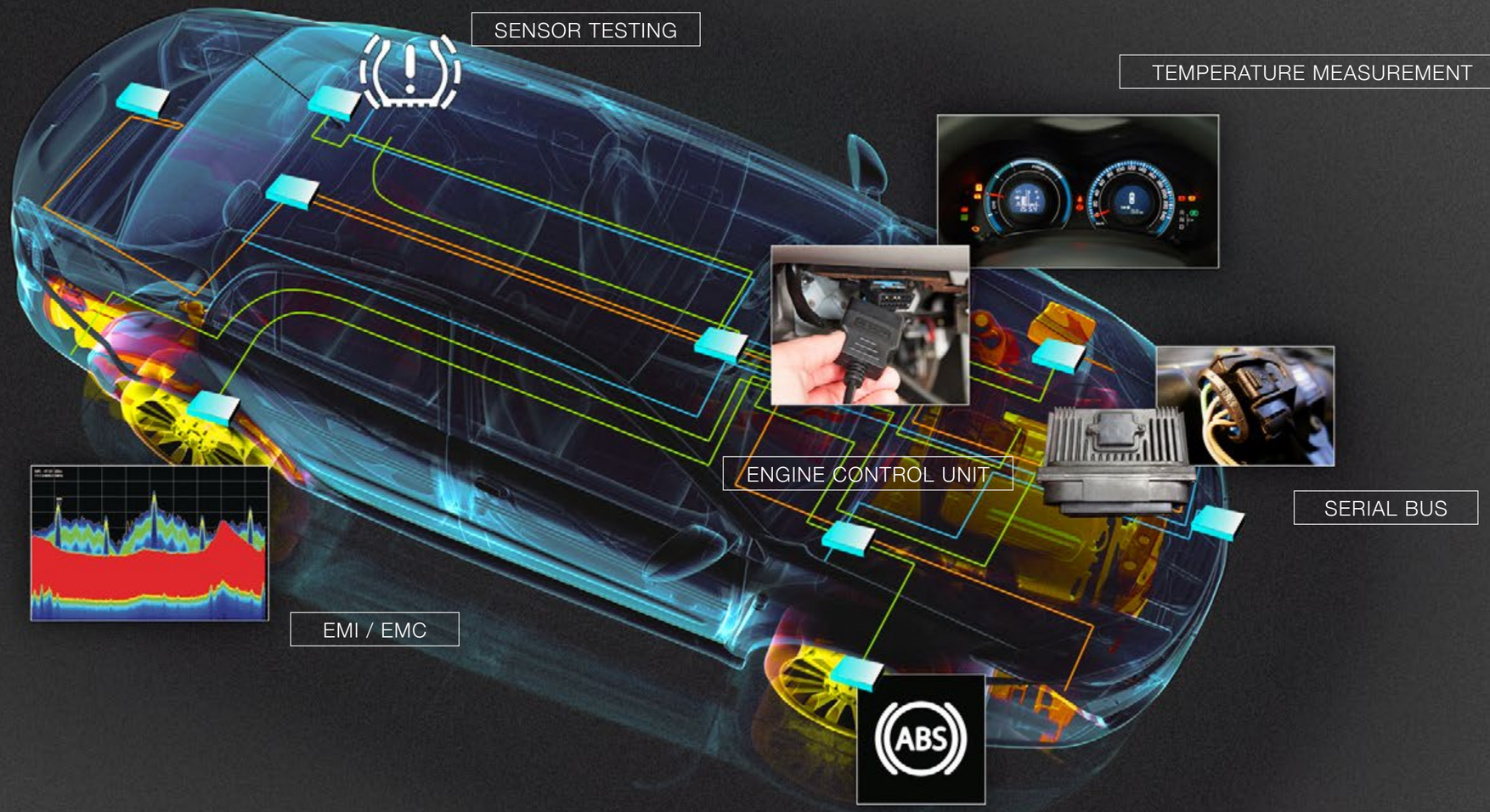
Tektronix®
KEITHLEY
A Tektronix Company

automotive

Understanding Test Methods for Automobile Control and Communications Systems



Introduction

The tremendous increase of electronic functions and controls and and the need to communicate vital information throughout the vehicle has increased the complexity of today's vehicle designs and the test processes needed to debug and verify these designs. This applications kit specifically addresses these control and communication systems testing challenges for today's automobiles so you can learn how to resolve the challenges that are driving you.

Get advice for your application.

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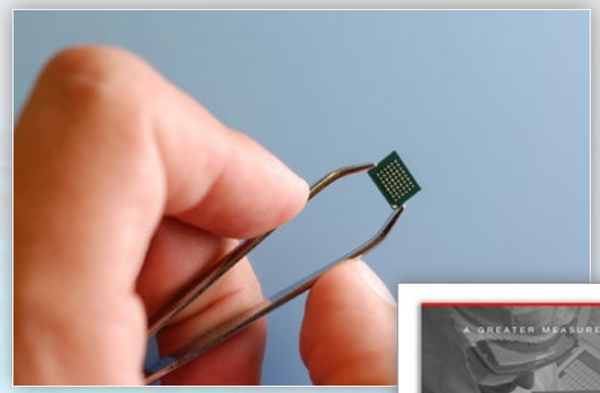
Sensor Development and Characterization

New technologies for electrical/electronic sensors offer numerous advantages in the design of detection systems to meet speed and ease of use criteria. With proper testing and calibration, sensors can meet these criteria while providing reliable results that minimize false positive and negative indications.

Performance criteria for sensor systems include:

- Sensitivity/resolution/accuracy/repeatability
- Dynamic range
- Environmentally robust – tolerance to temperature, electrical noise, physical shock, vibration, etc.
- Usable lifetime/adaptability/safety/integrity
- Speed and ease of use (testing/calibration/maintenance)

Automotive electronic control units require a wide variety of sensor applications. Automotive sensors are used to measure temperature, pressure, flow, position, gas concentration, speed, brightness humidity, etc. Future trends in the automotive sensor technology are making sensors miniaturized, multi-functional, integrated, and intelligent.



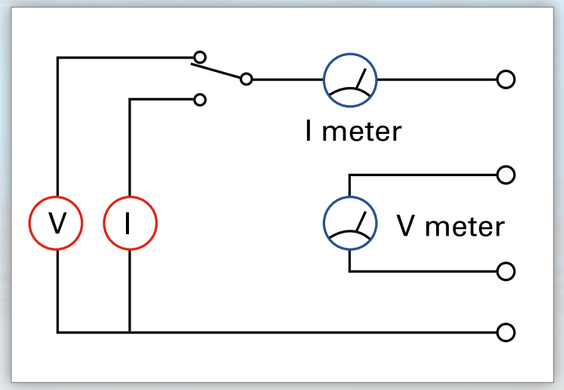
Micro-Electro-Mechanical Systems (MEMS) are vital components of automotive electronic systems, as modern vehicles rely on these electronic systems to make sure vehicles meet efficiency and security standards as well as environmental regulations.

Download the technical e-guide,
Source Measure Units Instruments: The Tool of Choice for Emerging R&D Applications

R&D DC Characterization of Sensors

Electrical characterization of sensors involves comprehensive current-voltage (I-V) testing, requiring instruments such as digital multimeters (DMMs) and power sources. Quite often, Keithley's source measure unit (SMU) instruments can provide a fully integrated, four-quadrant, all-in-one solution for I-V testing for sensors.

- Source and measure voltage and current, with best-in-class low current resolution
- Precision current and voltage, sourcing and measurement
- Source and load functionality
- Faster test time with high accuracy and repeatability
- Avoid complex synchronization, interconnection, and programming issues caused by using multiple instruments



Basic SMU Topology

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Production Testing of Sensors

Automotive sensor production testing requires the use of economic and flexible test equipment that has a high degree of automation, high speed, high performance, and high reliability. Sensor manufacturers need test systems that can easily adapt to technologies in next-generation sensors, and they need test systems that can maximize the effectiveness and life of their capital investment.

Keithley SMU instruments are very suitable for the production and automated sensor testing applications that need high accuracy and sensitivity.

Download the e-guide, How to Choose and Apply Source Measure Unit Instrument.

Download the New Materials and Devices e-guide.

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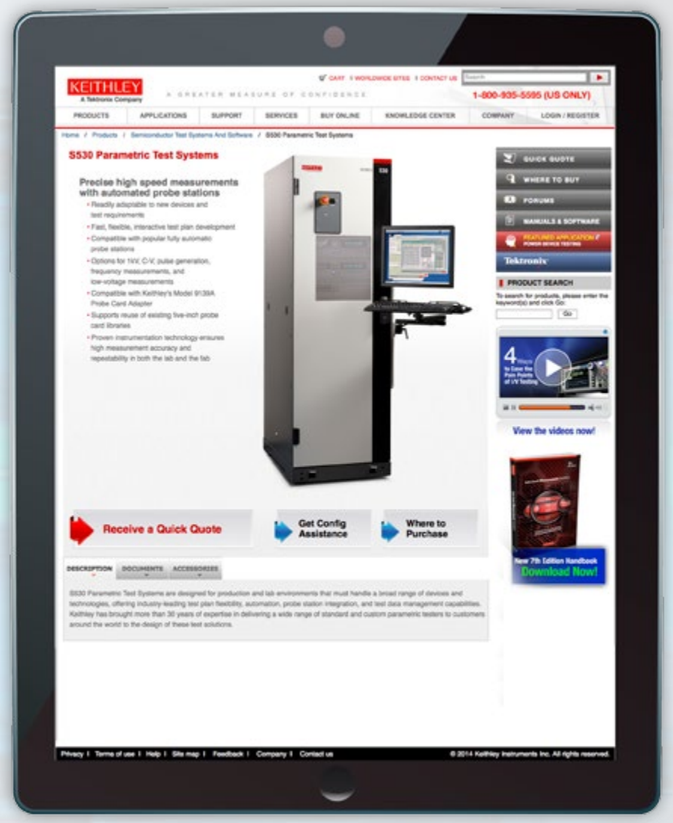
Testing MEMS Accelerometers for Cruise Control and Stability Control Systems

Testing MEMS wafers requires probing stations and test systems that are capable of making ultra-low level measurements. Keithley is well known for more than 30 years of expertise in and commitment to parametric test, and parametric test systems are designed to test new semiconductor wafers and MEMS devices that will be the core of new automotive sensors. Our S530 Parametric Test Systems are readily adaptable to new devices and test requirements and offer capabilities that:

- Minimize heat generation with low level sourcing and measurement
- Measure resistive electrode elements
- Measure capacitance between vibrating elements
- Measure stray leakage currents
- Provide excitation signals for functional test

The Keithley S530 Parametric Test System features:

- Current measurements with 1fA resolution and current sourcing with 20fA resolution
- Voltage measurement with 1µV resolution and voltage sourcing with 5µV resolution
- Capacitance measurements down to 10pF
- Probe card testing for up to 64 pins



Learn more about Keithley's S530 Semiconductor Parametric Test Systems.

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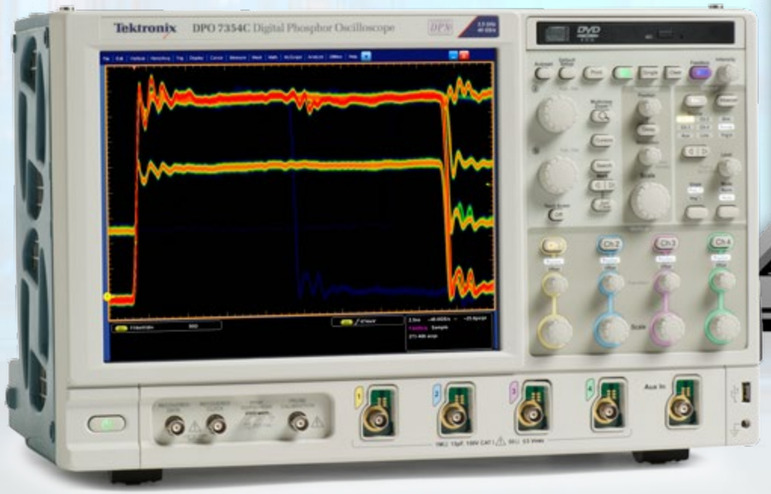
Testing Engine Control Units (ECUs)

Automotive engines are electronically controlled by an onboard computer known as an ECU. An ECU computes information in real time to determine optimum values for engine control parameters based on data relayed from sensors placed around the vehicle. Multiple control systems are used in contemporary automotive electronics systems, with as many as a 100 built into top-of-the-line luxury vehicles. These systems are required to function in an extremely challenging environment. Malfunctions cannot be tolerated, as this could jeopardize passenger safety.

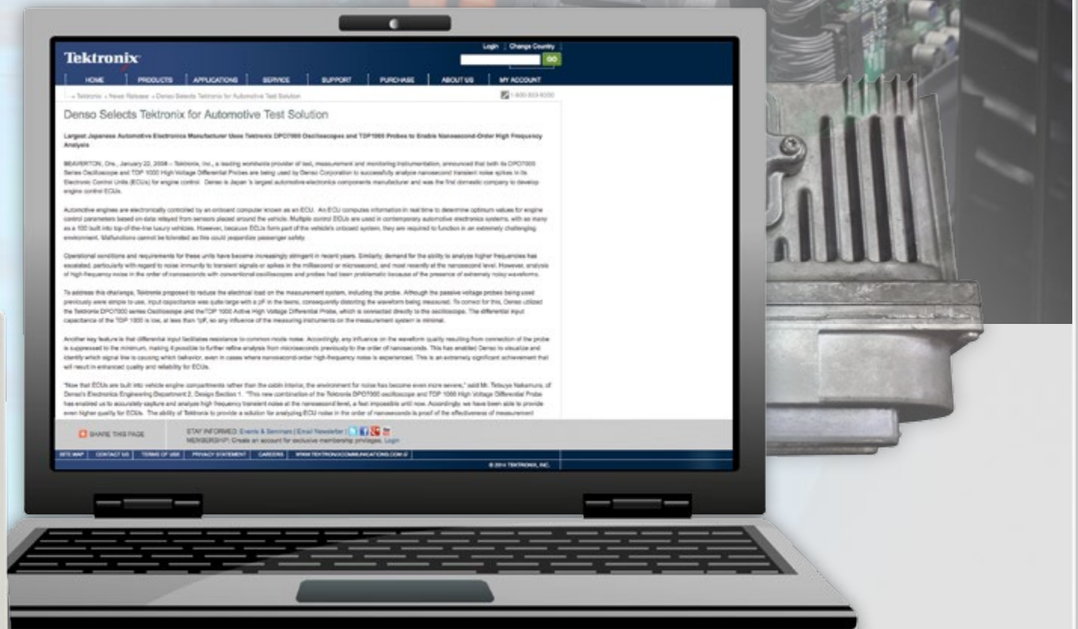
Numerous inputs are needed to stimulate and test the performance of an ECU. Sensor signals can be simulated with DC voltage levels. Signals from the camshaft and other types of sensors require AC voltage waveforms. Also, the ability for the ECU to drive outputs such as lighting, solenoids, and motorized components must be validated; and, the ECU's communication protocol performance must be verified.

Operational conditions and requirements for ECUs have become increasingly stringent in recent years. Similarly, demand for the ability to analyze higher frequencies has escalated, particularly with regard to noise immunity and transient signals capture. Noise spikes in the millisecond or microsecond, and, most recently, at the nanosecond level, need to be identified and acquired.

However, because of the presence of extremely noisy waveforms, analysis of high-frequency noise in the order of nanoseconds with conventional oscilloscopes and probes had been problematic. Tektronix DPO7000 Series Oscilloscopes and TDP 1000 High Voltage Differential Probes can be used to successfully analyze nanosecond transient noise spikes in ECUs for engine control.



Learn more about the DPO7000 Series Oscilloscopes



Read the case study
Denso Selects Tektronix for Automotive Test Solution

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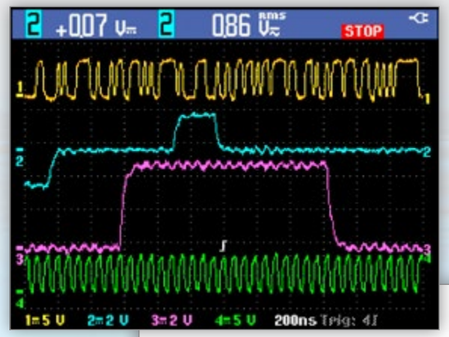
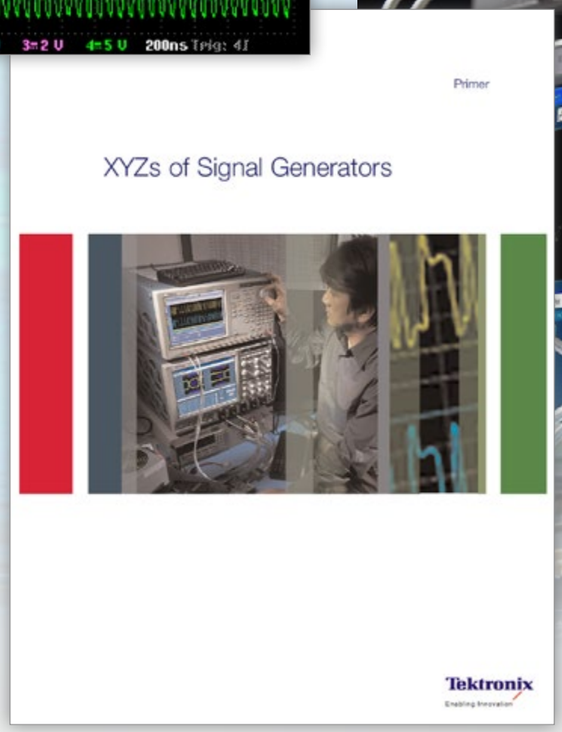
Simulating Sensor Signals

To test automotive electronic control units, the units must receive simulated sensor signals. Various automotive sensor signals, such as pressure, temperature, speed, angle of rotation and displacement, simulation shaft, camshaft, wheels, locks, and other automotive engine sensor signals need to be recreated for functional testing and optimization of control units performance.

In its various configurations, the signal generator can provide stimulus signals in the form of basic analog waveforms, custom analog waveforms, digital data patterns, modulated signals, distorted signals, and noise. The signal generator can generate any waveform encountered in the automotive environment.





Download the primer, XYZs of Signal Generators.

Get advice for your application.

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The World's Fastest and Most Versatile Signal Generators for Today's Complex Signals

Tektronix signal generators cover a wide range of applications, from replicating sensor signals to creating RF signals and the fastest high speed serial data signals. Each versatile signal generator can create a virtually unlimited number of signals:

- Analog or digital
- Ideal or distorted
- Standard or custom

From the world's only direct synthesis of high-speed serial data waveforms for testing, to the world's most versatile arbitrary function generator for common stimulus signals, Tektronix has a signal generator to overcome any automotive test challenge.

Learn more about Tektronix signal generators.

Get advice for your application.

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Multipoint Measurements in Automotive Test Applications

There are many automotive systems tests that require only common instruments, such as load banks, high current power supplies, and DMMs. However, more specialized tests of conductors and insulators require instruments designed specifically for the measurement extremes involved in low resistance, high resistance, and low current testing. Complex devices, such as DC/DC converters, inverters, airbag igniter systems, and other electronic controllers require more extensive testing and multifaceted test systems.

Automotive control units have a large number of inputs and outputs, and testing requires measurements at each of these inputs and outputs. Therefore, test systems that employ signal switching are essential for accurate, efficient, and fast testing of control units. In such a test system, the measuring instruments, signal switching, and other critical components should be selected for ease of integration and optimum overall performance. Ideally, a fully-integrated data logging and switch system, such as Keithley's Series 2700 and Series 3706A Integrated Digital Multimeter/Switch/Data Logger Systems, eliminates the need to mix test system components and is perfect for so many automotive applications:

- Monitoring temperature for air conditioning and heating elements of dashboards
- Automotive body control module testing for sensors
- Production/functional testing of signals from multiple sensors (MEMs) in ESPs and ABS systems
- Cable harness, wiring, connectors – low resistance testing

Download the e-guide
High Performance DMMs for single- and multi-channel applications

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The Role of Switching Systems for Testing Cables, Connectors, and Insulators

Continuity Testing

Continuity checks are performed on a variety of devices, including cable assemblies, printed circuit boards, and connectors, to ensure that these components meet their specifications. When setting up a continuity test, the maximum resistance at which the device is considered to be valid must be specified. For example, any measured resistance of 1Ω or less indicates a good device. Continuity checks require measuring low resistance, so a four-wire measurement technique used to eliminate lead and switch resistance errors and allow resistance measurements down to microΩ levels.

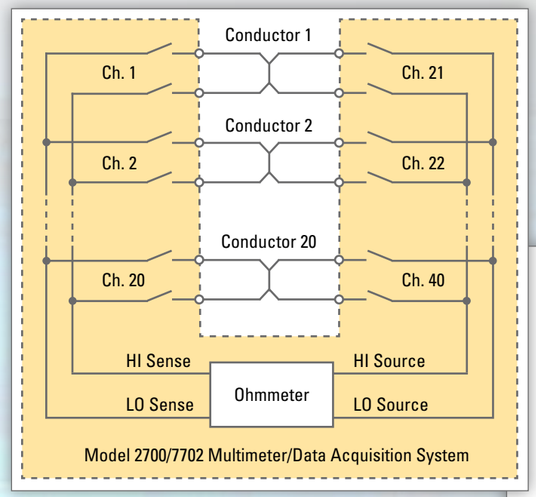
For testing multi-conductor devices, a switch system is useful for connecting the measurement instrument to each conductor automatically.

Insulation Resistance Testing

An isolation resistance or insulation resistance test is often performed in addition to the continuity test. DC insulation resistance (IR) is the ratio of the DC voltage applied between two conductors separated by an insulator to the total current flowing between the two conductors. The test voltage is applied for a specified period of time before the resulting current is measured. The measured current is usually quite small, so a picoammeter or electrometer is often required to make the measurement.

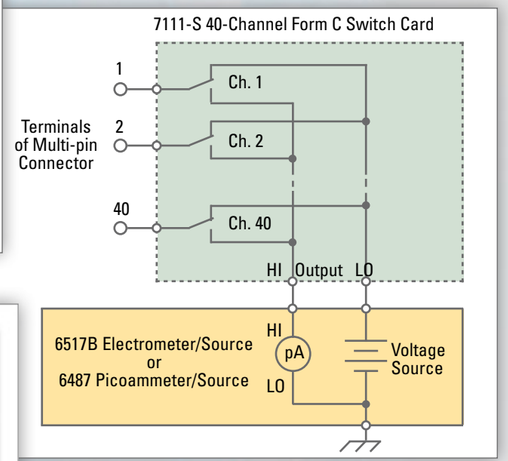
The insulation resistance of a DUT is measured to determine that it's greater than a specified minimum value.

An example of insulation resistance measurement would be the resistance between conductors in a multi-conductor cable. IR measurements often involve multiple conductors, so a switching system is often required to switch the picoammeter and the source to all the conductors in the test circuit. The design and type of switching cards used in an IR test system depend on several factors, including the test voltage, magnitude of resistance, and accuracy.



Continuity Test System

Testing IR from any one terminal of a multipin connector to all others.



Download the e-guide High Performance Switching Applications

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Testing the Communication Buses in Automotive Designs

The communication protocols that transmat and receive data between sensors, electronic control systems, and actuation devices must be highly resistant to EMI, have fast data transfer rates, and be low cost. To have a high noise tolerance, the communication protocols must have superior error detection algorithms. An automobile may use a number of different protocols for different applications; thus the se protocols must coexist in the harsh automotive environment. These protocols include CAN, LIN, MOST, and FlexRay.

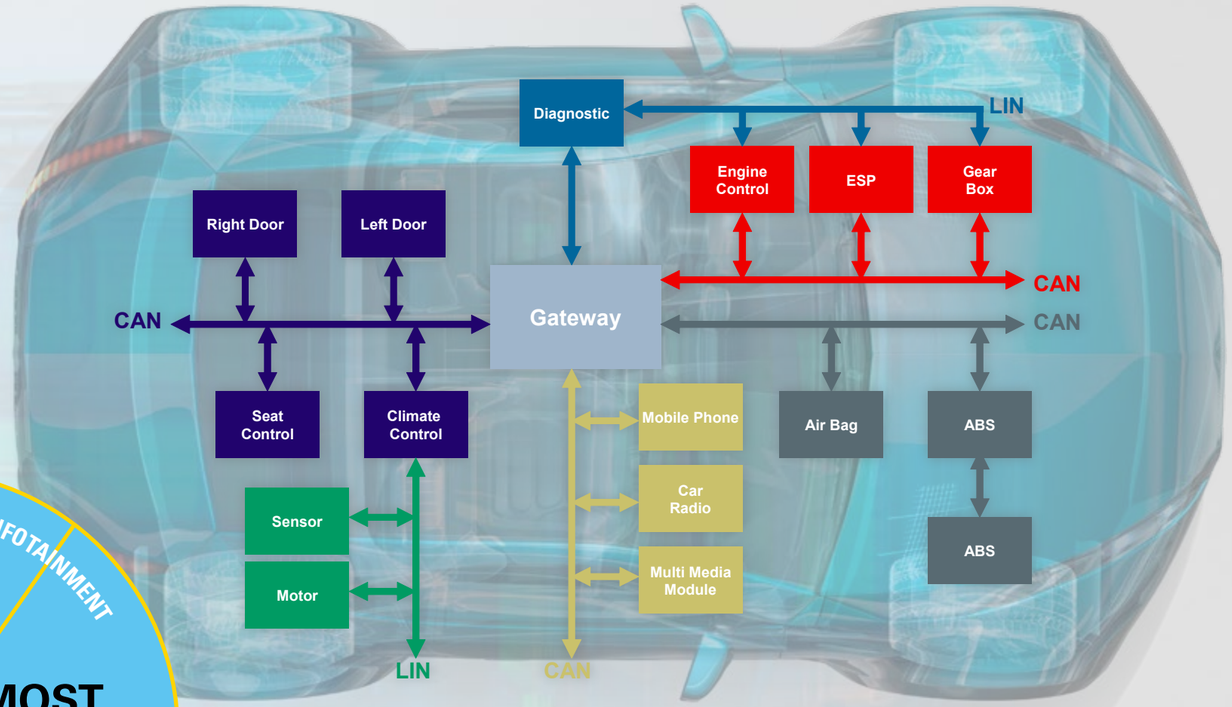
Debugging and testing these communication links is challenging and time consuming. Tools are needed to quickly and easily decode a transmission and time correlate the data with external events initiated by sensor signals. Tektronix oscilloscopes and logic analyzers provide all the necessary capabilities to decode automotive buses and provide protocol-level views of data sequences. Mixed signal oscilloscopes and logic analyzers also provide innovative troubleshooting capabilities and comprehensive support for monitoring, triggering, and decoding the various automotive buses. Tektronix instruments ensure measurement confidence and support for the most efficient debugging and testing of automotive links.

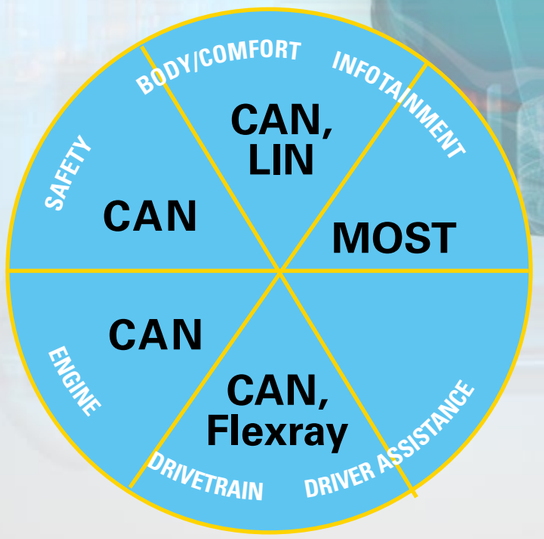
Trace serial data flow between nodes through a network

- Simultaneously display messages at transmitter and receiver to verify continuity and propagation delays

Trace serial data flow between network segments separated by a gateway

- Simultaneously display messages from multiple buses, at different speeds, or even different bus standards





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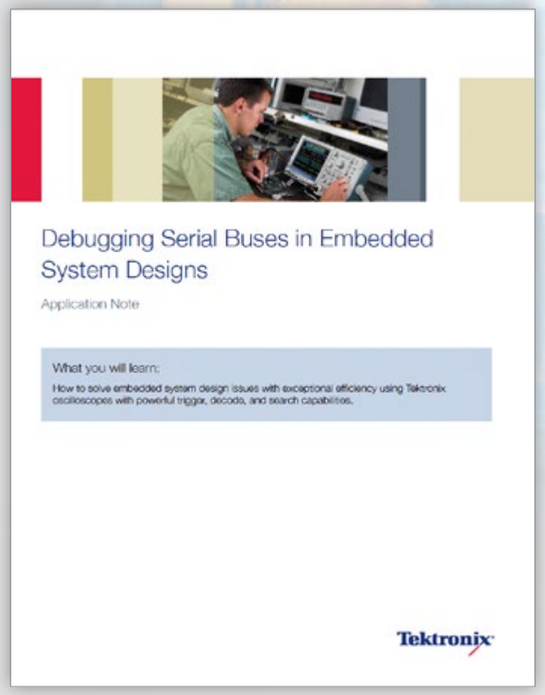
Superior Solutions for Testing Automotive Communication Protocols (Buses)

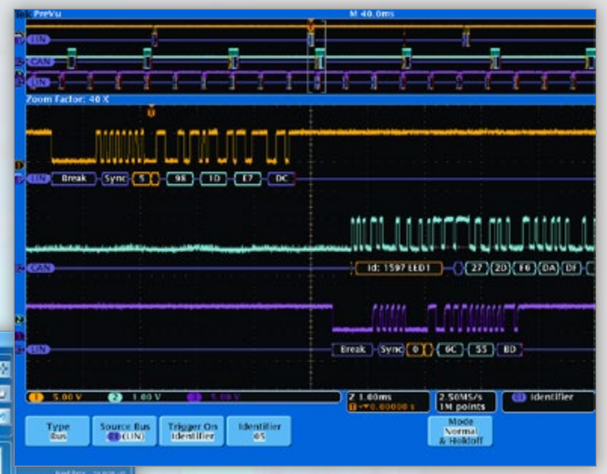
Tektronix oscilloscopes have power features for analyzing and verifying the performance of automotive buses:

- Advanced triggering modes that allow triggering on a wide range of signals and conditions
- Eye diagram and mask analysis
- Simultaneously display messages at transmitter and receiver to verify continuity and propagation delays
- Multiple protocol analysis on one instrument
- Powerful search capabilities to isolate an anomaly



Triggering on specific identifier and Data on a CAN bus and decoding all messages in the acquisition.

DPO4AUTOMAX Eye Diagram analysis of a FlexRay signal.



Simultaneous capture and decode of multiple automotive serial buses.

Learn how to solve embedded system design issues with exceptional efficiency. Download the application note Debugging Serial Buses in Embedded System Designs.

Get advice for your application.

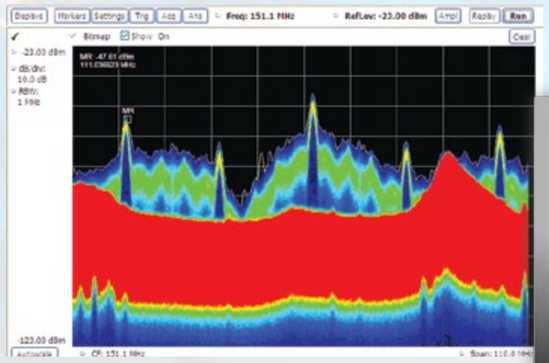
Send us your question or join the discussion in our **application forum**.

Controlling Electromagnetic Interference (EMI) and Complying with Electromagnetic Compatibility (EMC) Standards

Meeting EMC standards and eliminating EMI in automotive systems requires designs that both minimize emissions and can shield circuits from the increasing sources of noise in the automotive environment. The increase in noise sources is resulting from both integrated electronics and electronics devices brought into the automobile. Internal sources of intefering noise can originate from navigation systems, engine control systems, and wireless communication systems. External sources of noise brought into the automobile can include mobile phones, tablet computers, electronic gaming devices, and radar detection devices.

EMI/EMC test challenges include:

- Performing tests required by national and international EMC standards
- Identifying the sources of noise that are interfering with system performance
  - o RF interference
  - o Power transients
  - o Electrostatic discharge
  - o Changing electric and magnetic fields from drivetrain power electronics and motors
- Capturing random events



An infrequent transient is captured on a Tektronix RSA series real time spectrum analyzer using patented DPX™ spectrum display technology. The red areas are frequently-occurring signals, and the blue and green portions are transients.

View the webinar:
Practical Approach to EMI Diagnostics.

Get advice for your application.

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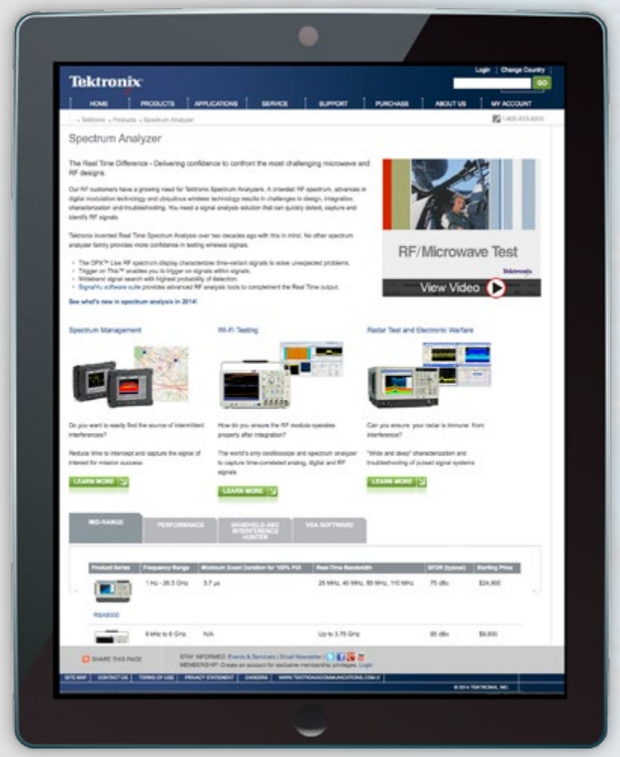
EMI/EMC Testing with Confidence

Tektronix real time spectrum analyzers are unprecedented in their ability to identify the source of EMI/EMC interference and to perform pre-compliance and compliance tests.



Learn more about the Tektronix family of real-time spectrum analyzers

Diagnostics and Debug

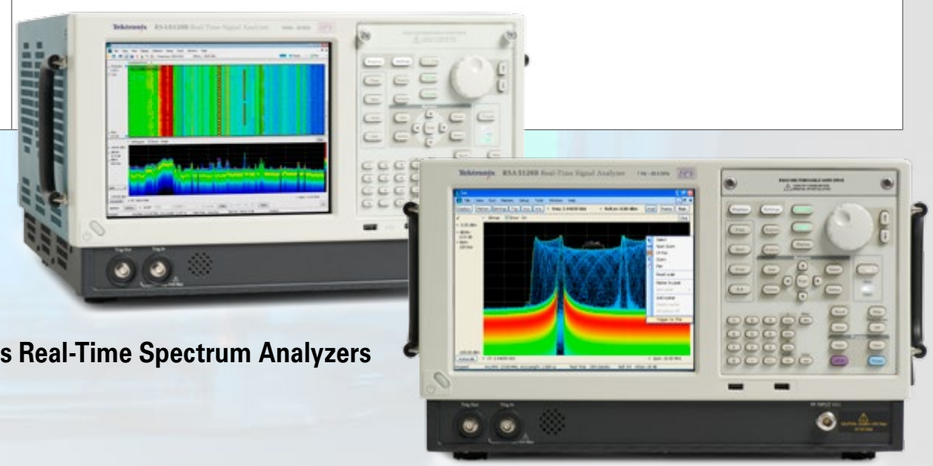
- Lo feed thru
- Detecting low-level signals in broad sweeps with narrow resolution bandwidths
- Detecting and characterizing impulse noise
- Finding signals-within-signals
- Determining clock stability and settling to tuning, microphonics, and phase-hits
- Correlating transient emissions to hardware and software states

Pre-Compliance and Compliance

- Testing to standards and compliance levels with required filters and detectors
- Applying corrected measurements and limit lines

Real-Time Spectrum Analyzers

- Discover elusive transient, impulse, and signal-within-signal events with 100% probability with over 292,000/s spectrum updates and swept DPX
- Trigger and isolate spectrum events with 100% probability using patented DPX DensityTM, Frequency Mask, and Time-qualified Triggering, Frequency Edge, and cross-trigger oscilloscopes or logic analyzers within the event record
- Capture long event records with up to 110 MHz of bandwidth
- Analyze signals with MIL-STD and CISPR compliant filters and detectors
- Quickly assess compliance with corrected data and limit lines displayed
- Speed spur testing with the fastest scanning technology for wide spans and narrow resolution bandwidths



RSA5000/6000 Series Real-Time Spectrum Analyzers

Get advice for your application.

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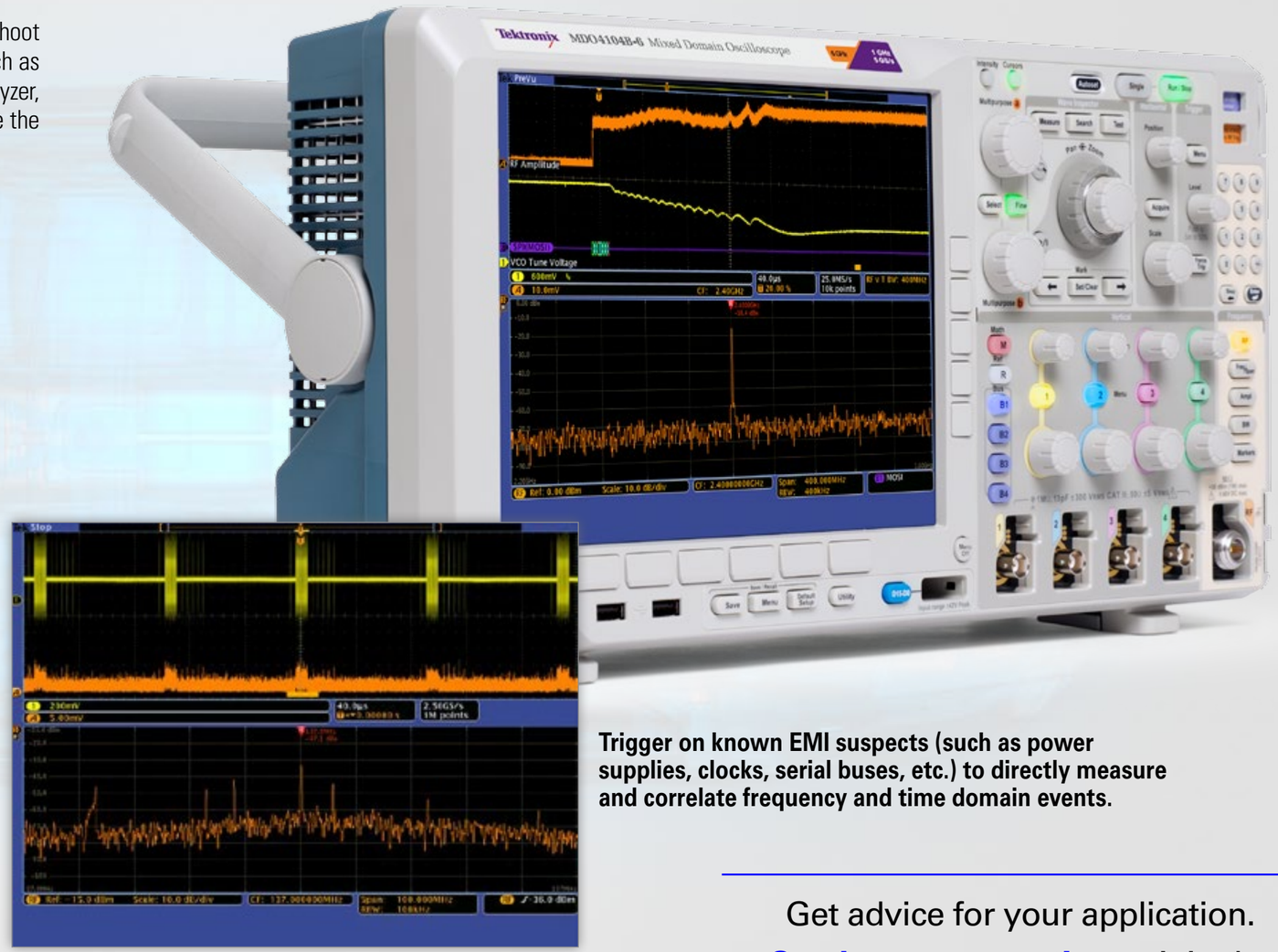
MDO4000B Mixed Domain Oscilloscope -
The First and Only Oscilloscope with a Built-in Spectrum Analyzer

The award-winning MDO4000B provides features that enable you to quickly troubleshoot EMI problems. Many EMI problems come from events rooted in the time domain, such as clocks, power supplies, and serial data links. The MDO4000B combines a spectrum analyzer, oscilloscope, and logic channels into a single instrument that enables you to measure the relationship between time-domain events and spectral emissions.

Learn more about troubleshooting EMI issues.
Watch the video

or download the application overview



Trigger on known EMI suspects (such as power supplies, clocks, serial buses, etc.) to directly measure and correlate frequency and time domain events.

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Automotive Testing Solutions that Keep Pace with Emerging Technologies, Standards, and Requirements

With the increased complexity of today's vehicle designs and their intricate electronic functions and embedded controls, it can be difficult to keep up with the standards and requirements for analyzing, debugging, and verifying these designs. Tektronix and Keithley have a collection of instruments and systems to specifically overcome even your most challenging test and measurement applications.

Oscilloscopes with Combined Time Domain and Frequency Domain Analysis and Protocol Analysis

Eight out of ten engineers around the world trust Tektronix to help them debug and test tomorrow's designs faster. With the broadest portfolio of digital oscilloscopes available, the richest set of product features, the most extensive analysis capability, and our award-winning service and support, Tektronix has the right oscilloscope to meet your automotive system test requirements. **Learn more.**

Switching Mainframes with up to 576 Channels and a High Speed 7.5-Digit DMM

The Model 3706A is a scalable, instrument grade switching and multi-channel measurement solution that is optimized for automated testing of electronic systems. A mainframe can support up to 576 two-wire multiplexer channels for unrivaled density and economical per channel costs; the high performance multimeter provides a tightly integrated switch and measurement system. **Learn more.**

Multiple-channel Arbitrary Waveform Generators

Providing leading-edge performance with sample rates to 50GS/s or lower sample rate solutions on up to four channels, Tektronix arbitrary waveform generators enable complex signal generation to seamlessly move from a simulation environment to the real world. **Learn more.**

Specialized Power Sourcing for a Wide Range of DC and Battery-simulating Waveforms

Keithley DC power supplies and source measure unit (SMU) instruments can supply precision voltage levels and specific waveforms to power control systems and simulate automotive test waveforms.

Automated Component Test Systems

Test semiconductors and MEMS at the device or wafer level with flexible and customizable Keithley parametric test systems.

Unprecedented Real-Time Spectrum Analysis

Tektronix real time spectrum analyzers enable you to identify the EMI/EMC interference source and perform pre-compliance and compliance testing with confidence.

Learn more about Tektronix AC instruments and systems.

Learn more about Keithley's DC instruments and systems.

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Tektronix and Keithley maintain a comprehensive, constantly-expanding collection of application notes, technical briefs, and other resources to help engineers stay on the cutting edge of technology. For further information, please visit **www.tektronix.com** or **www.keithley.com**.

17 March 2014 | Control and Communications Systems 3257