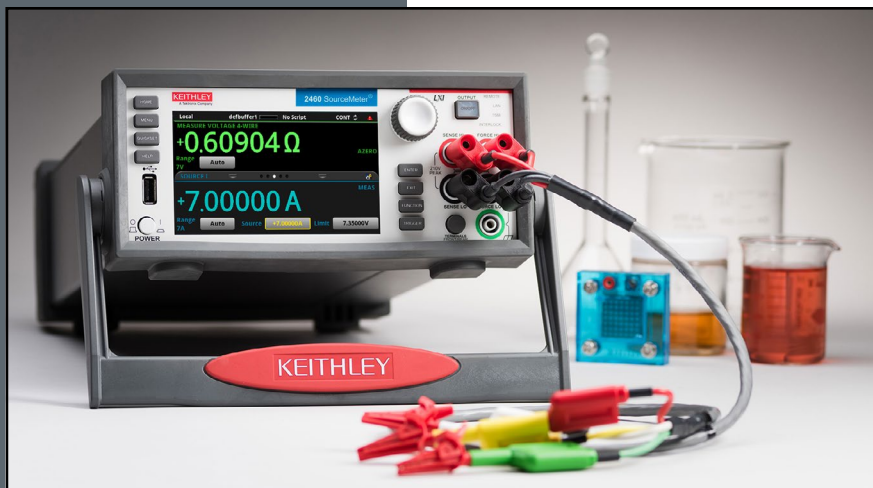


# 2460-EC

# Electrochemistry Lab System



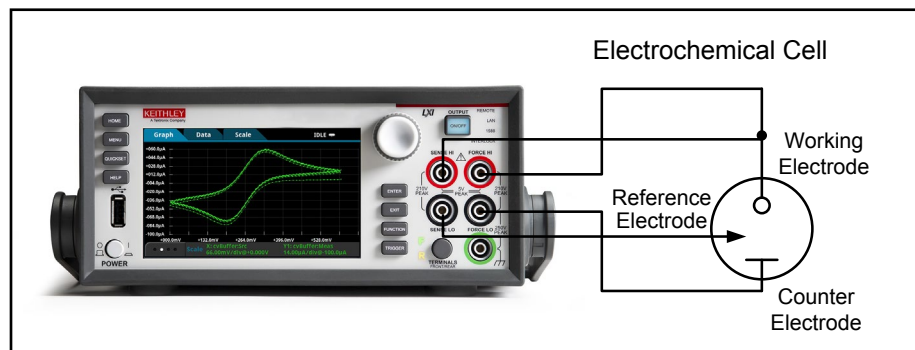
The 2460-EC Electrochemistry Lab System is Keithley's low cost alternative to traditional electrochemistry potentiostats. The 2460-EC brings speed, flexibility, and simplicity right to your fingertips. Its innovative graphical user interface (GUI) and advanced, capacitive touch-screen technology allow intuitive usage and minimize the learning curve to enable researchers, scientists, and students to learn faster, work smarter, and invent easier. The 2460-EC is a versatile instrument, particularly well-suited for research and development in fundamental electrochemical lab research, characterizing the next generation of materials and electrolytes, new energy storage devices, and faster, smaller sensors.

- Lower cost alternative to potentiostats
- Perform Cyclic, Squarewave, Galvanic Voltammetry, Chronoamperometry, and Chronopotentiometry
- Simplified user interface for faster test setup and analysis of results
- Real-time plotting of voltammograms on the front panel
- Analytical graph cursors for immediate analysis of results current without the need for a PC
- Create libraries of reusable, customizable experimental software with built-in open source scripting
- Screen capture function allows copying test results from the display to reports
- Wide coverage up to 105V, 7A DC/7A pulse, 100W max.
- Front panel input banana jacks; rear panel input mass termination screw connections
- Context-sensitive help function minimizes learning
- Front-panel USB 2.0 memory I/O port for transferring data, test scripts, or test configurations

## The Keithley 2460-EC Electrochemistry Lab System: A Low Cost Alternative to the Potentiostat

While potentiostats are excellent instruments for electrochemistry applications, they typically lack any front panel display and control knobs, often are 2-quadrant systems only, and must be completely controlled by a computer with software that is not always open for users to customize tests beyond what the software can do.

Keithley's 2460-EC is a smart alternative as a DC/low frequency potentiostat. The 2460-EC has features that, in many cases, can perform as well as a potentiostat at lower cost including a wide range of voltages and currents for sourcing or measuring, nV / fA sensitivities, and high impedance sense leads with a typical input resistance of 50G ohms and only 1pA of input bias current, typically acceptable with a wide variety of reference electrodes. The 2460-EC can run internal application test scripts so electrochemistry measurements can be run without the use of an external computer. Results (graphs) are immediately displayed right on the instrument front panel touchscreen. Connecting the 2460-EC to a 2-, 3-, or 4-electrode cell to perform the same tests as a potentiostat is simple with the included translation cable.



The 2460-EC can be easily connected to a 3-electrode cell.

# 2460-EC

## Ordering Information

2460-EC Electrochemistry Lab System, 105V, 7A, 100W SourceMeter Instrument

## Accessories Supplied

Electrochemistry Translation Cable Accessory Kit

2460-KIT Rear Panel Mating Mass Terminated Screw Connector

8608 High Performance Test Leads

USB-B-1 USB Cable, Type A to Type B, 1m (3.3 ft)

CS-1616-3 Safety Interlock Mating Connector

CA-180-3A TSP-Link/Ethernet Cable

Documentation CD

Application Test Scripts and Documentation

Test Script Builder Software (available at [www.tektronix.com](http://www.tektronix.com))

KickStart Startup Software (available at [www.tektronix.com](http://www.tektronix.com))

LabVIEW and IVI Drivers (available at [www.tektronix.com](http://www.tektronix.com))

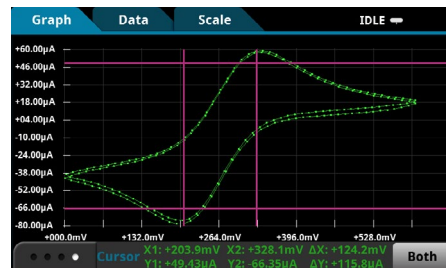
# Electrochemistry Lab System

## Learn Faster; Work Smarter; Invent Easier

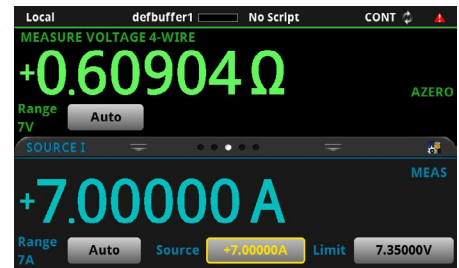
Unlike traditional potentiostats that lack a user-interface front panel to interact with, the 2460-EC features a five-inch, full-color, high resolution touchscreen that facilitates ease of use, and optimizes overall speed and productivity. Built-in, context-sensitive help enables intuitive operation and minimizes the need to review a separate manual. These capabilities combined with its application versatility make the 2460-EC inherently easy to use for basic and advanced measurement applications, regardless of your experience level with electrochemistry instruments.

## Convert Raw Data into Information

A full graphical plotting window converts raw data and displays it immediately as useful information, such as cyclic voltammograms. The touch screen interface makes it easy to observe, interact with, and explore measurements with “zoom and pinch” simplicity. By using the built-in graphing cursors, you can immediately analyze your data without a computer. All graphic screens can be saved to a USB thumb drive for incorporation into reports and journals. Using the graphical sheet view, test data can also be displayed in tabular form. The instrument supports exporting data to a spreadsheet for further analysis, dramatically improving productivity for research and development. This combination of high performance and high ease of use offers unparalleled insight into your test results.



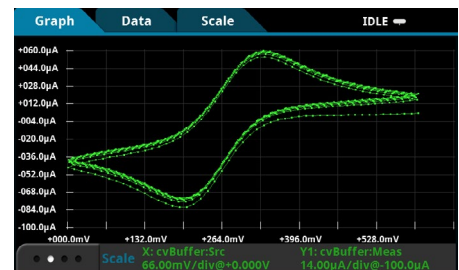
Built-in real-time graphing, charting, scope-like cursors, and data display spreadsheet for export simplifies converting test results into useful information.



2460-EC main home screen.



View of 2460-EC menu.



Graph view of results.

| READING TABLE |                       |             |             |
|---------------|-----------------------|-------------|-------------|
| Buffer        | Active (cvBuffer)     |             |             |
| Buffer Index  | Time                  | Reading     | Source      |
| 1             | 11/05 12:48:23.670575 | +0.00021 mA | +0.600000 V |
| 2             | 11/05 12:48:23.794896 | -0.00011 mA | +0.588000 V |
| 3             | 11/05 12:48:23.914909 | -0.00010 mA | +0.576000 V |
| 4             | 11/05 12:48:24.034908 | -0.00010 mA | +0.564000 V |
| 5             | 11/05 12:48:24.154903 | -0.00013 mA | +0.552000 V |
| 6             | 11/05 12:48:24.274905 | -0.00014 mA | +0.540000 V |
| 7             | 11/05 12:48:24.394871 | -0.00019 mA | +0.528000 V |
| 8             | 11/05 12:48:24.514902 | -0.00014 mA | +0.516000 V |
| 9             | 11/05 12:48:24.634899 | -0.00016 mA | +0.504000 V |
| 10            | 11/05 12:48:24.754894 | -0.00014 mA | +0.492000 V |

# 2460-EC

# Electrochemistry Lab System

## Test Applications

The 2460-EC's built-in open source scripting enables electrochemists, chemists, and materials scientists to create libraries of reusable, customizable experimental software for running tests including cyclic voltammetry, chronoamperometry, chronopotentiometry, and more. The following electrochemistry test scripts are loaded in the internal memory of the 2460-EC.

- **Cyclic Voltammetry:** Potential is swept at a user programmable scan rate between two to four defined vertices while current is measured. Current is measured using an analog integration method.
- **Linear Sweep Voltammetry:** Potential is swept at a user programmable scan rate between two defined points while current is measured.
- **Open Circuit Potential:** Measures the cell potential difference between two electrodes with high input impedance as a function of time.
- **Potential Pulse and Square Wave with Current Measure:** The 2460-EC sources potential at programmable peak and base levels while current is recorded at a user-defined position on the pulse peak level.
- **Current Pulse and Square Wave with Voltage Measure:** The 2460-EC sources current at programmable peak and base levels while potential is recorded at a user-defined position on the pulse peak level.
- **Chronoamperometry:** The potential is stepped to a programmed value while the resulting current is measured as a function of time.
- **Chronopotentiometry:** The current is stepped to a programmed value while the resulting potential is measured as a function of time.

In addition to preloaded test scripts, the built-in open source scripting language enables the user to create their own library of electrochemistry test scripts that can be modified as the test and measurements evolve.

## All-in-One Instrument

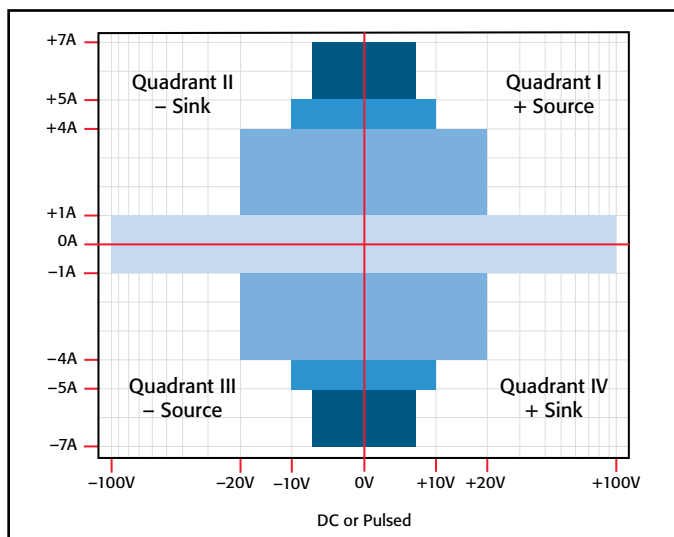
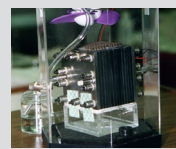
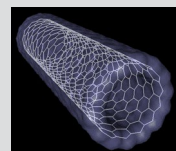
The 2460-EC offers a highly flexible, four-quadrant voltage and current source/load coupled with precision voltage and current meters. When not used in potentiostat type applications, this all-in one instrument can be re-purposed as a general lab instrument, including use as a:

- Precision power supply with V and I readback
- True current source
- Digital multimeter (DCV, DCI, ohms, and power with 6½-digit resolution)
- Precision electronic load
- Trigger controller

## TYPICAL APPLICATIONS

Ideal for electrochemical research and development in a wide variety of applications studies, including:

- **Basic Analytical Research**
  - Electrochemical cells
  - Electrode studies
  - Solid electrolytes
- **Materials Research**
  - Electrode compositions
  - Electrolyte solutions
  - Ceramics, polymers, ferro/ piezoelectrics
  - Organic semiconductors
  - Low- $\kappa$  dielectrics
  - Biomaterials
  - Nanomaterials
  - Electrodeposition
- **Energy Systems and Storage**
  - Dye-sensitized solar cells
  - Batteries
  - Fuel cells, flow batteries
  - Supercapacitors
- **Sensors**
  - Environmental monitoring
  - Industrial process control
  - Healthcare/medical



2460-EC power envelope.

# 2460-EC

# Electrochemistry Lab System

## Ease of Use Beyond the Touchscreen

In addition to its five-inch, color touchscreen, the 2460-EC front panel has many features that supplement its speed, user-friendliness, and learnability, including a USB 2.0 memory I/O port, a HELP key, a rotary navigation/control knob, a front/rear input selector button, and banana jacks for basic bench applications. The USB 2.0 memory port supports easy data storing, saving instrument configurations, loading test scripts, and system upgrades. Plus, all front panel buttons are backlit to enhance visibility in low-light environments.

## Comprehensive Built-in Connectivity

Rear panel access to rear-input triax connectors, remote control interfaces (GPIB, USB 2.0, and LXI/Ethernet), D-sub 9-pin digital I/O port (for internal/external trigger signals and handler control), instrument interlock control, and TSP-Link® jacks enables easy configuration of multiple instrument test solutions and eliminates the need to invest in additional adapter accessories.

## Free Instrument Control Start-up Software

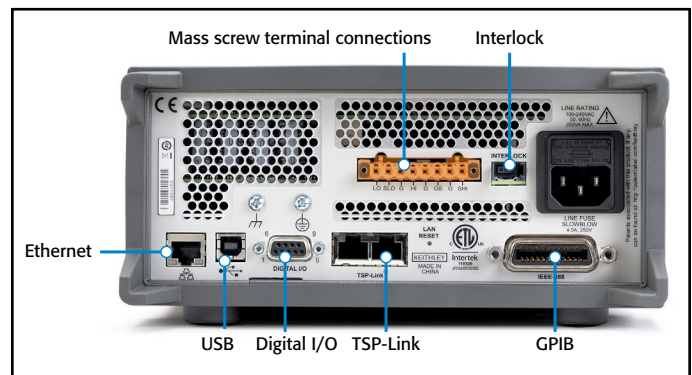
The 2460-EC can be repurposed for applications beyond electrochemistry as a general purpose lab tool, e.g. I-V testing, leakage testing, battery charge/discharge profiling, etc. KickStart, Keithley's instrument control non-programming start-up software, lets users start taking measurements in minutes for typical current versus voltage applications. In most cases, users merely need to make quick measurements, graph the data, and store the data to disk to perform analysis in software environments such as Excel.

KickStart offers the following functionality:

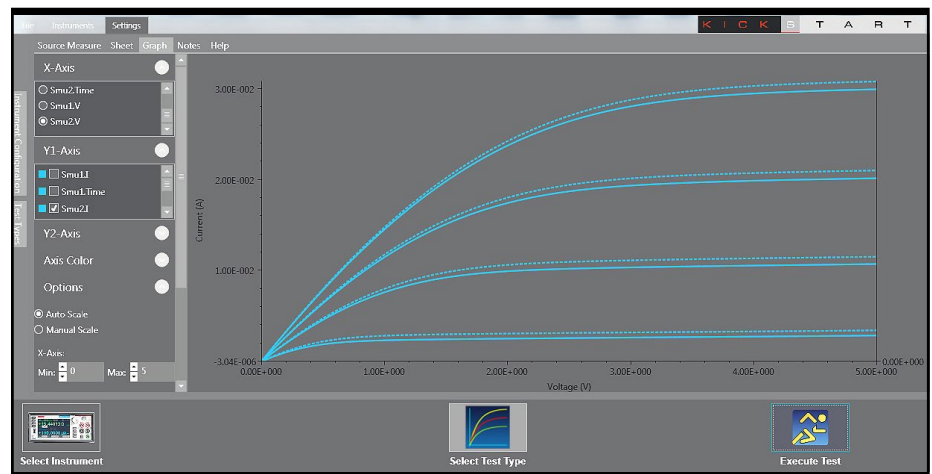
- Instrument configuration control to perform I-V characterization
- Native X-Y graphing, panning, and zooming
- Spreadsheet/tabular viewing of data
- Saving and exporting data for further analysis
- Saving of test setups
- Screenshot capturing of graph
- Annotation of tests
- Command line dialog for sending and receiving data
- HTML help
- GPIB, USB 2.0, Ethernet compliant



Model 2460-EC front panel with high resolution, capacitive touchscreen.



Rear panel connections are optimized for signal integrity.



With KickStart start-up software, users are ready to take measurements in minutes.

### Simplified Programming with Ready-to-Use Instrument Drivers

For those who prefer to create their own customized application software, native National Instruments LabVIEW® drivers, as well as IVI-C and IVI-COM drivers are available at [www.tektronix.com](http://www.tektronix.com).

### Test Script Specifications

#### CYCLIC VOLTAMMETRY

**Potential Range:**  $\pm 5V$ .

**Voltage Step Size During Ramping:**

- 100 $\mu V$  ( $1mV/s \leq \text{scan rate} < 35mV/s$ )
- 1mV ( $35mV/s \leq \text{scan rate} < 350mV/s$ )
- 10mV ( $350mV/s \leq \text{scan rate} \leq 3500mV/s$ ).

**Scan Rate:** 0.1mV/s to 3500mV/s.

**Current Measurement Range (full scale):** 100 $\mu A$ , 1mA, 10mA, 100mA, 1A.

**Number of Cycles:** 1 to 100.

**User Selectable Sampling Interval Units:** Points/Test, Points/Cycle, Seconds/Point, Points/Second.

**Maximum Number of Points:** Up to 100,000 readings.

#### OPEN CIRCUIT POTENTIAL

**Vrange:** 0.2V, 2V, 7V, 10V, 20V.

**Number of Samples:**  $1 \leq n \leq 100,000$ .

**Measure Interval:** 0.75s  $\leq$  measurement interval  $\leq$  100s.

#### POTENTIAL PULSE AND SQUARE WAVE

**Peak Potential:**  $V_{\text{peak}} \leq \pm 20V$ .

**Base Potential:**  $V_{\text{base}} \leq \pm 20V$ .

**Current Ranges:** 1 $\mu A$ , 10 $\mu A$ , 100 $\mu A$ , 1mA, 10mA, 100mA, 1A, 4A, 5A, 7A.

**Pulse Period and Width:**

- $I_{\text{range}} = 1\mu A, 10\mu A, 100\mu A$ .
- 80ms  $\leq$  period  $\leq$  3600s.
- 40ms  $\leq$  pulse width  $\leq$  (0.99  $\times$  period)s.
- $I_{\text{range}} = 1mA, 10mA, 100mA, 1A, 4A, 5A, 7A$ .
- 10ms  $\leq$  period  $\leq$  3600s.
- 5ms  $\leq$  pulse width  $\leq$  (0.99  $\times$  period)s.

**Number of Cycles:**  $1 \leq n \leq 100,000$ .

**Program Time:**

- 10ms  $\leq$  program time  $\leq$  (100,000  $\times$  period)s.

**Sample Time:** 0.01 PLC  $\leq$  sample time  $\leq$  10 PLC & sample time  $\leq$  (pulse width - 0.001)s.

#### CURRENT PULSE AND SQUARE WAVE

**Peak and Base Current:**  $I_{\text{peak}} \leq \pm 7A, I_{\text{base}} \leq \pm 7A$ .

**Potential Ranges:** 0.2V, 2V, 7V, 10V, 20V.

**Pulse Period and Width:**

- $I_{\text{peak}} \leq 1.05\mu A$
- 80ms  $\leq$  period  $\leq$  3600s
- 40ms  $\leq$  pulse width  $\leq$  (0.99  $\times$  period)s.
- 1.05 $\mu A < I_{\text{peak}} \leq 7A$
- 10ms  $\leq$  period  $\leq$  3600s
- 5ms  $\leq$  pulse width  $\leq$  (0.99  $\times$  period)s.

**Number of Cycles:**  $1 \leq n \leq 100,000$ .

**Program Time:**

- 10 ms  $\leq$  program time  $\leq$  (100,000  $\times$  period)s.

**Sample Time:** 0.01 PLC  $\leq$  sample time  $\leq$  10 PLC & sample time  $\leq$  (pulse width - 0.001)s.

#### CHRONOAMPEROMETRY

**Step Potential:**  $V_{\text{step}} \leq \pm 20V$

**Current Ranges:** 1 $\mu A$ , 10 $\mu A$ , 100 $\mu A$ , 1mA, 10mA, 100mA, 1A, 4A, 5A, 7A

**Step Duration:** 10ms  $\leq t \leq$  99,999s

**Measurement Interval:**

- 10 ms  $\leq$  measurement interval  $\leq$  100 s

**Sample Period:** 0.01 PLC  $\leq$  sample period  $\leq$  10 PLC & sample period  $\leq$  (measurement interval - 0.005)s & sample period  $\leq$  (t - 0.005)s

#### CHRONOPOTENTIOMETRY

**Step Current:**  $I_{\text{step}} \leq \pm 7.35A$ .

**Potential Ranges:** 0.2V, 2V, 7V, 10V, 20V.

**Step Duration:** 10ms  $\leq t \leq$  99,999s.

**Measurement Interval:**

- 10 ms  $\leq$  measurement interval  $\leq$  100s.

**Sample Period:** 0.01 PLC  $\leq$  sample period  $\leq$  10 PLC & sample period  $\leq$  (measurement interval - 0.005)s & sample period  $\leq$  (t - 0.005)s.

### ACCESSORIES AVAILABLE

#### TEST LEADS AND PROBES

|      |   |
|------|---|
| 1754 | 2-wire Universal 10-Piece Test Lead Kit |
| 5805 | Kelvin (4-Wire) Spring-Loaded Probes    |
| 5808 | Low Cost Single-pin Kelvin Probe Set    |
| 5809 | Low Cost Kelvin Clip Lead Set           |
| 8605 | High Performance Modular Test Leads     |
| 8606 | High Performance Modular Probe Kit      |
| 8608 | High Performance Clip Lead Set          |

#### CABLES, CONNECTORS, ADAPTERS

|           |   |
|-----------|---|
| 2460-BAN  | Screw Terminal Connector to Banana Cable  |
| 2460-KIT  | Mating Mass Termination Connector         |
| 8607      | 2-Wire, 1000V Banana Cables, 1m (3.3 ft.) |
| CS-1616-3 | Safety Interlock Mating Connector         |

#### COMMUNICATION INTERFACES & CABLES

|             |  |
|-------------|--|
| 7007-1      | Shielded GPIB Cable, 1m (3.3 ft)           |
| 7007-2      | Shielded GPIB Cable, 1m (6.6 ft)           |
| CA-180-3A   | CAT5 Crossover Cable for TSP-Link/Ethernet |
| KPCI-488LPA | IEEE-488 Interface for PCI Bus             |
| KUSB-488B   | IEEE-488 USB-to-GPIB Interface Adapter     |
| USB-B-1     | USB Cable, Type A to Type B, 1m (3.3 ft)   |

#### TRIGGERING AND CONTROL

|            |   |
|------------|---|
| 2450-TLINK | DB-9 to Trigger Link Connector Adapter.     |
| 8501-1     | Trigger Link Cable, DIN-to-DIN, 1m (3.3 ft) |
| 8501-2     | Trigger Link Cable, DIN-to-DIN, 2m (6.6 ft) |

#### RACK MOUNT KITS

|               |  |
|---------------|--|
| 4299-8        | Single Fixed Rack Mount Kit  |
| 4299-9        | Dual Fixed Rack Mount Kit  |
| 4299-10       | Dual Fixed Rack Mount Kit. Mount one 2460 and one Series 26xxB                   |
| 4299-11       | Dual Fixed Rack Mount Kit. Mount one 2460 and one Series 2400, Series 2000, etc. |
| 2450-BenchKit | Ears and Handle for 2460-NFP-RACK and 2460-RACK models                           |

### SERVICES AVAILABLE

|                 |   |
|-----------------|---|
| 2460-3Y-EW      | 1 Year Factory Warranty extended to 3 years from date of shipment |
| 2460-5Y-EW      | 1 Year Factory Warranty extended to 5 years from date of shipment |
| C/2460-3Y-17025 | KeithleyCare® 3 Year ISO 17025 Calibration Plan                   |
| C/2460-3Y-DATA  | KeithleyCare 3 Year Calibration w/Data Plan                       |
| C/2460-3Y-STD   | KeithleyCare 3 Year Std. Calibration Plan                         |
| C/2460-5Y-17025 | KeithleyCare 5 Year ISO 17025 Calibration Plan                    |
| C/2460-5Y-DATA  | KeithleyCare 5 Year Calibration w/Data Plan                       |
| C/2460-5Y-STD   | KeithleyCare 5 Year Std. Calibration Plan                         |
| C/NEW DATA      | Calibration Data for New Units                                    |
| C/NEW DATA ISO  | ISO-17025 Calibration Data for New Units                          |

## Voltage Specifications <sup>1, 2</sup>

| Range       | Source       |            |  |                     | Measure <sup>3</sup>    |                  |   |
|-------------|--------------|------------|--|---------------------|-------------------------|------------------|---|
|             | Max. Current | Resolution | Accuracy (23° ±5°C), 1 Year ±(% setting + volts) | Noise (RMS) (<10Hz) | Resolution <sup>4</sup> | Input Resistance | Accuracy (23° ±5°C), 1 Year ±(% rdg. + volts) |
| 200.0000 mV | 7.35 A       | 5 µV       | 0.015 % + 200 µV                                 | 1 µV                | 100 nV                  | >10 GΩ           | 0.012 % + 200 µV                              |
| 2.000000 V  | 7.35 A       | 50 µV      | 0.015 % + 300 µV                                 | 10 µV               | 1 µV                    | >10 GΩ           | 0.012 % + 300 µV                              |
| 7.000000 V  | 7.35 A       | 250 µV     | 0.015 % + 2.4 mV                                 | 100 µV              | 1 µV                    | >10 GΩ           | 0.015 % + 1 mV                                |
| 10.00000 V  | 5.25 A       | 500 µV     | 0.015 % + 2.4 mV                                 | 100 µV              | 10 µV                   | >10 GΩ           | 0.015 % + 1 mV                                |
| 20.00000 V  | 4.20 A       | 500 µV     | 0.015 % + 2.4 mV                                 | 100 µV              | 10 µV                   | >10 GΩ           | 0.015 % + 1 mV                                |
| 100.0000 V  | 1.05 A       | 2.5 mV     | 0.015 % + 15 mV                                  | 1 mV                | 100 µV                  | >10 GΩ           | 0.015 % + 5 mV                                |

## Current Specifications <sup>1, 2, 5</sup>

| Range       | Source       |            |   |                     | Measure <sup>3</sup>    |                             |  |
|-------------|--------------|------------|---|---------------------|-------------------------|-----------------------------|--|
|             | Max. Voltage | Resolution | Accuracy (23° ±5°C), 1 Year ±(% setting + amps) | Noise (RMS) (<10Hz) | Resolution <sup>4</sup> | Voltage Burden <sup>6</sup> | Accuracy (23° ±5°C), 1 Year ±(% rdg. + amps) |
| 1.000000 µA | 105 V        | 50 pA      | 0.025 % + 1 nA                                  | 40 pA               | 10 pA                   | <100 µV                     | 0.025 % + 700 pA                             |
| 10.00000 µA | 105 V        | 500 pA     | 0.025 % + 1.5 nA                                | 40 pA               | 10 pA                   | <100 µV                     | 0.025 % + 1 nA                               |
| 100.0000 µA | 105 V        | 5 nA       | 0.020 % + 15 nA                                 | 100 pA              | 100 pA                  | <100 µV                     | 0.020 % + 10 nA                              |
| 1.000000 mA | 105 V        | 50 nA      | 0.020 % + 150 nA                                | 1 nA                | 1 nA                    | <100 µV                     | 0.020 % + 100 nA                             |
| 10.00000 mA | 105 V        | 500 nA     | 0.020 % + 1.5 µA                                | 10 nA               | 10 nA                   | <100 µV                     | 0.020 % + 1 µA                               |
| 100.0000 mA | 105 V        | 5 µA       | 0.020 % + 15 µA                                 | 100 nA              | 100 nA                  | <100 µV                     | 0.020 % + 10 µA                              |
| 1.000000 A  | 105 V        | 50 µA      | 0.050 % + 750 µA                                | 5 µA                | 1 µA                    | <100 µV                     | 0.050 % + 500 µA                             |
| 4.000000 A  | 21 V         | 250 µA     | 0.100 % + 3 mA                                  | 25 µA               | 1 µA                    | <100 µV                     | 0.100 % + 2.5 mA                             |
| 5.000000 A  | 10.5 V       | 250 µA     | 0.100 % + 3 mA                                  | 25 µA               | 1 µA                    | <100 µV                     | 0.100 % + 2.5 mA                             |
| 7.000000 A  | 7.35 V       | 500 µA     | 0.150 % + 6 mA                                  | 125 µA              | 1 µA                    | <100 µV                     | 0.150 % + 5 mA                               |

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C): ±(0.10 × accuracy specification)/°C.

- Speed = 1 PLC.
- All specifications are guaranteed with output ON.
- Accuracies apply to 2- and 4-wire mode when properly zeroed.
- 6.5-digit measure resolution.
- Accuracy specifications guaranteed when using 2460-KIT screw terminal accessory.
- Four-wire mode.

## Resistance Measurement Accuracy (Local or Remote Sense) <sup>7, 8, 9</sup>

| Range                     | Default Resolution <sup>10</sup> | Default Test Current | Normal Accuracy                                  | Enhanced Accuracy <sup>11</sup>                 |
|---------------------------|----------------------------------|----------------------|--|---|
|                           |                                  |                      | (23°C ±5°C)<br>1 Year, ±(% rdg. + ohms)          | (23°C ±5°C)<br>1 Year, ±(% rdg. + ohms)         |
| <2.000000 Ω <sup>12</sup> | 1 µΩ                             | User defined         | Source I <sub>ACC</sub> + Meas. V <sub>ACC</sub> | Meas. I <sub>ACC</sub> + Meas. V <sub>ACC</sub> |
| 20.00000 Ω                | 10 µΩ                            | 100 mA               | 0.05 % + 0.003 Ω                                 | 0.04 % + 0.001 Ω                                |
| 200.0000 Ω                | 100 µΩ                           | 10 mA                | 0.05 % + 0.03 Ω                                  | 0.04 % + 0.01 Ω                                 |
| 2.000000 kΩ               | 1 mΩ                             | 1 mA                 | 0.05 % + 0.3 Ω                                   | 0.04 % + 0.1 Ω                                  |
| 20.00000 kΩ               | 10 mΩ                            | 100 µA               | 0.05 % + 3 Ω                                     | 0.04 % + 1 Ω                                    |
| 200.0000 kΩ               | 100 mΩ                           | 10 µA                | 0.05 % + 30 Ω                                    | 0.05 % + 10 Ω                                   |
| 2.000000 MΩ               | 1 Ω                              | 10 µA                | 0.06 % + 100 Ω                                   | 0.06 % + 50 Ω                                   |
| 20.00000 MΩ               | 10 Ω                             | 1 µA                 | 0.14 % + 1000 Ω                                  | 0.12 % + 500 Ω                                  |
| >20.0000 MΩ <sup>12</sup> | —                                | User defined         | Source I <sub>ACC</sub> + Meas. V <sub>ACC</sub> | Meas. I <sub>ACC</sub> + Meas. V <sub>ACC</sub> |

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C): ±(0.10 × accuracy specification)/°C.

### SOURCE CURRENT, MEASURE RESISTANCE MODE:

Total uncertainty = I source accuracy + V measure accuracy (4-wire remote sense).

### SOURCE VOLTAGE, MEASURE RESISTANCE MODE:

Total uncertainty = V source accuracy + I measure accuracy (4-wire remote sense).

- Speed = 1 PLC.
- All specifications are guaranteed with output ON.
- Accuracies apply to 2- and 4-wire mode when properly zeroed.
- 6.5-digit measure resolution.
- Source readback enabled. Offset compensation ON.
- Source current, measure resistance or source voltage, measure resistance only.

## SUPPLEMENTAL CHARACTERISTICS

**MAX. OUTPUT POWER:** 100W, four-quadrant source or sink operation.

### SOURCE LIMITS:

**Vsource:** ±7.35V (≤7A range), ±10.5V (≤5A range), ±21V (≤4A range), ±105V (≤1A range).

**Isource:** ±7.35A (≤7V range), ±5.25mA (≤10V range), ±4.2A (≤20V range), ±1.05mA (≤100V range).

**OVERRRANGE:** 105% of range, source and measure.

### REGULATION:

**Voltage:Line:** 0.01% of range. **Load:** 0.01% of range + 100µV.

**Current:Line:** 0.01% of range. **Load:** 0.01% of range + 100µA.

### SOURCE LIMITS:

**Voltage Source Current Limit:** Bipolar current limit set with single value. Min. 10% of range.

**Current Source Voltage Limit:** Bipolar voltage limit set with single value. Min. 10% of range.

**V-LIMIT / I-LIMIT ACCURACY:** Add 0.3% of setting and ±0.02% of reading to base specification.

### OVERSHOOT:

**Voltage Source:** <0.1% typical (full scale step, resistive load, 20V range, 10mA I-Limit).

**Current Source:** <0.1% typical (1mA step, RLoad = 10kΩ, 20V range)

**RANGE CHANGE OVERSHOOT:** Overshoot into a fully resistive 100kΩ load, 10Hz to 20MHz BW, adjacent ranges: <250mV typical

**OUTPUT SETTLING TIME:** Time required to reach 0.1% of final value, 20V range, 100mA I-Limit: <200µs typical.

**MAXIMUM SLEW RATE:** 1V per µs, 100V range, 100mA limit into a 20kΩ load (typical). 0.6V per µs, 20V range, 100mA limit into a 20kΩ load (typical).

**OVER VOLTAGE PROTECTION:** User selectable values, 5% ±0.5V tolerance. Factory default = none.

**VOLTAGE SOURCE NOISE:** 10Hz–20MHz (RMS): <4.5mV typical into a resistive load.

**COMMON MODE VOLTAGE:** 250V DC.

**COMMON MODE ISOLATION:** >1GΩ, <1000pF.

### NOISE REJECTION (typical):

| NPLC | NMRR  | CMRR   |
|------|-------|--------|
| 0.01 | —     | 60 dB  |
| 0.1  | —     | 60 dB  |
| 1    | 60 dB | 100 dB |

### LOAD IMPEDANCE:

**Normal Mode:** 20nF typical.

**High Capacitance Mode:** Stable into 50µF typical. High-C mode valid for ≥100µA ranges.

**MAX. VOLTAGE DROP BETWEEN FORCE and SENSE TERMINALS:** 5V.

**MAX. SENSE LEAD RESISTANCE:** 1MΩ for rated accuracy.

**SENSE INPUT IMPEDANCE:** >10GΩ.

**GUARD OFFSET VOLTAGE:** <300µV, typical.

## System Measurement Speeds <sup>13</sup>

Reading rates (readings per second) typical for 60Hz (50Hz), script (TSP<sup>®</sup>) programmed

| NPLC      | Trigger Origin | Measure to Memory | Measure to GPIB/<br>USB/LAN | Source Measure to<br>Memory | Source Measure to GPIB/<br>USB/LAN |
|-----------|----------------|-------------------|-----------------------------|-----------------------------|------------------------------------|
| 0.01 NPLC | Internal       | 3050 (2800)       | 2800 (2500)                 | 1700 (1600)                 | 1650 (1550)                        |
| 0.01 NPLC | External       | 2300 (2100)       | 2150 (2000)                 | 1650 (1550)                 | 1600 (1450)                        |
| 0.1 NPLC  | Internal       | 540 (460)         | 530 (450)                   | 470 (410)                   | 470 (400)                          |
| 0.1 NPLC  | External       | 500 (420)         | 500 (420)                   | 460 (390)                   | 450 (350)                          |
| 1 NPLC    | Internal       | 59 (49)           | 59 (49)                     | 58 (48)                     | 58 (48)                            |
| 1 NPLC    | External       | 58 (48)           | 58 (48)                     | 57 (48)                     | 57 (46)                            |

Reading rates (readings per second) typical for 60Hz (50Hz), SCPI programmed.

| NPLC      | Trigger Origin | Measure to Memory | Measure to GPIB/<br>USB/LAN | Source Measure to<br>Memory | Source Measure to GPIB/<br>USB/LAN |
|-----------|----------------|-------------------|-----------------------------|-----------------------------|------------------------------------|
| 0.01 NPLC | Internal       | 3000 (2800)       | 3000 (2790)                 | 1700 (1600)                 | 1550 (1500)                        |
| 0.01 NPLC | External       | 2330 (2150)       | 2330 (2150)                 | 1650 (1550)                 | 1500 (1450)                        |
| 0.1 NPLC  | Internal       | 540 (460)         | 540 (460)                   | 470 (410)                   | 460 (400)                          |
| 0.1 NPLC  | External       | 510 (430)         | 510 (430)                   | 470 (400)                   | 460 (390)                          |
| 1 NPLC    | Internal       | 59 (49)           | 59 (49)                     | 58 (48)                     | 58 (48)                            |
| 1 NPLC    | External       | 58 (49)           | 58 (49)                     | 58 (48)                     | 58 (48)                            |

13. Reading rates applicable for voltage or current measurements, autozero off, autorange off, filter off, binary reading format, and source readback off.

### GENERAL CHARACTERISTICS (default mode unless specified)

**FACTORY DEFAULT STANDARD POWER-UP:** SCPI Mode.

**SOURCE OUTPUT MODES:** Fixed DC Level, Memory/Configuration List (mixed function), Sweep (linear and logarithmic), Sweep (dual linear and dual logarithmic).

**MEMORY BUFFER:** >250,000 readings. Includes selected measured value(s) and time stamp.

**REAL-TIME CLOCK:** Lithium battery backup (3 yr. + battery life).

**REMOTE INTERFACES:**

**GPIB:** IEEE-488.1 compliant. Supports IEEE-488.2 common commands and status model topology.

**USB Device (rear panel, type B):** 2.0 Full Speed USBTMC.

**USB Host (front panel, type A):** USB 2.0, support for flash drives, FAT32.

**Ethernet:** RJ-45 (10/100BT)

**DIGITAL I/O INTERFACE:**

**Lines:** 6 Input/Output user defined for digital I/O or triggering

**Connector:** 9-pin female D

**Input Signal Levels:** 0.7V (maximum logic low), 3.7V (minimum logic high)

**Input Voltage Limits:** -0.25V (Abs. minimum), +5.25V (Abs. maximum)

**Maximum Source Current:** +2.0mA @ >2.7V (per pin)

**Maximum Sink Current:** -50mA @ 0.7V (per pin, solid-state fuse protected)

**5V Power Supply Pin:** Limited to 500mA @ >4V (solid-state fuse protected)

**Handler:** User definable Start of Test, End of Test, 4 category bits

**PROGRAMMABILITY:** SCPI or TSP command sets.

**TSP Mode:** Embedded Test Script Processor (TSP) accessible from any host interface.

**IP CONFIGURATION:** Static or DHCP

**EXPANSION INTERFACE:** The TSP-Link expansion interface allows TSP enabled instruments to trigger and communicate with each other.

**LXI COMPLIANCE:** 1.4 LXI Core 2011.

**DISPLAY:** 5 inch capacitive touch, color TFT WVGA (800×480) with LED backlight.

**INPUT SIGNAL CONNECTIONS:** Front: Banana. Rear: Mass termination screw terminal.

**INTERLOCK:** Active High Input.

**COOLING:** Forced air, variable speed.

**OVER TEMPERATURE PROTECTION:** Internally sensed temperature overload puts unit in standby mode.

**POWER SUPPLY:** 100V to 240V RMS, 50–60Hz (automatically detected at power up).

**VA RATING:** 350 volt-amps max.

**ALTITUDE:** Maximum 2000 meters above sea level.

**EMC:** Conforms to European Union EMC Directive.

**SAFETY:** Compliance with CE and NRTL listed to UL61010-1 and UL61010-2-30. Conforms with European Union Low Voltage Directive.

**VIBRATION:** MIL-PRF-28800F Class 3 Random.

**WARM-UP:** 1 hour to rated accuracies.

**DIMENSIONS:** (With handle and bumpers): 106mm high × 255mm wide × 425mm deep (4.18 in × 10.05 in × 16.75 in). (Without handle and bumpers): 88mm high × 213mm wide × 397mm deep (3.46 in × 8.39 in × 15.63 in.)

**WEIGHT:** With bumpers and handle: 4.75 kg (10.5 lbs.).  
Without bumpers and handle: 4.35 kg (9.6 lbs.).

**ENVIRONMENT:**

**Operating:** 0°–50°C, 70% R.H. up to 35°C. Derate 3% R.H./°C, 35°–50°C, non-condensing.

**Storage:** -25°C to 65°C.

**ACCESSORIES SUPPLIED:** Test Leads, Mating Mass Terminated Screw Connector, USB Cable, Ethernet/TSP Cable, Interlock Adapter, Power Cord, QuickStart Guide, CD User's Manual.

**Contact Information:**

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