

SCA Series

Capacitance Standard Operation Manual



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SCA im/Nov 2023

◆ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ◆



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WARRANTY

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable IET specifications. If within one year after original shipment, it is found not to meet this standard, it will be repaired or, at the option of IET, replaced at no charge when returned to IET. Changes in this product not approved by IET or application of voltages or currents greater than those allowed by the specifications shall void this warranty. IET shall not be liable for any indirect, special, or consequential damages, even if notice has been given to the possibility of such damages.

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Safety Symbols

General definitions of safety symbols used on the instrument or in manuals are listed below.



Caution symbol: the product is marked with this symbol when it is necessary for the user to refer to the instruction manual.



Hazardous voltage symbol: the product is marked with this symbol when high voltage maybe present on the product and an electrical shock hazard can exist.



Indicates the grounding protect terminal, which is used to prevent electric shock from the leakage on chassis. The ground terminal must connect to earth before using the product



Direct current.



Alternating current.



Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.



On supply.



Off supply.



Hot surface. Avoid contact. Surfaces are hot and may cause personal injury if touched.

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Waste Electrical and Electronic Equipment (WEEE) Directive 2002/96/EC

This product complies with the WEEE Directive (2002/96/EC) marking requirements.

The affixed label indicates that you must not discard this electrical/ electronic product in domestic household waste.

Product Category: With reference to the equipment types in the WEEE directive Annex 1, this product is classified as a "Monitoring and Control instrumentation" product.

Do not dispose of electrical appliances as unsorted municipal waste, use separate collection facilities.

Contact your local government for information regarding the collection systems available. If electrical appliances are disposed of in landfills or dumps, hazardous substances can leak into the groundwater and get into the food chain, damaging your health and well-being.

When replacing old appliances with new one, the retailer is legally obligated to take back your old appliances for disposal.

Proposition 65 Warning for California Residents



WARNING: Cancer and Reproductive Harm - www.P65Warnings.ca.gov.

This product may contain chemicals known to the State of California to cause cancer, birth defects, or other reproductive harm

SAFETY PRECAUTIONS

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific WARNINGS elsewhere in this manual may impair the protection provided by the equipment. Such noncompliance would also violate safety standards of design, manufacture, and intended use of the instrument.

IET Labs assumes no liability for the customer's failure to comply with these precautions.

If an instrument is marked CAT I (IEC Measurement Category I), or it is not marked with a measurement category, its measurement terminals must not be connected to line-voltage mains.

The SCA is an indoor use product.



Comply with all WARNINGS - Procedures throughout in this manual and instructions on the instrument prevent you from potential hazard. These instructions contained in the warnings must be followed.



- DO NOT Operate in an Explosive Atmosphere
- Do not operate the instrument in the presence of inflammable gasses or fumes
- Operation of any electrical instrument in such an environment clearly constitutes a safety hazard
- Use Caution around live circuits and whenever hazardous voltages > 45 V are present
- Operators must not remove instrument covers
- Component replacement and internal adjustments must be made by qualified maintenance personnel only
- DO NOT substitute parts or modify the instrument
- When working with high voltages; post warning signs, train personnel and keep unauthorized personnel away.

Do not apply any voltage or currents to the terminals of the instrument in excess of the maximum limits indicated in the specifications section of this manual.

To avoid the danger of introducing additional hazards, do not install substitute parts or perform unauthorized modifications to the instrument.

Return the instrument to an IET Labs for service and repair to ensure that safety features are maintained in operational condition.



WARNING



OBSERVE ALL SAFETY RULES
WHEN WORKING WITH HIGH VOLTAGES OR LINE VOLTAGES.

**Dangerous voltages may be present inside this instrument. Do not open the case
Refer servicing to qualified personnel**

HIGH VOLTAGES MAY BE PRESENT AT THE TERMINALS OF THIS INSTRUMENT

WHENEVER HAZARDOUS VOLTAGES (> 45 V) ARE USED, TAKE ALL MEASURES TO
AVOID ACCIDENTAL CONTACT WITH ANY LIVE COMPONENTS.

USE MAXIMUM INSULATION AND MINIMIZE THE USE OF BARE
CONDUCTORS WHEN USING THIS INSTRUMENT.

Use extreme caution when working with bare conductors or bus bars.

WHEN WORKING WITH HIGH VOLTAGES, POST WARNING SIGNS AND
KEEP UNREQUIRED PERSONNEL SAFELY AWAY.



CAUTION



DO NOT APPLY ANY VOLTAGES OR CURRENTS TO THE TERMINALS OF THIS
INSTRUMENT IN EXCESS OF THE MAXIMUM LIMITS INDICATED ON
THE FRONT PANEL OR THE OPERATING GUIDE LABEL.

Contents

| | |
|--|----------|
| Chapter 1 Introduction | 1 |
| 1.1 Description of the SCA Series | 1 |
| 1.2 Optional Transit Case..... | 1 |
| Chapter 2 Specifications | 2 |
| Specifications | 2 |
| Chapter 3 Operation | 3 |
| 3.1 Initial Inspection and Setup | 3 |
| 3.2 Connections to Capacitor..... | 3 |
| 3.2.1 Low capacitors - 190 pF and under | 3 |
| 3.2.2 Intermediate Capacitors - from 1 nF to 1 μ F | 4 |
| 3.2.3 High capacitors - 1.9 μ F and over | 4 |
| 3.2.4 SCA-XXX-8588A Capacitors | 4 |
| 3.3 Environmental Conditions | 5 |
| 3.3.1 Operating Temperature | 5 |
| 3.3.2 Storage Temperature | 5 |
| 3.4 Shipping and Handling | 5 |
| Chapter 4 Maintenance..... | 7 |
| 4.1 Preventive Maintenance..... | 7 |
| 4.2 Calibration..... | 7 |
| 4.2.1 Calibration Interval..... | 7 |
| 4.2.2 General Considerations..... | 7 |
| 4.2.3 Calibration Procedure | 8 |
| 4.3 Calibration with Digibridge | 8 |
| 4.4 Calibration with GenRad 1620 or AH2500A..... | 8 |
| 4.5 Replaceable Parts List..... | 9 |

Figures and Tables

| | |
|---|---|
| <i>Figure 1-1: SCA Series Resistance Standard</i> | 1 |
| <i>Figure 1-2: Optional Transit Case (SRC-100)</i> | 1 |
| <i>Figure 2-1: Sample label attached to an SCA unit</i> | 2 |
| <i>Figure 3-1: Low SCA capacitor standard with bnc connectors</i> | 3 |
| <i>Figure 3-2: Capacitance shunted by leakage to case</i> | 3 |
| <i>Figure 3-3: Intermediate SCA capacitor standard with 3 binding posts</i> | 4 |
| <i>Figure 3-4: High SCA capacitor standard with 5 binding posts</i> | 4 |
| <i>Figure 3-5: SCA as a 5-terminal capacitor</i> | 4 |
| <i>Table 4-1: Replaceable Parts List</i> | 7 |
| <i>Figure 4-1: SCA replaceable parts</i> | 7 |
| <i>Figure 4-2: New style SCA replaceable parts</i> | 7 |

Chapter 1

INTRODUCTION

1.1 Description of the SCA Series

The SCA Series (Figure 1-1) are stable, precise, laboratory or portable capacitance standards. They are working and laboratory standards grade. The SCA units are available in values ranging from 1 pF to 10,000 μ F with custom values or combinations available, to satisfy any requirement.

Each value range is built with the type of capacitor that will provide the best performance for high stability, low dissipation, low temperature coefficient, and high operating voltage. Most are hermetically sealed and mechanically stabilized.

Low values have bnc connectors to minimize lead stray capacitance; higher values have two or four (Kelvin-type) binding posts. All have a ground terminal.

1.2 Optional Transit Case

Optional **Model SRC-100** lightweight transit case with handle, suitable for transporting and storing two units. See Figure 1-2. The case provides mechanical protection and insulation from temperature changes during transportation or shipping.



Figure 1-1: SCA Series Resistance Standard



Figure 1-2: Optional Transit Case (SRC-100)

Chapter 2

SPECIFICATIONS

For convenience to the user, the pertinent specifications are given in a label, shown in Figure 2-1 affixed to the case of the instrument.

SPECIFICATIONS

| Nominal value | Model | Adjustment to nominal | Temperature coefficient (ppm/°C) | Calibration Conditions | Dissipation (typical) | Stability (per year) | Max voltage | | Terminals | Capacitor type |
|---------------|--------------|--|----------------------------------|--|-----------------------|----------------------|-------------|-----------------------|--|---|
| | | | | | | | Peak (V) | Max Frequency | | |
| 1 pF | SCA-1pF | ±0.1 pF | +20 to +40 | ≤ 15 Vac Parallel Model 1 kHz AH2700A or equivalent | 0.002 | ±0.1 pF | 500 | 10 kHz | 2 bnc connectors + gnd | Air capacitors |
| 1.9 pF | SCA-1.9pF | ±0.1 pF | +20 to +40 | | 0.002 | ±0.1 pF | 500 | 10 kHz | | |
| 10 pF | SCA-10pF | ±0.1 pF | +20 to +40 | | 0.002 | ±0.1 pF | 500 | 10 kHz | | |
| 19 pF | SCA-19pF | ±0.1 pF | +20 to +40 | | 0.001 | ±0.1 pF | 500 | 10 kHz | | |
| 100 pF | SCA-100pF | ±0.1 pF | 20 | | 0.0005 | ±0.1 pF | 500 | 10 kHz | | |
| 190 pF | SCA-190pF | ±0.1 pF | 20 | | 0.0005 | ±0.1 pF | 500 | 10 kHz | 2 binding posts + gnd | Silvered mica mechanically stabilized hermetically sealed |
| 1.0 nF | SCA-1nF | ±0.02% | 20 | | 0.0003 | ±100 ppm | 500 | 10 kHz | | |
| 1.9 nF | SCA-1.9nF | ±0.02% | 20 | | 0.0003 | ±100 ppm | 500 | 10 kHz | | |
| 10 nF | SCA-10nF | ±0.02% | 20 | | 0.0003 | ±100 ppm | 500 | 10 kHz | | |
| 19 nF | SCA-19nF | ±0.02% | 20 | | 0.0003 | ±100 ppm | 500 | 10 kHz | | |
| 100 nF | SCA-100nF | ±0.02% | 20 | 0.0003 | ±100 ppm | 500 | 10 kHz | 4 binding posts + gnd | Metallized polypropylene sulfide hermetically sealed | |
| 190 nF | SCA-190nF | ±0.02% | 20 | 0.0003 | ±100 ppm | 500 | 10 kHz | | | |
| 1 μF | SCA-1μF | ±0.02% | 20 | 0.0002 | ±100 ppm | 500 | 10 kHz | | | |
| 1.9 μF | SCA-1.9μF | ±0.02% | 20 | 0.0002 | ±100 ppm | 100 | 10 kHz | | | |
| 5 μF | SCA-5μF | ±0.02% | ±50 | Series Model 1 kHz | 0.0005 | ±200 ppm | 50 | | | 10 kHz |
| 10 μF | SCA-10μF | ±0.04% | ±50 | 1 Vac Series Model 100 Hz (1 kHz data included) | 0.0005 | ±200 ppm | 22 Vrms† | 1 kHz | 4 binding posts + gnd | Metallized polypropylene sulfide hermetically sealed |
| 19 μF | SCA-19μF | ±0.04% | ±50 | | 0.0005 | ±200 ppm | 44 Vrms† | 1 kHz | | |
| 100 μF | SCA-100μF | ±0.05% | ±50 | | 0.001 | ±500 ppm | 22 Vrms† | 1 kHz | | |
| 190 μF | SCA-190μF | ±0.05% | ±50 | | 0.001 | ±500 ppm | 22 Vrms† | 1 kHz | | |
| 1,000 μF | SCA-1000μF | ±0.4% | -150 | | 0.001 | ±500 ppm | 22 Vrms† | 1 kHz | | |
| 5,000 μF | SCA-5000μF | ±2% | -150 | 0.001 | -- | 22 Vrms† | 1 kHz | Polypropylene | | |
| 10,000 μF | SCA-10000μF | ±2% | -150 | 0.001 | -- | 22 Vrms† | 1 kHz | | | |
| SCA-8588A | SCA-XXX-8588 | ±5% | -150 | ≤ 15 Vac 50 Hz and 1 kHz | 0.0003 | ±100 ppm | 500 | 1 kHz | Polystyrene/PTFE hermetically sealed | |
| XXX F | SCA-XXX | customer-selected value and power specifications | | | | | | | | |

† Maximum allowable Vrms; subject to maximum Vdc = 50 V and max Vrms = (39000/f) for C = 10 μF; (26000/f) for C = 19 μF; (13000/f) for C ≤ 100μF, where f = frequency (in Hz).

Environment:

Operating: +10 to +40°C, <80% RH

Storage: -20 to +65°C

Calibration Conditions:

Calibrated at 23°C, <80% RH, Traceable to SI

Mechanical:

| Nominal Values | Dimensions | Weight |
|-----------------|---|------------------|
| 1 pF < 1 μF | 8.6 cm H x 10.5 cm W x 12.7 cm D (3.4" x 4.15" x 5") | 0.73 kg (1.6 lb) |
| 1 μF (only) | 14.3 cm H x 8.3 cm W x 6.9 cm D (5.6" x 3.2" x 2.7") | 1.1 kg (2.25 lb) |
| > 1 μF ≤ 190 μF | 8.6 cm H x 10.5 cm W x 12.7 cm D (3.4" x 4.15" x 5") | 0.73 kg (1.6 lb) |
| 1,000 μF | 31 cm W x 8.9 cm H x 10.2 cm D (12.2" x 3.5" x 4") | 1.7 kg (3.8 lb) |
| 5,000 μF | 53.3 cm W x 27.3 cm H x 44.5 cm D (21" x 10.75" x 17.5") | 27.2 kg (60 lb) |
| 10,000 μF | | 36.3 kg (80 lb) |
| SCA-xxx-8588A | 12 cm H x 8.6 cm W x 9.5 cm D (4.75" x 3.4" x 3.75") | 0.73 kg (1.6 lb) |

SC-A Series 1 μF CAPACITANCE STANDARD

Capacitance Type: Hermetically sealed silvered mica.
Temp. Coefficient: <20 ppm/°C
Operating Temp: 10°C to 50°C
Maximum Voltage: 500 V
Test Conditions: Calibrated as a 5-terminal capacitor, series model, at 1 Vrms.

| | | | |
|------------------|-------------|--|--|
| Date | 18-Jan-2010 | | |
| C (μF) @ 1592 Hz | 1.000 36 | | |
| D @ 1592 Hz | 0.002 430 | | |
| C (μF) @ 10 kHz | 1.000 103 | | |
| D @ 10 kHz | 0.001 023 | | |
| C (μF) @ 50 kHz | 0.999 124 | | |
| D @ 50 kHz | 0.004 013 | | |
| C (μF) @ 100 kHz | 0.996 463 | | |
| D @ 100 kHz | 0.008 931 | | |
| By | NPL/JOS | | |

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Figure 2-1: Sample label attached to an SCA unit

Chapter 3

OPERATION

3.1 Initial Inspection and Setup

This instrument was carefully inspected before shipment. It should be in proper electrical and mechanical order upon receipt.

To provide ready reference to specifications, a label, shown in Figure 2-1, is attached to the case of the instrument.

3.2 Connections to Capacitor

3.2.1 Low capacitors - 190 pF and under

Low SCA capacitors have 2 bnc connectors labeled **HI** and **LO**, and a ground binding post labeled **GND** as shown in figure 3-1.



Figure 3-1: Low SCA capacitor standard with bnc connectors

The capacitance of the unit is shown as C_{HL} in Figure 3-2. There is additional capacitance to the case shown by C_{HG} and C_{LG} . These capacitances will add to C_{HL} unless the 3rd terminal, **GND**, is connected to the **GUARD** of the measuring instrument.

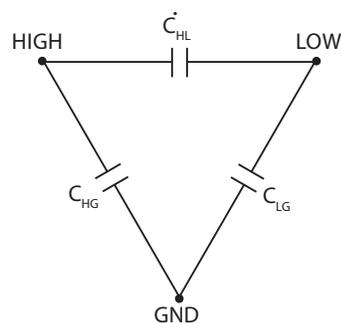


Figure 3-2: Capacitance shunted by leakage to case

3.2.2 Intermediate Capacitors - from 1 nF to 1 μ F

Intermediate SCA capacitors have 3 binding posts -- **HI**, **LO**, and **GND** -- as shown in figure 3-3.



Figure 3-3: Intermediate SCA capacitor standard with 3 binding posts

These intermediate values are connected the same way as low capacitances (Section 3.2.1), except they use binding posts because lead and stray resistances are less critical.

3.2.3 High capacitors - 1.9 μ F and over

High SCA capacitors have 5 binding posts -- **HI CURRENT**, **HI SENSE**, **LO CURRENT**, **LO SENSE**, and **GND** -- as shown in figure 3-4.



Figure 3-4: High SCA capacitor standard with 5 binding posts

This 4-terminal connection circuit has special wiring and low-resistance conductors to minimize dissipation and parasitic inductance, and improve frequency characteristics. See Figure 3-5. To use as a 2-terminal capacitor, connect to only the two **SENSE** terminals.

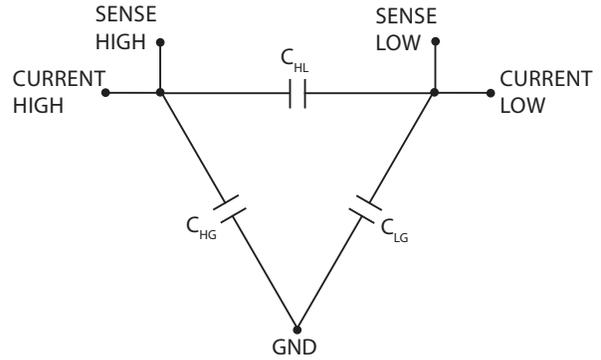


Figure 3-5: SCA as a 5-terminal capacitor

To use as a 2-terminal capacitor, connect to only the two **SENSE** terminals.

3.2.4 SCA-XXX-8588A Capacitors

The SCA-XXX-8588A capacitors are designed for direct connection to the Fluke 8588A Reference DMM.



Figure 3-6: SCA-8588A Front and Rear

The SCA-8588A is available with standard values of 900 pF, 1 nF and 1.8 nF with custom values available.

The SCA-8588A is ideal for calibration/verification of the lowest capacitance range per the Fluke verifying capacitance webpage. The link to this page is shown below

<https://us.flukecal.com/literature/articles-and-education/electrical-calibration/application-notes/verifying-capacitance-fun>

The SCA-8588A is constructed using a hermetically sealed polystyrene or PTFE capacitor.

The Fluke 8588A uses a dc discharge method to make capacitance measurements, so dielectric absorption and leakage has to be kept to a minimum otherwise the capacitance standard will read higher than the calibrated value using an LCR meter or capacitance bridge that uses a sine wave.



Figure 3-7: SCA -8588A on the Fluke 8588A

The SCA-8588A is also a 2-terminal capacitance standard with no guard connection only chassis ground to minimize noise.

Calibration of the SCA-8588A is performed at 1 kHz and 50 Hz so that the low frequency capacitance value of the standard can be extrapolated.

The SCA-8588A should be calibrated within $\pm 3^{\circ}\text{C}$ of the temperature as it will be used on the Fluke 8588A to minimize errors due to TC of the capacitor.

A zero should be performed on the Fluke 8588A prior to connection and measurement of the SCA-8588A and a rolling average is recommended.

3.3 Environmental Conditions

3.3.1 Operating Temperature

For optimal accuracy, SCA models should be used in an environment of $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$. They should be allowed to stabilize at those temperatures after any significant temperature variation.

3.3.2 Storage Temperature

The SCA units should be maintained within the storage temperature range of 0°C to 40°C to retain its accuracy within the specified limits.

3.4 Shipping and Handling

The SCA Series should not be exposed to any excessive shock or temperature extremes. The option SRC-100, a lightweight transit case capable of storing two SCA units, is recommended for shipping or transporting the models.

Intentionally blank

Chapter 4

MAINTENANCE

4.1 Preventive Maintenance

Keep the unit in a clean environment. This will help prevent possible contamination.

SCA's are packaged in a closed case, which limits the entry of contaminants and dust into the instruments. If they are maintained in a clean or air-conditioned environment, cleaning will seldom be required. In a contaminated atmosphere, cleaning may be required.

4.2 Calibration

The SCA units may be employed as stand-alone instruments or as integral components of a system. If used as part of a system, they should be calibrated as part of the overall system to provide an optimum system calibration.

4.2.1 Calibration Interval

The recommended SCA Series calibration interval is twelve (12) months.

The calibration procedure may be carried out by the user if a calibration capability is available, by IET Labs, or by a certified calibration laboratory.

If the user should choose to perform this procedure, then the considerations below should be observed.

4.2.2 General Considerations

It is important, whenever calibrating an SCA unit, to be very aware of the capabilities and limitations of the test instruments used.

Recommended Instruments:

- **IET Model 1689 Digibridge** (direct reading)
or
- **IET Model 1620 or 1621 Precision Capacitance Measurement System** (bridge)

The test instruments must be significantly more accurate than $\pm(0.1\% + 1.0 \text{ pF})$ for all ranges, allowing for a band of uncertainty of the instrument itself.

It is important to allow both the testing instrument and the SCA to stabilize for a number of hours at the nominal operating temperature of 23°C, and at nominal laboratory conditions of humidity. There should be no temperature gradients across the unit under test.

bnc test terminals should be used to obtain accurate shielded readings on low value SCAs

4.3 Calibration Procedure with Digibridge

To calibrate an SCA unit, proceed as follows:

1. SCA capacitors with bnc connectors should be connected to the Digibridge such that the shields are connected to both the high and low terminals.
2. Determine and employ proper metrological practices.
Allow a confidence band for the uncertainty of the measuring instrument and setup.
3. Set test conditions:
At 1 Vrms, series model, 23°C
 ≤ 190 pF: 3-terminal measurement
bnc connection
 1 nF - 1 μ F: 3-terminal measurement
binding post connection
 ≥ 1.9 μ F: 5-terminal measurement
binding post connection
4. Determine the allowable drift limits for the capacitance reading.
 $<(0.1\%+0.1\text{pF})$ per year - up to 1 μ F
5. Confirm that the readings fall within these drift limits, allowing for the uncertainty band.
If the reading falls outside the limits, it has to be repaired by IET or another qualified facility.

4.4 Calibration Procedure with GenRad 1620 or AH2500A/AH2700A Capacitance Bridge

To calibrate an SCA unit, proceed as follows:

1. SCA capacitors with bnc connectors should have the shield disconnected at the **HI** terminal to minimize stray capacitance. The shield on the LO terminal should be maintained.

This connection mimics the connection on the IET/GenRad 1404 Standard Capacitor.

2. Determine and employ proper metrological practices.
Allow a confidence band for the uncertainty of the measuring instrument and setup.
3. Set test conditions:
At 1 Vrms, series model, 23°C
 ≤ 190 pF: 3-terminal measurement
bnc connection
 1 nF - 1 μ F: 3-terminal measurement
binding post connection
 ≥ 1.9 μ F: 5-terminal measurement
binding post connection
4. Determine the allowable drift limits for the capacitance reading.
 $<(0.1\%+0.1\text{pF})$ per year - up to 1 μ F
5. Confirm that the readings fall within these drift limits, allowing for the uncertainty band.
If the reading falls outside the limits, it has to be repaired by IET or another qualified facility

4.5 Replaceable Parts List

| Reference | IET Pt No | Description |
|-----------|-------------|--|
| 1 | 32-21 | Binding Post, Red |
| 2 | 32-20 | Binding Post, Black |
| 3 | 32-19 | Binding Post, Gold |
| 4 | BP-1000-RED | Binding Post, Red |
| 5 | BP-1000-BLK | Binding Post, Black |
| 6 | BP-1000-GRN | Binding Post, Green |
| Not Shown | UG-194 | bnc connecor |
| Not Shown | SCA-*Cap | SCA capacitor assembly |
| Not Shown | 425AA | Banana Plug, Gold-Plated, BeCu for SCA-8588A |

Replace * with nominal capacitance value

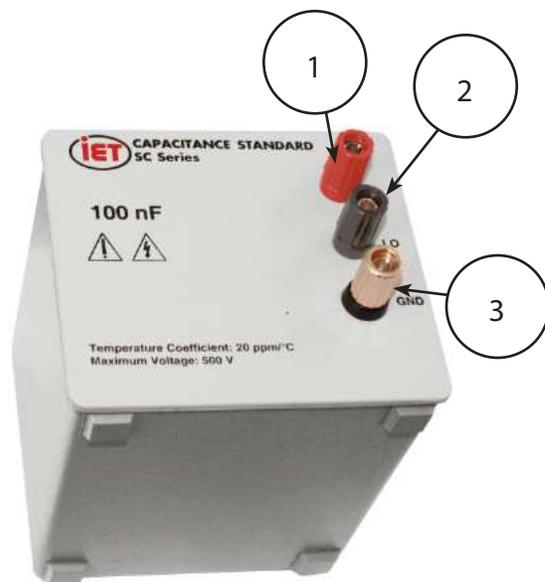


Figure 4-1 Old style SCA replaceable parts

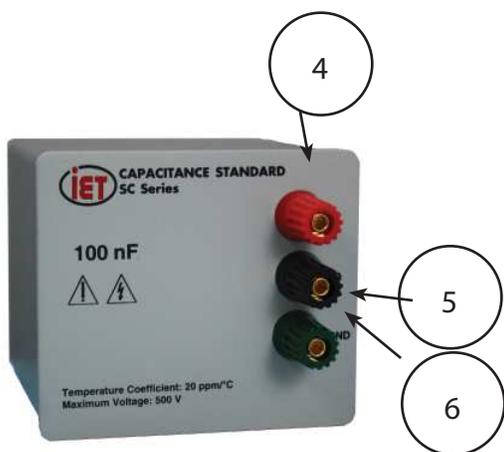


Figure 4-1 New style SCA replaceable parts