

# Series 2290

- Source voltages up to 5kV and 10kV
- 1 $\mu$ A current measurement resolution
- Low noise for precision sourcing and sensitive measurements; selectable filters reduce noise to less than 3mV<sub>RMS</sub> on the 5kV supply
- Safety interlock controls high voltage output
- IEEE-488 programmable
- Protection module prevents damage to low voltage instrumentation

## TYPICAL APPLICATIONS

- High voltage device breakdown testing
- High voltage component testing
- Insulation testing
- High voltage resistivity measurements
- High energy physics research

## Ordering Information

- 2290-5 5kV Power Supply, 120VAC Nominal Input Voltage
- 2290E-5 5kV Power Supply, 240VAC Nominal Input Voltage
- 2290J-5 5kV Power Supply, 100VAC Nominal Input Voltage
- 2290-10 10kV Power Supply
- 2290-PM-200 10kV Protection Module

## Accessories Supplied

- CD with user manual, software drivers, and accessory information
- Power cord

# High Voltage Power Supplies



Series 2290 High Voltage Power Supplies facilitate high voltage device and material testing, as well as high energy physics experimentation. The Model 2290-5 5kV Power Supply provides voltage outputs up to 5000V, and the Model 2290-10 10kV Power Supply offers up to 10,000V. The Model 2290-5 has a 5mA current capacity, and the Model 2290-10 has a 1mA current capacity. These supplies measure both output voltage with 1V resolution and output current with 1 $\mu$ A resolution. In addition to the voltage and current output displays, a third display shows one of four settings: output voltage, voltage limit, current limit, or current trip. These values can be set precisely with the front panel keypad. The settings can also be programmed over the IEEE-4888 interface, or the output voltage can be set with an analog control voltage.

## Low Noise Ensures Accurate Low Level Measurements

Low output noise is essential when using sensitive measurement instruments to make leakage current or high resistivity measurements. The maximum output ripple for the Model 2290-10 is less than 1V<sub>RMS</sub>. The maximum output ripple of the Model 2290-5 is 100mV<sub>RMS</sub>. Two selectable, internal filters on the Model 2290-5 reduce the maximum output ripple to only 3mV<sub>RMS</sub>. Extremely low noise from both power supplies enables sensitive measurement instruments to make accurate current measurements down to picoamp levels.

## Protecting User and Instrumentation

Series 2290 Power Supplies and a Model 2290-PM-200 Protection Module protect both user and instrumentation from hazardous voltages. An interlock circuit built into the power supplies can be used to ensure that the output voltage is disabled if a high voltage test fixture access door is open. In addition, all Series 2290 power supplies have low voltage analog outputs to permit safe monitoring of the high voltage and the output current.

When low voltage measurement instrumentation is used in the high voltage circuit, the protection module safely clamps the voltage across the instrument to a maximum value of 200V even when a device under test (DUT) breaks down. Thus, a Series 2290 Power Supply, Model 2290-PM-200 Protection Module, and Keithley accessories provide all the elements for building a safe, high voltage test environment.



The Model 2290-PM-200 Protection Module protects low voltage measurement equipment from voltages greater than 200V.

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# Series 2290

# High Voltage Power Supplies

## ACCESSORIES AVAILABLE

For 2290-5:	
2290-5-SHV	5kV SHV Female–SHV Female Cable, 3m (10 ft)
2290-5-MHV	5kV SHV Female–MHV Male Cable, 3m (10 ft)
2290-5-SHVBH	5kV SHV Male Bulkhead Connector
2290-5-RMK-1	Single Fixed Rack Mount Kit for 5kV Power Supply
2290-5-RMK-2	Dual Fixed Rack Mount Kit for 5kV Power Supply
For 2290-10:	
2290-10-SHVUC	10kV SHV Male to Unterminated Cable, 3m (10ft)
2290-10-SHV	10kV SHV Male–SHV Male Cable, 3m (10 ft)
2290-10-SHVBH	10kV SHV Female Bulkhead Connector
2290-10-RMK-1	Single Fixed Rack Mount Kit for 10kV Power Supply
2290-10-RMK-2	Dual Fixed Rack Mount Kit for 10kV Power Supply
For both:	
2290-PM-200	10kV Protection Module
2290-INT-CABLE	3-Pin Connector to Unterminated Interlock Cable
4299-7	Fixed Shelf Rack Mount Kit
KPCI-488LPA	IEEE-488.2 Interface Board for the PCI Bus
KUSB-488B	IEEE-488.2 USB-GPIB Interface Adapter for USB port with built-in 2m (6.6 ft) cable
7007-05	Double Shielded Premium IEEE-488 Interface Cable, 0.5m (1.6 ft)
7007-1	Double Shielded Premium IEEE-488 Interface Cable, 1m (3.2 ft)
7007-2	Double Shielded Premium IEEE-488 Interface Cable, 2m (6.5 ft)
7007-3	Double Shielded Premium IEEE-488 Interface Cable, 3m (10 ft)
7007-4	Double Shielded Premium IEEE-488 Interface Cable, 4m (13 ft)

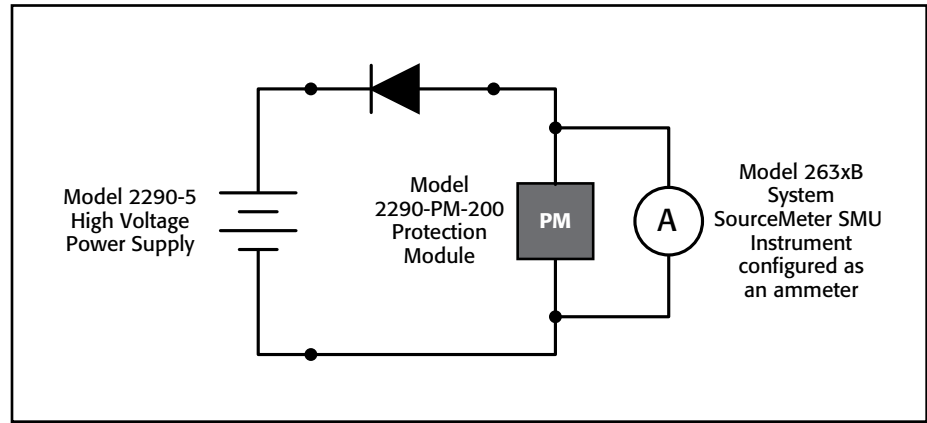
## SERVICES AVAILABLE

<i>Model Number</i> -EW	1 Year Factory Warranty extended one additional year from date of shipment
<i>Model Number</i> -3Y-EW	1 Year Factory Warranty extended to 3 years from date of shipment
<i>Model Number</i> -5Y-EW	1 Year Factory Warranty extended to 5 years from date of shipment
<i>C/Model Number</i> -3Y-STD	KeithleyCare 3 Year Standard Calibration Plan
<i>C/Model Number</i> -3Y-DATA	KeithleyCare 3 Year Calibration with Data Plan
<i>C/Model Number</i> -5Y-STD	KeithleyCare 5 Year Standard Calibration Plan
<i>C/Model Number</i> -5Y-DATA	KeithleyCare 5 Year Calibration with Data Plan

\*Insert model number. Examples: 2290-5-EW, C/2290E-10-3Y-STD

## Make Precise Current Measurements Lower Than 1µA

Use a sensitive Keithley measurement instrument, such as a Keithley SourceMeter® Source Measure Unit (SMU) instrument, to measure current drawn by the device under test (DUT) that is below the sensitivity of the Series 2290 Power Supplies. Keithley SourceMeter SMU instruments can provide sensitivity as low as 0.1fA. The following diagram shows how the Model 2290-PM-200 Protection Module protects the low voltage SourceMeter SMU instrument from high voltages when the DUT breaks down. The leakage current of the protection module limits the measurement resolution to picoamp levels, which is five decades more sensitive than the current measurement resolution of the Series 2290 Power Supplies. Keithley can provide a complete high voltage test capability with the most current measurement sensitivity available anywhere.



**Reverse breakdown testing of a high voltage diode using a Keithley SourceMeter SMU instrument to measure leakage current. The Model 2290-PM-200 SMU Protection Module protects the SourceMeter SMU instrument from high voltage when the diode breaks down.**

## Easily Automate a High Voltage Test System

The Series 2290's IEEE-488 interface allows the creation of an automated high voltage test system. Software drivers are supplied to simplify and accelerate test system development. This further enhances safety as the high voltage can be controlled from a remote location.

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## 2290-5 Specifications

### 5kV Voltage Power Supply Characteristics

#### CONDITIONS

This document contains specifications and supplemental information for the Model 2290-5 High Voltage Power Supply. Specifications are the standards against which the Model 2290-5 is tested. Upon leaving the factory, the Model 2290-5 meets these specifications. Characteristics, supplemental characteristics, and typical values are not warranted, apply at 23°C ±5°C, <70% relative humidity, and are provided solely as useful information.

#### CHARACTERISTICS

##### VOLTAGE RANGE:

Output Voltage <sup>1</sup>	Maximum Output Current	Conditions
50 to +5000 V DC	5.000 mA DC	No filter
50 to +3000 V DC	5.000 mA DC	Filter 1
50 to +5000 V DC	3.000 mA DC	Filter 2

VOLTAGE SET ACCURACY<sup>2</sup>: ±(0.01% of setting + 2.5V).

VOLTAGE DISPLAY ACCURACY: Voltage set accuracy ±1V, typical (±2V, maximum).

VOLTAGE RESOLUTION: 1V (set and display).

VOLTAGE LIMIT RANGE: 0 to 100% full scale.

VOLTAGE REGULATION<sup>3</sup>:  
**Line:** 0.001% for ±10% line voltage change.  
**Load:** 0.005% for 100% load change, typical.

OUTPUT RIPPLE (10kHz–100kHz)<sup>4</sup>: 0.002% of full scale,  $V_{RMS}$ , maximum – No filter.  
 1.0mV<sub>RMS</sub> @ 1kV – Filter 1 or Filter 2.  
 2.0mV<sub>RMS</sub> @ 3kV – Filter 1 or Filter 2.  
 3.0mV<sub>RMS</sub> @ 5kV – Filter 2.

RISE TIME (full load)<sup>6,7</sup>: 1.5 seconds for 0 to within 1V of 5000VDC – No filter.  
 3 seconds for 0 to within 1V of 3000VDC – Filter 1.  
 4 seconds for 0 to within 1V of 5000VDC – Filter 2

DISCHARGE TIME (full load)<sup>6,7</sup>: 1 second for 5000VDC to 1VDC – No filter.  
 3 seconds for 3000VDC to 1VDC – Filter 1.  
 4 seconds for 5000VDC to 1VDC – Filter 2

DISCHARGE TIME (no load)<sup>6</sup>: <12 seconds (to <50VDC) – No filter.  
 <30 seconds (to <50VDC) – Filter 1 or Filter 2.

SETTLING TIME<sup>6,7</sup>: From 0 to programmed voltage; to within 99.9% of final value within 3 seconds.

RECOVERY TIME<sup>6,7</sup>: 120ms for 40% step change in load current (typical).

Current Limit and Trip Range	Voltage Range	Filter
0.4 mA to 5.25 mA	0 V to 1.5 kV	No filter or Filter 1
0.4 mA to 3.25 mA		Filter 2
0.5 mA to 5.25 mA	1.5 kV to 5.0 kV	No filter or Filter 1
0.4 mA to 3.25 mA		Filter 2

CURRENT SET ACCURACY<sup>5</sup>: 0.01% ±(0.01% + 2.5μA).

CURRENT RESOLUTION: 1μA.

CURRENT DISPLAY ACCURACY: ±1μA, typical (±2μA, maximum).

STABILITY: ±0.01% per hour; <0.03% per eight hours.

TEMPERATURE DRIFT: 50ppm/°C, 0° to 40°C, typical.

PROTECTION: Arc and short circuit protected; programmable voltage and current limits and current trip.

#### MONITOR OUTPUTS

OUTPUT SCALE: 0 to +10V to full scale.

CURRENT RATING: 10mA maximum.

OUTPUT IMPEDANCE: <1Ω.

ACCURACY: ±0.2% of full scale with a 100kΩ load, minimum.

UPDATE RATE: 8Hz.

#### EXTERNAL VOLTAGE SET

INPUT SCALE: 0 to +10V for 0 to full scale.

INPUT IMPEDANCE: 1MΩ.

ACCURACY: ±0.2% of full scale.

UPDATE RATE: 16Hz.

OUTPUT SLEW RATE: <(rise time + 0.3 seconds) for 0 to full range under full load.

#### GENERAL

INPUT POWER: 55 watts.

2290-5 INPUT VOLTAGE: 120V ±10%, 50 or 60Hz.

2290E-5 INPUT VOLTAGE: 240V ±10%, 50 or 60Hz.

2290J-5 INPUT VOLTAGE: 100V ±10%, 50 or 60Hz.

#### REAR PANEL CONNECTORS:

SHV male (Kings type 1704-1 or equivalent).

Output high-voltage connector GPIB connector.

BNC Connector (two): Voltage set/Voltage monitor; Current monitor.

TOGGLE SWITCH: Voltage setting or Voltage monitor.

#### HIGH-VOLTAGE SAFETY INTERLOCK:

Connector: 3-pin press-in connector, 3M part number: 37103-A165-00E-MB.

Pin 1: 5V out, 1.5mA maximum out.

Pin 2: Input: High-voltage output enabled: 3–24V DC.

High-voltage output disabled: <1.2V DC.

Pin 3: Chassis ground through a 100Ω resistor.

INTERFACE PROTOCOL: IEEE-488.1.

OPERATING ENVIRONMENT: 0° to 40°C; non-condensing.

DIMENSIONS: 89mm high × 206mm wide × 406mm deep (3.5 in. × 8.1 in. × 16 in.).

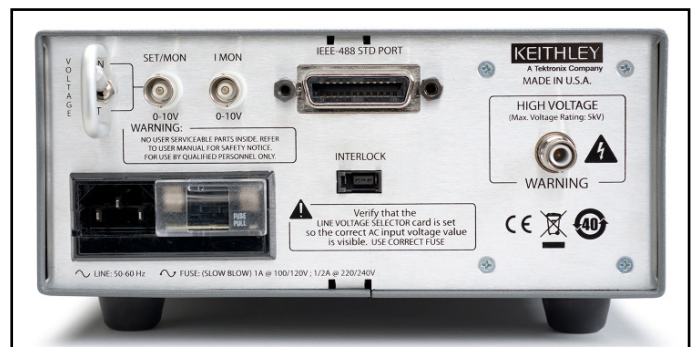
WEIGHT: 5.5kg (12 pounds).

SAFETY: Conformance to European Union low voltage directive.

WARRANTY: One year.

WARM-UP TIME: One hour.

- The output voltage can be programmed to a voltage lower than 50V; however, performance below 50V is not specified.
- Add ±2.5VDC when Filter 1 or Filter 2 is enabled.
- Regulation specifications apply for greater than 25VDC (with full load), or 50VDC (with no load). Below these values, the unit may not regulate correctly.
- Peak-to-peak values are within five times the RMS value.
- Add 2.5μA offset when Filter 1 or Filter 2 is enabled.
- Times apply with the current limit set to 105% of full scale.
- Loads are fully resistive.



Model 2290-5 rear panel showing the IEEE-488 interface connector, high voltage output connector, analog control/output connectors, and interlock connector.

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## 2290-10 Specifications

### 10kV Voltage Power Supply Characteristics

#### CONDITIONS

This document contains specifications and supplemental information for the Model 2290-10 High Voltage Power Supply. Specifications are the standards against which the Model 2290-10 is tested. Upon leaving the factory, the Model 2290-10 meets these specifications. Characteristics, supplemental characteristics, and typical values are not warranted, apply at 23°C ±5°C, <70% relative humidity, and are provided solely as useful information.

#### CHARACTERISTICS

##### VOLTAGE RANGE:

Output Voltage <sup>1</sup>	Maximum Output Current
+100 to +10,000 V DC	1.000 mA DC

VOLTAGE SET ACCURACY: ±0.06% of full scale.

VOLTAGE DISPLAY ACCURACY: Voltage set accuracy ±1V, typical (±2V, maximum).

VOLTAGE RESOLUTION: 1V (set and display).

VOLTAGE LIMIT RANGE: 0 to 100% full scale.

VOLTAGE REGULATION<sup>2</sup>: Line: 0.001% for ±10% line voltage change.

Load: 0.04% for 100% load change, typical.

OUTPUT RIPPLE (300Hz–300kHz): 0.01% of full scale,  $V_{RMS}$ .

RISE TIME (from high voltage turn on to final value under full load)<sup>3,4</sup>: <6 seconds to within 1V of the final value.

DISCHARGE TIME (to 0V under full load)<sup>3,4</sup>: 1 second to under 10V.

DISCHARGE TIME (no load)<sup>3</sup>: <6 seconds (to <1% of full scale voltage with no load, typical).

SETTLING TIME<sup>3,4</sup>: <4 seconds to within 1V of the final value.

RECOVERY TIME<sup>3,4</sup>: 120ms for 40% step change in load current (typical).

CURRENT LIMIT RANGE: 0 to 105% of full scale.

CURRENT SET ACCURACY: 0.5% of full scale.

CURRENT RESOLUTION: 1μA.

CURRENT DISPLAY ACCURACY: ±1μA, typical (±2μA, maximum).

TRIP CURRENT RANGE: 10μA to 105% of full scale (excluding stored output charge).

OUTPUT STORED CHARGE: <20μC maximum.

TRIP RESPONSE TIME: <10ms.

STABILITY: ±0.01% per hour; <0.03% per eight hours.

TEMPERATURE DRIFT: 50ppm/°C, 0° to 40°C, typical.

PROTECTION: Arc and short circuit protected; programmable voltage and current limits and current trip.

#### MONITOR OUTPUTS

OUTPUT SCALE: 0 to +10V for 0V to full scale.

CURRENT RATING: 10mA maximum.

OUTPUT IMPEDANCE: 100Ω.

ACCURACY: ±0.2% of full scale with a 1MΩ load, minimum.

UPDATE RATE: 87.5Hz.

#### EXTERNAL VOLTAGE SET

INPUT SCALE: 0 to +10V for 0 to full scale.

INPUT IMPEDANCE: 1MΩ.

ACCURACY: ±0.2% of full scale.

UPDATE RATE: 87.5Hz.

OUTPUT SLEW RATE (5% to 95% under full load): <3 seconds

### GENERAL

INPUT POWER: 75 watts.

INPUT VOLTAGE: 90V–264VAC, 47 to 63Hz.

#### REAR PANEL CONNECTORS:

Output high-voltage connector: SHV male (Kings type 1764-1 or equivalent).

BNC Connector (three): Input, voltage monitor; current monitor.

GPIB connector, 23-pin.

RS-232, 9-pin D-sub

#### HIGH-VOLTAGE SAFETY INTERLOCK:

Connector: 3-pin press-in connector, 3M part number: 37103-A165-00E-MB.

Pin 1: 5V out, 70mA maximum out.

Pin 2: Input: High-voltage output enabled: 5V DC.

High-voltage output disabled: 0V DC or open connection.

Pin 3: Chassis ground.

INTERFACE PROTOCOL: IEEE-488.1.

OPERATING ENVIRONMENT: 0° to 40°C; non-condensing.

DIMENSIONS: 89mm high × 206mm wide × 406mm deep (3.5 in × 8.1 in × 16 in).

WEIGHT: 3.7kg (8 pounds).

SAFETY: Conformance to European Union low voltage directive.

WARRANTY: One year.

WARM-UP TIME: One hour.

1. The output voltage can be programmed to voltages below 100V, but accuracy below 100V is not specified.
2. Regulation specifications apply for greater than 100V.
3. Times apply with the current limit set to 105% of full scale.
4. Loads are fully resistive.



Model 2290-10 rear panel showing the IEEE-488 interface connector, RS-232 interface connector, high voltage output connector, analog control/output connectors, and interlock connector.

## 2290-PM-200 Specifications

### SMU Protection Module Characteristics

#### CONDITIONS

This document contains specifications and supplemental information for the Model 2290-PM-200 Protection Module. Specifications are the standards against which the Model 2290-PM-200 is tested. Upon leaving the factory, the Model 2290-PM-200 meets these specifications. Characteristics, supplemental characteristics, and typical values are not warranted, apply at 23°C ±5°C, <70 percent relative humidity, and are provided solely as useful information.

#### CHARACTERISTICS

**LEAKAGE:** <10pA at 200V typical.

**DC CURRENT CARRYING CAPABILITY:** <1.5A in unclamped condition.

**PULSED CURRENT CARRYING CAPABILITY:** 10A maximum at 1% duty cycle in unclamped condition.

**MAXIMUM PROTECTION ACTIVE CURRENT:** Current must be limited to <120mA in clamped condition (~230V).

**PROTECTION VOLTAGE:** 220VDC minimum, 230VDC typical, 240VDC maximum.

**DIMENSIONS:** 81.28mm long × 81.53mm wide × 54.10mm high (3.20 in. long × 3.21 in. wide × 2.13 in. high) Maximum length with high-voltage connectors: 5.34 in (135.64mm).

**WEIGHT:** 0.25kg (0.55 lb.).

#### GENERAL

**WARRANTY:** 1 year.

**SAFETY:** Listed to UL 61010-1:2012 (3rd edition). Conforms to European Union Low Voltage Directive.

#### CONNECTORS:

**High Voltage: 5kV connector:** male SHV, 0.38 inches (9.35mm) diameter, Kings 1704-1.

**10kV connector:** female SHV, 0.535 inches (13.59mm) diameter, Kings 1764-1.

**Low Voltage:** Triax, female, quantity of 2

**SAFETY:** Screw ground terminal, quantity of 2



# Series 2290

# High Voltage Power Supplies

High voltage power supplies

DC POWER SUPPLIES

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