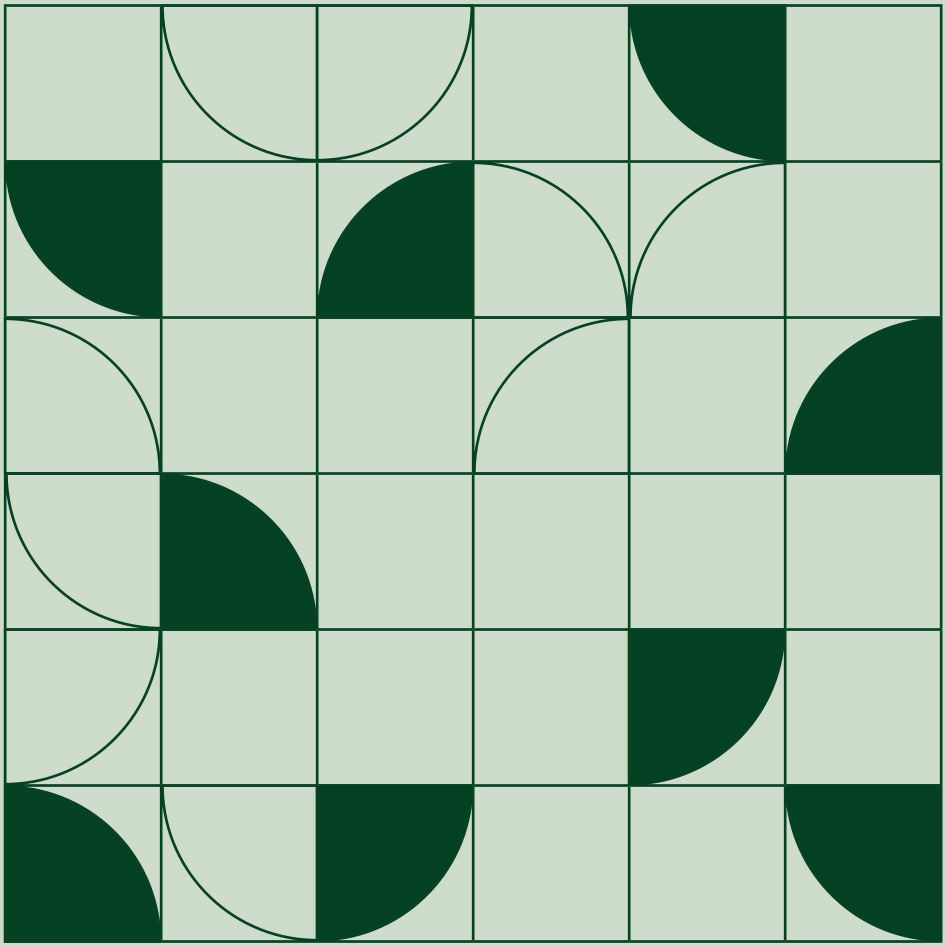
WHITE PAPER

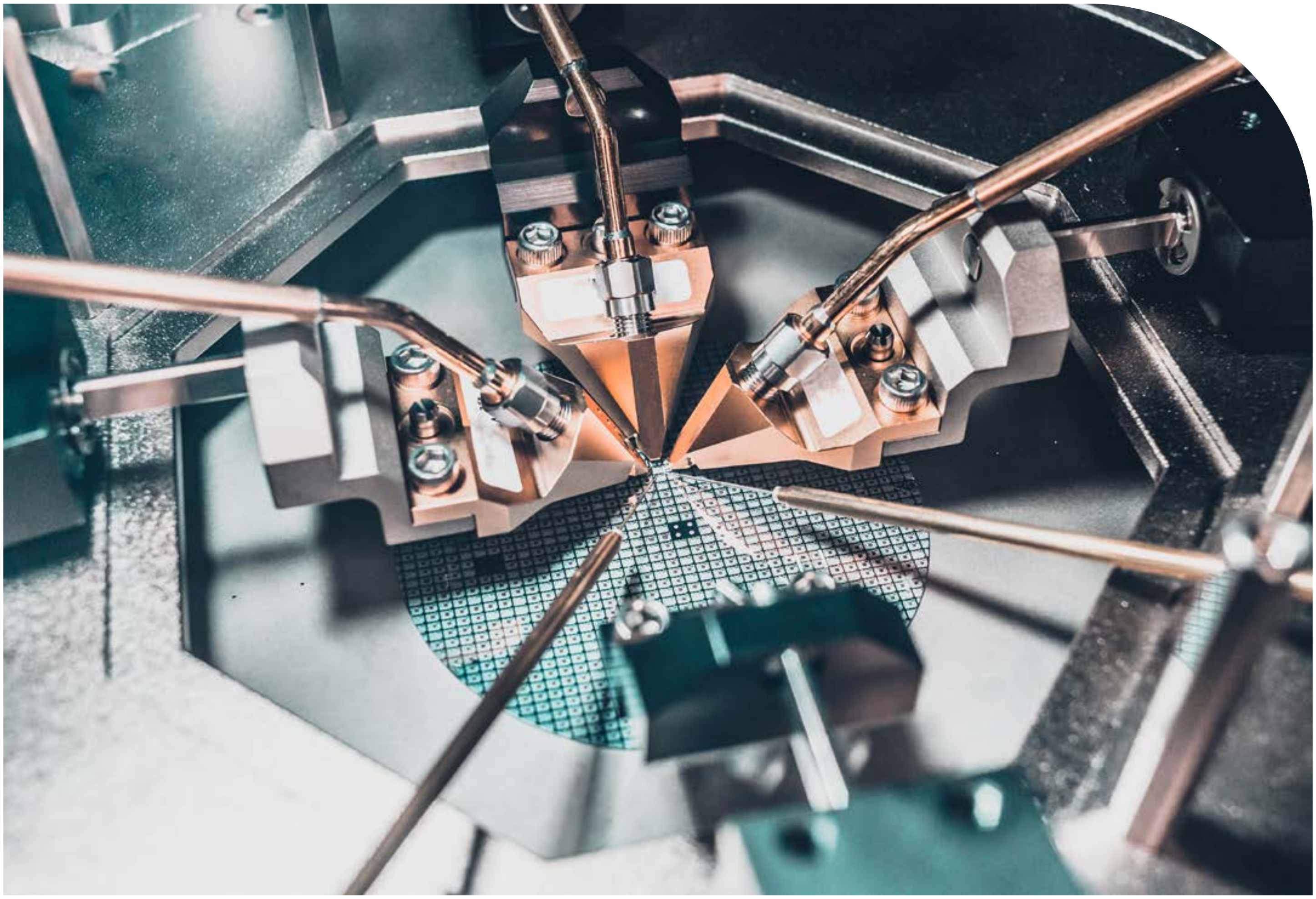
CV/IV Measurement Systems with PXIe-4190 LCR Meter and SMU



Many semiconductor elements and devices require both current voltage (IV) and capacitance voltage (CV) measurements to extract critical information about a manufacturing process or validate device performance. Traditionally, IV measurements are made with a source measure unit (SMU) and the CV measurements are made with an LCR meter, capacitance measurement unit (CMU), or impedance analyzer.

To improve testing procedures, many measurement systems have been designed to work in an automated fashion, in which no manual user interference is needed to switch between these two measurement types for a given device under test. However, many of these traditional automated systems have not adapted to semiconductor industry trends and come with challenges and limitations.

As semiconductor complexity continues to rise rapidly and time-to-market windows narrow, measurement system throughput must adapt past traditional system architectures without an exorbitant cost.



Challenges of Traditional CV/IV Measurement Systems

Rack and Stack Solutions

Rack and stack solutions are defined as boxed test and measurement instrumentation that are stacked together in a rack, sometimes with one or many switch matrices to share instrument resources. While measurement performance of a rack and stack solutions may satisfy requirements, there are significant drawbacks to this approach that should be considered.

Rack and stack systems are limited by the low channel density of traditional box instruments. These can result in bulky systems with large footprints, inconsistent programming experience, and longer test times due to heavily serialized approaches. Switch matrices may also degrade signal fidelity. Additionally, these architectures do not scale well to meet growing measurement and data requirements.

Turnkey Systems (Integrated Testers)

Integrated systems have clear advantages when it comes to an out-of-the-box, one-size-fits-most solution. However, many customers may find themselves maintaining obsolete integrated test systems in order to avoid the immense capital cost of a new system—especially when only a fraction of the functionality is needed.

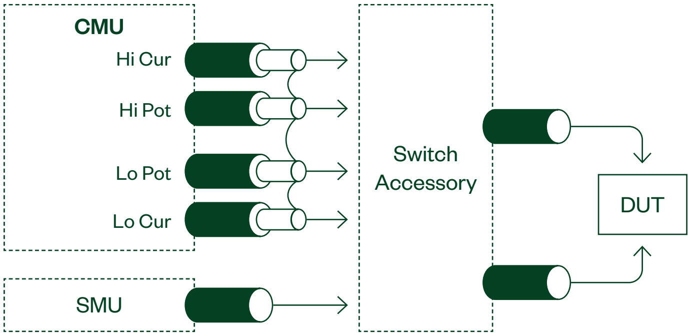
Additionally, turnkey systems do not provide the flexibility needed to modify the test software or hardware as measurement requirements change, or the modifications are prohibitively expensive.

A Better Approach: CV/IV Measurements with the PXI Platform and PXIe-4190

Whether it is a rack and stack system or an integrated tester, the underlying architecture of these traditional systems requires at least three components to realize an automated CV/IV measurement system: SMU, CMU/LCR, and a cabling assembly or switching matrix.

The new PXIe-4190 LCR Meter and SMU combines the functionality of both these instrumentation types into a single-slot PXI card—allowing for a more seamless test experience with higher throughput, higher channel density, simpler integration, and lower cost of ownership—all complemented by our powerful software driver and portfolio of supporting PXI instruments. No switch accessory required.

Traditional CV/IV Measurement System Architecture (Simplified)



NI CV/IV System Architecture (Simplified)

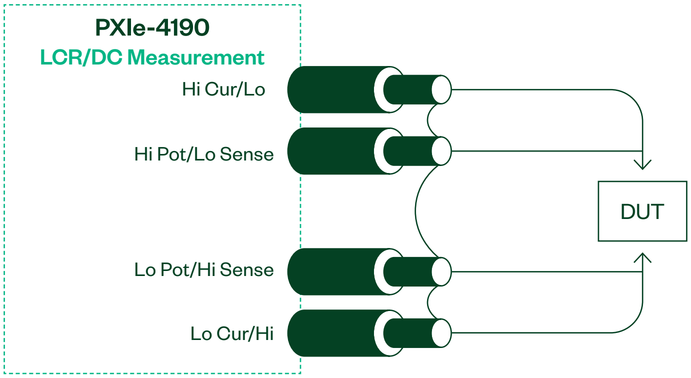


FIG 1 Reduce CV/IV measurement system complexity with the PXIe-4190.

This approach allows users to build high-channel-count IV/CV systems for parallel execution at a competitive cost and small footprint. In addition, the feature set and specifications of the PXIe-4190 allow it to be used in a wide variety of applications due to its single-digit fA current resolution and fF-class capacitance measurement capability. Our open, modular platform also allows users to tailor and optimize their systems as needs change over time.

NI PXIe-4190: A Deeper Look

Best of Many Worlds

Users looking for an accurate solution that can be used across a wide range of devices and impedances typically choose an LCR Meter and High Precision SMU for their measurement needs. The PXIe-4190 has the benefit of featuring capabilities that straddle both of these instrument types with best-in-class quality and performance.

Key Features:

LCR Meter with fF-class capacitance measurements

- Frequency: 40 Hz – 2 MHz
- DC bias: ± 40 V, ±100 mA
- AC Stimulus: 7.07 Vrms

SMU with fA-class current measurements

- ± 40 V (AC+DC), ± 100 mA
- 1 nA to 100 mA current ranges

NI DC-POWER driver support for LabVIEW, C, C# .NET, and Python

Instrument Benefits

- NI PXIe-4190 SMU circuits provide extensive DC bias capability in LCR mode which improves precision and accuracy normally found in an LCR meter.
- Utilization of the latest high-speed ADCs enable extremely fast measurements and are complemented with high-precision ADCs to provide precision at lower frequencies.
- LCR + SMU architecture enables CV and IV measurements without a switch at the connections to the DUT.
- Outer shield provides return currents for LCR mode and guarding to enable low current measurements in SMU mode.

PXIe-4190 Block Diagram

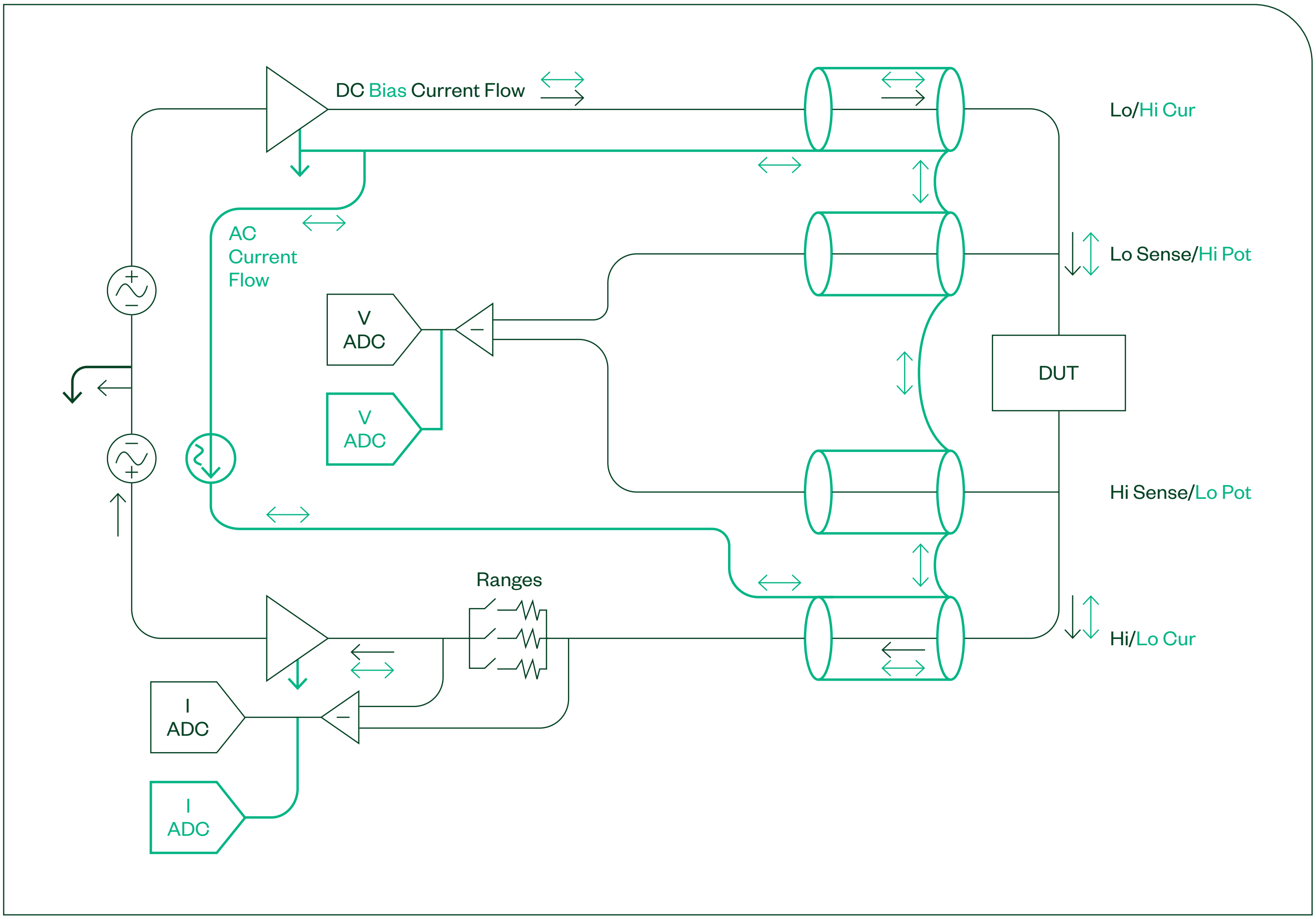


FIG 2 SMU + LCR architecture enables CV and IV measurements without a switch at the connections to the DUT.

Semiconductor Applications and CV/IV Measurements

MEMS Structure Electrical Test

The world of microelectromechanical systems (MEMS) technology is full of extremely small and precise micro-fabricated devices that require very accurate test instrumentation with a high level of repeatability in measurements.

As MEMS business grows due to ever-increasing complexity of applications and smart devices, optimizing yield has become paramount to lowering production costs. This can be accomplished through electrical testing early in the MEMS fabrication process.

When compared to traditional device testing, MEMS testing throughput is typically low due to the need for mechanical stimuli such as pressure, acceleration, and/or sound waves to test and characterize the device. While this is still necessary in final test, performing electrical modeling tests earlier in the fabrication process has significant benefits in gaining earlier, faster insight to yield optimization.

Electrical tests such as impedance measurements do not require these mechanical stimuli—so throughput can be improved. While the stability of mechanical stimuli is difficult to control, electrical stimuli and measurements are easier to maintain, which improves repeatability. Repeatability of the tester is key to improving yields.

For example, in the case of a MEMS sensor such as pressure sensors, accelerometer sensors, and microphones, mechanical displacement can be detected by capacitance change. This mechanical displacement can also be controlled by a DC bias voltage across the movable and fixed electrodes of the device through generation of an electrostatic force. Therefore, a correlated relationship between physical quantities and DC voltage can be determined through DC bias sweeps and measuring the associated capacitance across the sweep.

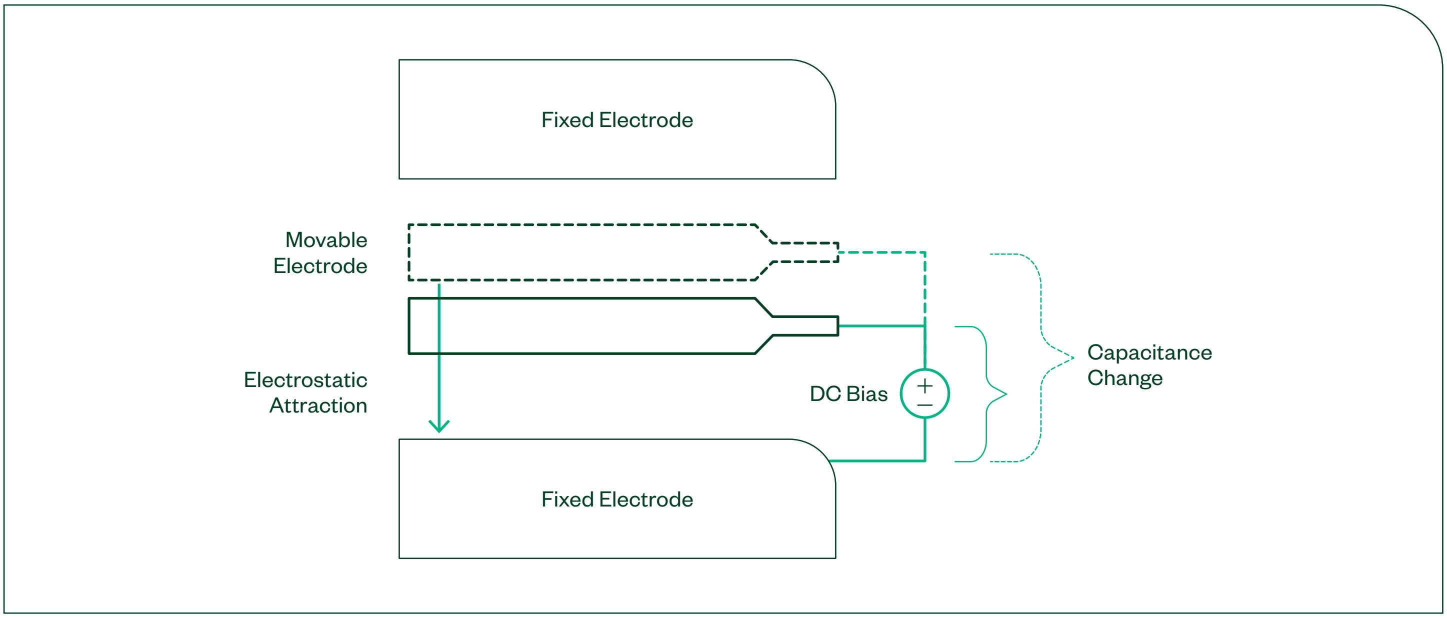


FIG 3 Mechanical displacement of a moveable electrode can be controlled by a DC bias voltage.

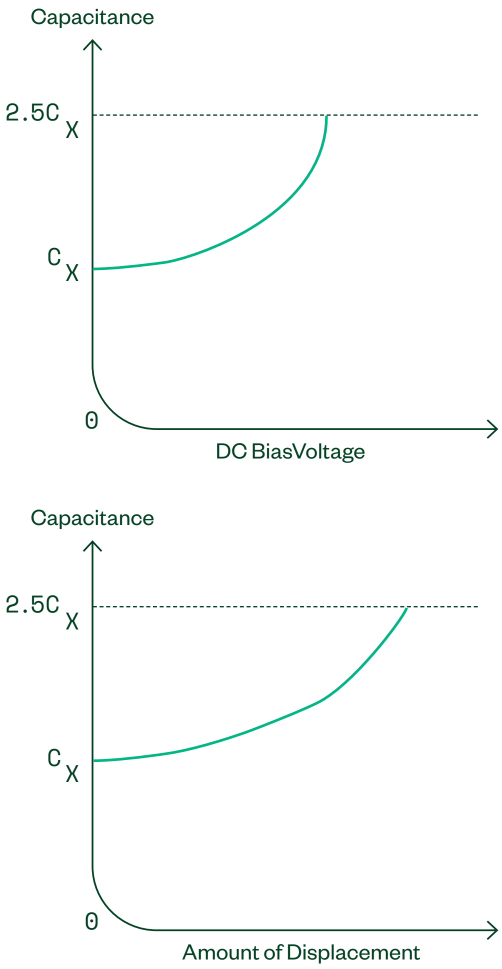


FIG 4 The mechanical displacement of the moveable electrode corresponds to a change in capacitance

MEMS devices also commonly conduct DC leakage current measurements as an effective test for quality management. This is typically done with a separate SMU, ammeter, or high-resistance meter.

The PXIe-4190 LCR Meter and SMU can cover both AC and DC MEMS electrical test needs—all in one module.

Wafer-Level Parametric and Acceptance Test

In general, wafer-level parametric testing involves the electrical testing and characterization of four main types of semiconductor devices: resistors, diodes, transistors, and capacitors.

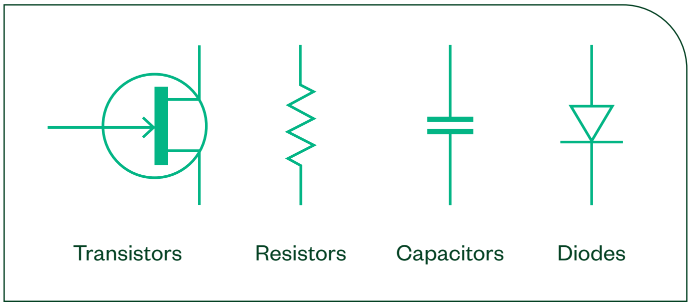


FIG 5 Common 2-Terminal and 4-Terminal Test Structures

Most of parametric testing involves current versus voltage (IV) and capacitance versus voltage (CV) measurements with the intention of revealing qualities of the fabrication process itself.

This sort of parametric testing may happen earlier on in the fabrication process for process development or wafer-level reliability (WLR), or even later for process control monitoring (also referred to as wafer acceptance test).

In the red ocean of the semiconductor industry, data velocity and depth from these types of tests can have an immense impact on technical and business success. Competition across foundries and fabrication facilities is increasingly fierce, and many users are burdened with maintaining aging fleets of integrated testers that are not flexible enough to adapt over time, prompting a search for a more ergonomic alternative.

To keep up with demand and trend semiconductor companies need flexible, supportable, efficient, and accurate measurement systems. NI's LCR Meter and SMU combination instrument, along with the rest of the PXI Platform, is the system that rises to those requirements.

By rolling both CV and IV capabilities into one instrument with the PXIe-4190, users will have a simpler and more efficient parametric test solution.

Footnotes/Related Links

LCR Product Overview Page

LCR Spec Doc and/or User Manual

ni.com/semiconductor