E-Mobility: Innovative Design & Test Solutions for the

Electric Powertrain and HEV/EV Ecosystem

KEYSIGHT TECHNOLOGIES

Keysight's Global Automotive & Energy Footprint

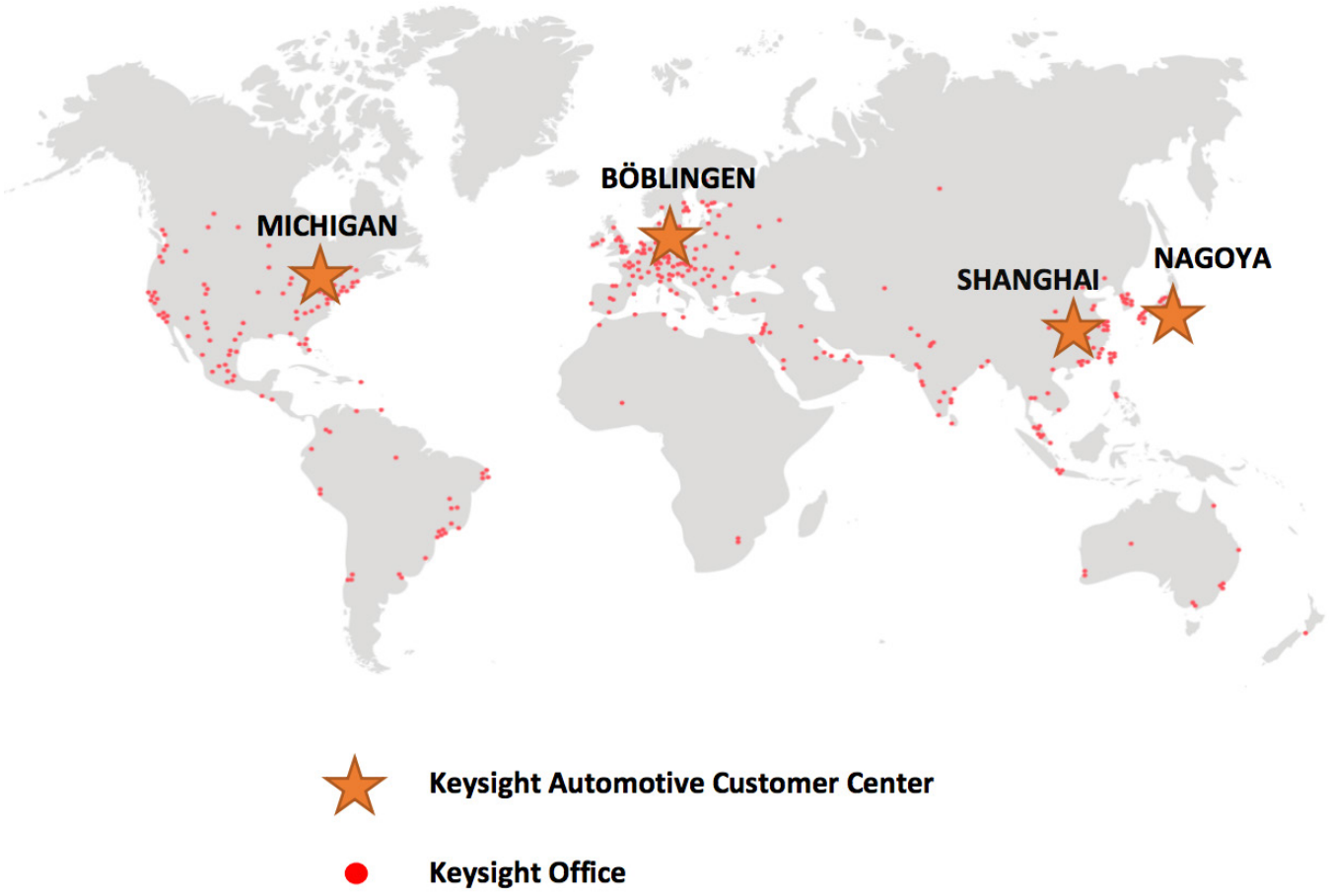
Keysight's global footprint ensures we deliver solutions where you need them.

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

These centers underscore our commitment to work with and serve 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).

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 250 million by 2030, the International Energy Agency forecasts.

That is a big leap from the IEA's 5.1 million reported for such vehicles in 2018. This growth is matched by advances in technologies for powertrains, power electronics, cells and batteries, and the charging infrastructure (Figure 1).

Manufacturers must ensure their EV fleets comply with CO_2 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 drive demand for design and test solutions that can 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.

- Policies have a major influence on the development of e-mobility
- Technology advances are delivering substantial cost reductions for batteries
- Importance of the battery technology value chain increasingly recognized

Highlights from IEA 2019 Report, Global EV Outlook 2019

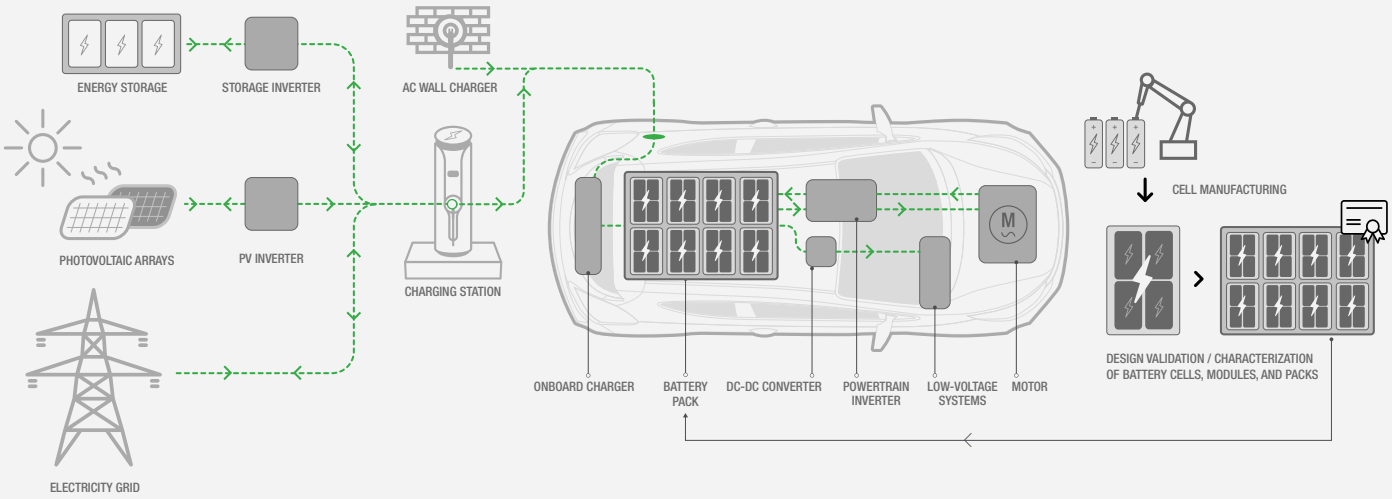
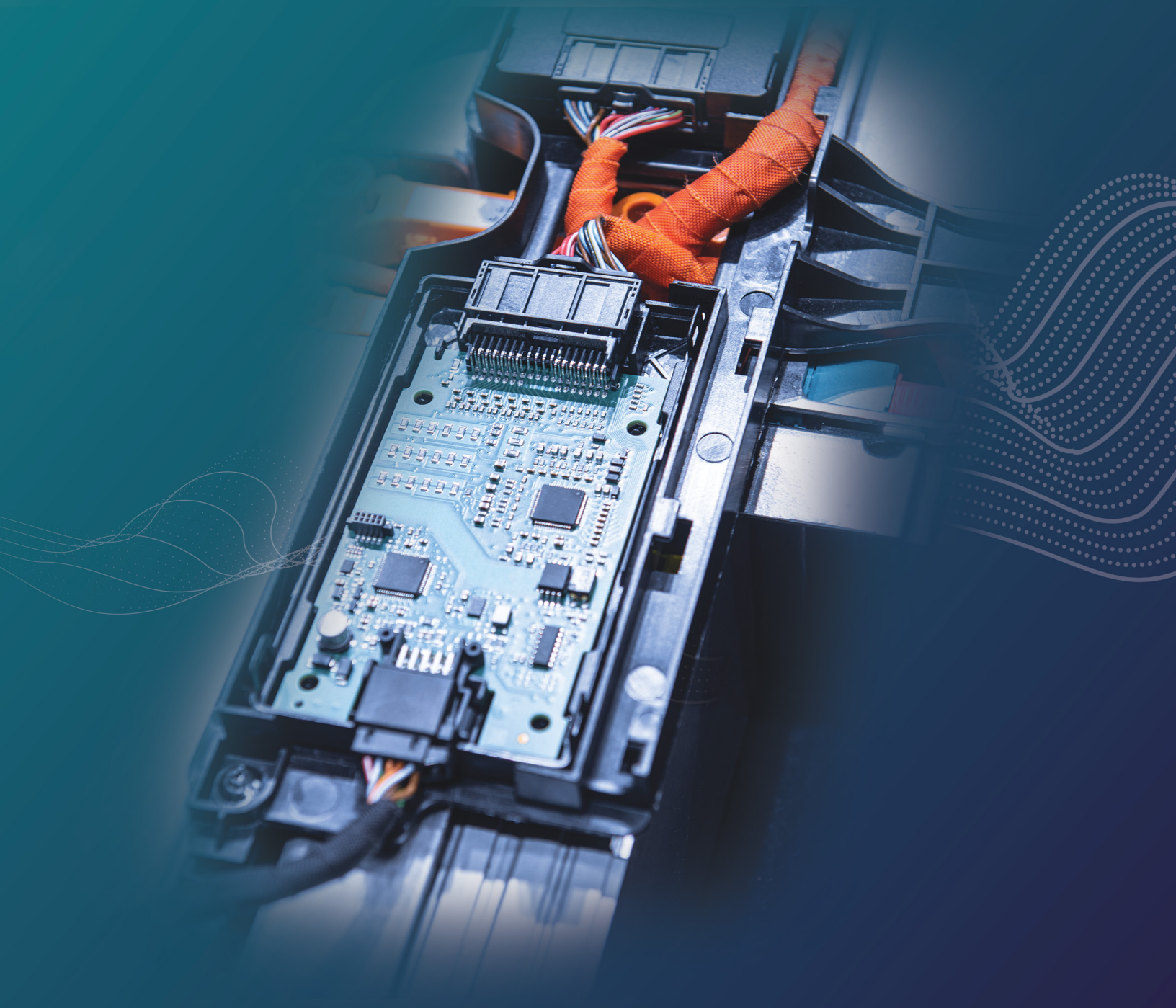


Figure 1. The e-mobility energy ecosystem

Testing in the High-Power E-Mobility Environment



Testing in the High-Power E-Mobility Environment

Bidirectional test: Testing bidirectional power flow demands equipment that can source and sink power to the converter. 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 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 converters will last under harsh operating conditions. Given the power levels used with converters, designers need to be careful when testing them. This requires special safety mechanisms in manufacturing, including redundant systems that do not expose personnel and equipment to high voltages if a failure occurs.

Maximizing efficiency: It is difficult for testers to simulate all of the operational and environmental influences on efficiency to evaluate the real-world, whole-system operation of the converter. Measuring small percentage changes in efficiency demands instruments with high dynamic range.

Test Solutions for Electric Vehicles and Power

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, as well as cell characterization and power efficiency tests for battery modules and packs, while addressing safety, time, and cost concerns.

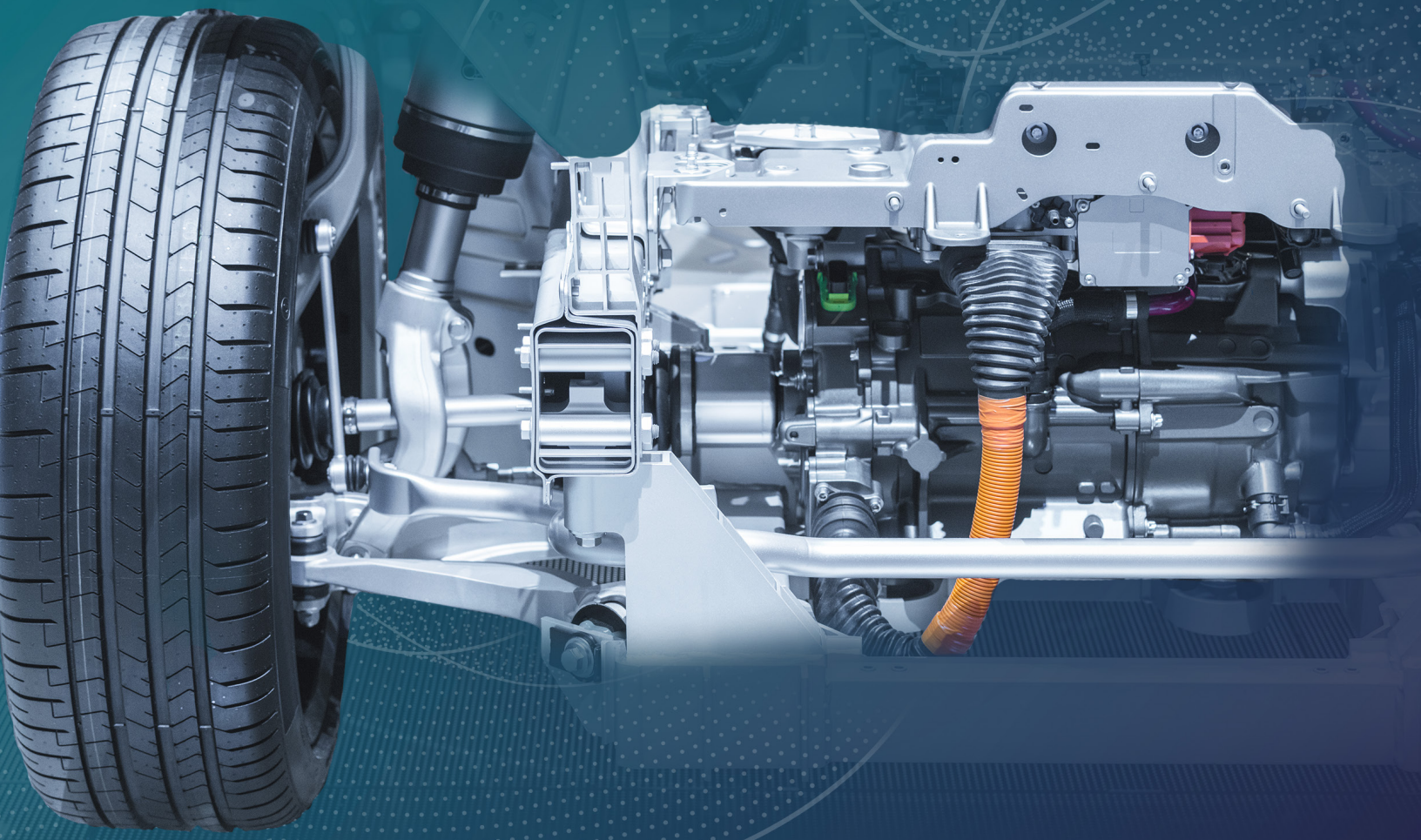
Charging technology and infrastructure testing: Test the EV and electric vehicle supply equipment (EVSE) charging interfaces in the field or laboratory, from mobile use to comprehensive applications.

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

Electric Powertrain Testing



Electric Powertrain Testing

HEVs and EVs have multiple architectural variations

For the strong (or parallel) hybrid and the pure EV (no engine), a high-voltage (HV) bus supplied by a large battery drives the electric powertrain (Figure 2).

Power levels of the inverter and motor/generator range from ~ 60 kW to more than 180 kW. Along with the large lithium-ion (Li-ion) battery, development of these architectures requires a significant investment.

Most of the components are bidirectional, allowing power to go from the battery to the inverter, which turns the motor and moves the vehicle (traction drive). When decelerating, the momentum of the vehicle turns the generator, driving power back through the inverter and charging the battery (regenerative braking). Each step of this powertrain requires thorough testing to maximize energy efficiency for the HEV/EV.

Power conversion happens at various points in the e-mobility ecosystem, starting from the AC power grid, and at these points:

- Charging station
- Onboard charger
- Powertrain converter

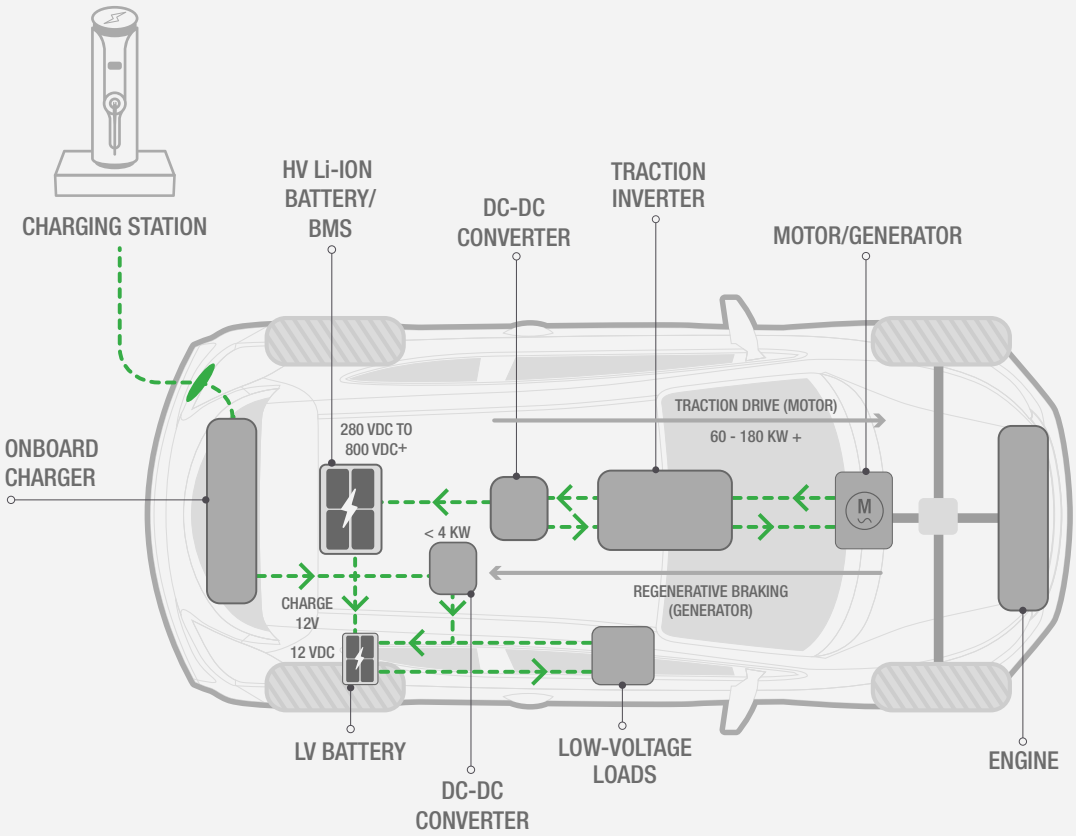


Figure 2. Simplified block diagram of a strong/full-hybrid EV

In the mild hybrid (MH), the motor/generator, inverter, and battery are also bidirectional. They are not large enough to drive the vehicle by themselves (as in the HEV or EV). Instead, they supplement the engine power during acceleration and recharge the battery during deceleration.

The voltage level for MHs is typically 48 V, keeping the bus structure under the 60 V safety rating for HEVs. That provides four times the potential power of the 12 V bus with the same current rating (Figure 3).

Each component and step of these powertrain systems requires full testing to maximize energy efficiency in the conversion process.

The design and manufacturing phases must account for cohesive functionality of each component and subsystem, as well as safety considerations.

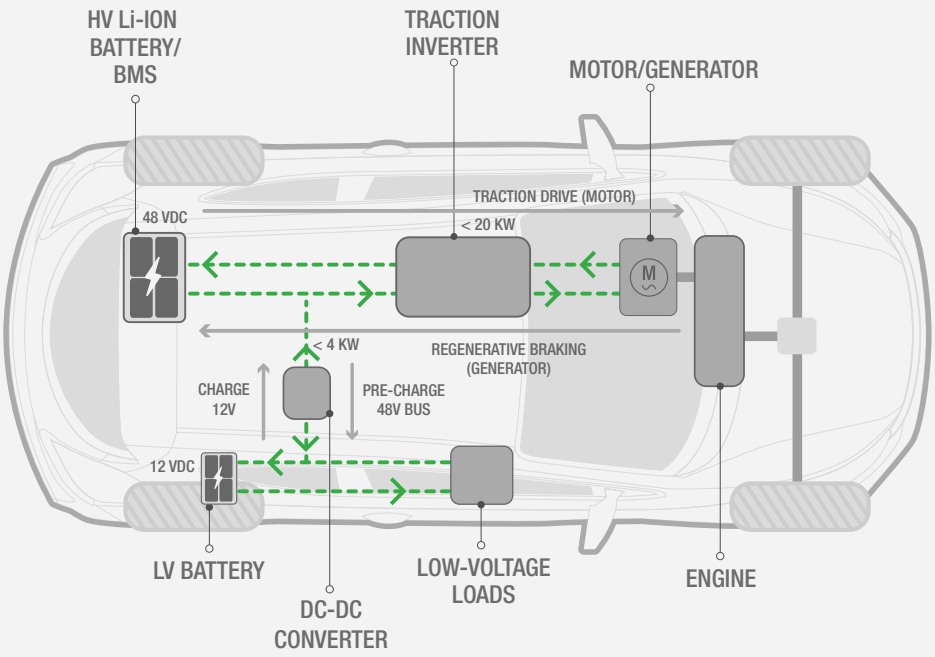


Figure 3. Block diagram of a mild hybrid EV

Inverter test

Inverters are essential components for numerous applications because they convert electrical voltage bidirectionally. Traction inverters convert DC voltage from a battery to AC voltage for an electric machine. This functionality makes inverters an important component in electromobility, as well as numerous industrial applications. Quality, durability, and safety requirements are demanding in the automotive sector. All components are subject to stringent testing throughout development and production. The earlier tests can be performed during the development phase, the more efficient the next steps are. Comprehensive test scenarios and independent component testing can reduce development expenses and speed innovation (Figure 4).

To emulate the inverter environment, replace the battery with a Scienlab Dynamic DC Emulator from Keysight. Replace the electric machine with a Scienlab Machine Emulator.

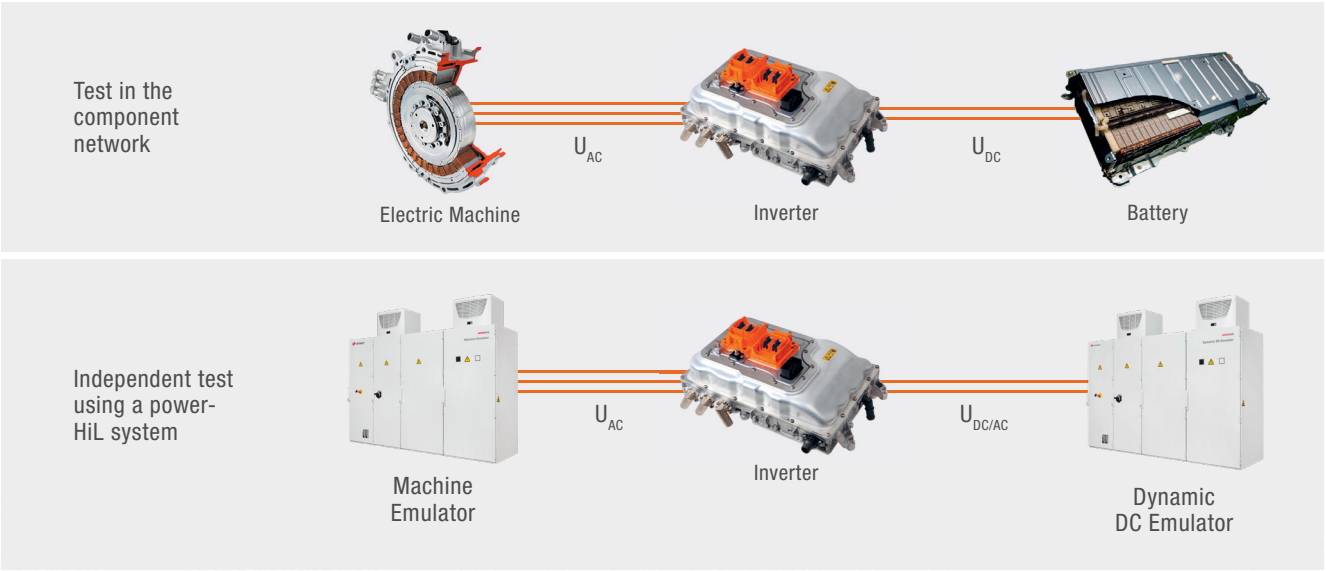


Figure 4. Real and emulated inverter environment

Scienlab Machine Emulator

For thorough testing of inverters, it is necessary to extensively emulate the electric machine. The Scienlab Machine Emulator from Keysight provides the facility for stressing the inverter using predefined load cycles in conjunction with the Scienlab Dynamic DC Emulator. Refer to “Supporting E-Mobility Test Technologies” for details about the Dynamic DC Emulator.

A variety of machines (e.g., PMSM, ASM, and induction machines) can be realistically emulated. That is possible in both motor and generator mode (four-quadrant mode). The emulation of the electric machine also encompasses all necessary sensors.

In addition, the open interface architecture enables easy connection of the Machine Emulator to an existing automation unit. The Machine Emulator is available for high-voltage, as well as 48 V applications.

Comprehensive test scenarios and independent component testing using the Scienlab Machine Emulator enables EV development cost to be reduced and innovations to be achieved faster.

Battery cell, module, and pack test

E-mobility has escalated the need for better cells and batteries with a common goal — improved performance, range, and cost. These devices must be high quality and meet the demands for power, energy density, safety, and durability. Marketplace survival requires cost optimization. For these reasons, comprehensive tests must be carried out to ensure successful design and production (Figure 5).

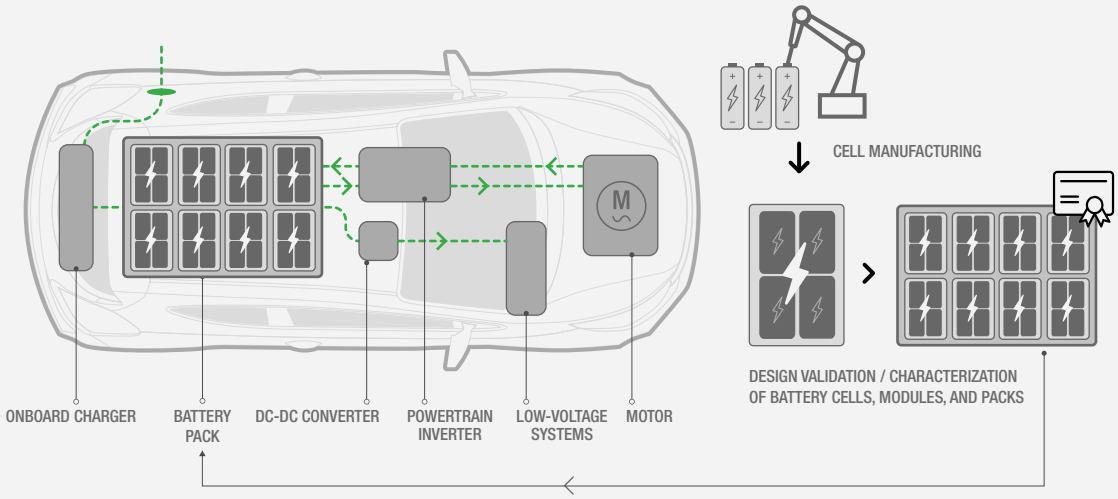


Figure 5. EV power is determined by how battery cells, modules, and packs work together to provide better power and range

Cell self-discharge analysis

32-channel BT2152B Self-Discharge Analyzer

The Keysight BT2152B Self-Discharge Analyzer directly measures self-discharge current on large numbers of Li-ion cells. Using a potentiostatic measurement technique, it reduces the time required to discern good versus bad cell self-discharge performance from days or weeks to minutes or hours. For cell manufacturers, this 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 6). The BT2152B, along with the complementary BT2155A software, enables the following key features:

- Up to 32 channels of self-discharge current measurement available in four-channel increments
- Current measurement accuracy: ± (0.30% + 250 nA)
- Voltage measurement accuracy: ± (0.04% + 0.1 mV)

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

Figure 6. Keysight's potentiostatic measurement technique cuts time needed to discern good versus bad cell self-discharge performance

Cell charge-discharge platform

Keysight BT2200 Charge-Discharge Platform

The Keysight BT2200 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:

- 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 BT2200 helps manufacturers respond quickly to requirements for different cell types at a low cost.

Cell sample, cell, module, and pack testing

Scienlab test systems from Keysight comprehensively and reliably test battery cells, modules, and packs, including battery management systems (BMS) for e-mobility, mobile, industrial, and stationary use. Keysight's test systems with the best-in-class Scienlab Energy Storage Discover (ESD) software help you run customized performance, function, aging, and environmental tests, as well as standards compliance and conformance tests (e.g., ISO, DIN EN, and SAE).

Testing Cell Samples SL1004A & SL1005A	Testing Battery Cells SL1002A, SL1003A, SL1007A, SL1132A & SL1133A	Testing Battery Modules SL1001A & SL1006A	Testing Battery Packs SL1000A
			
• Voltage range: -2 to 8 V • Output current: up to ±5 A • Measuring ranges: ±150 µA, ±5, mA, ±150 mA, ±5 A, automatic range switchover • Up to 96 channels • Manual parallel connection: 2 channels to increase the current to maximum 10 A • Control modes: current, voltage, and power • Optional electrochemical impedance spectroscopy	• Output voltage: 0 to 6 V • Output current: ±25 A to ±600 A (parallel channel connections enable even greater current and power) • Up to 150 channels • Current dynamics: -90% to +90%: 0.8 - 3.0 ms typ. • Voltage measuring accuracy: ±1 mV typ. 500 µV • Current measuring accuracy: ± 0.05% of measured value • Up to 3 temperature sensors per channel • Optional electrochemical impedance spectroscopy	• Output voltage: 20 to 300 V • Output current: ±100 A, ±300 A, ±600 A, ±750 A • Current dynamics: -90% - 90%: 0.8 ms typ. • Voltage measuring accuracy: ±16 mV ±0.05% of measured value • Current measuring accuracy: ±20/40/60/ 120 mA ±0.05% of measured value	• Output power: up to ±360 kW • Voltage range: 50 to 1,000 V (optional 0 to 1,000 V for systems up to 180 kW) • Current ranges: ±300 A, ±600 A, ±900A (±2400 A when switched in parallel) • Current dynamics: -90% - 90%: typ. 1.6 ms • Voltage measuring accuracy: ±200 mV ±0.05% of measured value • Current measuring accuracy: up to ±60/120/180 mA ±0.05% of measured value

Software to Control Cell, Module, and Pack Test Systems

Keysight provides test system software that starts with Energy Storage Discover to control your individual test systems, and extends to PathWave Lab Operations for Battery Test to manage and coordinate your entire battery testing laboratory with multiple systems used to test cells, modules, and battery packs.

SL1091A Scienlab Energy Storage Discover (ESD)

Scienlab Energy Storage Discover (ESD) is the intuitive test-software environment for developing, performing, and analyzing tests for an individual test system.

- Central controlling component for all Scienlab-brand energy storage test environments.
- Powerful visualization of tests and results. Comprehensive overview, user-friendly operation.
- ESD offline versions support creating test programs.
- Available simulation environment for offline test.
- Ethernet communication with the battery test system.
- Easy integration with external control and monitoring software via optional standardized remote-interface.
- Vehicle emulation from the perspective of battery cell, module and pack levels.
- Integration of external components into the test environment & process, such as environmental chambers, cooling and heating equipment.

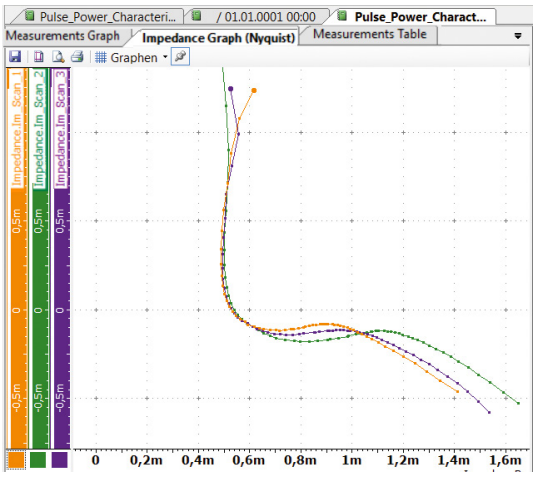
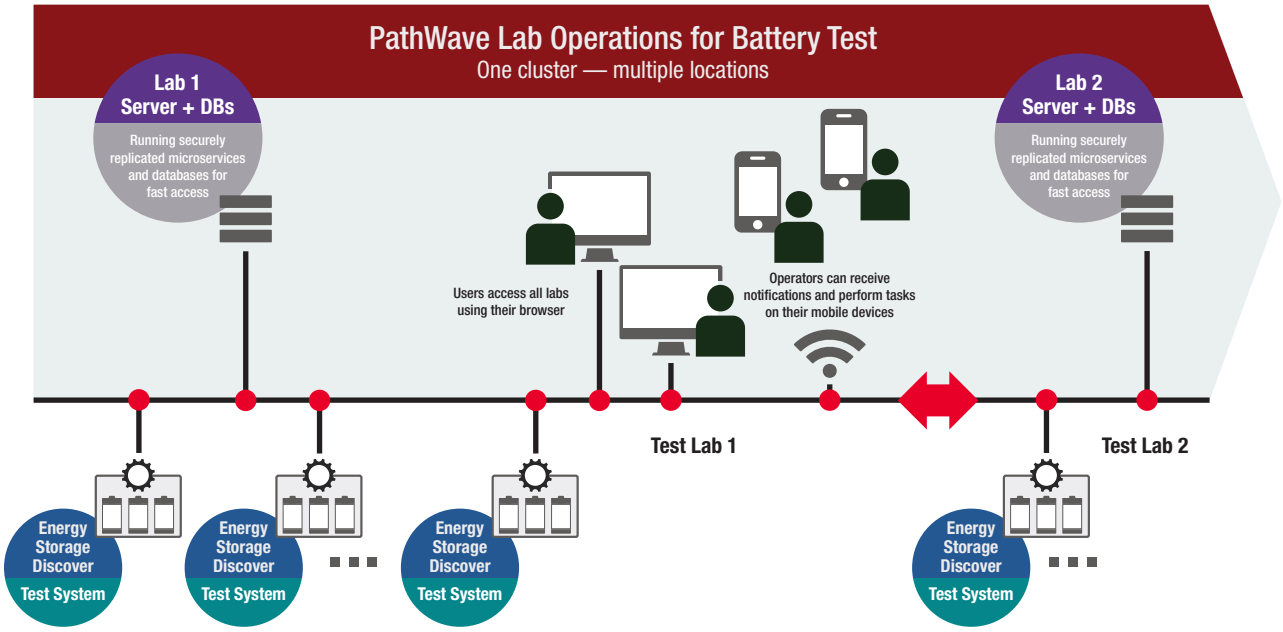


Figure 7: Impedance graph visualized in ESD software

EP1150A 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 DUTs. It provides an integrated, web-based lab management platform that helps you modernize test workflows, eliminating legacy paper-based processes, and increasing data integrity and traceability.



This powerful set of tools helps you to improve test throughput for the cells and batteries you need to test, to fulfill the testing requirements for your projects on-schedule, and to optimize test asset utilization.

- 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.
- Share and control test plans, results, data, and other documents. Collaboration and discussion among lab staff become easy and productive.
- Remotely control your lab and its devices anywhere, anytime.
- Manage and route notifications to your preferred device or email service.
- Automated, networked, and scalable for any size of testing lab – up to thousands of channels.

Battery management system and testing

The introduction of storage technologies and the interconnection of multiple energy storage cells to form modules or packs requires an intelligent BMS.

A BMS assumes important safety, control, and regulation functions. Those functions include monitoring parameters such as voltage, current, temperature, and state of charge. A BMS is also responsible for thermal management, energy management, cell balancing, and performance.

SL101xA Series Scienlab BMS Environment

The Scienlab battery management system (BMS) Environment from Keysight provides all the above-mentioned capabilities and more. The system comes with a hardware-in-the-loop test environment for reproducible testing and BMS optimization. Instead of the cells, Scienlab Cell Emulators connect to emulate various cell types for a range of cell models:

- Voltage: 0 to 8 V
- Current (parallel operation): ±5 A (±10 A)
- Power (parallel operation): ±40 W (±80 W)
- Measuring range: up to ±2 µA ± 0.05% of measured value
- Voltage measuring accuracy: <1 mV

The Scienlab BMS Environment also emulates the following:

- Cell temperature through emulation of typical resistance temperature detector (RTD) sensors such as PT-100, PT-500, PT-1000, Ni, and KTY
- Battery current sensors (up to ±1,000 A at a 100 µOhm shunt)
- Individually defined errors such as insulation faults at the battery voltage, line breaks, short-circuits, and reverse polarity

Charging Technology Tests

Charging Technology and Infrastructure Test

One of the crucial factors for the breakthrough of electromobility is making it possible for all drivers to charge their EVs/HEVs conveniently and safely. This 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 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.

SL1040A Scienlab Charging Discovery System

For comprehensive testing of all EV and EVSE charging interfaces, Keysight offers an all-in-one test solution. Keysight's SL1040A Scienlab Charging Discovery System (CDS) Series is a breakthrough solution for holistic test of all AC and DC charging interfaces of EVs and EVSEs. Thanks to its modular and innovative design, the CDS can be configured to customers' specific needs, and replace multiple real EVs/EVSEs with one test solution to ensure an optimal price-performance ratio.

Highlights of the SL1040A CDS:

- Automated functional, conformance, interoperability and quality testing for R&D, end-of-line (EOL) 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.
- CE, UL and KC-Mark conformance, certified by CSA Group.
- Extensive test case library for automated conformance testing of CCS, CHAdeMO and GB/T standards.

SL1047A Scienlab Charging Discovery System – High-Power Series

The SL1047A Scienlab Charging Discovery System (CDS) – High-power series from Keysight 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, which 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 the CDS, customers can perform all necessary conformance and interoperability tests according to worldwide charging standards. The new solution, which features the separate Scienlab Cooling Unit with interchangeable liquid-cooled charging adapters, also enables a high-power upgrade of the SL1040A Scienlab Charging Discovery System – Portable Series.

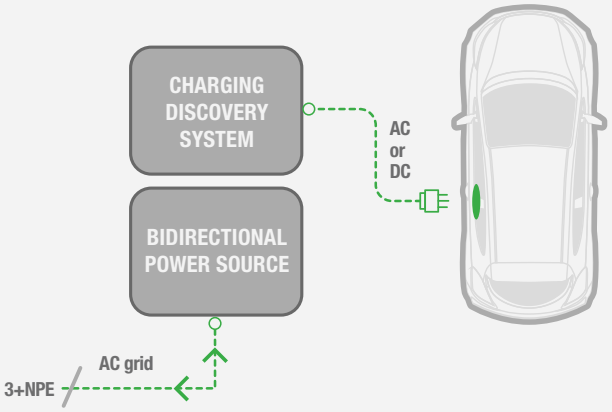
Highlights of the SL1047A CDS – High-Power Series:

- Automated functional, conformance, interoperability and quality testing for R&D and end-of-line (EOL) 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.
- CE, UL, and KC-Mark conformance.
- Extensive test case library for automated conformance testing of CCS, CHAdeMO, and GB/T standard.

Use case 1: EV test

In this use case, the CDS serves as a universal but configurable charging infrastructure (e.g., DC charging column or AC wall box).

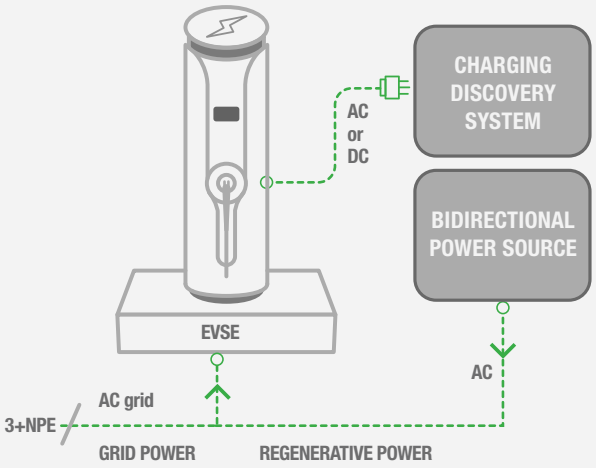
Use it for functional testing of the charging interface of any electric vehicle, as well as for safety, interoperability, conformance, and durability testing.



Use case 2: EVSE test

Here, the CDS is a universal but configurable charging interface emulator replacing a real electric vehicle.

This allows for functional, safety, interoperability, conformance, and durability testing of any EVSE product.



Use case 3: Man-in-the-middle test

In this third use case, the CDS sits between two real devices to capture all electrical signals and digital communication between an EVSE and EV.

This allows the user to identify and trace potential interoperability issues.

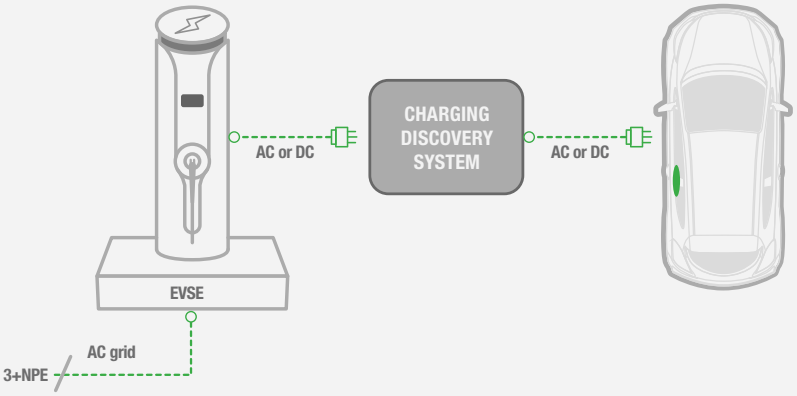


Figure 8: Different CDS uses cases

Supporting E-Mobility Test Technologies

Supporting E-Mobility Test Technologies

SL1200A Series Scienlab Regenerative 3-Phase AC Emulator

The SL1200A series is designed to handle all your 3-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 test, as well as EV and EVSE charging test applications. The 1,200 VAC models allow for (HVRT) testing at the IEC LV-AC limit without the need for a large, complex test setup.

Key features of the SL1200A Series:

- High-Power 3-phase AC and DC power source; up to 1,200 VL-L; up to 130 A; up to 630 kVA.
- 1,200 VL-L is achieved 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.
- 100% regenerative (bidirectional) power solution with > 85% efficiency.
- Get up and running immediately with intuitive soft front panel.
- A complete, one-vendor solution of hardware, software, consulting, and support services worldwide for all grid-edge applications, such as EVSE / EV charging test, solar / PV inverter test, battery energy storage system test (see page 4 for details).

SL104XA Series Scienlab Dynamic DC Emulator

The Scienlab Dynamic DC Emulator from Keysight boasts bidirectionality, integrated DC voltage and current controllers, high dynamics, and regenerative energy feedback capacity. It serves as an all-in-one system for the efficient and effective testing of power electronic components in EVs and EVSEs. The Dynamic DC Emulator is available for high-voltage and 48 V applications.

Some application examples include:

- Testing of power electronic components and systems for maximum failure safety, energy efficiency, and quality (e.g., traction inverters).
- Emulation of batteries using an integrated battery model.
- Bidirectional mode testing – enabling EVs to be emulated as a sink or charging infrastructure as a source – to investigate the interoperability of both EVs and EVSEs in combination with the Scienlab Charging Discovery System.
- Validation of DC charging processes.

SL106xA Series Scienlab Measurement and Control Modules

Scienlab measurement and control modules from Keysight 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 (e.g., in a climate chamber).

Capabilities include:

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

PD1500A Dynamic power device analyzer / double pulse tester

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

Keysight's PD1500A dynamic power device analyzer / double pulse tester delivers repeatable, reliable measurements of wide-bandgap (WBG) 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.
- Safe test environment for both the device under test and the user.

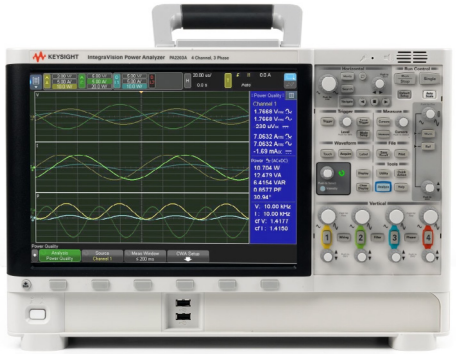
EV1003A power conversion testing for HEV/EV

HEV and full EV batteries are 300 V and higher, versus the conventional 12 V platform used in many vehicles. 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 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 EV1003A Power Converter Test Solution to help you overcome these challenges. The solution comprises three key components:

PA2203 Series IntegraVision Power Analyzer

The IntegraVision Power Analyzer makes EV testing for AC and DC power measurements simple. 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.

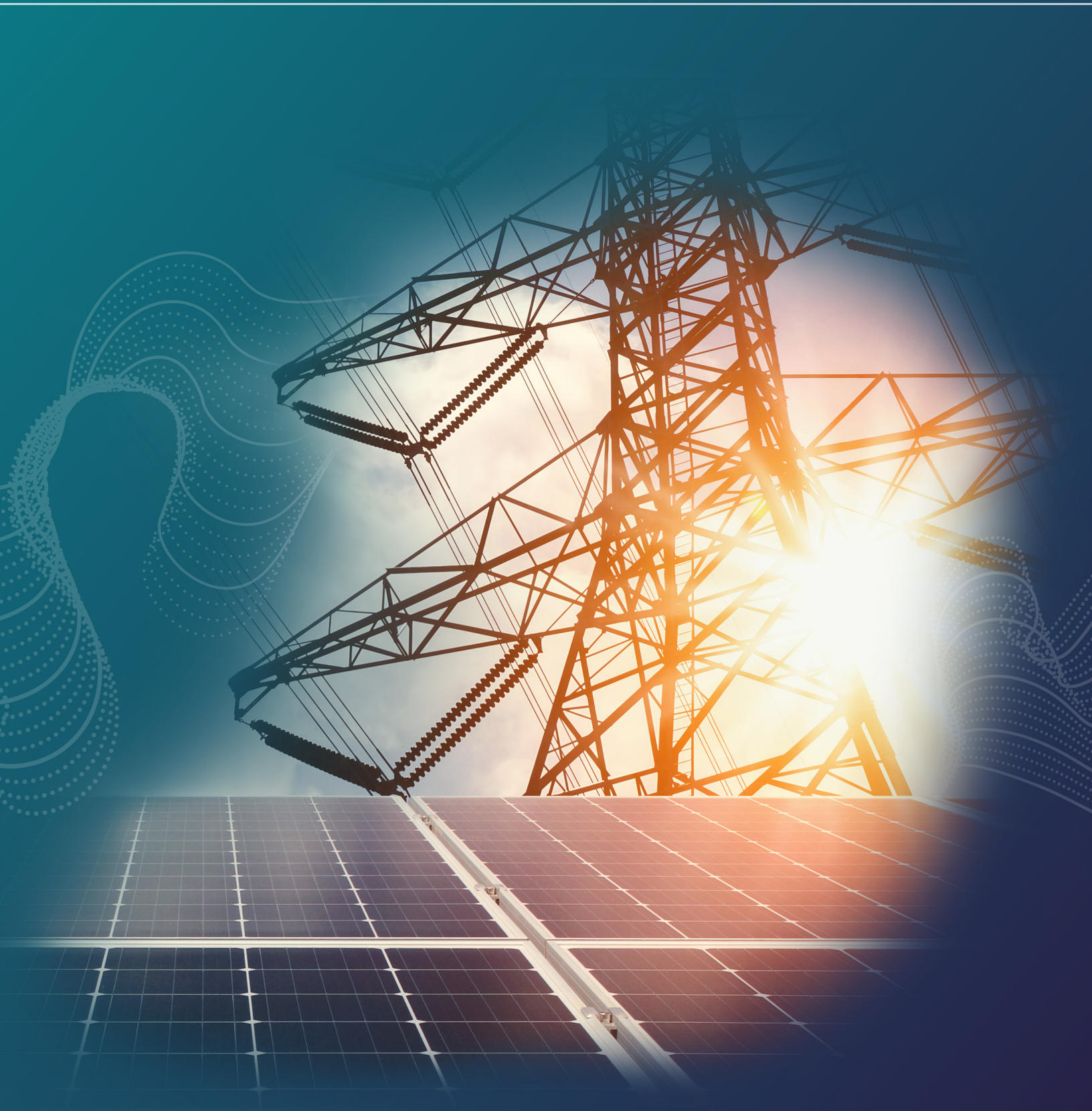
RP7900 Series Regenerative Power System

The RP7900 Series 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.

SD1000A Safety Disconnect System

The SD1000A Safety Disconnect Solution works exclusively with the RP7900 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 RP7900 can generate faults, or the user can generate them manually. The system complies with key global EMC and safety regulations.

Energy Ecosystem

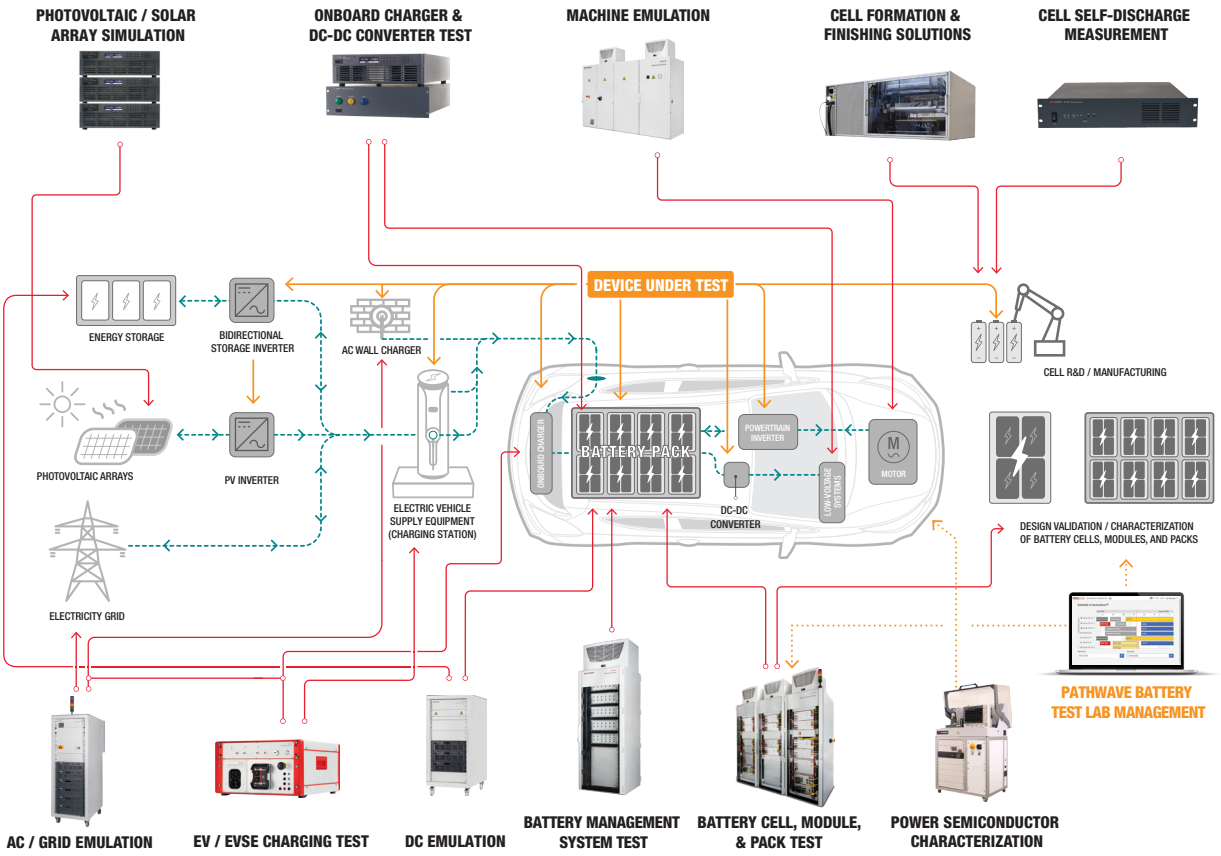


Energy Ecosystem

PV and smart grid technologies

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.

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.



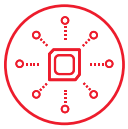
Keysight provides a comprehensive range of solutions to help address your design and test challenges, so you can drive your e-mobility innovations to reality faster. For more information, visit www.keysight.com/find/e-mobility

Agile Design and Test Software

Agile Design and Test Software

Engineering leaders know that every step in 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 ground-breaking way to approach the development of electronic systems. It combines new software, new workflows, and 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 lifecycles.



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

PATHWAVE

Your Partner in Automotive Design and Test Solutions

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.

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

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 five, seven, or 10 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 high performance and three-year standard 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 TECHNOLOGIES