Wafer Level Reliability Systems

Comprehensive, highly scalable solutions for today's reliability test needs and tomorrow's technology

KEITHLEY

Only Keithley delivers the industry's most comprehensive range of solutions for WLR testing and analysis

Scalable, flexible hardware configurations that adapt to changing reliability test needs economically

Protect your hardware investment by preventing premature obsolescence

The speed and accuracy advanced technology development applications demand

Get the tools to take on the 45nm and 32nm process nodes

Compliant with many JEDEC standard test methodologies

Create new test routines quickly to characterize advanced nanoscale structures

Produce lifetime predictions 2-5× faster than conventional WLR test solutions

Accelerate technology development, process integration, and process monitoring for faster time to market

Want greater reliability testing confidence from the lab to the fab?

Keithley Instruments has long been an industry leader in both overall parametric test technology and Wafer Level Reliability testing. Several generations of Keithley's parametric test solutions have offered WLR test algorithm libraries as options. That gives us decades of experience to draw upon in creating integrated hardware and software solutions for emerging test needs in device characterization, semiconductor parametric test, and electrical parametric process monitoring. Our years of working with WLR users at every technology node have given us an in-depth understanding of the changing needs associated with reliability testing.

Need reliability test solutions that deliver greater speed and simplicity?

Our Integrated WLR Test Systems, based on our Automated Characterization Suite (ACS), let you produce lifetime predictions from two to five times faster than conventional WLR test solutions. By accelerating WLR testing during technology development, process integration, and process monitoring, ACS WLR test systems slash time to market for new products. They also have the built-in system scalability and configuration flexibility you need to protect your hardware investment, preventing premature obsolescence as your product mix evolves beyond existing materials and processing technologies. This not only minimizes your capital expenses but minimizes disruptions by allowing you to continue using familiar, already proven systems.

Applications

- Device Reliability
  - HCI
  - NBTI
  - PBTI

- Gate Oxide Integrity
  - TDDB
  - V_{RAMP}
  - J_{RAMP}

- Metal Interconnect
  - Isothermal EM
  - Poly Heater
  - Constant Current
  - ILD TDDB

The highly scalable and flexible architecture simplifies configuring an ACS WLR system to match your specific testing requirements or upgrade an existing one to handle new test needs as they evolve.

What's your old reliability tester missing?
Find out with ACS WLR.

Processing smaller devices demands the ability to acquire ever-larger data sets. Keithley's ACS WLR systems are engineered to let you acquire that huge mass of data quickly and accurately, then turn it into the material knowledge, device knowledge, and process knowledge you need to bring new devices to market faster.

Comprehensive WLR Testing
ACS WLR integrated test systems offer comprehensive single-device and parallel-device WLR testing capability. Largely based on our innovative Series 2600A System SourceMeter® instruments, these systems provide unmatched testing speed and accuracy via an SMU-per-pin architecture. Standard configurations can support more than 40 SMUs in a single rack for true parallel WLR characterization applications.

The ACS WLR architecture supports both high voltage (200V) and high current (1.5A) sourcing and measurement to every test structure pad. Whether you are testing thick oxide or advanced gate stacks, you can characterize lifetime acceleration with a single touchdown—every SMU can be programmed independently so that splits can be performed on a single structure.
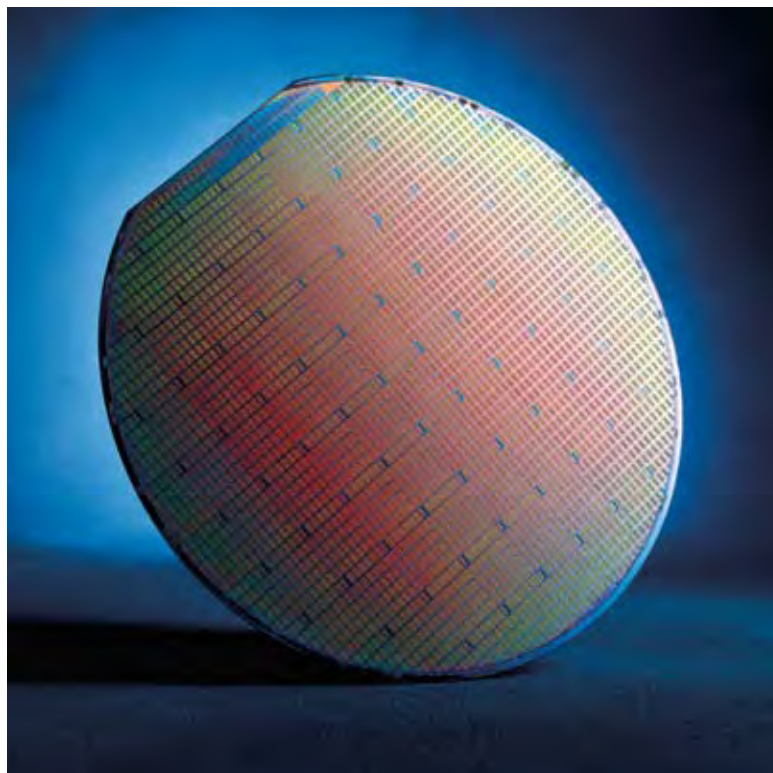
- Reliability Test Module (RTM) complies with JEDEC standard test methodologies

- Create new test routines quickly and easily with RTM and characterize advanced nanoscale structures or emulate existing WLR test methods

- Flexible test setup editor and sequencing capabilities support pre- and post-testing, as well as intra-stress testing and stress monitoring

- Built-in database engine provides a simple-to-use file structure for selecting, merging, exporting, archiving, and retrieving results

- Integrated formulator allows simple point-and-click analysis

- Optional off-line analysis module (ACS Data Analysis) lets you import results from the database, eliminating the need to create custom analysis software or manipulate data manually with spreadsheets

- SMU-per-pin hardware configuration for parallel testing of multiple sites allows for increased system throughput by a factor of 2–5×

- Scalable, modular system architecture lets you economically grow your system as necessary just by adding SMUs

- Test results can be logged into the database and/or plotted in real time

- Series 2600A System SourceMeter instruments (SMUs) ensure wide dynamic ranges and high measurement throughput

- Built-in software support for popular probers and hot chucks

- Both wafer- and cassette-level automation

Need to get from "data" to "decision" sooner?

The latest ACS WLR systems leverage the parallel test power of Keithley's ACS software with the addition of a powerful Reliability Test Module (RTM), which provides an intuitive, interactive, no-coding-required environment for setting up stress/measure sequences. The RTM supports traditional JEDEC standard reliability tests and is flexible enough to accelerate the development of the new test methodologies necessary to characterize emerging technologies. RTM projects for TDDB, J_{RAMP}, V_{RAMP}, HCI, Isothermal Electromigration, and NBTI are included. An integrated formulator populated with standard parametric extraction calculations allows easy point-and-click analysis. A variety of modeling, line fitting, and standard math functions allows custom data manipulation without programming.
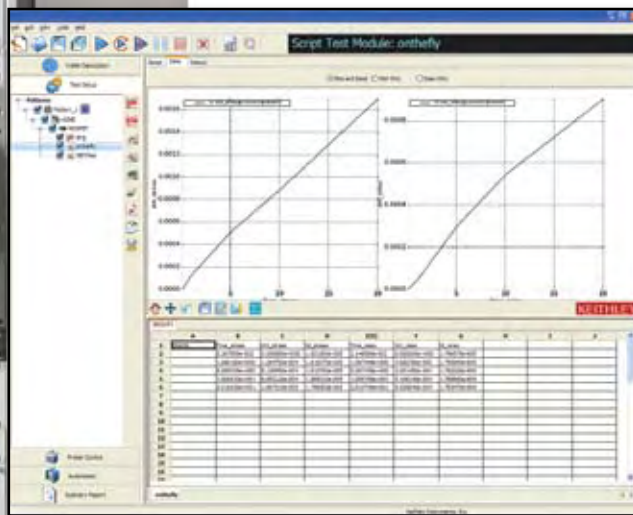
Data Analysis Capabilities

An optional off-line data analysis capability designed to pull data from the system's database is available. ACS Data Analysis software is optimized for lifetime calculations for all major device reliability needs. It supports standard analysis including normal fitting, acceleration and distribution models such as Lognormal and Weibull. A built-in scripting language makes it easy to define your own models. If you already have custom analysis tools and you want to continue using them, ACS WLR provides software tools that simplify the extraction of data from the system database.

Log raw reliability data into the database and/or plot it in real time while testing is still going on. This "sneak peek" at a test's outcome lets you know early whether time-consuming tests are on track to deliver meaningful results.

Flexible Data Aquisition and Analysis

This flexible analysis environment is optimized for working with the massive data sets common in WLR testing. So you can stop juggling countless Excel files, complex macros, and spreadsheets. Once you've defined an analysis process, it's easy to reuse—there's no need to copy and paste data from various CSV files as you do with some competitive solutions.

Thought you needed more flexibility than a single test solution could deliver?

Within an ACS WLR integrated test system, multiple Series 2600A SourceMeter units are networked together via their on-board processors and the TSP-Link® virtual backplane. This architecture provides high precision source/measure timing to capture fast time-resolved breakdown events. Because the ACS WLR system dynamically reallocates resource connections, the array of SMUs in the system is automatically instructed either to work together as a single tightly coordinated group or as several small groups operating in concert to characterize several devices.

For parallel testing, test scripts are pre-loaded into each "master" Series 2600A instrument and stored in its memory. Once triggered, the ACS WLR system controller issues a function call to each group's master, which executes the script in coordination with the other units in that group. The controller then scans the bus to receive the test results from the master instruments.

Each Series 2600A System SourceMeter instrument has an embedded Test Script Processor (TSP®) that allows you to program it with high speed test scripts to operate independently from the ACS WLR system's controller. This simplifies maintaining tight control of currents in applications such as isothermal electromigration and poly heaters (for HCI, BTI, mobile ion, etc.). The thermal control loop is closed within the SMU hardware itself, eliminating time-consuming interaction with the control computer.

Model 4200-SCS Semiconductor Characterization System

Model 4200-PIV-A Option setup
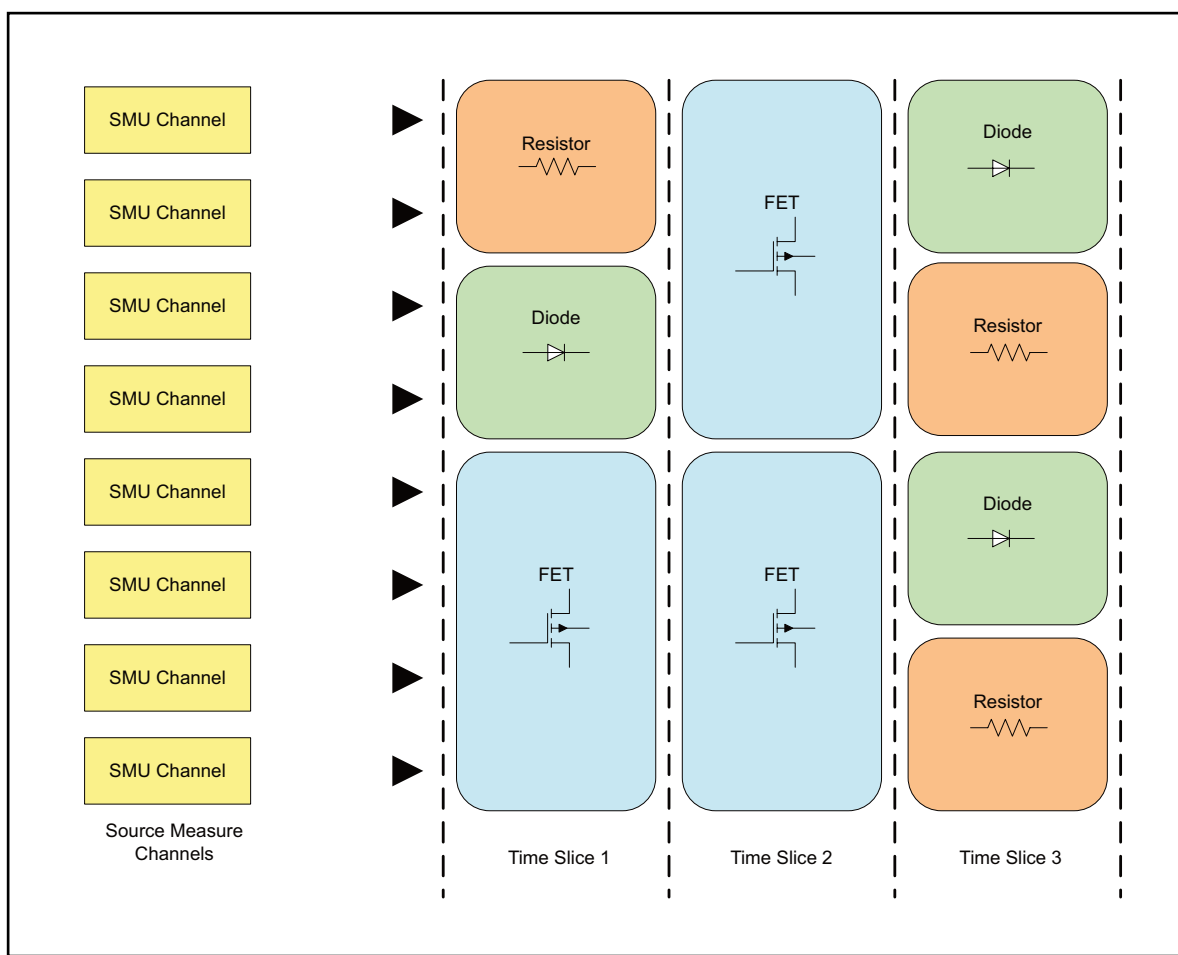
For applications that demand the ultimate in testing flexibility, ACS not only incorporates the software tools necessary to control multiple Series 2600A SMUs, but the Model 4200-SCS Semiconductor Characterization System and its pulse testing and capacitance-voltage testing options as well. This means that advanced characterization techniques, such as single-pulse charge trapping, pulse I-V sweeps, and charge pumping, can be combined with DC techniques in a single system with an integrated software platform. Multi-channel source capabilities up to 1A and 200V and measurement resolution down to 100aA and 1μV make the Model 4200-SCS suitable for a wide variety of devices and technologies.
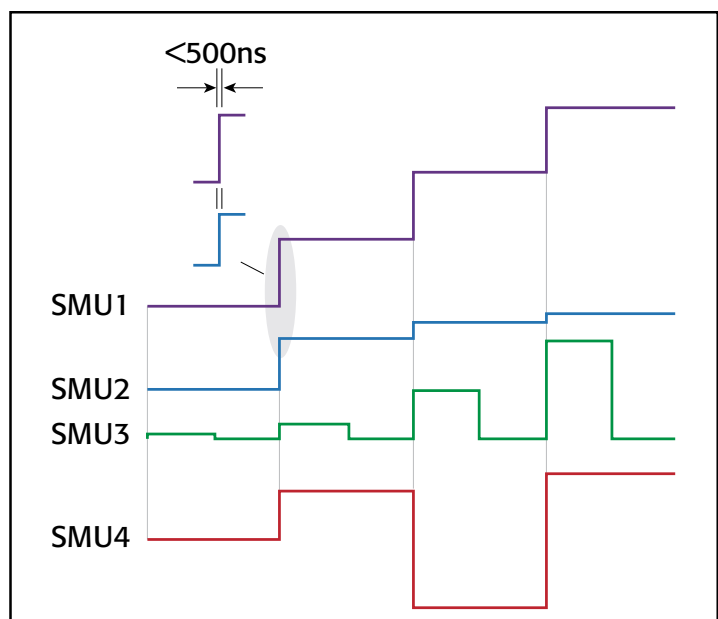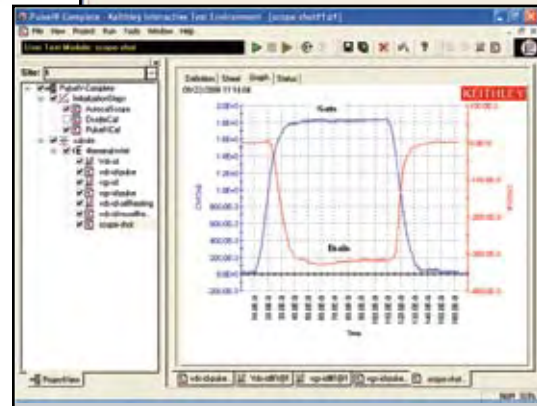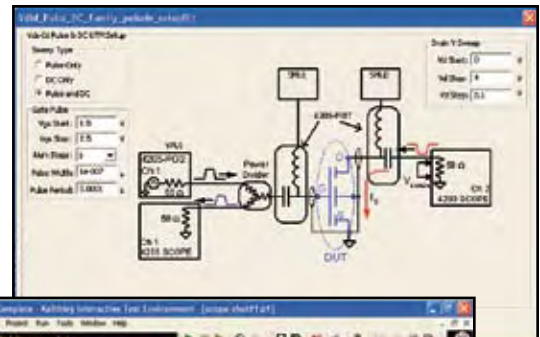
Model 4200-SCS options include:

– Multi frequency C-V module

– Pulse I-V option for pre/post WLR characterization

Traditional stress/measure techniques for NBTI characterization just can't deliver the speed needed to capture real device degradation and predict device lifetimes. ACS WLR systems support three different NBTI characterization techniques:

■ **DC On-the-Fly:** Makes measurements at the stress condition then extracts the device's degradation at the operating condition.

■ **Pulse On-the-Fly:** Uses a series of very short pulses to capture the complete I-V curve before and during stress and extracts VTH directly.

■ **Fast DC NBTI:** Measures a single point (ID) directly at the operating condition as fast as possible.

Series 2600A SourceMeter Instruments provide deterministic timing for WLR testing.

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Need a system equipped to handle tomorrow's challenges as well as today's?

From high speed pulse I-V testing to traditional C-V measurements, the Model 4200-SCS Semiconductor Characterization System provides the broadest range of characterization capability available in a semiconductor parametric analyzer. Measurement hardware includes precision medium- and high-power SMUs with optional preamps for ultra low-level current measurements. High-performance, high-channel-count switching options are also available.

The Model 4200-SCS's pulse I-V capabilities are ideal for characterizing very fast phenomena such as charge trapping/detrapping and isothermal behaviors. The pulse I-V options include a dual channel PG2 pulse generator card and dual channel SCP2 (standard resolution) or SCP2-HR (high resolution) oscilloscope card, as well as the complete interconnect and software for performing tests such as single pulse charge trapping (SPCT), charge pumping, and pulse I-V characterization. PIV measurements can also reveal the full performance of a FET independent of charge trapping and thermal effects. Combining stress cycling with PIV measurements provides unparalleled visibility into stress-induced trap generation.

When incorporated into an ACS WLR system, either with or without Series 2600As, the Model 4200-SCS becomes a self-contained fully automatic characterization system. ACS provides wafer and cassette level automation and runs directly on the 4200-SCS's internal PC controller. Regardless of the hardware configuration, ACS WLR systems can drive test results to the database for analysis with ACS Data Analysis software.

The Model 4200-FLASH option provides all the hardware and software needed to add FLASH memory reliability testing capabilities. The Model 4205-PG2 pulse generator supports up to 20V pulsing to accommodate FLASH memory cell technology.

MODEL 4200-SCS CAPABILITIES			
DC I-V	SMU measurement range	Voltage	1µV/200V
		Current	0.1fA/1A
	SMU measurement resolution	Voltage	1µV
		Current	0.1fA
	SMU measurement accuracy	Voltage	100µV
		Current	10fA
Capacitance-Voltage (C-V)	Frequency range		10kHz to 10MHz
	Measurement parameters		Cp-G, Cp-D, Cs-Rs, Cs-D, R-jX, Z-theta
	Measurement terminal configuration		Four-terminal pair
	Available sweep parameters		DC bias voltage, frequency
	Sweep type		Linear, custom
	Sweep direction		Up sweep, down sweep
Pulse I-V	Minimum pulse width of dual channel pulse generator		10ns (20ns period)
	Maximum voltage of dual channel pulse generator		±20V into 50Ω
	Dual channel digital oscilloscope sample rate		1.25 gigasamples/sec/channel

Base Level Voltage Sweep

Amplitude Sweep
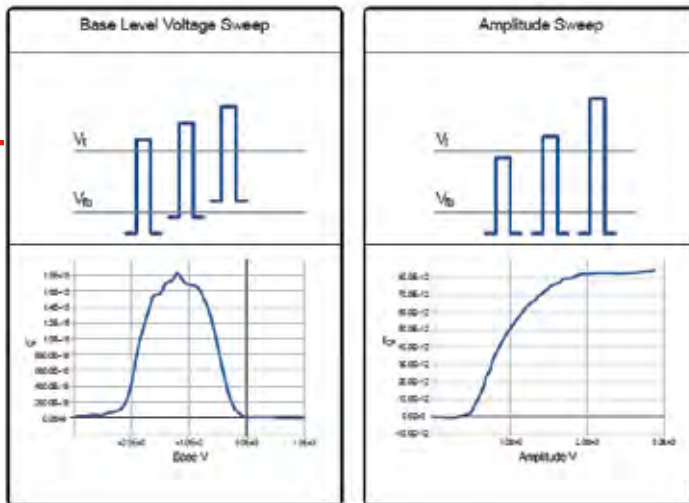
The Model 4205-PG2 Dual-Channel Pulse Generator provides voltage pulses as short as 10ns in high speed mode or up to ±20V (into 50Ω) in high voltage mode. Each Model 4200-SCS chassis can support four pulse generators for up to eight pulse generation channels. This option expands the system's applications significantly, adding charge pumping (including tri-level charge pumping), parallel AC stress for stress/measure reliability testing, basic clock generation for test vectoring and failure analysis, and digital triggering for multi-pin device testing. A new trigger-in capability makes it simple to synchronize the operation of multiple pulse channels.
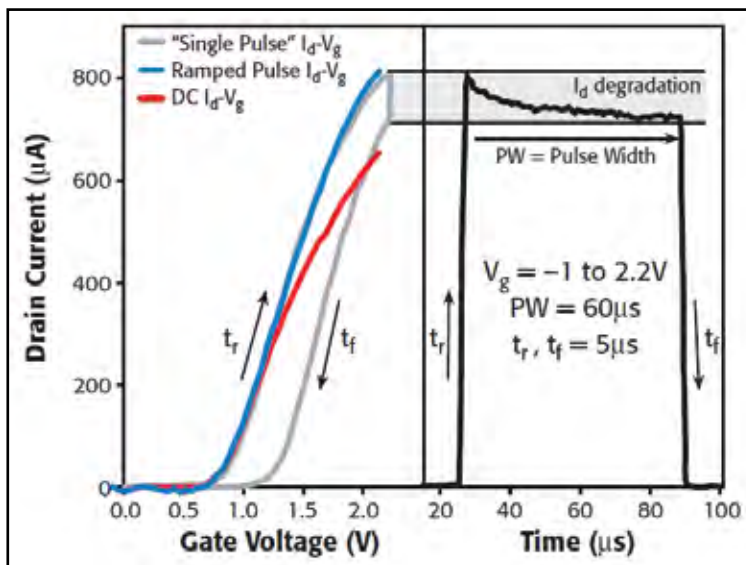
The Model 4205-PG2 supports two waveform generation modes in addition to the standard pulse capability. The Arbitrary Waveform Mode can generate complex waveforms composed of up to 256K data points at clock speeds up to 25MHz. The Segment ARB™ Mode (patent pending) simplifies the creation, storage, and generation of waveforms consisting of up to 1024 user-defined line segments. Each segment can have a different duration, allowing exceptional waveform generation flexibility, which is crucial for applications such as single-pulse charge trapping.

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How do ACS WLR systems stack up against the competition?

PERFORMANCE COMPARISON[1]

		ACS-WLR System	Competitor X	Competitor Y
Measurement Capabilities	Current Resolution (high speed ADC)	20fA	50fA	250fA
	Maximum Current	1.5A	100mA	1A
	Lowest Current Range/Offset (1nA range)	2pA	3pA	3pA
	Voltage Resolution	1µV	0.5µV	7µV
	Maximum Voltage	200V	100V	100V
	Lowest Voltage Range/Offset	300µV	300µV	250µV
	Dual (I and V) High Resolution ADC per SMU	YES	1 per 8 SMUs	NO
	Measurement Speed (minimize recovery effects)	50µs full parallel	>100µs[2]	50ms
	Maximum SMU Configuration	40 per rack	40 per Rack	8 max.
	High Power SMU Option	STANDARD	NON-STANDARD	NON-STANDARD
	Test-Specific Source/Measure Modules	Universal	Universal	Separate I and V
	Full Four-Quadrant Sources (force either I or V)	YES	YES	NO
Data Acquisition, Control, and Management	Hardware Architecture	TSP-Link® Virtual Backplane	GPIB	Proprietary Bus
	Embedded Microprocessor/Memory per SMU	YES	NO	NO
	Real Time Data Thinning and Event Detection	YES	YES	NO
	Interactive Measurements	YES	LIMITED	YES
	No-Code Test Programming	YES	YES	NO
	Interactive WLR Test Development Tool	HCI, BTI, TDDB, EM, etc.	HC/BTI Only	NO
	Advanced BTI Techniques	On-the-fly, Fast ID, etc.	OTF	NONE
	Off Line Test Development	YES	YES	NO
	Global Variables	YES	YES	NO
	Additional Cost per WLR Test	NONE	>$10,000 USD	NO
	User Interface	WINDOWS/GUI	WINDOWS/GUI	DOS
	Operating System	WINDOWS XP	WINDOWS XP	DOS
	Multiple Stress Acceleration Conditions	Per Source Unit	Per Source Unit	NO
	Extract Voltage Acceleration in Single Touchdown	Configuration Dependent	Configuration Dependent	NO
Parallel Test	Pseudo Per Pin	YES	YES	NO
	True Per Pin	YES	YES	NO
	Multi Structure	YES	YES	NO
	Multi Subsite	YES	NO	NO
	Multi Site	YES	YES	NO
	Formulator with Parametric Extractions	YES	NO	NO
	Interactive Plotting	YES	YES	NO
	Real-Time Plotting	YES	YES	YES
	Per Test/Parameter Limit Settings	YES	NO	NO
	Test Binning	YES	NO	YES
	Wafer Level Binning Plot	YES	NO	YES
	Cassette/Wafer Level Results Browser	YES	NO	NO
	Flexible Filterings and Mapping of Test Attributes	YES	YES	NO
	Standard and User-Defined Lifetime Detection	YES	YES	NO
	Manual Adjustment of Detected Events	YES	NO	NO
	Integrated Modeling Editor	YES	NO	NO
	Integrated Formulator with Parametric Extractions	YES	YES	NO
	Save and Repeat Analysis Processes	YES	YES	NO
	Hide/Restore Flyers - Plots Automatically Reflect Changes	YES	YES	NO

Notes:
1 All specifications represent typical performance at instrument terminals.
2 Each additional channel reduces the speed of the measurement sequence.

Ready to probe more complex reliability problems?

The ACS software can control fully automated probers in both cassette-level automation and semi-automatic mode (i.e., move around on a single wafer), which is useful for doing test development work or debugging. When run from the Model 4200-SCS's embedded PC, the ACS software can also control other instruments and hardware over the 4200-SCS's GPIB port and bring any resulting data back into ACS for parameter extraction and data management. Running C-V tests and controlling pulsers, switch matrices, and probers is common in R&D labs and intuitively easy to set up and operate in the ACS environment.

High precision probing is critical to characterizing the reliability and functionality of today's devices accurately. Keithley works closely with developers of both single-site and multi-site probe cards to ensure our ACS WLR systems are compatible with the developers' products and to optimize tester/card configurations to deliver accurate reliability data quickly.

Keithley's Model 9139A-PCA Probe Card Adapter supports traditional single-site reliability test applications:

■ Positive probe card mounting with a vacuum lock mechanism allows quick changing of probe cards with repeatable, highly accurate alignment

■ Motherboard accommodates 64 DUT cables; probe card contains 64 fully guarded measure and sense lines

■ Preserves full Kelvin connections to probe pin

■ Guarded source and measure lines minimize leakage currents and crosstalk for improved low current measurement accuracy

■ DUT cables can be routed to the motherboard vertically or horizontally, supporting many different probers
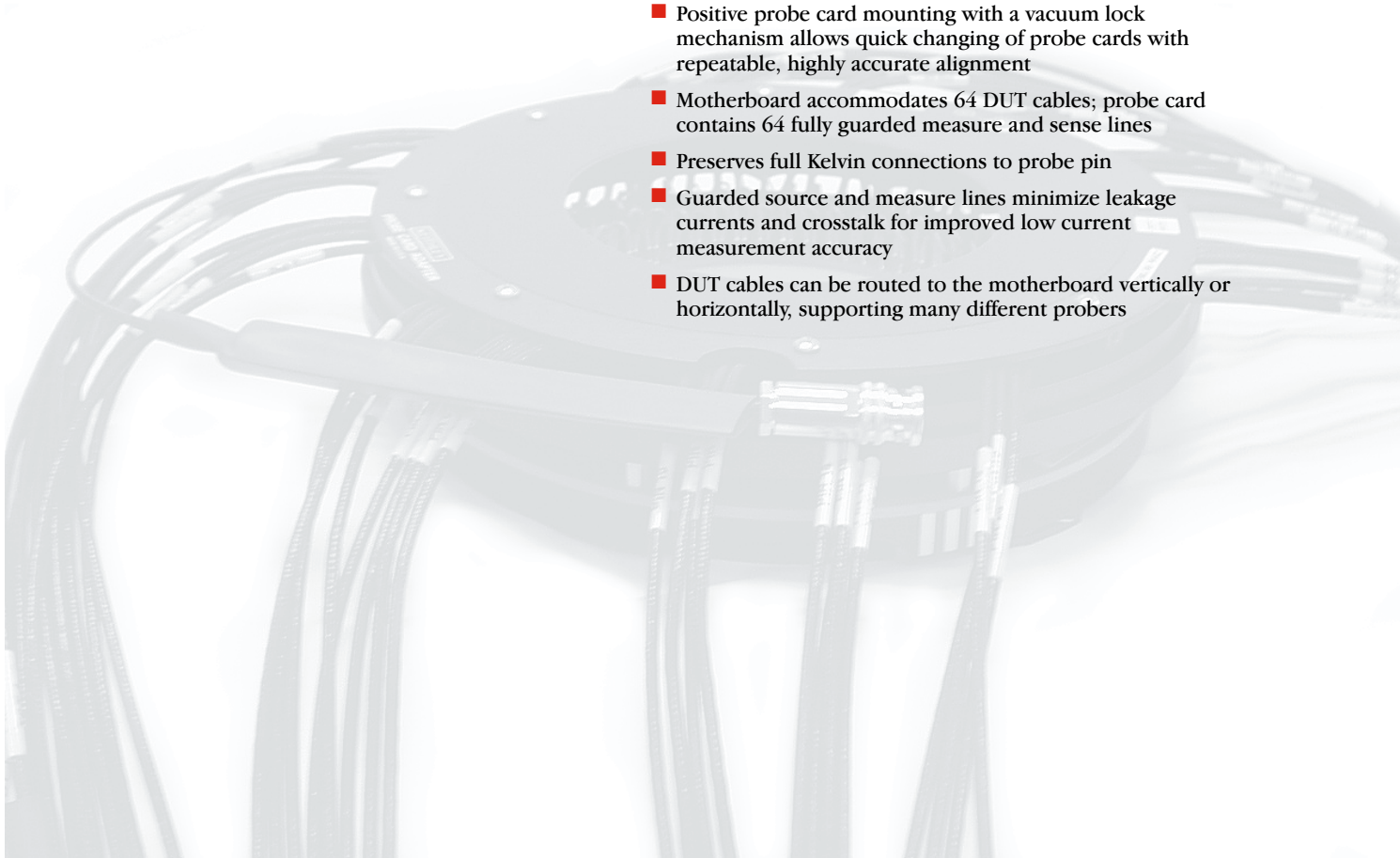
Need to maximize the return on your WLR test system investment?

System Development Services. Let us help you maximize your WLR test productivity by integrating additional instrumentation into your ACS system.

Software Services. Short of in-house programmers? We can develop custom test projects and drivers for your application or review and can optimize other software you've already developed.

Installation Services. We'll get your new system up and running quickly with services such as installation, setup, configuration, and basic user training.

Consulting Services. Our applications engineers can help you develop test plans, optimize your test processes, or take on time-consuming measurements challenges.

Training Services. We'll deliver in-depth training on system operation, making and optimizing measurements, and system troubleshooting.

Services Contracts. We'll help you avoid unbudgeted maintenance expenses and ensure ongoing system accuracy and performance.

To learn more about the advantages of Keithley's System SourceMeter instruments for semiconductor test applications, read Keithley's **Semiconductor Device Test Applications Guide** online at www.keithley.com/knowledgecenter. This informative guide includes applications and test scripts for testing diode forward characteristics, common-emitter and common-source characteristics, current gain, threshold tests, and Gummel plots. Additional applications include using multiple system channels to test multi-terminal devices. The guide also includes applications notes, white papers, and presentations to help you reduce your cost of test while simplifying the most challenging applications.

All the support you need
For applications assistance, call us on our toll-free hotline at 1-888-534-8453 from 8:00 am to 8:00 pm ET (U.S. only). For assistance beyond those hours, send our Applications Engineering Department a facsimile (440-248-6168) or an e-mail message (product_info@keithley.com). Our worldwide facilities and affiliates offer native language support services.

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