

정밀소자 특성 측정을 위한 커브트레이서 솔루션

텍트로닉스
김수길 부장



KEITHLEY
A Tektronix Company

Tektronix[®]

What is a Parametric Curve Tracer?

A configurable bench top system for characterizing power devices

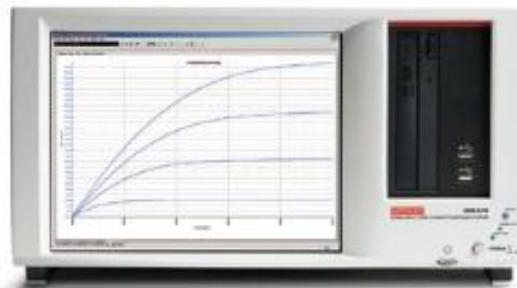
Comprehensive solution including instruments, cables, test fixture and/or prober interface, software, and test libraries

Supports both *Parametric* and *Trace* test modes

Includes the best of a Curve Tracer and a parameter analyzer



+



=



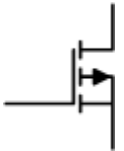
Typical Device Parameters (and many more!)

Diodes & Rectifiers



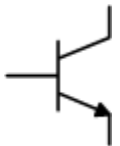
Forward Voltage (V_f)
Reverse Voltage (V_r)
Reverse Leakage (I_r)

MOSFETs & JFETs

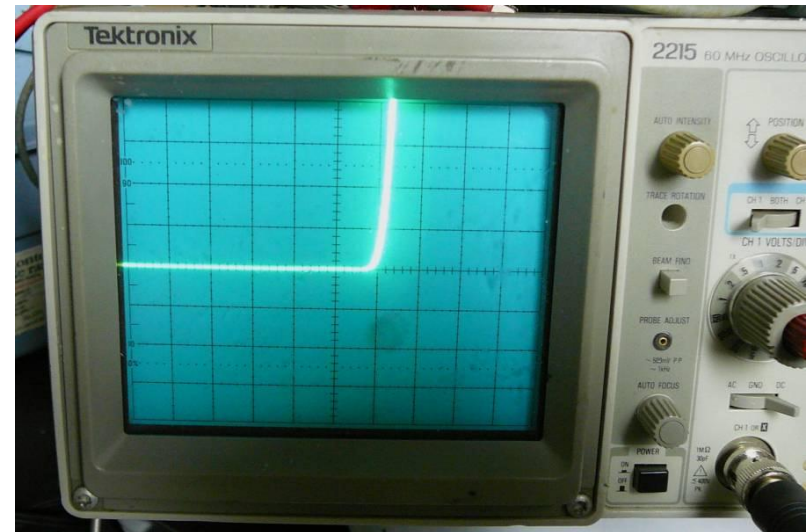
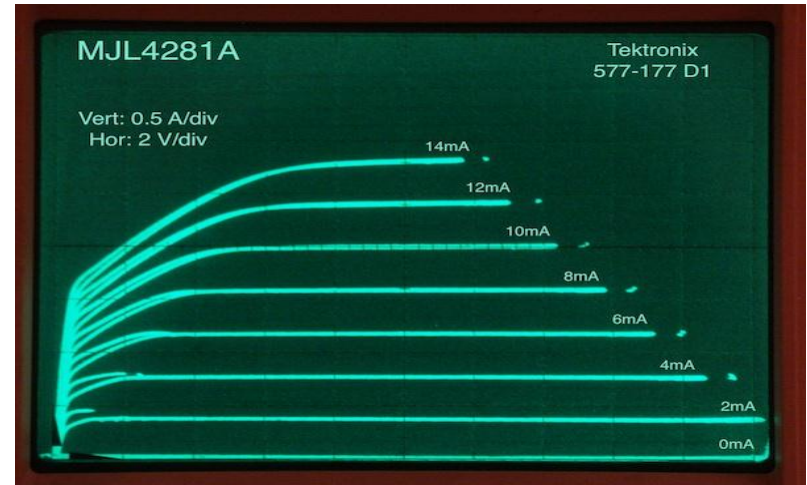


Family of Curves ($V_{ds}-I_d$)
Transfer characteristics ($V_{gs}-I_d$)
On-resistance (R_{dson})
Breakdown voltages (BV_{dss} , BV_{dg})
Leakage Currents (I_{dss} , I_{gss})

Bipolar transistors & IGBTs



Saturation Voltage (V_{cesat})
Family of curves ($V_{ce}-I_c$)
Breakdown voltages (V_{ceo} , V_{ebo} , V_{cbo})
Leakage Currents (I_{ceo} , I_{ces} , I_{ebo})
DC Current Gain (h_{fe})

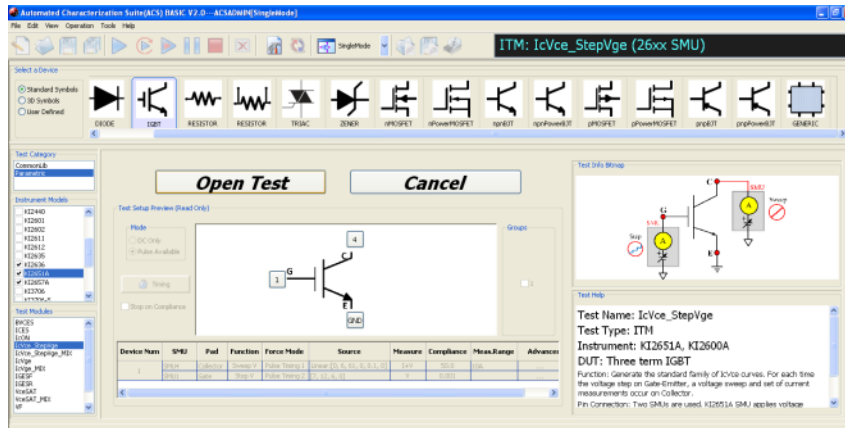


Example Libraries Included with PCT

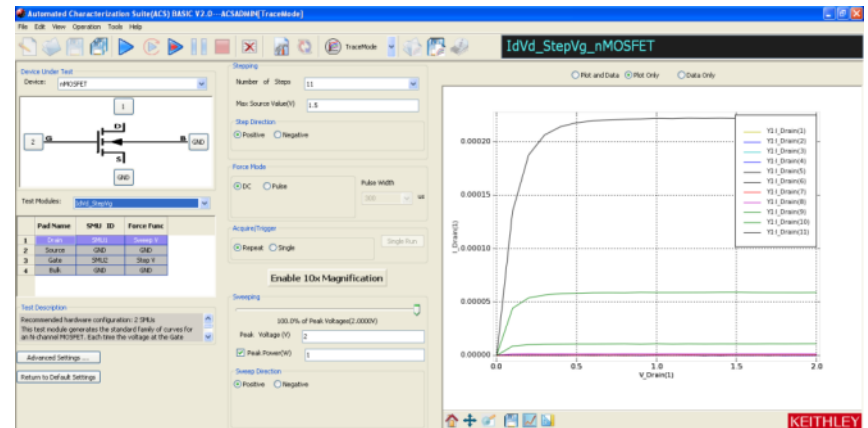
Typical Power Transistor Parameter	Symbol	Test Method (1)	Maximum Range	Typical Best Resolution	Typical Accuracy
Breakdown Voltage	Bvdss, Bvceo	Id-Vd or Id(pulse)	+/-3000V (2)	100uV 10fA	0.05% rdg + 0.05% rng
On State Current (DC)	Vdson Vcesat Vf	Id-Vd	+/-20A (4) Optional: +/-40A (4)	100nA 1uV	0.05% rdg + 0.05% rng
On State Current (Pulse)	Vdson Vcesat Vf	Id-Vd	+/-50A (4) Optional: +/-100A (4)	100uA 1uV	0.05% rdg + 0.05% rng
Drain/Collector Leakage Current	Idss Ir/Icbo Iceo	Id-Vd	+/-20mA @3000) (2,5)	10fA 1uV	0.2% rdg + 1% rng
Gate/Base Leakage Current	Igss Ib	Ig-Vg	+/-1A or +/- 10A Pulsed (3)	10fA 1uV	0.2% rdg + 1% rng
On State threshold Voltage or Cutoff Voltage	Vth,Vf Vbeon Vcesat	Id-Vg	+/-200V (3)	10fA 1uV	0.2% rdg + 0.5% rng
Forward Transfer Admittance or Forward Transconductance	yfs Gfs Hfe gain	Vd-Id @Vds	1 mS ~ 1000 S6	1pA 1uV	1%
On-State Resistance	RDS(on) Vcesat	Vd-Vg @Id	less than 100 $\mu\Omega$ (7)	10 $\mu\Omega$ 1uV	1%
Input Capacitance	Ciss	C-V 100KHz	10nF (8) +/-200V	10fF 10uV	Better than 5% at C<10 nF
Output Capacitance	Coss	C-V 100KHz	10nF (8) +/-200V	10fF 10uV	Better than 5% at C<10 nF
Reverse Transfer Capacitance	Crss	C-V 100KHz	10nF (8) +/-200V	10fF 10uV	Better than 5% at C<10 nF

Parametric Curve Tracer software: ACS Basic 2.1

For fast and simple single device testing!



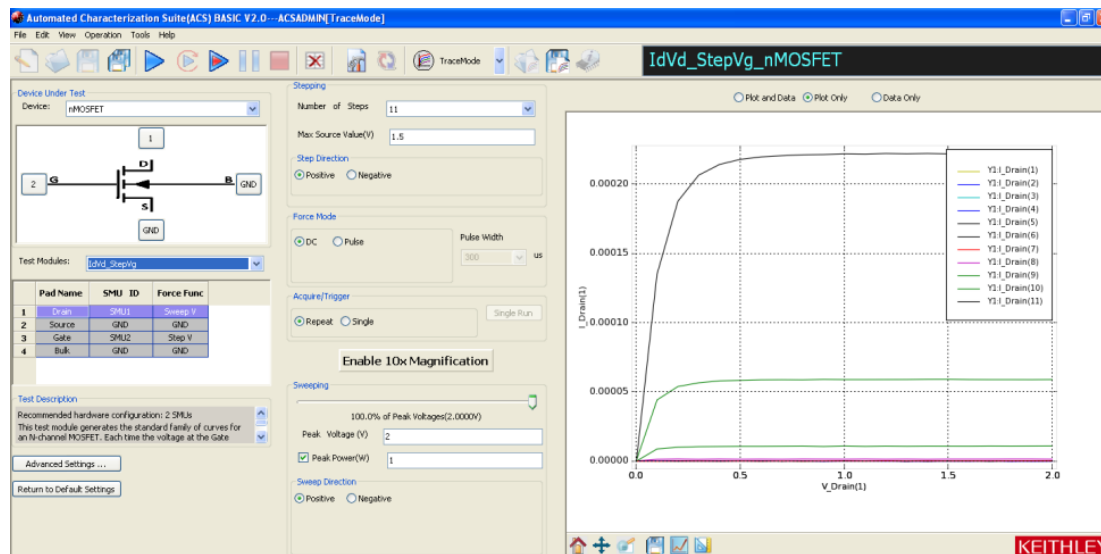
Parametric Test Mode



Trace Mode

What is Trace Test Mode?

- Generates rapid visual results of device characteristics
- Requires real-time operator control based upon visual inspection of test results (graph, plot)
 - The “knob” for the Tektronix curve tracer
 - The slider for the Keithley Parametric Curve Tracer
- Used to determine condition of device (bad or good) or boundaries of device (breakdown voltage)
- Common in Device development and Failure analysis



What is Parametric Test Mode?

- Each test has clearly defined variables (e.g. start, stop, and step levels of sweep)
- Outputs precise digital data, which is necessary for parameter extraction (e.g. hfe, RdsON, gm)
- Operator controls test programmatically. Tests and extractions with a single button push (no slider needed)
- Used for Device qualification, Process monitoring, Data sheet generation

The screenshot displays the Automated Characterization Suite (ACS) software interface. The title bar reads "Automated Characterization Suite(ACS) BASIC V2.0 - ACSADMIN[SingleMode]". The main window title is "ITM: IcVce_StepVge (26xx SMU)".

The interface includes a "Select a Device" section with various component symbols like DIODE, IGBT, RESISTOR, TRIAC, ZENER, nMOSFET, nPowerMOSFET, npnBJT, npnPowerBJT, pMOSFET, pPowerMOSFET, pnpBJT, and pnpPowerBJT. The IGBT symbol is selected.

The "Test Category" is set to "Parametric". The "Instrument Models" list includes KI2440, KI2601, KI2602, KI2611, KI2612, KI2635, KI2636, KI2651A (selected), KI2657A, KI3706, and KI3706_e.

The "Test Modules" list includes BVCES, ICES, IGM, IcVce_StepVge (selected), IcVce_StepVge_MIX, IcVge, IcVge_MIX, IGESF, IGESR, VceSAT, VceSAT_MIX, and VF.

The main workspace shows a schematic diagram of an IGBT with terminals G, C, and E connected to test points 1, 4, and GND. A large "Open Test" button is visible.

The "Test Setup Preview (Read Only)" section shows "Mode" options: "DC Only" (selected) and "Pulse Available". There are also "Timing" and "Stop on Compliance" options.

The "Test Info Bitmap" section shows a circuit diagram with two SMUs connected to the IGBT. One SMU is connected to the Gate (G) terminal, and the other is connected to the Collector (C) terminal. The SMU connected to the Collector is labeled "Sweep" and has a red "X" over it, indicating it is not active for this test.

The "Test Help" section provides the following information:

- Test Name: IcVce_StepVge
- Test Type: ITM
- Instrument: KI2651A, KI2600A
- DUT: Three term IGBT
- Function: Generate the standard family of IcVce curves. For each time the voltage step on Gate-Emitter, a voltage sweep and set of current measurements occur on Collector.
- Pin Connection: Two SMUs are used. KI2651A SMU applies voltage

Device Num	SMU	Pad	Function	Force Mode	Source	Measure	Compliance	Meas.Range	Advanced
1	SMU4	Collector	Sweep V	Pulse Timing 1	Linear [0, 6, 61, 0, 0.1, 0]	I+V	50.0	10A	...
	SMU1	Gate	Step V	Pulse Timing 2	[7, 15, 6, 0]	V	0.001		...

Core I-V Instrumentation: Series 2600B and 2650A SMUs

Model 2636B SMU

- Two independent SMU channels
- Up to 200V
- Up to 10A pulsed
- 0.1fA measurement resolution



Model 2651A SMU

- Up to 50A pulsed (up to 100A with 2 units)
- Up to 2000W pulse / 200 W DC power
- Pulse widths from 100us to DC
- High speed and integrating ADCs



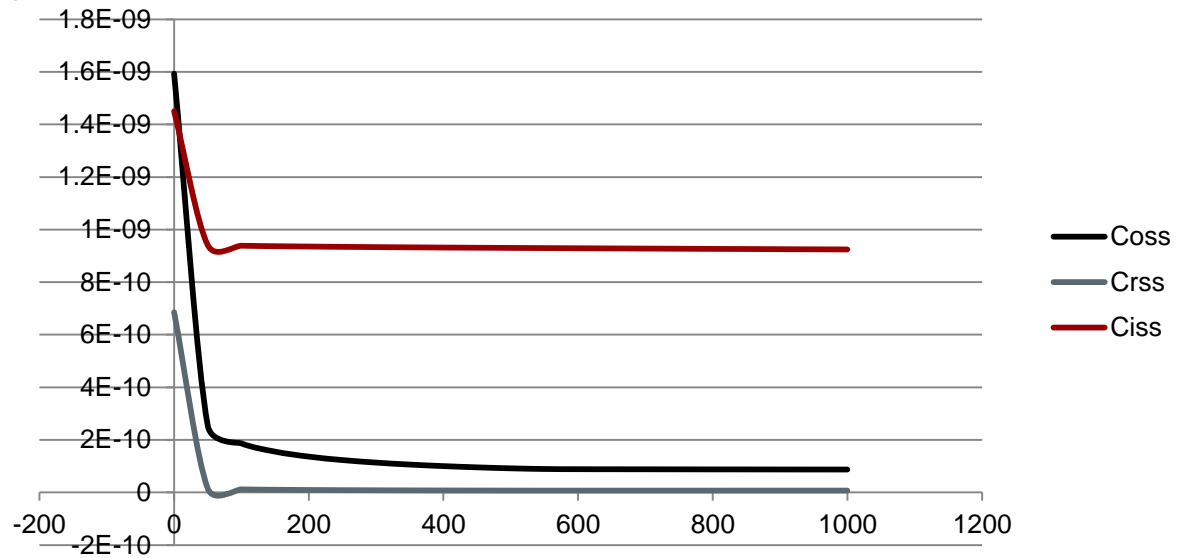
Model 2657A SMU

- Up to 3000V, Up to 180W of power
- 4-Quadrant operation (source and sink power)
- 10fA measurement resolution
- High speed and integrating ADCs



Add HV C-V capability as well – Model PCT-CVU

- 2,3 and 4 terminal C-V
- 10KHz to 2MHz
- 200V CV solutions
- 3000V CV solutions
- Simplified interconnect



Example of Coss, Crss, Ciss on SiC FET

Series 2650A accessories for optimal performance

- High Current, Low Inductance, Low Resistance Cable
 - Custom design
 - Critical for achieving 100us pulses at 100A
 - Supplied with Parametric Curve Tracer



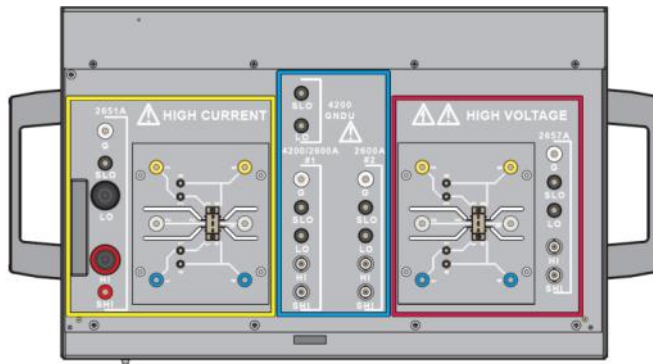
- High Voltage Low Noise Triaxial Cable
 - Custom design
 - Critical for achieving guarded pA-level current measurements at 3kV
 - Supplied with Parametric Curve Tracer



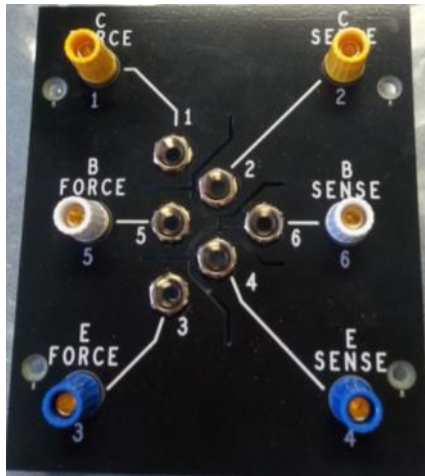
Model 8010 Test Fixture



- Provides safe environment for testing at 3kV and at 100A.
- Includes test sockets for TO-247 packages, axial lead and custom devices.
- Optional Curve Tracer Socket adaptor
- Optional 2,3 or 4 terminal CV at up to 3KV
- Separate areas for high voltage and high current testing



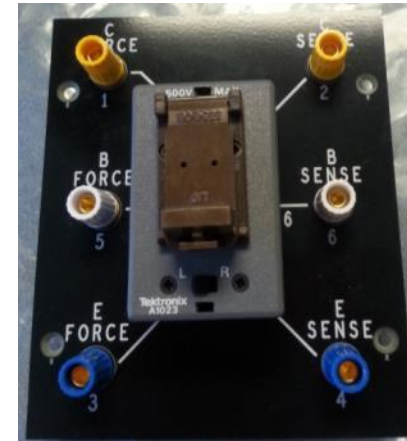
NEW! Model 8010-DTB-CT Tektronix Curve Tracer Adapter Module



Model 8010-DTB-CT



Typical Tek module
that will fit into our Adapter



Our Adapter with a
different Tek module or
socket plugged in

Makes Keithley Model 8010 compatible with all existing Tektronix curve tracer test modules

Note: Some users have made their own test adapters for use with Tektronix curve tracers. The 8010-DTB-CT makes the 8010 compatible with such test modules for use with PCT system

PCT - Designed to Grow with Your Needs

Features	Benefits
Field upgradability and reconfiguration	Instrumentation can be added, removed, or repurposed easily in the field without factory intervention. Convert your Parametric Curve Tracer to a reliability tester or a wafer sort tester.
Complete solution engineered for optimum price and performance	Best in class SourceMeter instruments, optimized cables, safe and flexible test fixture and Windows based control software.
Economical power device characterization	Start with a low-cost, entry-level configuration and upgrade at any time to any other configuration.
Full range of C-V capability	2,3 and 4 terminal Capacitance-Voltage (CV) up to 3KV required for some device tests, but Curve Tracers did not support CV.
Powerful ACS Basic Edition device characterization software	Observe devices in real time by controlling the sources with trace mode, then switch to parametric mode for detailed characterization. Sample test libraries for power devices like transistors, diodes, resistors, etc.



Introducing the Model 8020 Interface Panel



Model 2657A

200V Channels for Series
2600 and 4200 SMUs

For two Model 2651A
(100A pulse in parallel)

- Model 8020 High Power Interface Panel supports 5 instrument channels
 - 1 Model 2657A SMU (For up to 3 KV)
 - 3 200V SMUs (2612, 2636, 4200/10-SMU)
 - 1 or 2 Model 2651A SMUs, connected in parallel (for up to 100A)
- Automatically connects instrument LO terminals correctly to create a system reference (ground unit)

Model 8020-CVU Bias Tee Option

- Factory-installed option
- Includes 4 bias tees, one integrated on each of the 3KV and 200V channels
- Supports 2, 3 or 4 terminal HV C-V
- Bias Tees have multi-mode capability to optimize DC IV and CV measurements
 - No need to change cables between IV and CV testing

Model 8020-CVU option



ACS Basic Edition 2.1

- Updated for HV C-V measurements with PCT-CVU with any PCT configuration
 - Includes new PTMs for general purpose HVCV
 - Includes new PTMs for device-specific HVCV (Ciss, Crss, Coss etc.)
 - Includes new CV compensation window for HV C-V on 2,3, or 4 terminal devices
- Supports hardware-specific features of 8010 and 8020 setup using a new Device Interface selection in the Hardware Configuration window
- Includes PTM that controls ultra-high voltage (>5kV) use case with Series 2290 HV power supply and Series 2600 SMU
- Highly trained Keithley Apps Eng. are familiar with all ACS BE 2.1 features

Keithley's Value Proposition

- The products released with the 8020 give Keithley an advantage in meeting the needs of users who have difficulty in selecting and using a power device test system to meet their packaged device and on-wafer test needs
 - Almost all previous solutions required the user to create his own test systems, leading to measurement and safety problems.
- Now Keithley offers an engineered set of tools that are complete including powerful software.
- This panel reduces complexity and errors in high power device characterization. It solves complex interconnect cabling problems for probe stations and other test fixtures.

“So how is the PCT different from my Tektronix curve tracer?”

Model	2600-PCT-1B	2600-PCT-2B	2600-PCT-3B	2600-PCT-4B
	Entry Level	High Current	High Voltage	High Current and Voltage
Tektronix Curve Tracer	N/A	N/A	Tek 370B (2kV / 20A)	Tek 371B (3kV / 400A)



Keithley Benefits
High resolution
High precision / accuracy
Flexible configuration
Including C-V
Package and wafer support
Worldwide product support



“So I’ve seen the Agilent solution at a trade show / or on the web. How do you compare?”

Model	2600-PCT-1B	2600-PCT-2B	2600-PCT-3B	2600-PCT-4B	PCT-2B w/ CV	PCT-3B w/CV	PCT-4B w/CV
	Entry Level	High Current	High Voltage	High Current and Voltage	High Current + C-V	High Voltage + C-V	High Current and Voltage + C-V
Agilent Power Device Analyzer Model	B1505A (200V / 20A)	B1505A (200V / 40A)	B1505A (3kV / 1A)	B1505A (3kV / 40A)	B1505A (200V / 40A / 200V CV)	B1505A (3kV / 1A / 3kV CV)	B1505A (3kV / 40A / 3kV CV)



Keithley Benefits
 Cost effective
 Flexible, scalable configuration
 Package AND wafer level
 Re-purposable



Who Needs 5 or 10kV Supplies?

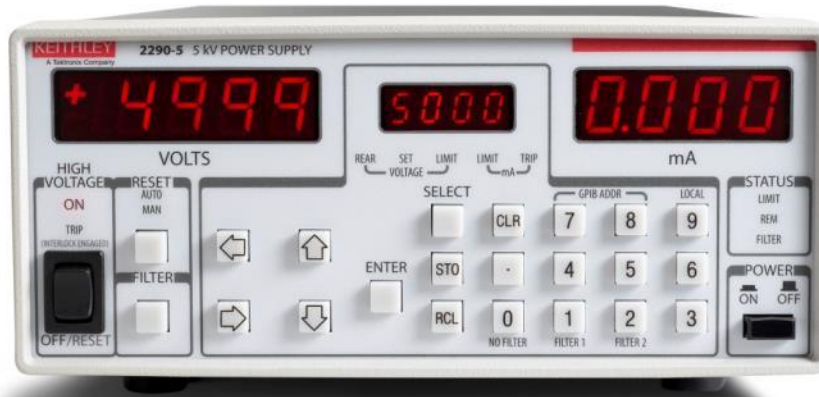
- **Industry:** Semiconductor Industry
- **Application:** High voltage semiconductor device research, development, and characterization
- **Devices:**
 - Silicon Carbide (SiC) diodes and transistors
 - Aluminum Nitride (AlN) diodes and transistors

Users	Facility
Materials researchers Semiconductor physicists Semiconductor characterization engineers	Semiconductor facilities Research Institutes Universities

- **Key applications:**
 - Wide bandgap semiconductors
 - SiC, AlN
 - Breakdown testing, leakage current testing

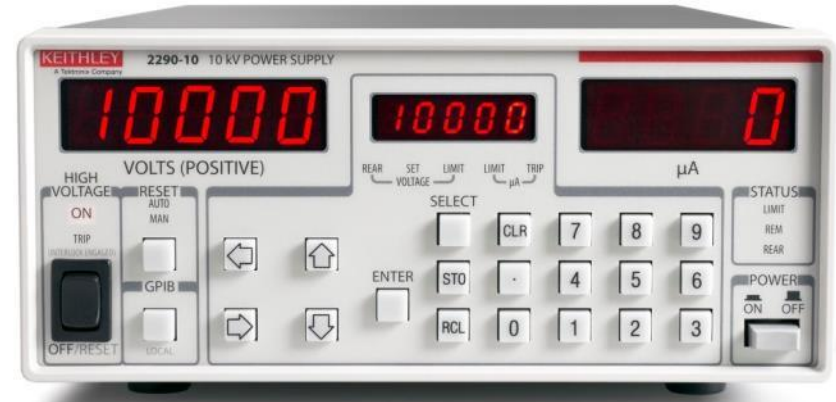
New kV Supplies

Model 2290-5 **5kV** Power Supply



- +50V to +5,000VDC
- Up to 5mA current output (25W)
- 1 μ A current measurement resolution
- Ultra-low output noise; 3mVrms @5kV with output filter enabled
- Safety interlock
- GPIB interface

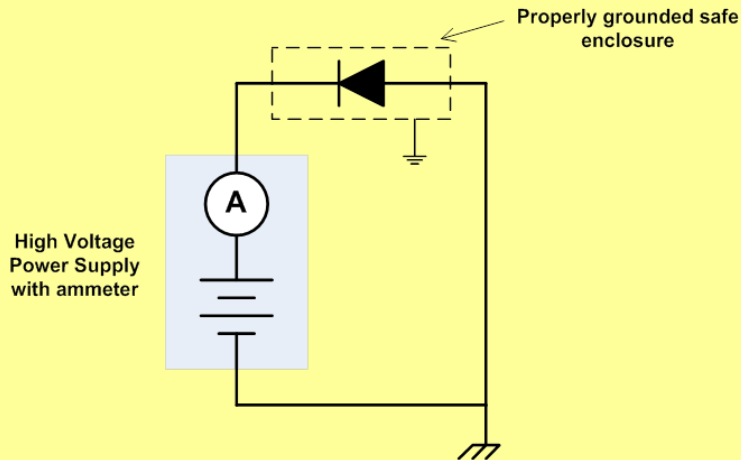
Model 2290-10 **10kV** Power Supply



- +100V to +10,000VDC
- Up to 1mA output (10W)
- 1 μ A current measurement resolution
- Low output noise; 1Vrms maximum
- Safety interlock
- RS-232 and GPIB interfaces

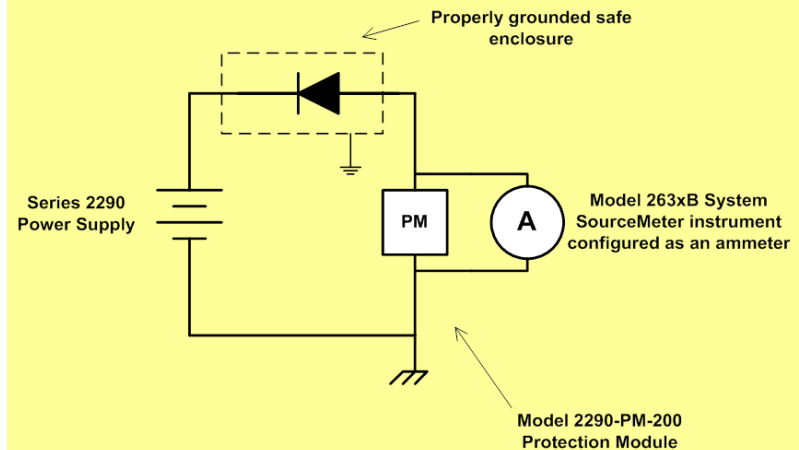
Ultra-HV Applications Enabled by Series 2290 Power Supplies

Breakdown Voltage



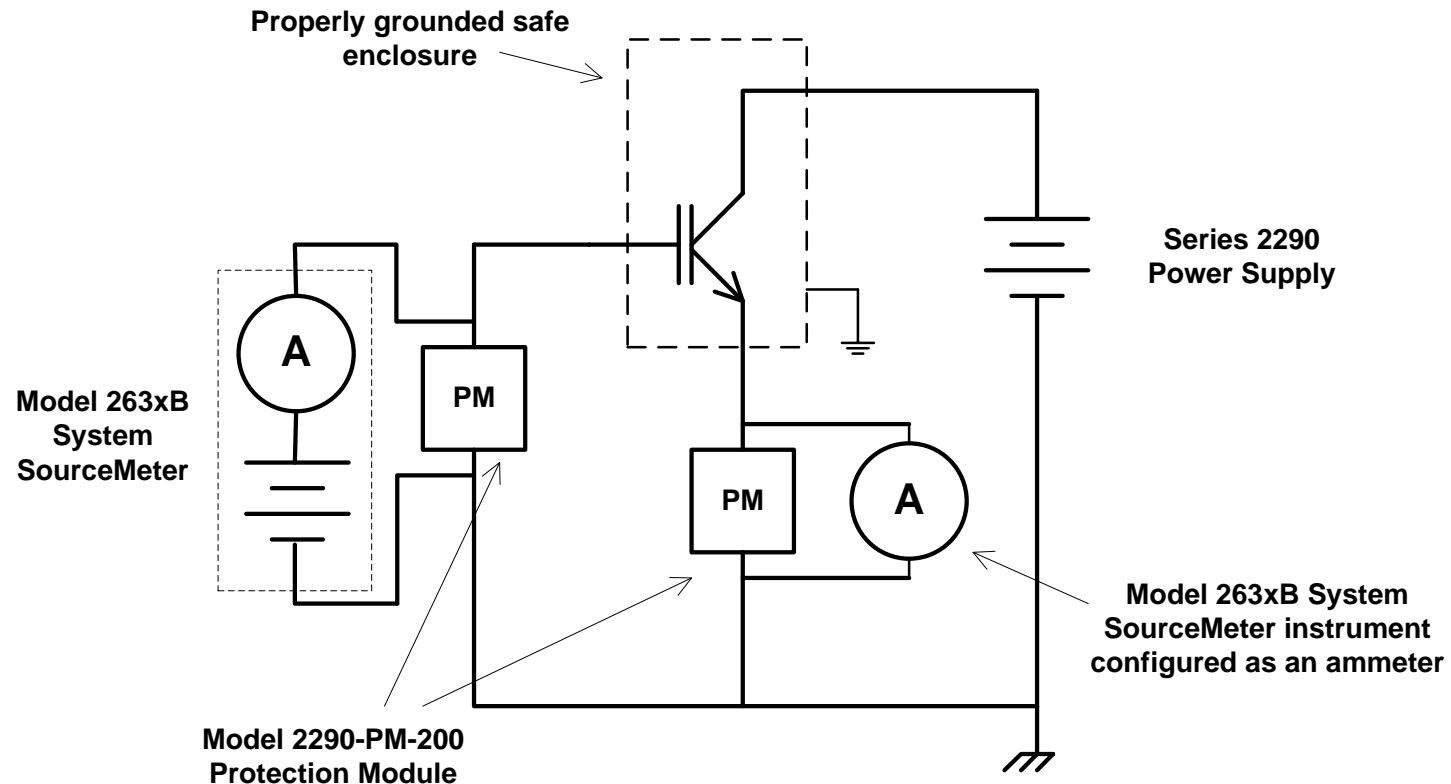
- Typically a coarse measurement of device current to determine if breakdown voltage has been reached
- V-source method is likely in device development
 - I-source method in higher speed tests
- Can be measured by high voltage power supply alone

Leakage Current



- Accurate measurement of device current at specified voltage
- SMU instrument used primarily as an ammeter. Also allows for more precise control over the current limit.

Example: Measuring Ices of IGBT with 1 Model 2290 and 1 Model 2636B



Additional SMU permits DC voltage at gate terminal.

Value Proposition – A Very Cost Effective Complete Solution

- Only Keithley offers an independent, stand-alone, safe, high voltage breakdown test package
 - 5kV or 10kV power supply
 - 10kV Protection module
 - SourceMeter for higher sensitivity leakage current measurements
 - Software with flexible sample libraries (ACS Basic V 2.1)
 - High voltage cables and bulkhead connectors
- Third party probe station and test fixtures for 10KV are available (see www.signatone.com)
- Keithley has associated instrumentation for more complete device characterization
 - Parametric Curve Tracer for 3KV, 100A package and wafer level
- Keithley has semiconductor test and low level measurement expertise



Signatone 10KV Package Part Test Fixture
Optional thermal plate available