♦ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ♦

HACS-Z SERIES

High Accuracy Decade Capacitance Substituter

User and Service Manual

Effectivity: Serial Numbers prefixed G1
HACSZim/July, 2000

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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.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTIBILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

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 qulified 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

WARRANTY ..... **i**
WARNING ..... **ii**
CAUTION ..... **ii**

Chapter 1: INTRODUCTION **1**
1.1 General Description 1
1.2 Switches 1
1.3 Double Shielded Construction 1

Chapter 2: SPECIFICATIONS **3**

Chapter 3: OPERATION **5**
3.1 Initial Inspection and Setup 5
3.2 Switch Setting 5
3.3 Connection to Terminals 5
3.3.1 Introduction to Capacitor Terminals, 2, 3, 4, or 5 5
3.3.2 Choice of terminal connections 7

Chapter 4: CALIBRATION **8**

Figures

Figure 1.1 Capacitance Shunted by Leakage to case. 2
Figure 1.2 HACS-Z Construction 2
Figure 3.1 OPERATING Guide Affixed to Unit 6

Chapter 1

INTRODUCTION

1.1 General Description

The HACS-Z series of decade capacitors is a calibration grade capacitance substituter capable of meeting exacting requirements for fixed or adjustable calibration capacitance or any applications requiring precise stable capacitance values. It features a wide range, very low zero capacitance, high accuracy, and excellent stability. It may be used on the bench or rack mounted.

For the lowest decades, the l pF and 10 pF decade steps, trimmable air capacitors are used. The capacitors are selected for maximum resolution, high mechanical stability, and low dissipation factor.

The mid-range decades, 100 pF, 1000 pF, 0.01 □F and 0.1 □F steps, are implemented with the highest grade mechanically stabilized sealed India Ruby mica capacitors, especially selected for optimum electrical characteristics and excellent stability.

The highest decades are implemented with polystyrene for 1 □F steps, and metallized polycarbonate for 10 □F and 100 □F steps. These capacitors are hermetically sealed high reliability components approved for critical aerospace applications. Hermetic sealing prevents the intrusion of moisture into the capacitor packages.

The stability of the capacitors is such that the instrument would not require readjustment with proper care and normal use. Should recalibration become necessary, easily accessible trimmer capacitors are provided for the l 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 so 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 1.2.

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 achieve the low residual capacitance requirement for this instrument,

1) proper wiring,
2) the particular switching scheme described above, and
3) a double shielded construction serve to keep the zero capacitance at an extremely low level.

Figure 1.1 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.

In order to circumvent this problem, a second inner shield design is added as conceptually shown in Figure 1.2. 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 □F steps or higher). All unused capacitors are shorted at their high ends to this inner shield and open at their low end.

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.

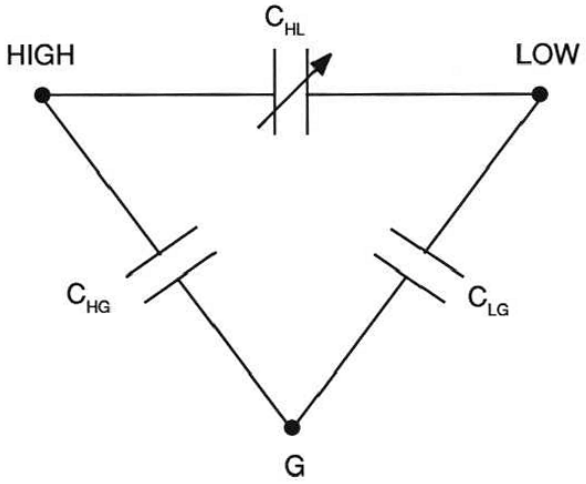

Figure 1.1 Capacitance Shunted by Leakage to case.

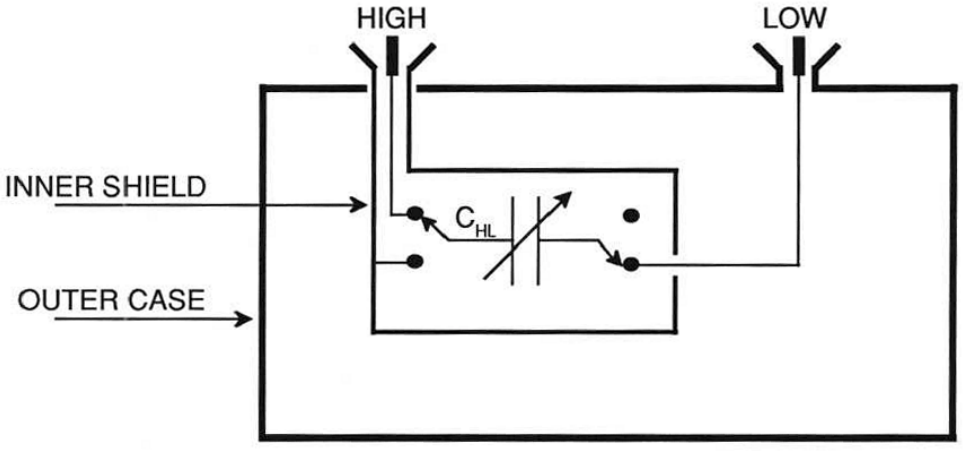

Figure 1.2 HACS-Z Construction

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 3.1, is attached to the case of the instrument to provide ready reference to specifications.

3.2 Switch Setting

The HACS-Z Precision Capacitor has up to seven 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. If, for example, the dials are set: to 10-9-9-10-1-1, the resultant capacitance is:

```
          1
         1
        10
        9
       9
     10
Total 11100011 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

3.3.1 Introduction to Capacitor Terminals: 2, 3, 4, or 5

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 1.1 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. In the case of the HACS-Z, the ground or guard is any of outer conductors of the four BNC connectors which are electrically connected to the case of the instrument. The **HIGH** and **LOW** terminals shown in the figure are **either** pair of **HI** and **LO** terminals on the instrument, although the pair marked **CURRENT** are preferred. This is the description of the HACS-Z as a 2 or 3-terminal capacitor.

The HACS-Z, may be used as a 2-terminal capacitor with the realization that the capacitance to ground will be added to the net capacitance. Also, not using the guard will circumvent the double shielding scheme of the instrument. The result is that not using the ground or guard will cause an error of about 100 to 150 pF to be added. It is not necessarily constant for every setting. It also makes the unit susceptible to noise. However, for high capacitance, it may be used.

In order to connect to a low impedance, 4 Kelvin terminals are required to eliminate lead impedances and this becomes important for capacitance over 10 □F. The 4 terminals are the two **HI** and the two **LO** terminals. The two additional terminals added to the 2 or 3 above make for 3 or 5 terminals.

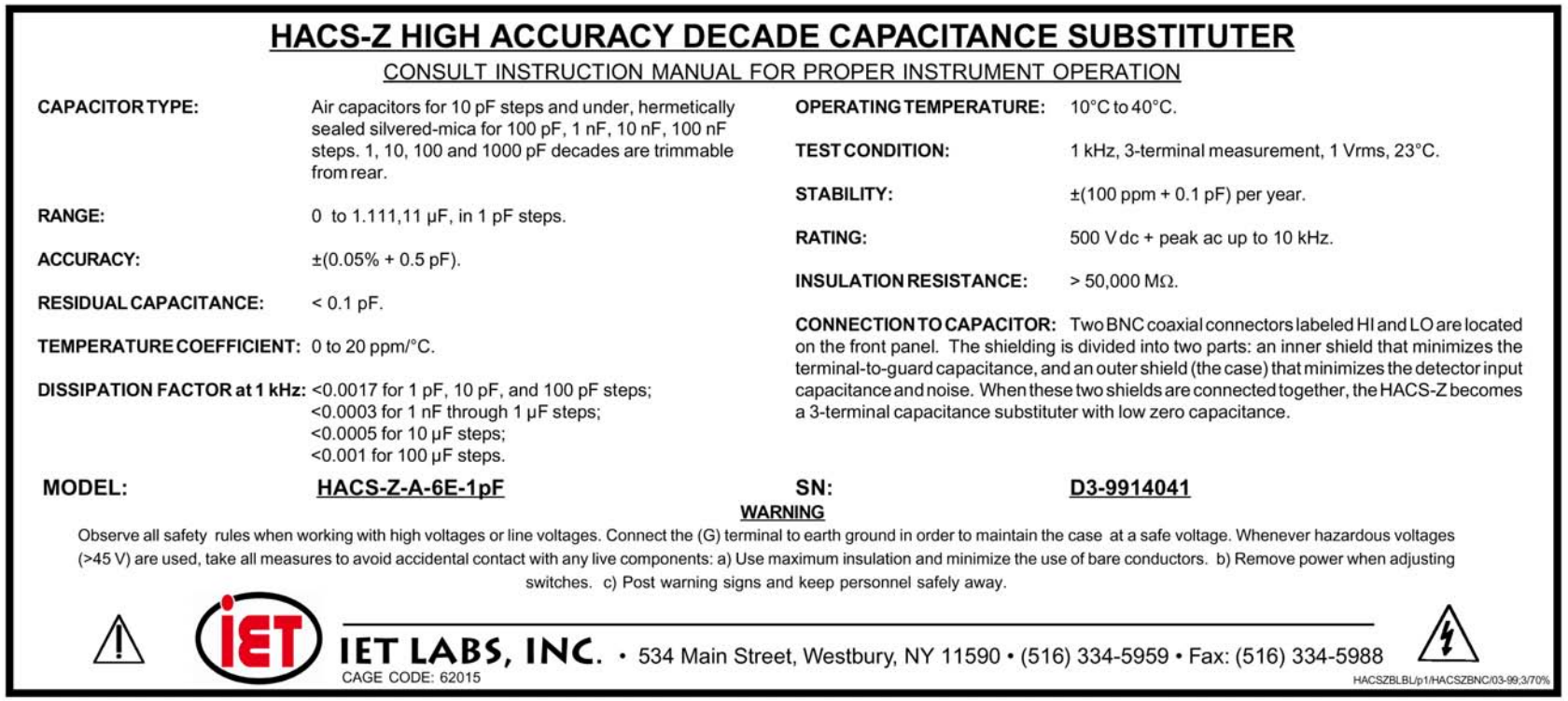

Figure 3.1 OPERATING Guide Affixed to Unit

3.3.2 Choice of terminal connections

For capacitance up to 10 □F, rated accuracy is valid with a 3-terminal measurement..

For 5-terminal units, best results are obtained using both pairs of **HI** and **LO** terminals. The fifth conductor is connected to the measuring instrument guard. For capacitance up to 10 □F, rated accuracy is valid with a 3-terminal measurement, i.e. without the **SENSE HI** and **LO** terminals. Higher capacitances will result in a slightly reduced accuracy.

Chapter 4

CALIBRATION

To calibrate the **HACS-Z**, a high accuracy 3-terminal capacitance bridge and/or transfer standards of sufficient accuracy must be used.

The l pF, 10 pF, 100 pF, and 1,000 pF decades allow adjustment using trimmable air capacitors accessible from the rear of the unit. The 1 pF and 10 pF decades are entirely composed of air capacitors. The four upper decades provide most of the capacitance with sealed high quality mica capacitors.

To calibrate any of these four decades, remove the rear panel. This exposes the trimmers for each decade. For units with high value capacitance, it is necessary to remove the housing by sliding it off from the back in order to access the trimming air capacitors.

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

To make the adjustment, set all dials to zero except for the decade in question. Set that decade to the value indicated on the trimmer label, in the nominal order of 1-2-4-5 starting with the smallest. Use a nonmetallic screw driver or remove the screw driver when taking a measurement.