Automotive Power Testing Solutions



KEYSIGHT TECHNOLOGIES

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Predict and analyze power consumption in your automotive applications

Automotive electronics operate in one of the harshest environments, countering constant mechanical vibration, noise, and wide temperature ranges, from subzero to > 1,600 ºF, or 800 ºC, temperatures.

What's more challenging is the electrical environment. Carmakers are adding high-speed and high-power electronics to enable advanced driver-assistance systems, infotainment, connectivity for vehicle-to-everything (V2X) applications, and, of course, longer-range EVs.

All this puts pressure on the automotive electronics designer, who must consider all requirements, including load dump, cold crank, reverse battery polarity, double battery jump, spikes, and other transients defined in LV 124, ISO 7637-2, ISO 16750-2, and TL 82066:

- input transients
- electromagnetic interference
- low quiescent current
- input voltage range
- output voltage / current

This brochure looks at the design and test challenges for automotive electronics that support the modern vehicle, and solutions that can ensure safer and better performance.

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Validating Power at the Device Level

The term *automotive power device* describes diodes, insulated-gate bipolar transistors (IGBTs), MOSFETs, and the newer silicon carbide (SiC) and gallium nitride (GaN) devices. These devices control and convert electric power for various automotive applications, such as body electronics, infotainment and telematics, safety and security, chassis, and, increasingly, powertrains in electric vehicles (EVs).

Using devices with low conduction loss and low switching loss is essential to create fuel- and energy-efficient systems. The higher converter / inverter operating frequencies that GaN and SiC devices offer allow the surrounding capacitors and inductors to be smaller. The use of smaller parts reduces weight and increases energy efficiency for the vehicle.

The challenge lies in validating the energy efficiency of this device circuitry. Keysight offers power device test solutions for automotive components in various applications.



CX3300A device current waveform analyzer and anomalous waveform analytics

Critical EV functions use numerous microcontroller units (MCUs) and field-programmable gate array (FPGA) units. Any malfunction could lead to potential fatalities and detrimental business impacts, such as mass product recalls.

The Keysight CX3300A device current waveform analyzer and anomalous waveform analytics software (Figure 1) rapidly detect and analyze anomalous signals in these MCUs and FPGAs, enabling fast rectification of hardware, firmware, and software defects.

The CX3300A includes the following features:

- rare anomalous signal capture, measuring the subtle differences between normal and anomalous signals with high precision
- long-duration measurement up to 100 hours with 10 MSa/s sampling rate
- wide bandwidth up to 200 MHz
- high-resolution at 14 bits / 16 bits
- low noise with high sensitivity from sub-nA and sub-uV



CX3300A device current waveform analyzer

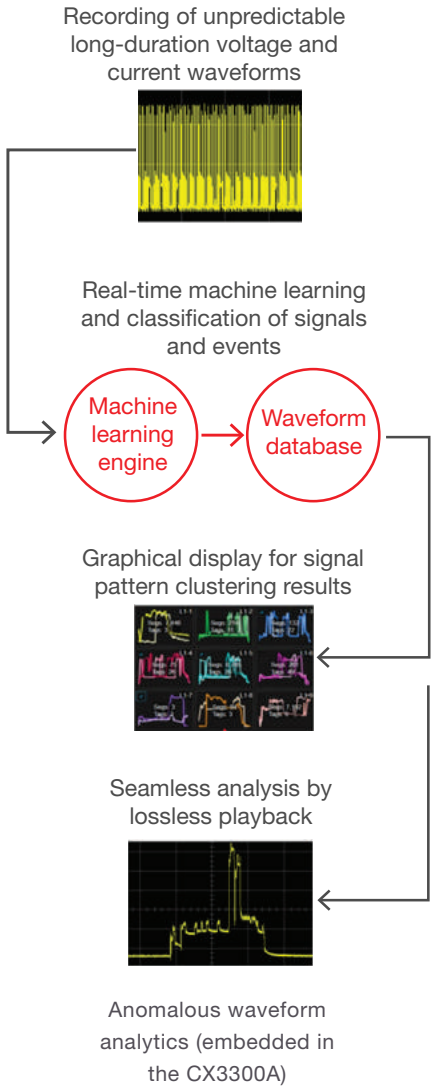


Figure 1. Keysight CX3300A device current waveform analyzer and anomalous waveform analytics

B1505A power device analyzer / curve tracer

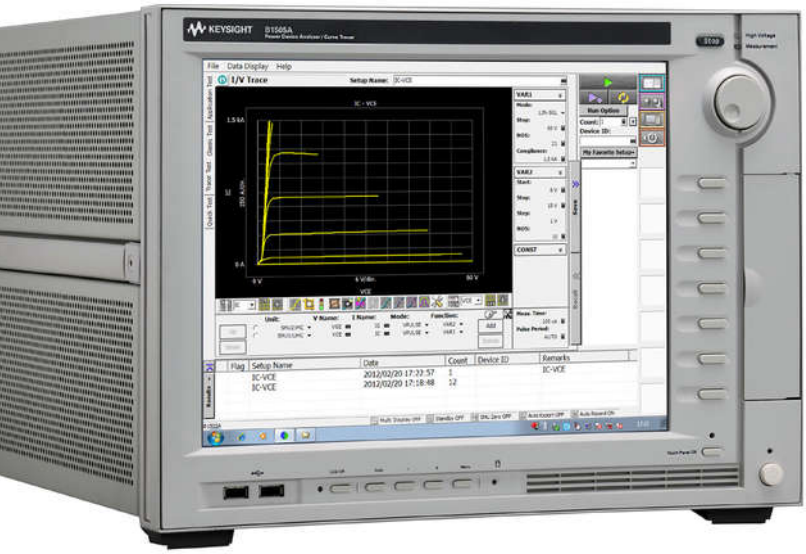


Figure 2. Keysight B1505A power device analyzer / curve tracer

The Keysight B1505A is a single-box solution that can characterize high-power devices from the sub-picoamp level up to 10 kV and 1,500 A. The B1505A does the following:

- evaluates novel devices such as IGBT and materials such as GaN and SiC
- supports a variety of source and measurement units (SMUs), including high-voltage and high-current SMUs and ultra-high-current and -voltage modules

B1506A power device analyzer for circuit design

The Keysight B1506A is a complete solution that tests the efficiency, safety, and reliability of automotive electrical systems. It covers a wide range of currents and voltages, from sub-nA to 1,500 A and microvolts to 3 kV. This range supports the evaluation of most automotive electronic components and devices. The B1506A offers the following features:

- automatic IV / CV test
- automatic thermal test
- CV (Ciss, Crss, Coss, Cgs, Cds, Cgd) up to 3 kV
- power loss calculation

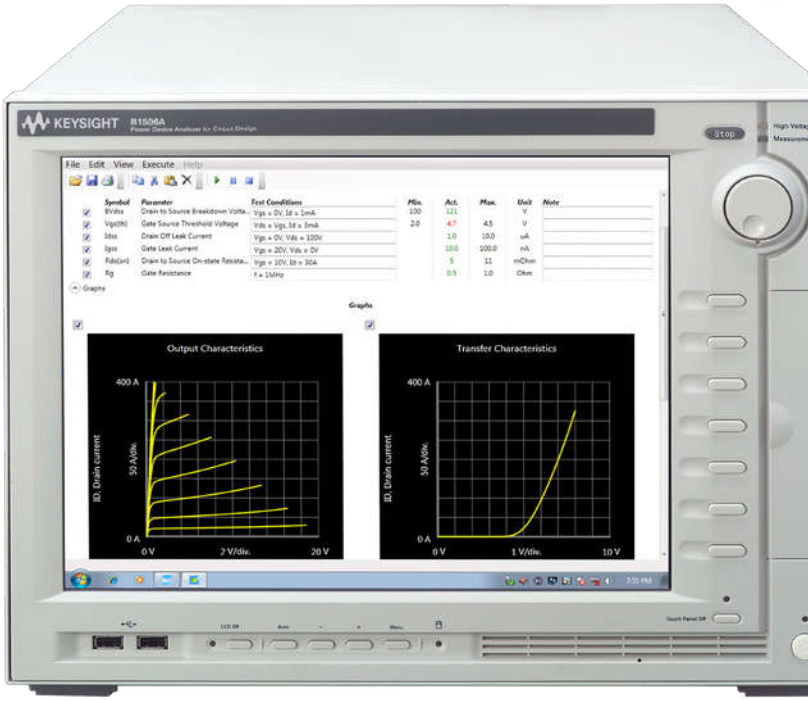


Figure 3. Keysight B1506A power device analyzer

E4990A impedance analyzer



The Keysight E4990A has a frequency range of 20 Hz to 120 MHz and provides an industry-best 0.045% (typical) basic accuracy over a wide impedance range, with a 40 V built-in DC bias source. It does the following:

- reduces overall cost of test for accurate evaluation of resonators or inductors or for incoming inspection requiring measurements of many points per device or many DUTs
- characterizes and evaluates electronic components, semiconductor devices, and materials during R&D, quality assurance, and inspection

Figure 4. Keysight E4990A impedance analyzer

E4991B impedance analyzer

The Keysight E4991B has a frequency range of 1 MHz to 3 GHz and provides 0.65% basic accuracy over a wide impedance range with a 40 V built-in DC bias source. It offers the following functions:

- The equivalent circuit analysis function supports seven multiparameter models and helps you simulate equivalent parameter values of components.
- It supports a variety of test accessories for material measurement, accurate on-wafer or microcomponent impedance measurement, and others.



Figure 5. Keysight E4991B impedance analyzer

Keysight oscilloscopes and pulse generators

Switching characteristics are an important part of component-level testing, and Keysight has oscilloscopes and pulse generators that can help evaluate these parameters (see Figure 6). Keysight's InfiniiVision 4000-X Series oscilloscopes provide sufficient bandwidth and resolution at a reasonable cost, and you can use them with a current probe if necessary. The Keysight 81150A pulse generator provides voltage pulses fast and large enough to characterize automotive components.



Figure 6. Evaluating switching characteristics with an oscilloscope and a pulse generator

Sensor characterization solutions

You can quickly characterize DC microelectromechanical system (MEMS) performance using Keysight B1500A and B2900A SMUs. SMUs are convenient tools to characterize the IV performance of automotive sensors. For example, both the B1500A and the B2900A Series have SMUs that can perform DC current and voltage characterization on MEMS devices (such as accelerometers; see Figure 7).



Figure 7. From left, Keysight's B2900A SMU, B1500A semiconductor device analyzer, and MEMS accelerometer output voltage measurement

MEMS evaluation using the E4980A LCR meter

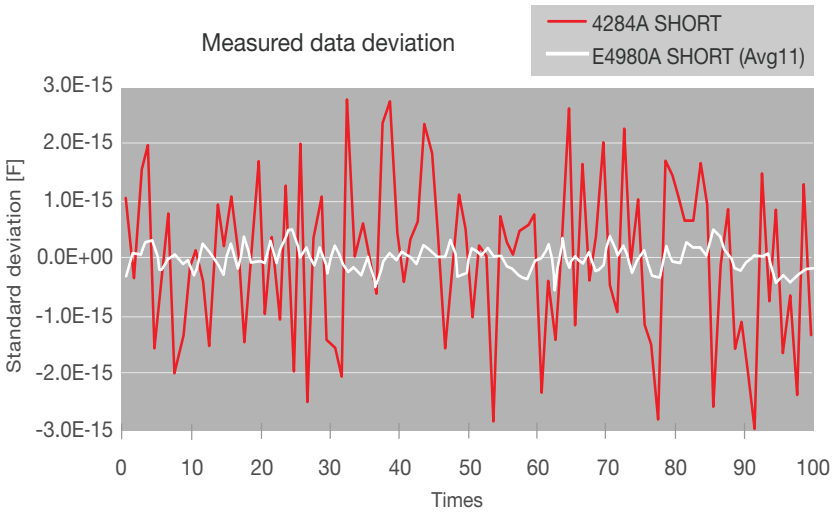




Figure 8. The Keysight E4980A LCR meter measures capacitance with sub-femtofarad resolution

MEMS capacitive sensors (such as pressure sensors or accelerometers) detect mechanical displacement through capacitance change. Functionality tests of these devices usually use electrostatic force (rather than physical stimulus), as it results in greater test efficiency. However, since the capacitive change in the actuator is tiny, test equipment with the ability to measure capacitance with sub-femtofarad resolution is necessary.

The E4980A inductance (L), capacitance (C), and resistance (R) meter is an ideal tool for this, as it measures capacitance with attofarad repeatability (σ < 1 fF) (see Figure 8).

Tackling Transients in ECUs

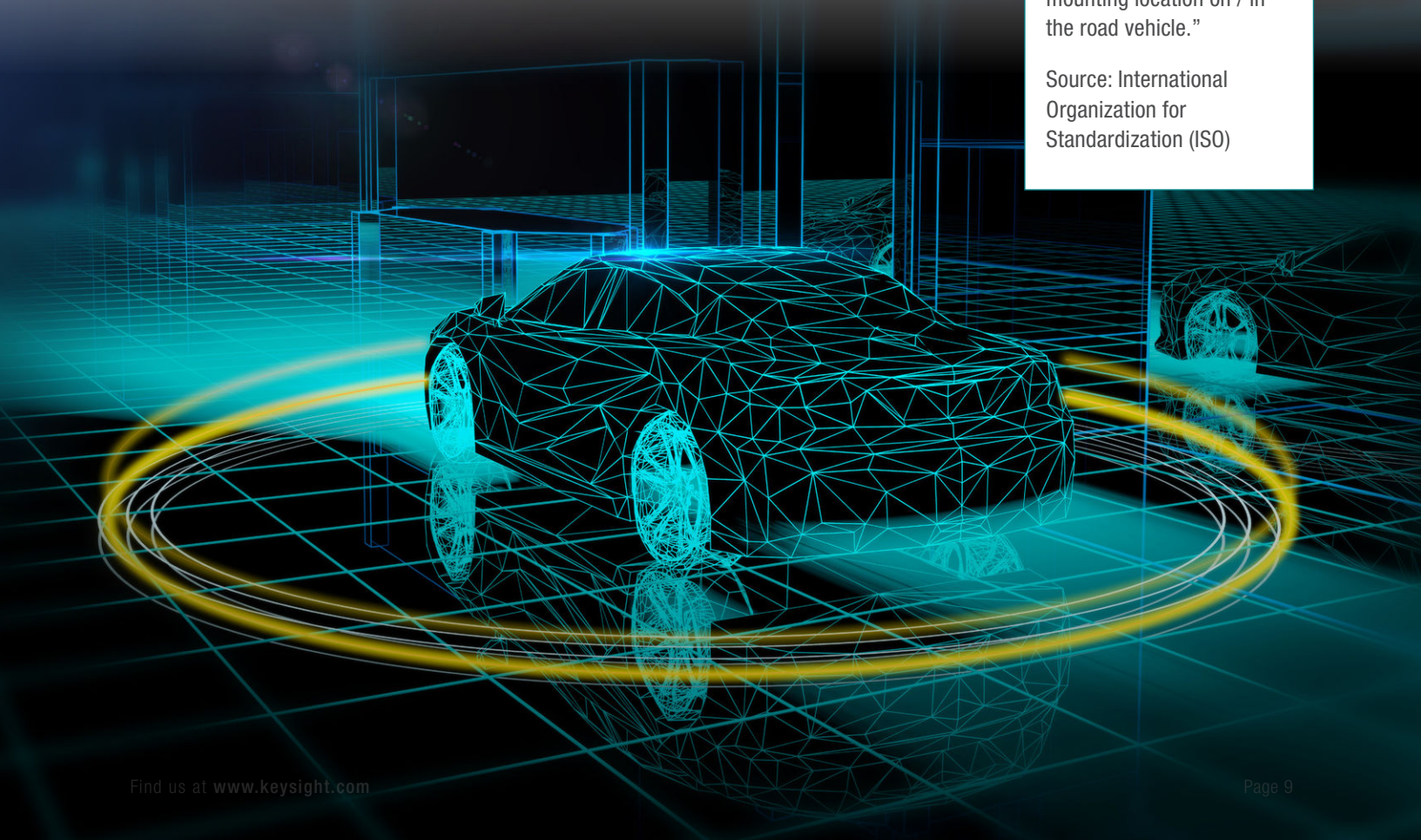
Electronic control units (ECUs) for automotive applications need to be immune to the harsh power systems in which they operate. Power system surges and dropouts are common, so the ECU designer needs tools that can replicate and analyze the power transients seen in automotive applications.

The designer also needs powerful tools that can replicate waveforms at different power, voltage, and current ratings to analyze and debug designs and ensure that the devices under test (DUTs) conform to ISO 7637-2 and ISO 16750-2 test specifications.

ISO 7637-2 “specifies test methods and procedures to ensure the compatibility to conducted electrical transients of equipment installed on passenger cars and commercial vehicles fitted with 12 V or 24 V electrical systems. It describes bench tests for both the injection and measurement of transients.”

ISO 16750-2 “applies to electric and electronic systems / components for road vehicles. It describes the potential environmental stresses and specifies tests and requirements recommended for the specific mounting location on / in the road vehicle.”

Source: International Organization for Standardization (ISO)



N3300 Series electronic load

Testing multiple-output DC power supplies and DC-DC converters can be time-consuming if you must test each output sequentially. Sequential testing happens when making measurements through a MUX using one digital multimeter (DMM).

Using the built-in measurement capabilities of the Keysight N3300A electronic load (Figure 9), you can measure all outputs simultaneously. Alternatively, you can test multiple single-output power sources simultaneously. It also does the following:

- processes commands more than 10 times faster than previous electronic loads
- simulates real-life loading patterns, with minimal programming commands
- operates with full stability even at subzero voltage levels



Figure 9.
N3300 Series electronic load

N6705C DC power analyzer

The Keysight N6705C DC power analyzer (Figure 10) offers both programmable power supplies and electronic loads in a single 4U bench platform. This bench mainframe provides five functions in a single instrument: power supply, voltmeter / ammeter, oscilloscope, arbitrary waveform generator, and data logger. You can do the following:

- Conduct source and sink testing with both power and load instruments in a single integrated platform.
- Easily program the N6705C power analyzer with a power source and electronic load.
- Efficiently charge and discharge a battery, analyze the efficiency of a DC-DC converter, or measure the transient recovery on a power supply.



Figure 10.
Keysight N6705C
DC power analyzer

N6790 Series electronic load

The new Keysight N6790 Series modular electronic loads (Figure 11) offer a 100 W module and a 200 W module, each in a 1U footprint. Four user-operation modes are available: constant voltage, constant current, constant resistance, and constant power. With a high, accurate measurement system and digitizing capabilities, it gives users quick insight into their power supply test. Also, the series offers a powerful built-in arbitrary waveform generator that allows users to emulate complex dynamic load waveforms. This is a must-have to tackle the high-power requirements of advanced automotive electronics testing.



Figure 11. Keysight N6791A (100 W) and N6792A (200 W) electronic load modules

Keysight N7900A advanced power system

An EV is a high-voltage assembly on wheels, comprising onboard chargers, traction battery pack, battery management systems, DC-DC converters, and motor control inverters, among other systems. Any transients can impact myriad functions, from power control for the wheels to charging and range efficiencies, as well as safety.

The Keysight N7900A Series advanced power supplies (Figure 12) provide a robust yet flexible solution to test higher-power transients:

- Deploy the N7900A's 1 kW and 2 kW system power supplies in parallel to deliver up to 10 kW.
- Get dynamic outputs, arbitrary waveforms, list capability, and 6x improvement in up / down programming time.
- The N7900A's output transitions from zero to full output voltage in < 0.5 ms. Fast slewing, along with built-in arbitrary waveform capabilities, enables it to generate almost all the dynamic power disturbances defined in ISO 16750-2 and related standards.



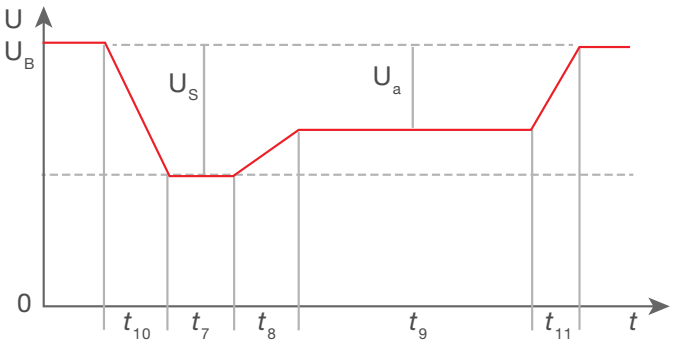
Figure 12. The Keysight 7900 advanced power system

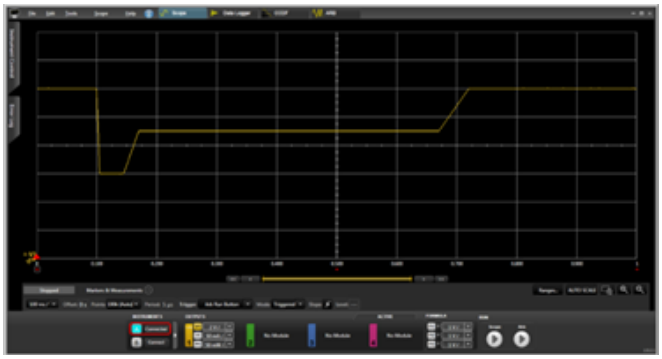
Advanced power control and analysis software

The Keysight PathWave BenchVue BV9200B advanced power control and analysis software gives you fast and easy access to the advanced sourcing and measurement functionality of your N6705 DC power analyzer, RP7900 Series regenerative power system, or advanced power system N7900 Series power supplies without any programming:

- Easily track and record your power supply outputs to understand an event's impact on power use.
- Graphically configure three modes of analysis: scope (short-term waveform capture), data logger (long-term waveform capture), and CCDF (statistical analysis).
- Quickly create complex waveforms to stimulate or load down a DUT by inputting a formula, choosing from built-in or imported waveform data.

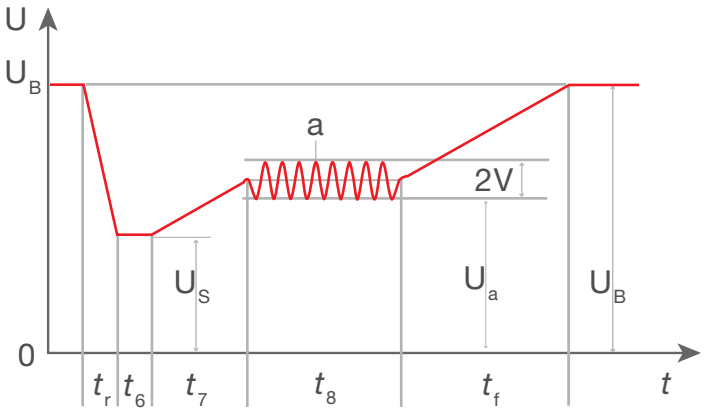
Figures 13 to 15 show some use cases of the BV9200 control and analysis software.

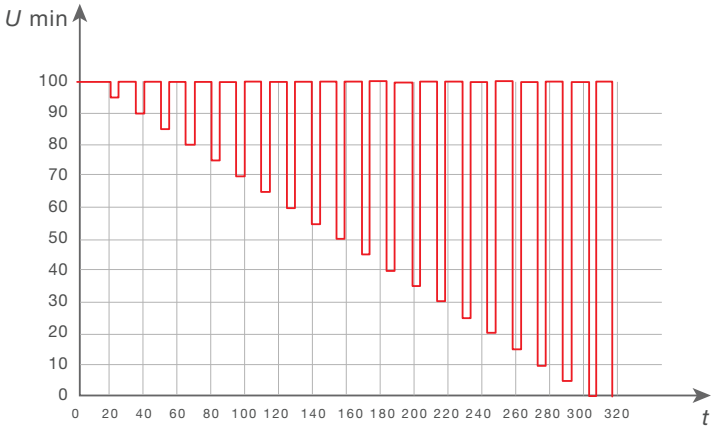




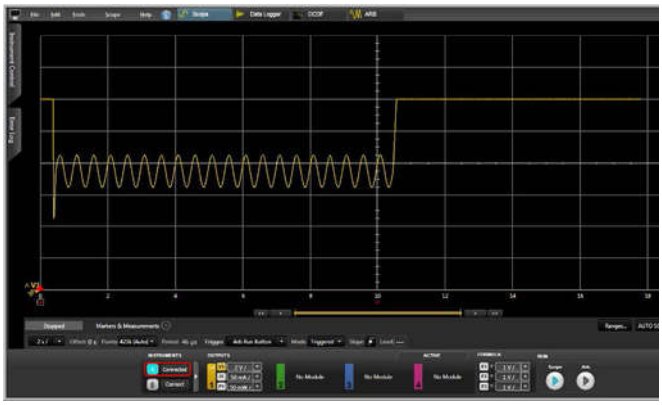
P	Value	P	Value
U_B	12 V	U_s	-6 V
U_a	-3 V	t_7	40 ms
t_8	25 ms	t_9	500 ms
t_{10}	5 ms	t_{11}	50 ms

Figure 13. Starter motor voltage transient





U min = 10.5 V
Vdrops 5% of *U* min for 5 sec





P	Value	P	Value
U_B	12 V	U_s	4.5 V
U_a	6.5 V	t_8	10 s
t_f	100 ms	t_r	5 ms
t_6	15 ms	t_7	50 ms

Figure 14. Engine cranking

Figure 15. Reset behavior caused by voltage drop

Sourcing and Sinking DC-DC Conversion

RP7900 regenerative power system

Consumer demand for extended EV range and faster charging times creates a need for larger-capacity batteries operating at higher voltages. Testing the high-voltage battery module and bidirectional electronics requires a power source and a load. A traditional load or power dissipater converts energy into heat. When testing high-power devices, the heat is excessive and difficult to exhaust.

A regenerative power supply (RPS) can test high-power devices more efficiently, returning energy to the grid while acting as an electronic load. The Keysight RP7900 Series provides several additional benefits over traditional solutions:

- Test higher-voltage components, up to 2,000 V.
- Achieve a seamless transition from sourcing current to sinking current.
- Program a single instrument for both sourcing and loading, even at higher power.
- Test devices above 20 kW with multiple power supplies paralleled but controlled by a single primary supply.



Use models of the RP7900 Series

High-power battery module and energy storage systems

Emulating the battery is critical when characterizing its operating life and detecting early product failures. Through programmable resistance up to 277 Ω, the RP7900 Series simulates the effects of the battery's internal resistance, enabling it to emulate the operation of batteries in different charge states.

The RP7900 uses active down programming to reduce settling times, shortening test times. When the power supply is set to a lower voltage, or down programmed, it will load its terminals until it achieves the lower voltage. During down programming, the power supply sinks current and returns the energy to the grid. Active down programming is particularly useful for testing modules with a large smoothing capacitor.

The RP7900 performs many tests through a single instrument, simplifying test setups. A regenerative power supply reduces the amount of equipment required for charging and discharging tests, as it performs both. Similarly, tests requiring more current than a single RP7900 power supply benefit from a built-in control port. The control port allows you to connect multiple supplies in parallel. The built-in control port allows the supplies to communicate and act as a single, more powerful regenerative power supply. You can perform many tests by programming a single RPS.

Testing high-voltage distribution modules and other bidirectional electronics

Using multiple RP7900 Series supplies streamlines the testing of bidirectional distribution modules. Newer distribution modules include an additional port for fast DC charging. To simultaneously test all the ports requires coordination and data logging between the supplies. The PathWave BenchVue advanced power control and analysis software controls, captures, and displays simultaneous data from one or more RPS. The power distribution module connects to several high-voltage modules, including the converter module, three-phase inverter, onboard charger, air conditioning compressor, and heating core. The RP7900 Series can test all these high-voltage modules.



Figure 16. The RP7900 RPS seamlessly transitions from sourcing current to sinking current

N8900 autoranging DC power supply

The high-voltage DC-DC onboard converters in hybrid and electric vehicles handle voltage conversions between the battery and the vehicle's 12 V power system. These high-power conversions require rigorous testing to meet safety and performance standards.



Traditional testing methods use power supplies with "rectangular" output characteristics. They provide full power at only one voltage and current combination, making test processes slow and cumbersome.

The Keysight N8900 Series high-power DC power supplies provide a wide range of voltage and current combinations at full power, automatically (see Figure 17). The N8900 Series provides the following benefits:

- does the job of multiple power supplies with autoranging output
- provides up to 1,500 V and up to 510 A, and > 100 kW power in parallel units
- comes with GPIB, Ethernet / LAN, USB 2.0, and analog interfaces to simplify connections

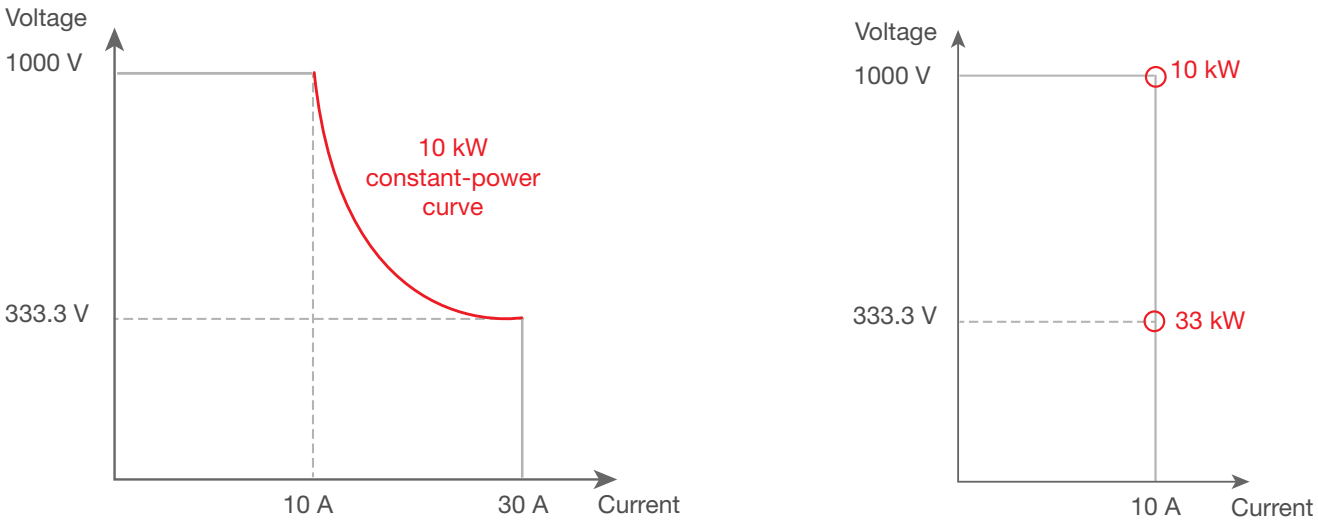


Figure 17. The N8900 provides autoranging output characteristics (left chart) versus traditional rectangular output characteristics (right)

DAQ970A / DAQ973A data acquisition system

The Keysight DAQ970A and DAQ973A (Figure 18) feature 6½ digits (22 bits) of resolution, 0.003% basic DCV accuracy, and ultra-low reading noise. Combine these with scan rates of up to 450 channels / sec, and you get the speed and accuracy you need to get the job done right the first time, even with challenging automotive electronics measurements.

Key features include the following:

- 3-slot mainframes with built-in 6½-digit DMM
- basic 0.003% DCV accuracy
- 9 switch, RF, and control plug-in modules, including a new four-channel simultaneous sampling digitizer
- up to 450 channel / sec scan rate and up to 120 channels per system
- up to 1 million points scanning memory



Figure 18. Keysight DAQ970A / DAQ973A data acquisition system

34980A data acquisition system



Figure 19. Keysight 34980A data acquisition system

Designers and manufacturers of automotive electronic subsystems often have too many test system applications to validate and test their systems. The Keysight 34980A data acquisition system (Figure 19) is a solution that responds to end users' need to simplify test development cost-effectively. It does the following:

- handles system switching up to 26.5 GHz
- configures channels independently for custom measurements with built-in digital mustimeter
- measures temperature, AC or DC voltage, resistance, frequency, current, and custom measurements in a single box

B2980 Series electrometers



Figure 20. Keysight B2980 Series electrometer

As automotive electronics evolve to match demanding specifications in modern sensor and electrification applications, parameters determining latency, safety, and sensitivity will become more stringent.

The Keysight B2980A Series femto / picoammeter and electrometer / high-resistance meter (Figure 20) is an SMU that provides a variety of high-precision measurements. It provides the following benefits:

- world's only graphical picoammeter / electrometer that confidently measures down to 0.01 fA and up to 10 PΩ
- high-speed reading rate up to 20,000 rdg / sec
- battery-operated models for measurements free of line noise

Testing Electric Vehicles and the E-Mobility Ecosystem

The cost pressure on EV powertrain components (traction motors, converters, power converters, and batteries) continues to drive new fundamental technologies. These technologies increase the 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 inverter and smart grid technologies. To address these emerging design and test issues, Keysight has created and introduced innovative approaches to help developers and manufacturers accelerate their programs.

Please refer to our e-mobility brochure *Innovative Design & Test Solutions for the Electric Powertrain and HEV / EV Ecosystem* for a comprehensive overview of the design and test solutions and services that Keysight offers in this ecosystem.





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