♦ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ♦

HACS-Z-A-6E-1pF
Decade Capacitance System

User and Service Manual

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HACS-Z-A-6E-1pF / July 2023

IET LABS, INC.
www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988

www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988

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Chapter 1
INTRODUCTION

1.1 General Description

The HACS-Z-A-6E-1pF Decade Capacitance System is capable of meeting exacting requirements for fixed or adjustable calibration capacitance or any applications requiring precise stable capacitance values.

Unit Features:

- Range: 1 pF - 1.111 11 µF
- Low zero-capacitance
- High accuracy
- Excellent stability
- Low temperature coefficient
- High voltage rating
- Bench-top or rack-mount operation

Figure 1-1: HACS-Z-B-6E-1pF

1 pF, 10 pF

For these, the lowest decade steps, trimmable air capacitors are used. The capacitors are selected for maximum resolution, high mechanical stability, and low dissipation factor.

100 pF - 0.1 µF decades

These mid-range decades are implemented with the highest grade, mechanically stabilized, sealed India ruby mica capacitors selected for optimum electrical characteristics and low dissipation. They are hermetically sealed to prevent intrusion of moisture and to obtain minimum drift.

Stability

The stability of the capacitors is such that the instrument should not require readjustment for the duration of the recommended calibration interval. Should recalibration become necessary, easily accessible trimmer capacitors are provided for the 1 pF, 10 pF, 100 pF, and 1000 pF decades. The other decades may also be calibrated with discrete padder capacitors.

1.2 Switches

Custom-designed switches are used to connect four capacitors in a parallel circuit for each decade. These are weighted in a 1-2-2-5 code to provide all the necessary combinations for ten equal steps for each decade.

The switch circuit is designed such that each unused capacitor is completely disconnected from the rest of the circuit and has its positive terminal connected to the inner shield. See Figure 1-3.

The stability of the switches is assured by the use of large gaps and secure mechanical construction.

1.3 Double Shielded Construction

In order to meet the low residual capacitance requirement, the unit utilizes:

- Specially shielded and routed wiring
- The switching scheme described above and shown in Figure 1-3
- A double-shielded construction to keep the zero capacitance at an extremely low level

Figure 1-2 demonstrates the need for the double shielded construction. It shows that a capacitor C_{HL} would be shunted by the series combination of the series combination of the capacitances from the HIGH and LOW terminals to the case. The net capacitance becomes:

$$C_{HL} + (C_{HG} \text{ in series with } C_{LG})$$

Clearly it would be very difficult to get a very low residual or zero capacitance, unless the G terminal is the ground terminal of 3-terminal measurement of the capacitance.

In order to accomplish this, an inner shield is added as conceptually shown in Figure 1-3. It is mechanically constructed to shunt away any capacitance between the HIGH and LOW terminals. This inner shield shunts this capacitance when it is electrically connected to the outer shield, forming a 3-terminal capacitor (5-teminal capacitor for units with 10 µF steps or higher). All unused capacitors are shorted to this inner shield at their high ends, and are open at their low ends.

This inner shield is not actually an internal enclosure but rather a cellular structure that optimally separates all conductors and capacitor elements. It also serves to minimize terminal-to-ground capacitance which is necessary when measuring small capacitances with various bridges.

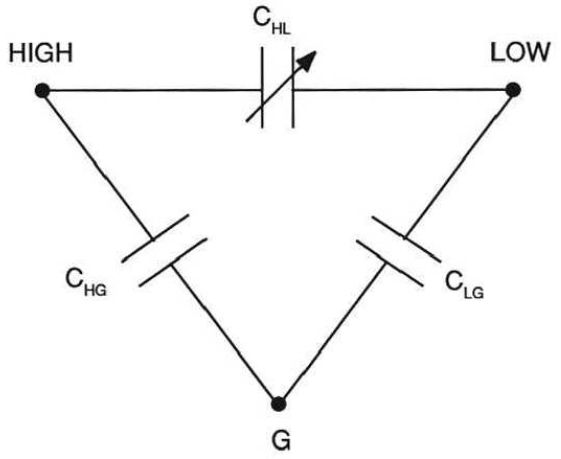

Figure 1-2: Capacitance Shunted by Leakage to case

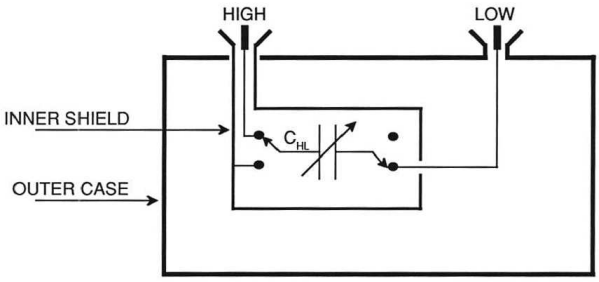

Figure 1-3: HACS-Z Construction

Chapter 2
SPECIFICATIONS

For convenience to the user, the pertinent specifications are given in an **Operating Guide**, similar to the one shown in Figure 2-2, which is affixed to the case of the instrument.

SPECIFICATIONS

Capacitance per step	Total decade capacitance	Max voltage	Accuracy*	Dissipation factor*	Stability	Capacitor type
HACS-Z-1pF Variable Decade	1 pF+	500 V peak max up to 10 kHz	±0.1 pF	<0.003 typical	±(100 ppm + 0.1 pF) per year	Air capacitors
1 pF	10 pF		± (0.05% + 0.5 pF)	<0.002		
10 pF	100 pF			<0.002		
100 pF	1 nF			Position 1: <0.002 All others: <0.001		Silvered mica Mechanically stabilized Hermetically sealed
1,000 pF	10 nF			Position 1: <0.001 Position 2: <0.0005 All others: <0.0003		
0.01 µF	100 nF			<0.0003		
0.1 µF	1 µF			<0.0004		

*1 kHz, 3-terminal measurement; series model; 1 Vrms, 23°C; traceable to SI

No zero-subtraction required

Range:
0 to 1.111 110 µF, in 1 pF steps

Zero Capacitance:
≤0.1 pF maximum capacitance obtained with all dials set to zero;

Temperature Coefficient:
≈20 ppm/°C

Insulation Resistance:
>50,000 MΩ

Operating Temperature Range:
10°C to 40°C

Shielding:
Double-shielded construction; see below.

Dimensions:
Bench: 43.2 cm W x 13.3 cm H x 27.7 cm D (17" x 5.2" x 10.9")
Rack: 48.3 cm W x 13.3 cm H x 27.7 cm D (19" x 5.2" x 10.9")

Weight:
8.6 kg (19 lb), for bench version

Connection to Capacitor:
Two bnc connectors labeled **HI** and **LO**. The shielding is divided into the following parts:
The inner shield: minimizes the terminal-to-guard capacitance
Outer shield (the case): minimizes the detector input capacitance and noise
The outer shell of the **HI** connector is connected to the switch shaft. The outer shell of the **LO** connector is connected to the outer case. To use the HACS-Z as a 3-terminal capacitance substituter with very low zero-capacitance connect these two shields together at the measuring instrument.

DOUBLE SHIELDED CONSTRUCTION

The shielding is divided into two different parts: an inner shield that minimizes the low terminal-to-guard capacitance, and an outer shield (the case) that minimizes the detector input capacitance and noise. (See Figure 2-1.)

When these two shields are connected together, the HACS-Z becomes an excellent 3-terminal capacitance substituter with low zero capacitance.

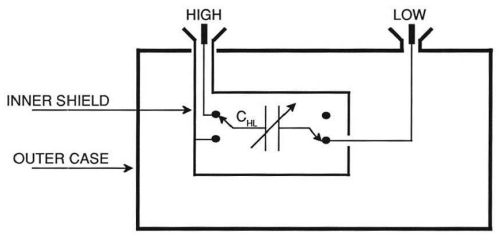

Figure 2-1: Double Shielded Construction

HACS-Z-A HIGH ACCURACY DECADE CAPACITANCE SUBSTITUTER

CONSULT INSTRUCTION MANUAL FOR PROPER INSTRUMENT OPERATION

Accuracy:
± (0.05% + 0.5 pF) at 1 kHz*
*1 kHz, 3-terminal measurement; series model; 1 Vrms, 23°C; traceable to SI
10 µF steps are measured at 100 Hz

Zero Capacitance:
≤0.1 pF maximum capacitance obtained with all dials set to zero

Operating Temperature Range:
10°C to 40°C

Shielding:
Double-shielded construction

Connection to capacitor:
Two bnc connectors labeled **HI** and **LO** located on the front. The shielding is divided into the following parts:
The inner shield: minimizes the terminal-to-guard capacitance
Outer shield (the case): minimizes the detector input capacitance and noise
The outer shells of the **HI** connectors are connected to the switch shaft.

Capacitance per step	Total decade capacitance	Max voltage	Stability	Dissipation factor	Temperature coefficient	Capacitor type
1 pF	10 pF	500 V peak max up to 10 kHz	±(100 ppm + 0.1 pF) per year	**<0.002**		
10 pF	100 pF				≈20 ppm/°C	Air capacitors
100 pF	1 nF			**Position 1: <0.002** **All others: <0.001**		Silvered mica Mechanically stabilized Hermetically sealed
1,000 pF	10 nF			**Position 1: <0.001** **Position 2: <0.0005** **All others: <0.0003**		
0.01 µF	100 nF			**<0.0003**		
0.1 µF	1 µF			**<0.0004**		
1 µF	10 µF	50 V peak max	±(200 ppm) per year	**<0.0007**	-50 ppm/°C	Sealed MPPS
10 µF	100 µF	(Vdc+Vac) < 30 V *or* (Vac) < 22 V		**<0.002**		

The outer shells of the **LO** connectors are connected to the outer case. To use the HACS-Z as a 3-terminal capacitance substituter with very low zero-capacitance connect the two shields together at the measuring instrument.

MODEL: HACS-Z-A-6E-1pF
SN: H1-1816441

WARNING

Observe all safety rules when working with high voltages or line voltages. Connect the (G) terminal to earth ground in order to maintain the case at a safe voltage. Whenever hazardous voltages (>45 V) are used, take all measures to avoid accidental contact with any live components: a) Use maximum insulation and minimize the use of bare conductors. b) Remove power when adjusting switches. c) Post warning signs and keep personnel safely away.

IET LABS, INC.
CAGE CODE: 62015
Email: info@ietlabs.com • (516) 334-5959 • Fax: (516) 334-5988
www.ietlabs.com

HACS-Z-A Feb 2018

Figure 2-2: Typical Operating Guide Affixed to HACS-Z-A-6E-1pF

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.

An **OPERATING GUIDE**, shown in Figure 2-2, is attached to the case of the instrument to provide ready reference to specifications.

3.2 Switch Setting

The HACS-Z Precision Capacitor has six capacitance decades. The actual capacitance for each decade is the product of the switch setting and the **CAPACITANCE PER STEP** indicated below each switch on the front panel.

Note, however, that if any dial is set on 10, a 1 is added to the next decade. For example, if the dials are set: to 10-9-9-10-1-1, the resultant capacitance is:

```
          1
        1
      10
      9
    9
  10
-------------
Total  1100011 pF
```

The zero capacitance of the **HACS-Z** unit is very low, but all settings are adjusted to accurately provide their nominal values, and it is *not necessary* to subtract the zero capacitance from any particular setting

3.3 Connection to Terminals

In order to properly use the HACS-Z capacitor, it is necessary to understand the use and function of each of the capacitor terminals. Refer to Figure 1-2 and note that a basic capacitor is a 2-terminal capacitor shown as C_{HL}. As described above, C_{HG} and C_{LG}, the capacitances to the case add to the capacitor C_{HL} unless the 3rd terminal G is connected to the guard of the measuring instrument.

The shielding is divided into two different parts: an inner shield that minimizes the low terminal-to-guard capacitance, and an outer shield (the case) that minimizes the detector input capacitance and noise.

When these two shields are connected together, the HACS-Z becomes an excellent 3-terminal capacitance substituter with low zero capacitance.

Using the unit as a 2-terminal capacitor will cause an error of about 100 to 150 pF to be added. This error is not necessarily the same for every setting. This also makes the unit susceptible to noise. However, for high capacitance, the unit *may* be used as a 2-terminal device.

Chapter 4
MAINTENANCE

4.1 Preventive Maintenance

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

The HACS-Z is packaged in a closed case, which limits the entry of contaminants and dust into the instrument. If it is maintained in a clean or air-conditioned environment, cleaning will seldom be required. In a contaminated atmosphere, cleaning may be required.

To clean the front panel, wipe the front panel using alcohol and a lint-free cloth.

4.2 Calibration Interval

The recommended calibration interval for the **HACS-Z Capacitance Substituter** 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.

4.3 General Considerations

It is important, whenever calibrating the HACS-Z 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 ±(0.1% + 1.0 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 **HACS-Z** to stabilize for a number of hours at the nominal operating temperature of 23^{O}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.

4.4 Calibration Procedure

To calibrate the unit, proceed as follows:

1. Determine and employ proper metrological practices.
   Allow a confidence band for the uncertainty of the measuring instrument and setup.
2. Set test conditions:
   No zero subtraction required
   At 1 Vrms, series model, 23°C
3. Using 3-terminal measurement confirm the zero capacitance of the unit is ≤0.1 pF.
4. Determine the allowable upper and lower limits for each capacitance setting of each decade based on the specified accuracy.
   For the HACS-Z series, these limits for any capacitance "C" are:
   C±(0.1% + 1.0 pF)
5. Confirm that the readings fall within these limits, allowing for the uncertainty band.
6. If any reading falls outside these limits, the associated step(s) may require adjustment (*See section 4.5 for details*).

4.5 Capacitance Adjustment

The various decades are adjustable as follows:

Steps	Capacitor Type
1 pF	Air capacitor/trimmable
10 pF	Air capacitor/trimmable
100 pF	Air and mica capacitor/trimmable
1,000 pF	Air and mica capacitor/trimmable
0.01 µF	Mica capacitor/padders
0.1 µF	Mica capacitor/padders

Table 4-1: Capacitor type

To adjust 1 pF - 1,000 pF decades, proceed as follows:

1. Remove the rear panel; see Figure 4-1.
   This exposes the trimmers for each decade; see Figure 4-2.

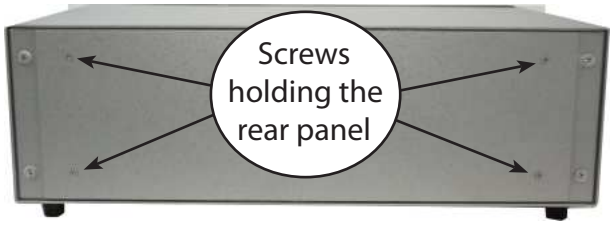

Figure 4-1: Screws holding the rear panel

2. Adjust each decade in ascending order, starting with the lowest value of the lowest decade.

Figure 4-2: Calibration access holes

To make adjustments:

A. Set all dials to zero except for the decade in question.
B. Set that decade to the value indicated on the trimmer label, in the nominal order of 1-2-4-5 starting with the smallest.
   When taking a measurement, use a nonmetallic screw driver or tool.

To adjust the 10 nF and 100 nF decades - *if technical capability for this process is available* - proceed as follows:

1. Loosen the four 10-32 screws holding the cabinet and slide the cabinet off the unit; see Figure 4-3.

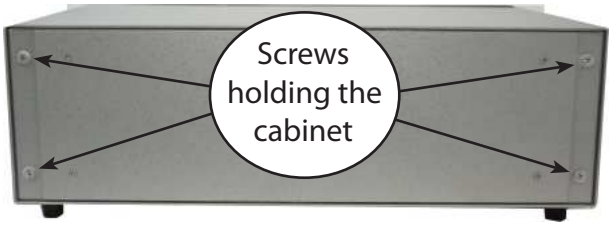

Figure 4-3: Screws holding the cabinet

2. Locate the particular capacitance of the 1-2-4-5 set of the particular decade that needs to be adjusted. See capacitor-labels; see Figure 4-4

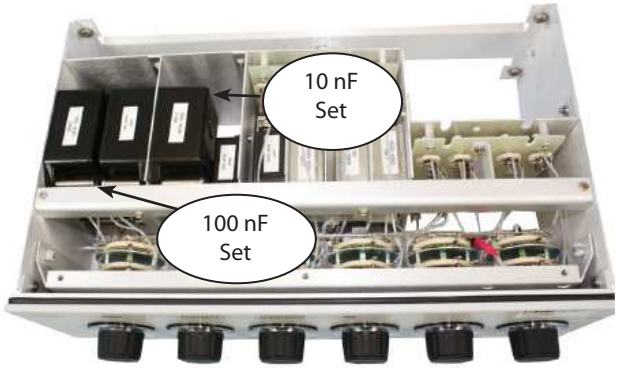

Figure 4-4: 10 nF & 100 nF capacitance sets

3. Locate the padder capacitor if installed across the particular capacitor in question.
4. Adjust the padder up or down by adding or removing a capacitor trimmer.
5. Confirm calibration.
6. Replace the cabinet.

4.6 Replaceable Parts

Model Ref	IET Pt No	Description
1	0505-4030	Mica Capacitor, 100 pF
1	0505-4031	Mica Capacitor, 200 pF
1	0505-4032	Mica Capacitor, 500 pF
1	0505-4033	Mica Capacitor, 1 nF
1	0505-4034	Mica Capacitor, 2 nF
1	0505-4035	Mica Capacitor, 5 nF
1	0505-4036	Mica Capacitor, 10 nF
1	0505-4037	Mica Capacitor, 20 nF
1	0505-4038	Mica Capacitor, 50 nF
1	0505-4039	Mica Capacitor, 100 nF
1	0505-4040	Mica Capacitor, 200 nF
1	0505-4041	Mica Capacitor, 500 nF
2	4380-3700	Air Capacitor, 2.7-19.6 pF
3	4380-3600	Air Capacitor, 1.7-8.7 pF
4	4380-3500	Air Capacitor, 1.5-5.0 pF
5	HACS-Z-520033	Switch Assembly
6	HACS-Z-4300-KNB	Knob Assembly
Not Visible	HACS-Z-PE4091	**HIGH** bnc connector
Not Visible	HACS-Z-31-221-RFX	**LOW** bnc connector
Not Visible	1413-BC-14215	Bail assembly

Table 4-2: Replaceable Parts List

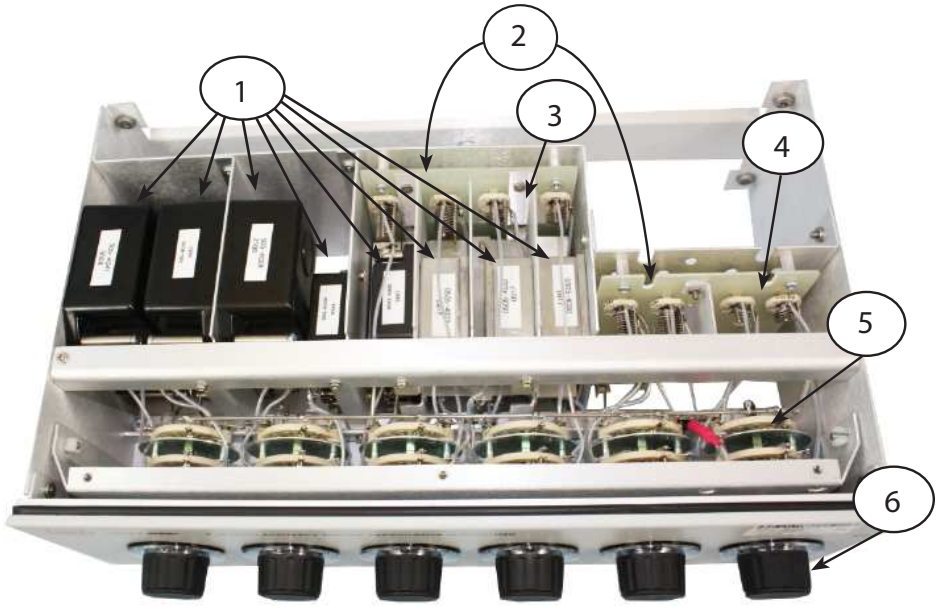

Figure 4-5: Replaceable Parts