# 236, 237, and 238 Source-Measure Units


The 236, 237, and 238 Source-Measure Units (SMU) are fully programmable instruments, capable of sourcing and measuring voltage or current simultaneously. These systems are really four instruments in one: voltage source, current source, voltage measure and current measure.

The 236 will source voltage from 100µV to 110V, and current from 100fA to 100mA. It can also measure voltage from 10µV to 110V and current from 10fA to 100mA. The 237 offers the same capabilities with a decade enhancement in voltage source and measure (1100V). In this higher voltage range, current source and measure is 10mA maximum. The 238 offers a decade enhancement in current source and measure (1A). In this higher current range, voltage source and measure is 15V maximum.

The 236, 237, and 238 will measure very small currents and voltages. With current sensitivity of 10fA, measurement capabilities are equal to those of an electrometer. Selectable integration and the filtering of multiple measurements enhances sensitivity for demanding applications.

Both source voltages and source currents settle to specified accuracy in as little as 500µs. Programmable delay and fast, integrating measurement capability can provide coordinated source-measure times of 1ms.

## Applications

These instruments address a wide variety of applications, including the characterization of semiconductor devices, and the measurement of leakage currents or resistivity. They are particularly useful as source and measuring instruments in automated test equipment (ATE).

The 236, 237, and 238 provide simple, accurate measurements in semiconductor applications. Multiple units controlled with a personal computer make a powerful semiconductor parameter analyzer. Non-standard tests are also performed efficiently because of the unique versatility of these units.

Two accessory semiconductor test fixtures maintain the signal integrity of the SMUs all the way to your device. The 8006 is a general purpose test fixture, and the 8007 is designed to accommodate either 24- or 48-pin devices. These test fixtures can be safety interlocked with the 236, 237, and 238 to prevent accidental shock.

A Keithley Model 707A or 708A switching matrix and semiconductor switching cards may be used in conjunction with the 236, 237, and 238 for optimum performance in automated semiconductor measurement applications.

Keithley SMUs are powerful tools for research and industrial test applications. The short set-up time and simplified programming are big advantages for tests that need to be up and running quickly. The overall versatility is ideal for constantly changing research use.

The large dynamic range of source and measure capabilities permits accurate measurement of insulation resistance, leakage current, and dissipation factors. The high sensitivity of these units make them ideal for characterizing the electrical properties of many materials.

## Enhanced System Versatility

A single Source-Measure Unit eliminates most of the complicated system integration problems involved with setting up and programming individual sources and meters. This new, compact module also saves rack space and can be more economical than separate components.

New test systems can be developed much faster with SMUs. There is only one set of device dependent commands (DDC) to learn, and the overall test system is better coordinated for more efficient operation.

- **Four instruments in one (voltage source, voltage measure, current source, current measure)**
- **10fA, 10µV measurement sensitivity**
- **1100V source and measure (237 only)**
- **1A source and measure (238 only)**
- **Standard and custom sweep capability including pulse**
- **1000 source/measurements per second**
- **Four quadrant source operation**
- **Internal 1000-reading memory**

### ORDERING INFORMATION

| | |
|---|---|
| **236** | Source-Measure Unit with two 7078- TRX-10 3-Slot Low Noise Triax Cables, 3m (10 ft), one 236-ILC-3 Interlock Cable, 3m (10 ft), and one 237-ALG-2 Low Noise Triax Cable, 2m (6.6 ft) |
| **237** | High Voltage Source-Measure Unit with two 7078-TRX-10 3-Slot Low Noise Triax Cables, 3m (10 ft), one 236-ILC-3 Interlock Cable, 3m (10 ft), and one 237-ALG-2 Low Noise Triax Cable, 2m (6.6 ft) |
| **238** | High Current Source-Measure Unit with two 7078-TRX-10 3-Slot Low Noise Triax Cables, 3m (10 ft), one 236-ILC-3 Interlock Cable, 3m (10 ft), and one 237-ALG-2 Low Noise Triax Cable, 2m (6.6 ft) |

These products are available with an **Extended Warranty.** See page 635 for complete ordering information.

# 236, 237, and 238 Source-Measure Units

*Figure 1: Internal Memory*


SELECT

| STEP | SOURCE | DELAY | MEASURE | TIME (ΔT) |
|---|---|---|---|---|
| 0001 | +1.0000 V | 00.100 s | +1.0921 nA | 000.002 s |
| 0002 | +02.000 V | 00.100 s | +1.1526 nA | 000.003 s |
| 0003 | +03.000 V | 00.100 s | +1.2234 nA | 000.005 s |
| 0004 | +04.000 V | 00.100 s | +2.3725 nA | 000.006 s |
| 0005 | +05.000 V | 00.100 s | +2.7713 nA | 000.008 s |
| - | - | - | - | - |
| 0028 | +028.00 V | 00.100 s | +3.6576 nA | 000.042 s |
| - | - | - | - | - |
| 1000 | +1000.0 V | 00.100 s | +8.5763 nA | 001.503 s |

### Measurements as a Function of Voltage, Current, or Time

Measurements can be taken and recorded in an internal memory along with corresponding values of the source voltage or current and time. Up to 1000 values of each variable, correlated in time, may be accessed by the front panel using either a rotary dial or a keypad. All measurement and source values along with the elapsed time may also be obtained over the IEEE-488 bus.

The internal memory is organized to obtain and present measurement results in a versatile and easy to understand manner. All source values and corresponding measurement values are stored in sequence and share a common index.

## ACCESSORIES AVAILABLE

**CABLES**

| | |
|---|---|
| 236-ILC-3 | Interlock Cable, 3m (10 ft) |
| 237-ALG-2 | 3-Slot, Low Noise Triax Cable, 2m (6.6 ft) |
| 7078-TRX-3 | 3-Slot, Low Noise Triax Cable, 0.9m (3 ft) |
| 7078-TRX-10 | 3-Slot, Low Noise Triax Cable, 3m (10 ft) |
| 7078-TRX-20 | 3-Slot, Low Noise Triax Cable, 6m (20 ft) |

**RACKS & RACK MOUNT KITS**

| | |
|---|---|
| 1938 | Fixed Rack Mount Kit |
| 1939 | Slide Rack Mount Kit |
| 8000-10 | Equipment Cabinet, 10 in high |
| 8000-14 | Equipment Cabinet, 14 in high |

**SOFTWARE**

Metrics-ICS

Metrics-ICS-IV/TestPoint

**SWITCHING (page 174)**

| | |
|---|---|
| 707A | Switching Matrix |
| 708A | Switching Matrix |
| 7072 | Semiconductor Matrix Card |
| 7072-HV | High Voltage Semiconductor Matrix Card |
| 7153 | High Voltage Low Current Matrix Card |
| 7172 | 8×12 Low Current Matrix Card |
| 7174A | 8×12 High Speed, Low Current Matrix Card |

**TEST FIXTURES**

| | |
|---|---|
| 8006 | Component Test Fixture |
| 8007 | Semiconductor Test Fixture |

**OTHER**

| | |
|---|---|
| 213 | Quad Voltage Source |
| 237-TRX-NG | 3-Slot Triax to 3-Lug Female Triax Connector |

See page 235 for descriptions of all accessories.

### Data Display

The contents of the internal memory may be accessed via the IEEE-488 bus or displayed in several formats using the front panel controls. Source and measure values may be displayed simultaneously or with the index value. Delay and elapsed time may also be displayed with the index. The choice between display modes is conveniently made using the Select keys. The delay time between source and measurement may be independently set from 0 to 65,000ms from the front panel or the IEEE-488 interface.

### Selectable Sweeps of Voltage and Current

The 236, 237, and 238 may be programmed to perform source-measurements as a function of a stepped voltage or current. Voltage and current may be swept linearly, logarithmically, or pulsed. The START, STOP, STEP method of setting sweep parameters allows operators to become proficient at using the instrument very quickly. Sweep parameters may be appended (APPEND key) to obtain more complex test sequences.

Creating custom sweeps of voltage or current is facilitated by the use of three waveform operations: CREATE, APPEND, and MODIFY. These allow the user to select waveform parameters, combine multiple waveforms, and select and change any points in a waveform previously created or appended.

### Fully-Guarded Four-Terminal Measurements

The 236, 237, and 238 outputs and inputs are fully guarded, and the units are configured to allow four-terminal measurements. Two-terminal measurements are also available for more standard test procedures. These outputs may be floated up to ±200V from ground.

### Source Capability

The 236, 237, and 238 deliver full output current at maximum voltage to allow for optimum characterization of high-power devices. The 236 delivers up to 100mA at 110V, the 237 delivers 10mA at 1100V, and the 238 delivers 1A at 15V.

### Suppression

Pushbutton suppression lets you make relative measurements with respect to a baseline or cancel background signals. Suppression for a particular measurement may be any value within the specified operating range of the instrument.

Fast, efficient programming makes these Source-Measure Units the ideal systems for a wide range of testing procedures in the most comprehensive systems.

*FIGURE 2: Data Displays*

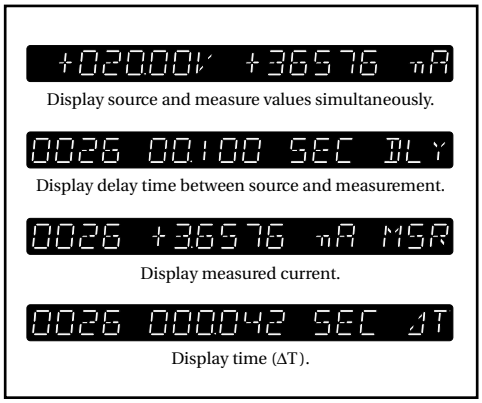
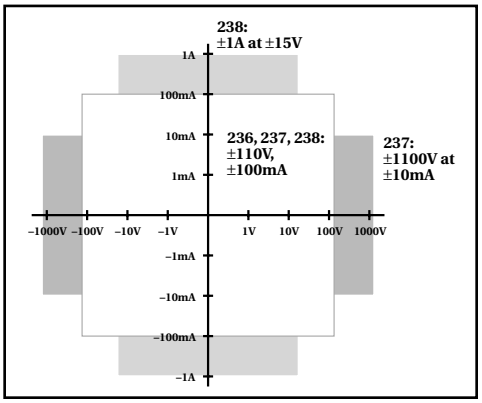
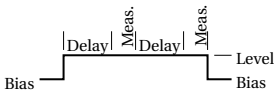
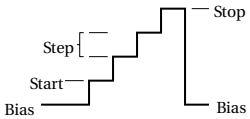
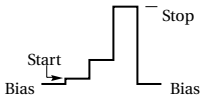
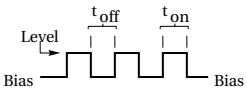
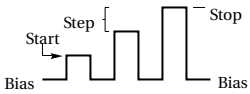
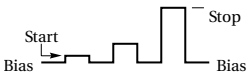
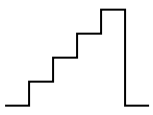
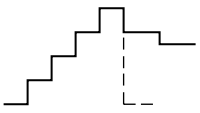
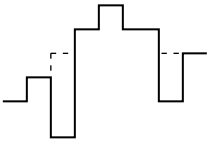



*FIGURE 3: SMU Source Capability*



# 236, 237, and 238 Source-Measure Units

| SWEEP WAVEFORMS | DESCRIPTION |
|---|---|
|  Fixed Level | LEVEL, COUNT (number of DELAY-MEASURE cycles), DELAY, BIAS |
|  Linear Stair | START, STOP, STEP, DELAY, BIAS |
|  Logarithmic Stair | START, STOP, POINTS/DECADE (5, 10, 25, or 50), DELAY, BIAS |
|  Pulse | LEVEL, COUNT, $T_{ON}$, $T_{OFF}$, BIAS |
|  Linear Stair Pulse | START, STOP, STEP, $T_{ON}$, $T_{OFF}$, BIAS |
|  Logarithmic Stair Pulse | START, STOP, POINTS/DECADE (5, 10, 25, or 50), $T_{ON}$, $T_{OFF}$, BIAS |

| WAVEFORM OPERATORS | DESCRIPTION |
|---|---|
|  Create | Allows selection of waveform parameters. Generates all source values. |
|  Append | Combines multiple waveforms and adds new points to those already in memory. |
|  Modify | Select and change any points in a previously created (or appended) waveform. |

**SOURCE-MEASURE UNIT:** Sources voltage while measuring current, or sources current while measuring voltage.

**FUNCTION:** Can be used as DC source or meter, sweep source, or full source-measure unit.

**SOURCE-DELAY-MEASURE CYCLE:**


**Default Delay:** Fixed delay for instrument settling.

**User Delay:** Additional delay for device under test or system capacitance.

**MEASURE**:

| Integration Time | | | |
|---|---|---|---|
| Fast | 416 µs | | 4-digit resolution |
| Medium | 4 ms | | 5-digit resolution |
| Line Cycle | 16.67 ms | (60 Hz) | 5-digit resolution |
| | 20.00 ms | (50 Hz) | |

**Elapsed Time:** Measures and stores time from sweep trigger to measurement complete for each step of sweep.

**RANGING:**

**Source:** Auto-ranging through keypad entry; fixed range selection using rotary dial and SELECT keys (DC function). Fully programmable in SWEEP function.

**Measure:** Auto or fixed range. Fixed range selection made by choice of COMPLIANCE value.

**FILTER:** Takes n measurements, calculates and outputs average (n = 2, 4, 8, 16, or 32, selectable).

**SUPPRESS:** Subtracts displayed measurement from subsequent readings.

**MENU**: DC Measurement Delay, Default Delay On/Off, Local/Remote Sense, 50/60Hz, IEEE Address, Self Tests.

**DATA ENTRY:** Numeric keypad or detented rotary dial.

**TRIGGER:**

**Input and Output:** Set for any phase of SOURCE-DELAY-MEASURE sequence or trigger output at end of sweep.

**Origin:** Internal, External (including front panel MANUAL TRIGGER button), IEEE-488 bus (TALK, GET, "X").

**MEMORY:** Stores one full sweep (up to 1000 points) of source, delay, and measure values, elapsed times, and sweep parameters. Lithium battery backup.

**INTERLOCK:** Use with test fixture or external switch. Normally closed; open puts instrument in standby.

# 236, 237, and 238 Source-Measure Units

## EXECUTION SPEED

**MINIMUM SOURCE-DELAY-MEASURE CYCLE TIME:** 1ms.

**RESPONSE TO IEEE-488 COMMAND (as a source):** 25ms.

**MEASUREMENT RATE:** 1ms per point into internal buffer.

**CONTINUOUS MEASUREMENT SPEED (source DC value over IEEE-488 bus):** 110 readings per second.

**TRIGGER LATENCY TIME:** <2ms.

## IEEE-488 BUS IMPLEMENTATION

**MULTILINE COMMANDS:** DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

**UNILINE COMMANDS:** IFC, REN, EOI, SRQ, ATN.

**INTERFACE FUNCTIONS:** SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

All front panel functions and setups are available over the IEEE-488 bus, in addition to Status, Service Request, Output Format, EOI, Trigger, and Terminator.

IEEE-488 address is set from the front panel menu.

## GENERAL

**LOAD CAPACITANCE:** Stable into 20,000pF typical.

**REMOTE SENSE:** Corrects for up to 2V drop in each output lead. Maximum 1kΩ per sense lead for rated accuracy. Residual output resistance (as a voltage source) is 0.5Ω.

**GUARD: Output Resistance:** ≤12kΩ.

**Maximum Output Current:** ±2mA.

**Offset Relative to Output HI:** ±2mV max.

**ISOLATION (Output LO to chassis):** Typically >$10^{10}$Ω in parallel with 500pF (650pF on Model 238).

**MAXIMUM COMMON MODE VOLTAGE:** 200V.

**CONNECTORS: Outputs:** 3-lug triax.

**Trigger Input/Output:** BNC.

**Interlock:** 3-pin miniature DIN.

**TEMPERATURE COEFFICIENT (0°–18°C & 28°–50°C):** ±(0.1 × applicable accuracy specification)/°C.

**ENVIRONMENT:**

**Operating:** 0°–50°C, 70% relative humidity up to 35°C. Linearly derate 3% RH/°C, 35°–50°C.

**Storage:** –25° to 65°C.

**EMC:** Conforms to European Union Directive 89/336/EEC.

**SAFETY:** Conforms to European Union Directive 73/23/EEC (meets EN61010-1/IEC 1010).

**WARM-UP:** One hour to rated accuracy.

**COOLING:** Internal fan forced air cooling.

**POWER:** 105–125 or 210–250V AC (external switch selectable), 90–110V and 180–220V version available. 100VA max. (120VA max. on Model 238).

**DIMENSIONS, WEIGHT:** 89mm high × 435mm wide × 448mm deep (3½ in × 17⅛ in × 17⅝ in). Net weight 9kg (19.75 lb).

## VOLTAGE

| | SOURCE V | | | MEASURE V | | |
|---|---|---|---|---|---|---|
| | RANGE (Max. Value) | STEP SIZE | ACCURACY (1 Year, 18°–28°C) | RESOLUTION 4-Digit | RESOLUTION 5-Digit | ACCURACY[1] (1 Year, 18°–28°C) |
| **236, 237** | ±1.1000 V[2] | 100 µV | ±(0.033%+650 µV + [$I_O/I_{FS}$] × 450µV) | 100 µV | 10 µV | ±(0.028% + 300µV + [$I_O/I_{FS}$] × 450µV) |
| | ±11.000 V | 1 mV | ±(0.033% + 2.4mV) | 1 mV | 100 µV | ±(0.025%+ 1mV) |
| | ±110.00 V | 10 mV | ±(0.033% + 24mV) | 10 mV | 1 mV | ±(0.025%+ 10mV) |
| **237 Only** | ±1100.0 V | 100 mV | ±(0.04 % + 240mV) | 100 mV | 10 mV | ±(0.035%+100mV) |
| **238 Only** | ±1.5000 V | 100 µV | ±(0.033% +800 µV + [$I_O/I_{FS}$] × 600µV)[3] | 100 µV | 10 µV | ±(0.028% + 450µV + [$I_O/I_{FS}$] × 600µV) |
| | ±15.000 V | 1 mV | ±(0.033% + 2.7mV) | 1 mV | 100 µV | ±(0.025%+ 1mV) |
| | ±110.00 V | 10 mV | ±(0.033% + 24mV) | 10 mV | 1 mV | ±(0.025%+ 10mV) |

$I_O$ = Output current; $I_{FS}$ = Full scale on selected current range

[1] Specifications apply for 5-digit resolution. For 4-digit resolution add 100ppm of range.

[2] Assumes remote sense for I > 100µA.

[3] On the 1A range use [$I_O/I_{FS}$] × 250µV.

**COMPLIANCE:** Bipolar current limit set with single value.

**Maximum:** ±100mA (except ±10mA on 1100V range in Model 237 and ±1A on 15V range in Model 238).

**Minimum:** ±1% of range, except 0.5% of 1.1V range.

**Accuracy, Step Size:** Same as current source.

**NOISE (p-p):**

| RANGE | 0.1–10Hz | DC–20MHz |
|---|---|---|
| 110 V – 1100 V | < 3ppm of range | 40 mV |
| 11 V (15 V on 238) | < 3ppm of range | 15 mV |
| 1.1 V (1.5V on 238) | <10ppm of range | 15 mV |

**WIDEBAND NOISE:** 0.1 to 20MHz, 8mV p-p typical.

**OVERSHOOT:** <0.01% (110V step, 10mA range).

**SETTLING TIME:** <500µs to 0.01% (110V step, 10mA range).

**NMRR:** >60dB at 50 or 60Hz (LINE CYCLE integration time selected).

**CMRR:** >120dB at DC, 50 or 60Hz (LINE CYCLE integration time selected).

**INPUT IMPEDANCE (as a voltmeter):** >$10^{14}$Ω paralleled by <20pF.

## CURRENT

| | SOURCE I | | | MEASURE I | | |
|---|---|---|---|---|---|---|
| | RANGE (Max. Value) | STEP SIZE | ACCURACY (1 Year, 18°–28°C) | RESOLUTION 4-Digit | RESOLUTION 5-Digit | ACCURACY[1] (1 Year, 18°–28°C) |
| **All** | ±1.0000 nA | 100 fA | ±(0.3 %+ 450 fA) | 100 fA | 10 fA | ±(0.3 % + 100 fA)[2] |
| | ±10.000 nA | 1 pA | ±(0.3 %+ 2 pA) | 1 pA | 100 fA | ±(0.3 % + 1 pA) |
| | ±100.00 nA | 10 pA | ±(0.21%+ 20 pA) | 10 pA | 1 pA | ±(0.21 % + 6 pA) |
| | ±1.0000 µA | 100 pA | ±(0.05%+ 200 pA) | 100 pA | 10 pA | ±(0.04 % + 6 pA) |
| | ±10.000 µA | 1 nA | ±(0.05%+ 2 nA) | 1 nA | 100 pA | ±(0.035% + 700 pA) |
| | ±100.00 µA | 10 nA | ±(0.05%+ 20 nA) | 10 nA | 1 nA | ±(0.035% + 6 nA) |
| | ±1.0000 mA | 100 nA | ±(0.05%+ 200 nA) | 100 nA | 10 nA | ±(0.035% + 60 nA) |
| | ±10.000 mA | 1 µA | ±(0.05%+ 2 µA) | 1 µA | 100 nA | ±(0.038% + 600 nA) |
| | ±100.00 mA | 10 µA | ±(0.1 %+ 20 µA) | 10 µA | 1 µA | ±(0.1 % + 6 µA) |
| **238 Only** | ±1.0000 A | 100 µA | ±(0.12%+ 700 nA) | 100 µA | 10 µA | ±(0.12 % + 300 µA) |

[1] Specifications apply for 5-digit resolution. For 4-digit resolution, all offset terms are 200ppm of range.

[2] Offset specification applies for 23°C ± 1°C with suppression. Temperature coefficient 50fA/°C.

**COMPLIANCE:** Bipolar voltage limit set with single value.

**Maximum:** ±1100V (except ±110V in Model 238 and on 100mA range in Model 237).

**Minimum:** ±0.1% of selected current range.

**Accuracy, Step Size:** Same as voltage source.

**NOISE (p-p of range):** 0.1–10Hz: <3ppm (<20ppm on 1nA and 10nA ranges and on 1A range in Model 238).

**OVERSHOOT:** <0.01% typical (10mA step, $R_L$ = 10kΩ).

**SETTLING TIME:** <500µs to 0.01% (10mA step, $R_L$ = 10kΩ).

**OUTPUT R, C:** >$10^{14}$Ω paralleled by <20pF (on 1nA range).