

# S540 Power Semiconductor Test System

## Datasheet



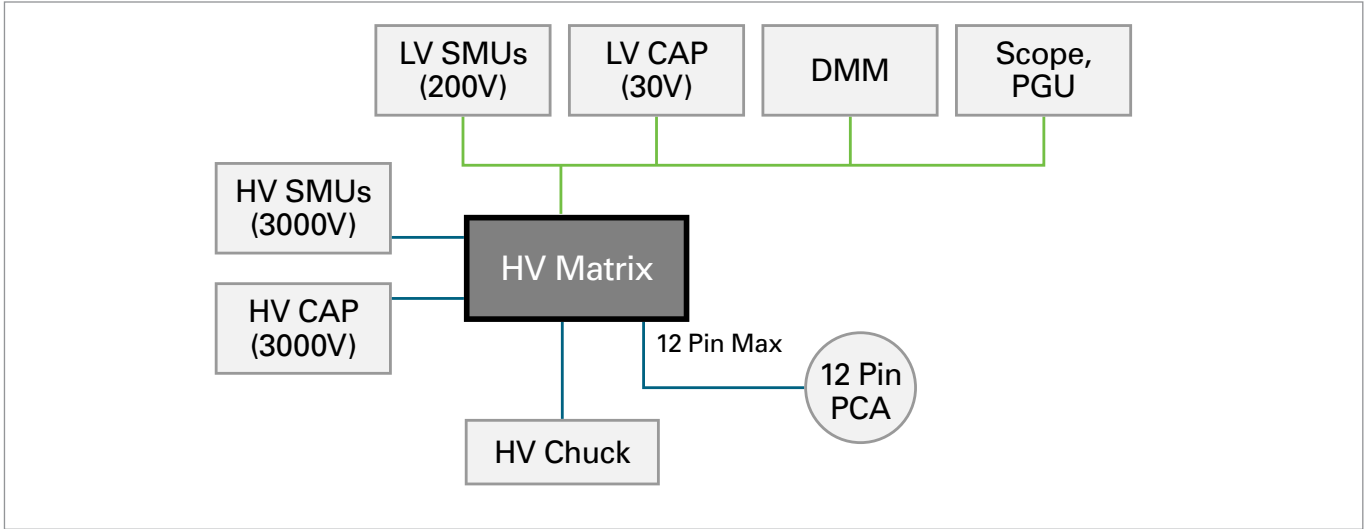
The Keithley S540 is a fully-automated, wafer-level parametric test system that can perform all high voltage, low voltage, low current, and capacitance tests up to 3kV in a single probe touch-down to maximize productivity and minimize cost of ownership. The system safely and seamlessly integrates Keithley's industry-leading measurement instrumentation with both low- and high-voltage switching matrices, cabling, probe card adapters, prober drivers, and KTE test software. The end result is a customizable 12 to 48 pin parametric test system that eliminates the need to re-configure the test setup or use two separate test systems when moving from high voltage to low voltage tests, enables fully automated 2- or 3-terminal transistor capacitance measurements, and delivers sub-pA level measurement performance.

### Key Features

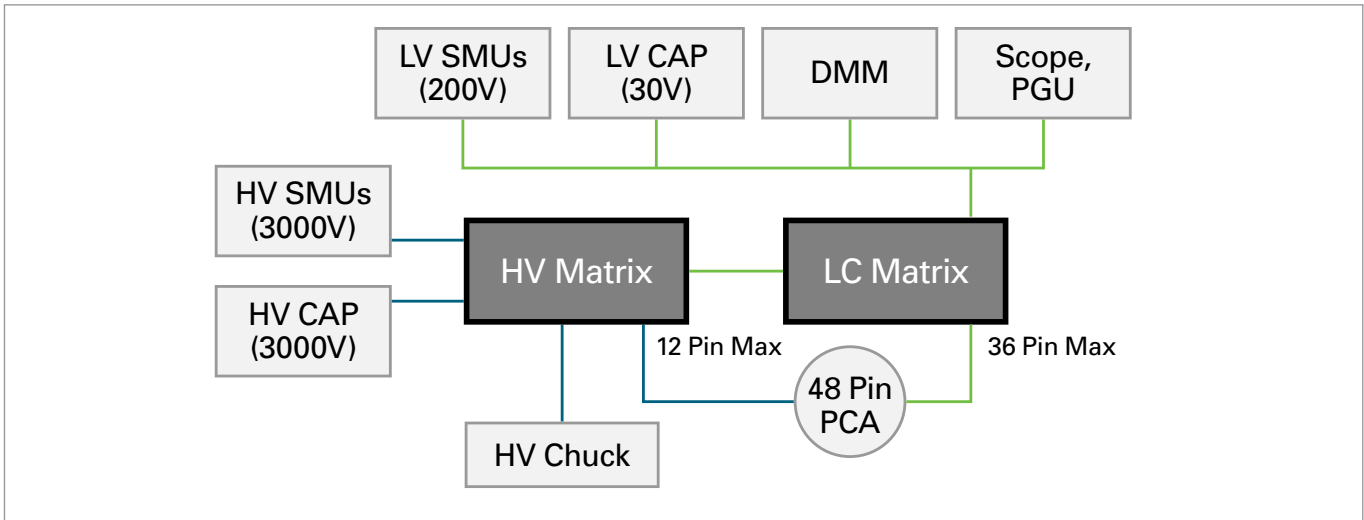
- Automatically perform all wafer-level parametric tests on up to 48 pins, including high voltage breakdown, capacitance, and low voltage measurements, in a single probe touch-down without changing cables or probe card infrastructure
- Perform transistor capacitance measurements such as Ciss, Coss, and Crss up to 3 kV without manual reconfiguration of test pins
- Achieve low-level measurement performance in a high-speed, multi-pin, fully automated test environment
- Linux-based KTE (Keithley Test Environment) system software for easy test development and fast execution
- Ideal for fully- or semi-automatic applications in Process Integration, Process Control Monitoring, and Production Die Sort
- Lowers the cost of ownership by minimizing test time, test set-up time, and floor space while achieving lab-grade measurement performance

### Complete, Single-pass Parametric Testing up to 3 kV

The S540 is optimized for use in environments with a broad mix of products, and can be configured as a 12, 24, 36, or 48 pin system. There are two main configurations: The basic high voltage configuration has 12 pins, while the high voltage / low current configuration has 12 pins of high voltage and up to 36 pins of low current. Both configurations support multiple SMU (Source Measure Unit) channels, two- and three-terminal capacitance measurements, differential voltage measurements, as well as pulse and frequency measurements. All test pins connect to a single probe card, therefore enabling all tests to be performed in a single probe touch-down to maximize productivity and minimize cost of ownership.



Block diagram of the 12 pin High Voltage S540 Configuration.



Block diagram of the 12 to 48 pin High Voltage / Low Current S540 Configuration.

## Fully Automated, Two- and Three-terminal Capacitance Measurements up to 3 kV

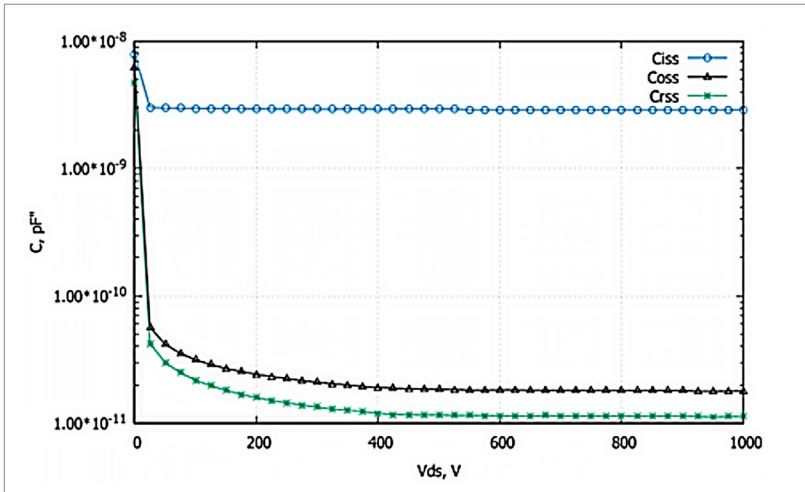
In addition to the typical 2-terminal capacitance measurements performed in fully automated production applications, the S540 can also perform 3-terminal transistor capacitance measurements typically found in semi-automatic R&D and process integration applications. Testing can be done at bias voltages up to 3 kV and at frequencies up to 1 MHz. The S540 performs these 3-terminal measurements, such as Ciss, Coss, and Crss, automatically and without manual reconfiguration of the

test pins. This speeds up testing and ultimately time-to-market by enabling more device data to be collected more quickly.

Since typical capacitance meters have internal bias voltages of less than 100 V, measuring the capacitance of high voltage power semiconductors requires the use of an external voltage source and Bias-Ts. Unlike other high voltage parametric measurement solutions, the S540 uses a system-level “open-short-load” compensation technique for ensuring the Bias-Ts do not inject errors into the measurements. This results in lab-quality capacitance measurements in a fully automated, production environment.

## High-Speed, Low-Level Measurement Performance

As the efficiency of today's power semiconductor designs increases, device leakage currents and on-resistances are



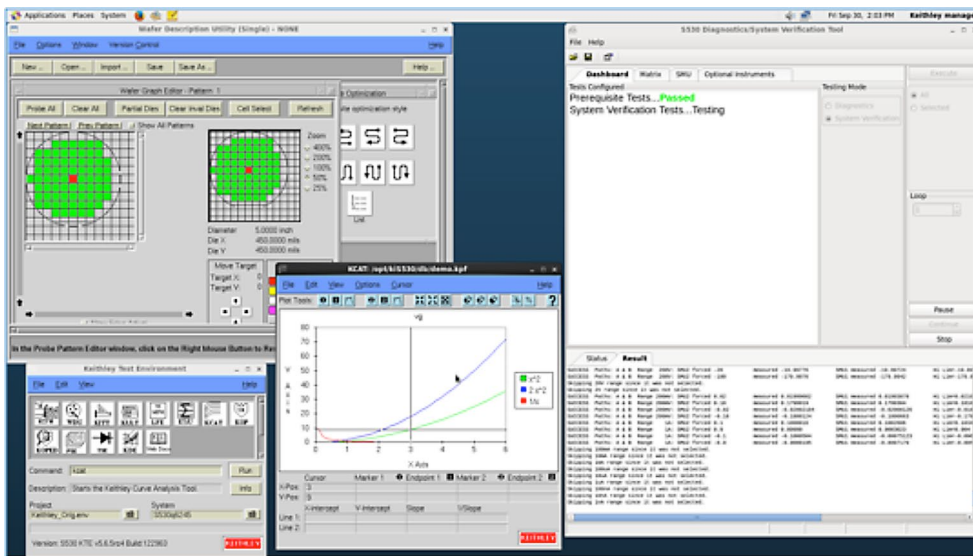
The S540 can perform fully automated, lab-quality three-terminal capacitance measurements.

being driven lower and lower. The S540's low current subsystem, based on Keithley's proven SMU instrument technology, provides sub pA current measurements at high voltage bias to support measurement of low current characteristics such as off-state leakage, gate leakage, sub-threshold leakage, and more. An optional high resolution digital multimeter (DMM) enables precise, micro-ohm level Rds-on measurements, as well as other differential and non-differential low voltage measurements such as metal sheet resistance, electrical critical dimensions, and more in a fully automated, multi-pin test environment.

## Powerful System Software

Keithley's S540 system features Keithley Test Environment (KTE) v5.7 software for test development and execution. KTE v5.7 delivers system-level speed improvements of up to 40% compared with KTE v5.5. Hosted on a standard industrial PC with a Linux OS, KTE incorporates decades of Keithley parametric test experience into its feature set. Measurement routines and test plans can be easily written, converted, or re-used, helping you get up and running faster. S540 software includes all the

key system software operations:



KTE software.

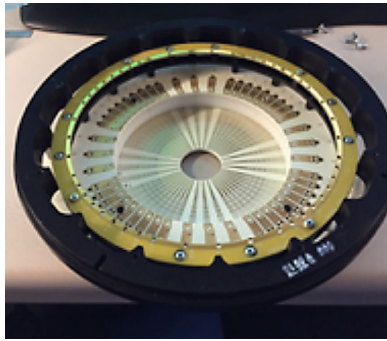
- Wafer description
- Test macro development
- Test plan development
- Limits setting
- Wafer or cassette level testing with automatic prober control
- Test data management
- User access points
- System diagnostics

### 3 kV Probe Card and Probe Card Adapter (PCA) Solutions

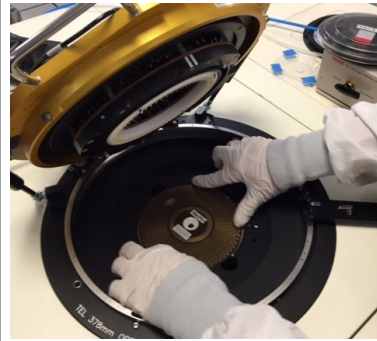
Making reliable high voltage measurements in multi-pin, fully automated production test applications present numerous challenges, including environmental, device layout, and probe design. Keithley has two qualified solutions for probing up to 3 kV while maintaining low-level measurement performance: The Keithley 9140 and the Celadon 45E. In addition, to simplify probe card mounting and dismounting, we offer the inTEST top loading probe card interface as a factory-installed option.



**Celadon High Voltage VC20™ and 45e Interface**  
 Quick change, low-leakage  
 12 pins @ 3 kV  
 32 pins @ 200 V



**Keithley 9140 Probe Card & Adapter**  
 High capacity, low leakage  
 12 pins @ 3 kV  
 36 pins @ 200 V



**inTEST Top-loading Probe Card Interface**  
 Enables quick change of probe cards

## S540 Specifications

### Configuration Guide

Key Feature	Quantity Available
<b>Number of pins (full force-sense Kelvin):</b>	
High Voltage (up to 3 kV using HV matrix) (includes 6 pin pass-thru from LC matrix)	12
Low Current (up to 200 V using 707B and 7531 matrix cards)	0, 12, 24, or 36
<b>Number of SMU channels</b>	
High Voltage (up to 3 kV using 2657A)	1 or 2
Low Voltage (up to 200 V using 2636B) (includes HV protection modules for each channel)	up to 8
<b>Capacitance Meter (using 4210-CVU)</b>	
High Voltage (up to 3 kV, includes Bias-Ts)	0 or 1
Low Voltage (up to 30 V, includes protection modules)	0 or 1
<b>High Resolution DMM (using 7510)</b>	0 or 1
<b>Pulse Generator (using 4220-PGU)</b>	0 or 1
<b>Oscilloscope (FMTR)</b>	0 or 1
<b>Industrial PC controller with Linux OS</b>	1
<b>KTE System Software</b>	1
<b>37U System cabinet with 100–240 V, 50/60 Hz power distribution (PDU), emergency off (EMO) switch, high voltage interlock, and monitor/keyboard arm</b>	1
<b>Probe Card Adapter</b>	
Keithley 9140 (48 pin maximum – 12 pin HV, 36 pin LV) Celadon (42 pin maximum – 12 pin HV, 30 pin LV) Customer Supplied	Choose One

The S540 is a fully configurable system. Choose the configuration to meet your application requirements.

### DC Current / Voltage Measurements

Measurement Type	SMU Instrument	Power	Range
High Voltage	Keithley 2657A	180 W	1 fA to 120 mA; 100 $\mu$ V to 3000 V
Low Voltage	Keithley 2636B	20 W	1 fA to 1.5 A; 1 $\mu$ V to 200 V

### Capacitance Measurements (2- and 3-terminal capacitance measurements including Ciss, Coss, Crss)

Measurement Type	Capacitance Meter	DC Bias Voltage	Frequency	Range
High Voltage	Keithley 4210-CVU	3000 V <sup>1</sup>	10 kHz, 100 kHz, 1 MHz	100 nF – 10 pF
Low Voltage	Keithley 4210-CVU	30 V	10 kHz, 100 kHz, 1 MHz	100 nF – 10 pF

1. Requires the use of 2657A SMU and Bias-T

### Differential and Low Voltage Measurements

Instrument	Range
Keithley 7510 DMM	10nV to 200V

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## Pulse Measurements

Instrument	Amplitude	Pulse Width	Pulse Transitions
Keithley 4220-PGU	100 mV to 40 V	100 nS to 1 S	50 nS to 200 $\mu$ S

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## Frequency Measurements

Instrument	Range	Amplitude
FMTR	10 kHz to 20 MHz	10 mV to 1 V rms

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## Switching Matrix - up to 48 measurement pins

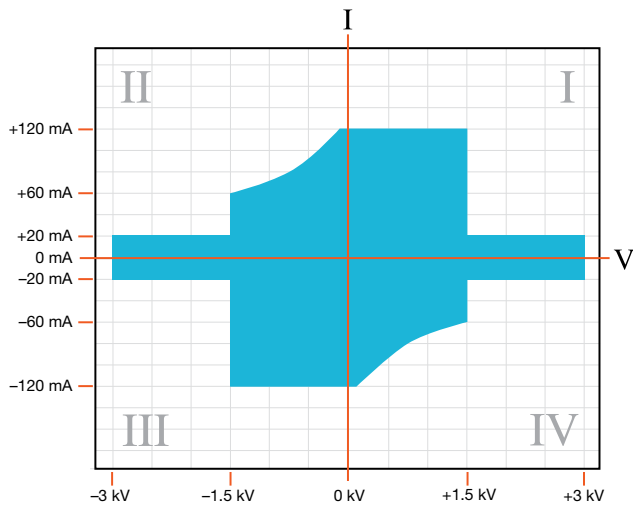
Pin Type	Max Voltage	Max Pin Count	Instrument Connections
High Voltage	3000 V	12	Up to 2 HV SMUs, 1 HVCMTTR and 6 pin pass-thru from LV switch matrix
Low Current	200 V	36	Up to 8 LV SMU channels, 1 LVCMTTR, DMM, Pulse, Frequency (all low voltage pins include over-voltage protection)

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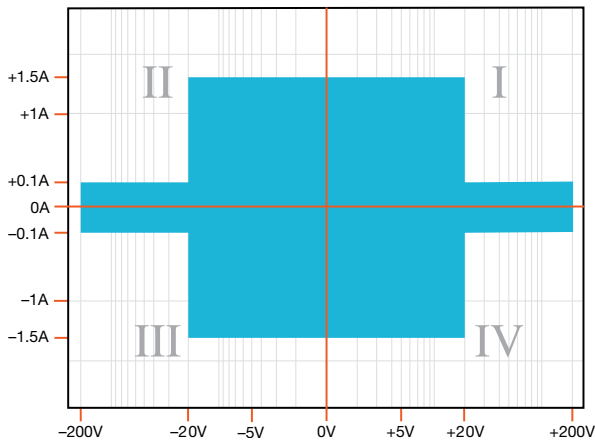
## System Specifications – Valid to the end of the Keithley or Celadon PCA

Operating Temperature	23 $\pm$ 5°C
Humidity	5%–60%
Warm up	1 hour
Integration Time	1 PLC
Calibration Cycle	1 year

## SMU (Source Measure Unit) Specifications



HV SMU (Keithley 2657A) Operating Range.



LV SMU (Keithley 2636B) Operating Range.

### High Voltage SMU (2657A) through High Voltage Matrix

		MEASURE		SOURCE	
Current Range	Resolution	Accuracy		Resolution	Accuracy
120 mA	10 $\mu$ A	0.03% + 24.0 $\mu$ A + 1.6 pA/V		3 $\mu$ A	0.03% + 36.0 $\mu$ A + 1.6 pA/V
20 mA	100 nA	0.02% + 5.0 $\mu$ A + 1.6 pA/V		300 nA	0.03% + 12.0 $\mu$ A + 1.6 pA/V
2 mA	10 nA	0.02% + 0.5 $\mu$ A + 1.6 pA/V		30 nA	0.03% + 1.2 $\mu$ A + 1.6 pA/V
1 mA	1 nA	0.02% + 200.0 nA + 1.6 pA/V		30 nA	0.03% + 300.0 nA + 1.6 pA/V
100 $\mu$ A	100 pA	0.02% + 25.0 nA + 1.6 pA/V		3 nA	0.03% + 60.0 nA + 1.6 pA/V
10 $\mu$ A	10 pA	0.03% + 1.5 nA + 1.6 pA/V		300 pA	0.03% + 5.0 nA + 1.6 pA/V
1 $\mu$ A	1 pA	0.03% + 400.8 pA + 1.6 pA/V		30 pA	0.03% + 700.8 pA + 1.6 pA/V
100 nA	100 fA	0.10% + 60.8 pA + 1.7 pA/V		3 pA	0.10% + 60.8 pA + 2.1 pA/V
10 nA	10 fA	0.10% + 10 pA + 1.6 pA/V		300 fA	0.10% + 12.0 pA + 1.6 pA/V
1 nA	1 fA	0.10% + 7.0 pA + 1.6 pA/V		30 fA	0.10% + 10.0 pA + 1.6 pA/V
		MEASURE		SOURCE	
Voltage Range	Resolution	Accuracy		Resolution	Accuracy
3000 V	1 mV	0.025% + 600.5 mV		80 mV	0.03% + 750.5 mV
1500 V	1 mV	0.025% + 300.5 mV		40 mV	0.03% + 375.5 mV
500 V	100 $\mu$ V	0.025% + 100.5 mV		10 mV	0.03% + 125.5 mV
200 V	100 $\mu$ V	0.025% + 50.5 mV		5 mV	0.03% + 50.5 mV

### Low Voltage SMU (2636B) through High Voltage Matrix

		MEASURE		SOURCE	
Current Range	Resolution	Accuracy		Resolution	Accuracy
1 A	10 $\mu$ A	0.15% + 4.5 mA + 1.6 pA/V		20 $\mu$ A	0.06% + 5.4 mA + 1.6 pA/V
100 mA	1 $\mu$ A	0.09% + 0.06 mA + 1.6 pA/V		2 $\mu$ A	0.05% + 0.09 mA + 1.6 pA/V
10 mA	100 nA	0.02% + 2.5 $\mu$ A + 1.6 pA/V		200 nA	0.03% + 6.0 $\mu$ A + 1.6 pA/V
1 mA	10 nA	0.02% + 0.2 $\mu$ A + 1.6 pA/V		20 nA	0.03% + 0.3 $\mu$ A + 1.6 pA/V
100 $\mu$ A	1 nA	0.02% + 25.0 nA + 1.6 pA/V		2 nA	0.03% + 60.0 nA + 1.6 pA/V
10 $\mu$ A	100 pA	0.02% + 1.5 nA + 1.6 pA/V		200 pA	0.03% + 5.0 nA + 1.6 pA/V
1 $\mu$ A	10 pA	0.03% + 0.5 nA + 1.6 pA/V		20 pA	0.03% + 0.8 nA + 1.6 pA/V
100 nA	1 pA	0.03% + 101.7 pA + 1.6 pA/V		2 pA	0.03% + 101.7 pA + 1.6 pA/V
10 nA	100 fA	0.06% + 4.7 pA + 1.6 pA/V		200 fA	0.06% + 6.7 pA + 1.6 pA/V
1 nA	10 fA	0.15% + 1.1 pA + 1.6 pA/V		20 fA	0.15% + 2.9 pA + 1.6 pA/V
		MEASURE		SOURCE	
Voltage Range	Resolution	Accuracy		Resolution	Accuracy
200 V	1 mV	0.02% + 50.3 mV		1 mV	0.02% + 50.3 mV
20 V	100 $\mu$ V	0.02% + 5.3 mV		100 $\mu$ V	0.02% + 5.3 mV
2 V	10 $\mu$ V	0.02% + 690.0 $\mu$ V		10 $\mu$ V	0.02% + 940.0 $\mu$ V
200 mV	1 $\mu$ V	0.02% + 565.0 $\mu$ V		1 $\mu$ V	0.02% + 715.0 $\mu$ V



## Low Voltage SMU (2636B) through Low Current Matrix

		MEASURE		SOURCE	
Current Range	Resolution	Accuracy		Resolution	Accuracy
1 A	10 $\mu$ A	0.03% + 1.5 mA + 1.3 pA/V		20 $\mu$ A	0.05% + 1.8 mA + 1.3 pA/V
100 mA	1 $\mu$ A	0.02% + 20.0 $\mu$ A + 1.3 pA/V		2 $\mu$ A	0.03% + 30.0 $\mu$ A + 1.3 pA/V
10 mA	100 nA	0.02% + 2.5 $\mu$ A + 1.3 pA/V		200 nA	0.03% + 6.0 $\mu$ A + 1.3 pA/V
1 mA	10 nA	0.02% + 200.0 nA + 1.3 pA/V		20 nA	0.03% + 300.0 nA + 1.3 pA/V
100 $\mu$ A	1 nA	0.02% + 25.0 nA + 1.3 pA/V		2 nA	0.03% + 60.0 nA + 1.3 pA/V
10 $\mu$ A	100 pA	0.03% + 1.5 nA + 1.3 pA/V		200 pA	0.03% + 5.0 nA + 1.3 pA/V
1 $\mu$ A	10 pA	0.03% + 501.1 pA + 1.3 pA/V		20 pA	0.03% + 801.1 pA + 1.3 pA/V
100 nA	1 pA	0.06% + 101.1 pA + 1.3 pA/V		2 pA	0.06% + 101.1 pA + 1.3 pA/V
10 nA	100 fA	0.15% + 4.1 pA + 1.3 pA/V		200 fA	0.15% + 6.1 pA + 1.3 pA/V
1 nA	10 fA	0.15% + 2.4 pA + 1.3 pA/V		20 fA	0.15% + 3.1 pA + 1.3 pA/V
100 pA	1 fA	0.15% + 1.9 pA + 1.3 pA/V			
		MEASURE		SOURCE	
Voltage Range	Resolution	Accuracy		Resolution	Accuracy
200 V	1 mV	0.02% + 50.2 mV		5 mV	0.02% + 50.2 mV
20 V	100 $\mu$ V	0.02% + 5.2 mV		500 $\mu$ V	0.02% + 5.2 mV
2 V	10 $\mu$ V	0.02% + 580.0 $\mu$ V		50 $\mu$ V	0.02% + 830.0 $\mu$ V
200 mV	1 $\mu$ V	0.02% + 455.0 $\mu$ V		5 $\mu$ V	0.02% + 605.0 $\mu$ V

## CMTR (Capacitance Measurement Unit) Specifications

### HVCMTR Specifications (typical)

Two terminal HVCV measurements (through HV matrix).

Capacitance	10 kHz	100 kHz	1 MHz
10 pF	10%	2%	1%
100 pF	2%	2%	2%
1 nF	0.5%	0.5%	4%
10 nF	0.5%	0.5%	7%

Three terminal HVCV measurements (through HV matrix)

100 kHz

HVCV Measurement Accuracy			
Capacitor Ratio Ciss : Coss : Crss	Ciss	Coss	Crss (1)
1nF : 100pF : 10pF	1%	5%	2%
1nF : 1nF : 1nF	1%	1%	2%
1nF : 1nF : 100pF	1%	1%	4%

1 MHz

HVCV Measurement Accuracy			
"Capacitor Ratio Ciss : Coss : Crss"	Ciss	Coss	Crss (1)
1nF : 100pF : 10pF	8%	5%	See footnote 1
1nF : 1nF : 1nF	18%	18%	See footnote 1
1nF : 1nF : 100pF	9%	9%	See footnote 1

### Notes

- Measurement of Crss requires guarding of the source. With a production system, the effectiveness of guarding is limited above 100 kHz. Measurements of Ciss and Coss do not require guarding.

## DMM (Digital Multimeter) Specifications - Keithley Model 7510

Range	Resolution	1 year accuracy
100 mV	10 nV	18 ppm rdg + 9 ppm rng
1 V	100 nV	15 ppm rdg + 2 ppm rng
10 V	10 $\mu$ V	14 ppm rdg + 1.2 ppm rng
200 V	100 $\mu$ V	22 ppm rdg + 5 ppm rng

## General Specifications and Software

<b>Cabinet Size</b>	60.0 cm wide $\times$ 91.5 cm deep $\times$ 190.5 cm high
<b>Line Power</b>	100 V, 115 V, 220 V, 240 V (50 Hz, 60 Hz)
<b>Software</b>	KTE 5.7. Includes wafer description, test macro development, test plan development, limit setting, test data management, user access points, and system diagnostics
<b>Probe Cards</b>	Keithley, Celadon, User Supplied
<b>EMC</b>	Complies with the European Union EMC Directive
<b>Safety</b>	Complies with the European Union Low Voltage Directive
<b>Certifications</b>	SEMI S2, S8, and S14
<b>Warranty</b>	1 year
<b>Support Services</b>	Contracts available for probe station integration, calibration, repair, test plan migration, and correlation studies

Note: All specifications are subject to change without notice.

Accuracy specifications are warranted through the Keithley 9140 PCA. Customer supplied PCA may provide different performance.

**Contact Information:**

**Australia\*** 1 800 709 465  
**Austria** 00800 2255 4835  
**Balkans, Israel, South Africa and other ISE Countries** +41 52 675 3777  
**Belgium\*** 00800 2255 4835  
**Brazil** +55 (11) 3759 7627  
**Canada** 1 800 833 9200  
**Central East Europe / Baltics** +41 52 675 3777  
**Central Europe / Greece** +41 52 675 3777  
**Denmark** +45 80 88 1401  
**Finland** +41 52 675 3777  
**France\*** 00800 2255 4835  
**Germany\*** 00800 2255 4835  
**Hong Kong** 400 820 5835  
**India** 000 800 650 1835  
**Indonesia** 007 803 601 5249  
**Italy** 00800 2255 4835  
**Japan** 81 (3) 6714 3010  
**Luxembourg** +41 52 675 3777  
**Malaysia** 1 800 22 55835  
**Mexico, Central/South America and Caribbean** 52 (55) 56 04 50 90  
**Middle East, Asia, and North Africa** +41 52 675 3777  
**The Netherlands\*** 00800 2255 4835  
**New Zealand** 0800 800 238  
**Norway** 800 16098  
**People's Republic of China** 400 820 5835  
**Philippines** 1 800 1601 0077  
**Poland** +41 52 675 3777  
**Portugal** 80 08 12370  
**Republic of Korea** +82 2 6917 5000  
**Russia / CIS** +7 (495) 6647564  
**Singapore** 800 6011 473  
**South Africa** +41 52 675 3777  
**Spain\*** 00800 2255 4835  
**Sweden\*** 00800 2255 4835  
**Switzerland\*** 00800 2255 4835  
**Taiwan** 886 (2) 2656 6688  
**Thailand** 1 800 011 931  
**United Kingdom / Ireland\*** 00800 2255 4835  
**USA** 1 800 833 9200  
**Vietnam** 12060128

\* European toll-free number. If not accessible, call: +41 52 675 3777



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