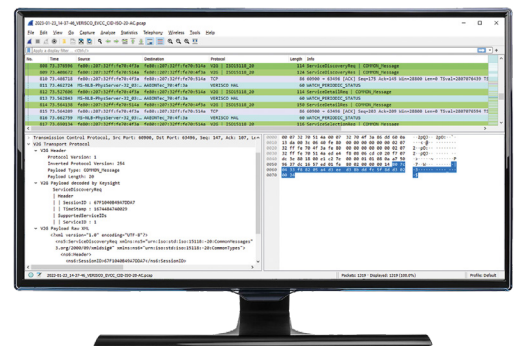
- Extensive test case library for automated conformance and interoperability testing of CCS.
- Support for the following test suites: DIN 70122, CharIN TCs for DIN 70121 Impl. Guide, DIN 70121 IOP, ISO 15118-4/-5, ISO 15118-2/-3 IOP.



CCS Charging Protocol Trace Viewer

The software enables decoding of CCS communication protocols used for charging. It features the following:

- Support for V2G and HAL protocol.
- Works with Wireshark, a packet analyzing tool, for detailed tracking of communication between the EV and EVSE.



Supporting E-Mobility Test Technologies

Regenerative Three-Phase AC Emulator

The AC emulator series handles all your three-phase AC test needs up to 1,200 VAC, from 30 kVA to 630 kVA, without the need for a transformer. You can choose from two voltage ranges: 600 VAC and 1,200 VAC. The 600 VAC models are ideal for low-voltage inverter tests, as well as EV and EVSE charging test applications. The 1,200 VAC models enable HVRT testing at the IEC LV- AC limit without the need for a large, complex test setup.

The complete, one-vendor solution consists of hardware, software, consulting, and support services worldwide for all grid-edge applications, such as EVSE / EV charging test, solar / PV inverter test, and battery energy storage system test.

The series enables you to do the following:

- Cover your test needs with a high-power three-phase AC and DC power source: up to 1,200 VL-L, up to 130 A, and up to 630 kVA.
- Achieve 1,200 VL-L at full specifications without extra equipment, such as a transformer.
- Test to IEC 61000 standards and grid compliance standards, such as UL 1741 SA and IEEE 1547.1.
- Save energy with a 100% regenerative (bidirectional) power solution with > 85% efficiency.
- Get up and running immediately with an intuitive soft front panel.



Regenerative DC Emulator — High-Power Series

The regenerative DC emulator enables users to emulate the large batteries in electric vehicles. The bidirectional power flow allows emulation of both power-sourcing applications, such as traction inverter tests, and power-absorbing (sinking) applications, such as EV charging.

- Achieves 1.5 MW power through parallelization.
- Supports up to 1,500 VDC for emulating high-voltage batteries.
- Offers up to 96% efficiency with recovery capability.
- Uses new high-voltage silicon carbide technology.
- Integrates seamlessly with SL1040A Charging Discovery System and SL1093A Charging Discover software.



Dynamic DC Emulator — Mid-Power Series

The dynamic DC emulator (DCE) provides up to five power stages, called regenerative power systems (RP7900 Series). It is a family of bidirectional, regenerative DC power supplies.

- Provides up to 950 V DC, ± 100 A, and 50 kW for a fully equipped rack with a total of five RPS units.
- Create a total power or loading of up to 150 kW (± 300 A DC) through easy paralleled connections of three fully equipped racks.
- Maximizes throughput with fast output speed and sub-millisecond command-processing time.
- Integrates fully with Charging Discovery System and Charging Discover software.



Measurement and control modules

Keysight measurement and control modules deliver precise results for a wide range of test, measurement, and control tasks in automotive and industrial product development. They are ideal for carrying out challenging measurement tasks, even under difficult environmental conditions, such as in a climate chamber.

Capabilities include the following:

- Provision of a safe working environment with contact protection up to 1,000 V.
- Connection via an open Ethernet interface.
- Automatic detection of ESD software.
- Application to challenging test environments (for example, -40 °C to 80 °C, IP20).



Dynamic Power Device Analyzer / Double Pulse Tester

EVs are increasing the demand for insulated-gate bipolar transistors, silicon carbide, and gallium nitride semiconductors. Accurately characterizing these devices requires both static and dynamic measurements. The double-pulse test method is the de facto industry standard for the dynamic characterization of power devices.

The Keysight Dynamic Power Device Analyzer / Double Pulse Tester delivers repeatable, reliable measurements of wide-bandgap semiconductors:

- Supports the latest evolving JEDEC standards for WBG devices.
- Measures characteristics like turn-on, turn-off, switching, reverse recovery, gate charge, and many others.
- Provides a safe test environment for both the device under test and the user.



HEV / EV power converter test solution

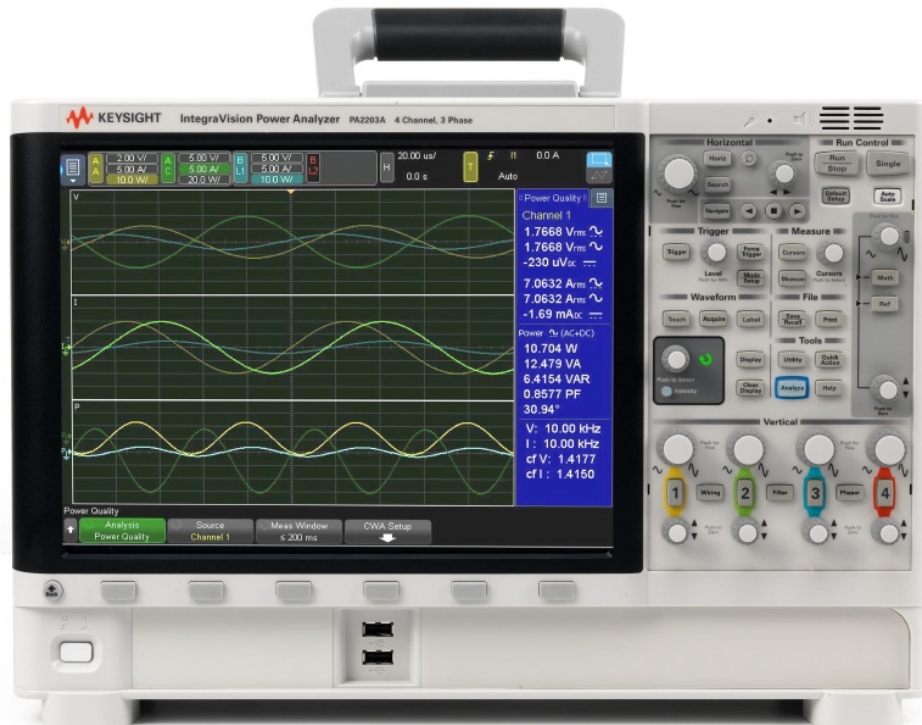
HEV and full EV batteries are 300 V and higher, while many conventional vehicles use a 12 V platform. EV test equipment suitable to handle this new high-voltage, high-power environment is expensive.

Test costs are also escalating. For example, a 10 kW power source consumes 10 times the energy of a 1 kW power source when sourcing full power. This power consumption creates a lot of heat, which incurs further cooling costs. You must also comply with high-voltage safety regulations, such as NFPA 79, and provide safety disconnect contingencies. Keysight created the power converter test solution to help you overcome these challenges. The solution comprises three key components:

IntegraVision Power Analyzer

The Keysight IntegraVision Power Analyzer simplifies EV testing for AC and DC power measurements. Easily measure power on any vehicle power converter, such as AC-to-DC power conversion efficiency of the onboard charger:

- Achieve power analyzer accuracies and scope-like waveform visualization with reduced setup time.
- Address multiple test scenarios with the flexibility of wide-ranging, isolated inputs.
- Visualize transients, in-rush currents, and state changes with a high-speed digitizer that captures voltage, current, and power in real time.



Regenerative power system

The Keysight regenerative power system is the core of the solution. It provides battery emulation capabilities for vehicle electrification tests, such as two-quadrant (source / sink) operation and programmable output resistance. It also regenerates greater than 85% of power back to the grid.



Safety disconnect system

The Keysight safety disconnect solution works exclusively with the regenerative power system series. In less than 15 ms, the safety disconnect will remove the output voltage to safeguard your device under test and your people in response to a fault. For testing purposes, the regenerative power supply can generate faults, or the user can generate them manually. The system complies with key global EMC and safety regulations.



PV and Smart Grid Technologies

New criteria are emerging to regulate the industry for safety, performance, and business viability. The challenge for engineers is how to verify and test each design, from development to high-volume production, to ensure a smooth and safe transition into this brave new world of e-mobility.

Energy ecosystem

Supporting the electrification of the modern vehicle is an entire energy ecosystem, from PV inverters that harness and convert solar energy to storage and distribution. Energy efficiency is an integral factor across this ecosystem.

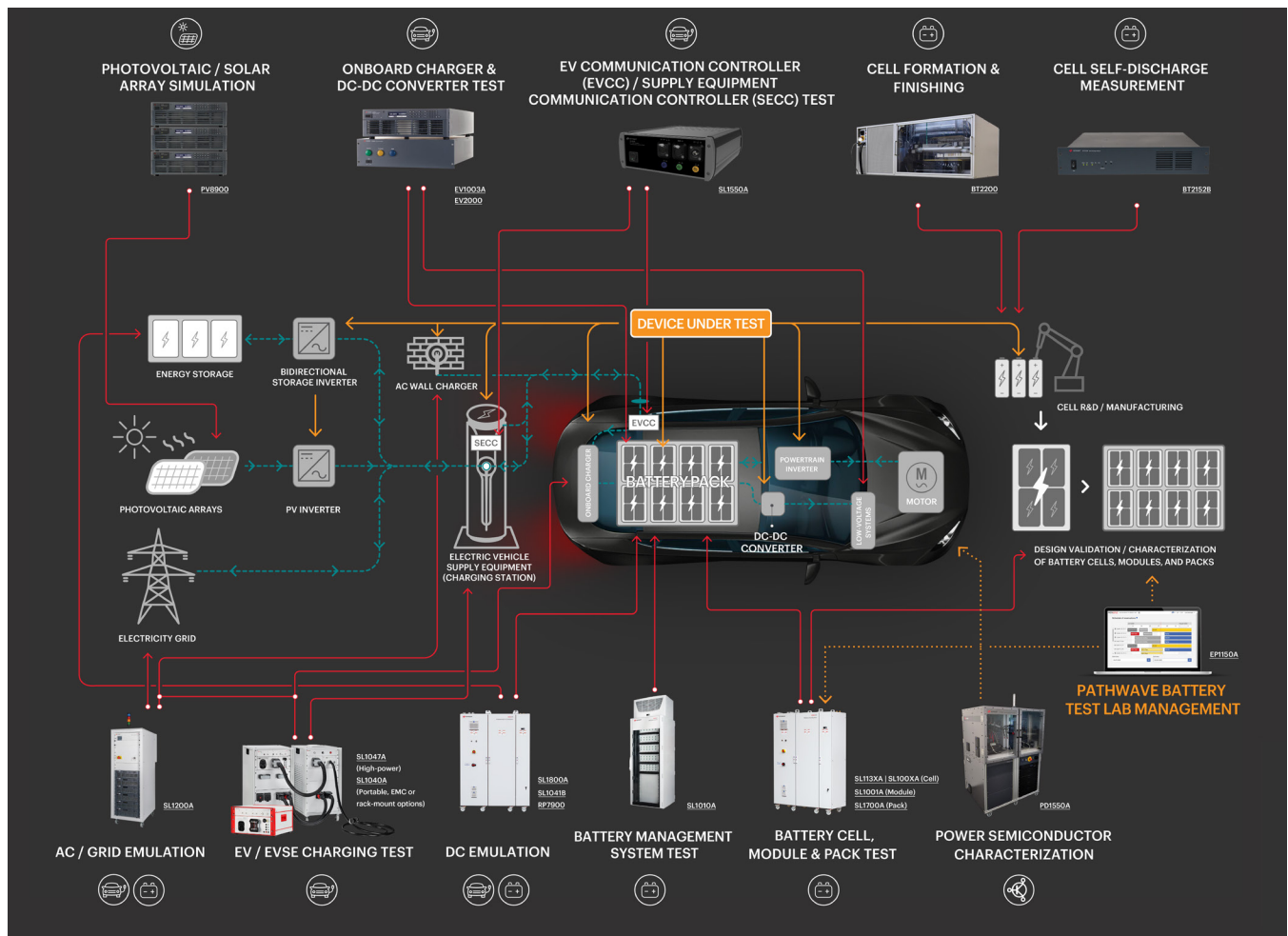


Figure 6. Advancing the E-Mobility Ecosystem

Keysight provides a comprehensive range of solutions to help address your design and test challenges so you can drive your e-mobility innovations to reality faster. For more information, visit www.keysight.com/find/e-mobility.

Agile Design and Test Software

Engineering leaders know that every step on the path to new electronic product development is crucial — from design and simulation to verification and manufacturing. Unfortunately, measurement results from one step don't seamlessly transition to the next. Test engineers spend hours correlating measurements from their design teams. Software engineers write workarounds because their hardware and software don't natively talk to each other. Most organizations use standalone products for design, test, measurement, and monitoring. This siloed structure creates disconnected and inefficient workflows and is a major cause of frustration.

Connected, agile design and test is a groundbreaking way to approach the development of electronic systems. It combines new software and workflows with powerful automation tools in a way that transforms legacy processes and yields substantial productivity and equipment utilization improvements. Integrating design and automation software throughout a product development workflow increases efficiency by accelerating routine tasks. Keysight PathWave software is a systems engineering platform that connects design and test, providing common data models and open standards to accelerate product development life cycles.



Bring Your Design Ideas to Life

PathWave Design is a collection of electronic design automation software tools that connect circuit design, EM analysis, and system simulation. PathWave Design accelerates product development by reducing the time engineers spend in the design and simulation phase.



Automate, Accelerate, and Scale Your Tests

PathWave Test is a collection of test software that connects teams and test stations. Scalable from a single user to a global enterprise, PathWave Test accelerates your test workflow, giving you the power to collaborate and manage test projects from your web browser.



Perform Analytics for Improved Decision-Making

PathWave offers powerful analytics to help you find, visualize, and understand big data to improve business knowledge. It includes visualization tools, real-time asset monitoring, and advanced algorithms that predict and anticipate anomalies to drive process improvements and increase productivity.

To learn more, go to www.keysight.com/find/pathwave

Your Partner in Automotive Design and Test Solutions

Calibration and repair services

Having the right measurement solution is only the beginning. Design engineers count on repeatable results across work groups to avoid discrepancies that can impact development cycle time, time to market, and budgets.

Manufacturing strives to meet production goals, but inaccurate measurements can affect yield and product quality. Keysight calibration and repair services keep instruments operating to warranted specifications over their lifetime, ensuring accurate, repeatable measurements across R&D and manufacturing.

Our partnership with you

Keysight offers a broad portfolio of services and support to address all your test equipment needs:

- Startup assistance and training help you quickly and effectively use your new equipment.
- Calibration and warranty assurance plans provide coverage for one, three, or five years.
- Flexible service delivery includes on-site mobile labs that reduce your calibration turnaround time from days to hours.
- Premium used equipment includes the same warranty as new units.
- Trade-in programs (available on both Keysight and non-Keysight models) offer you significant credits to upgrade to the latest Keysight technology.

Keysight's presence in key automotive design and manufacturing sites across the globe aims to provide the services and support for your success.



Keysight enables innovators to push the boundaries of engineering by quickly solving design, emulation, and test challenges to create the best product experiences. Start your innovation journey at www.keysight.com.