

# MODEL 3000 DIGITAL CAPACITANCE METER

## Operation and Calibration Manual

### Serial Numbers

This manual applies directly to instruments with serial numbers 30700 and up, main board assembly 8503000-0-3, revision 3.

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Serial Number: \_\_\_\_\_

For technical assistance, contact

*GLK INSTRUMENTS*

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## TABLE OF CONTENTS

Section	Page
I. Warranty	3
II. Product Use Restrictions	3
III. Return Material Authorization	3
IV. Specifications	4
V. Description	5
VI. Initial Preparation	7
VII. Operating Instructions	8
VIII. Servicing Information	12
IX. Calibration	14
X. Revisions	15

## I. WARRANTY

GLK Instruments products are warranted against defects in workmanship and materials under normal use and service for one year from date of their shipment by GLK Instruments, except that components obtained from others are warranted only to the extent of the original manufacturers' warranties, if any. This warranty does not extend to any products that have been repaired or altered by others. GLK Instruments' sole liability and the Purchaser's sole remedy under this warranty are limited to repairing or replacing defective products. The repair or replacement of defective products does not extend the warranty period. This warranty does not apply to components or products which by the nature of the applications are consumed in operation or which have a normal life inherently shorter than one year. Examples of this are batteries, components or products exposed to nuclear radiation, or used in the measurement or detection of explosions. GLK Instruments shall not be liable for consequential damages under any circumstances.

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## II. PRODUCT USE RESTRICTIONS

GLK Instruments does not recommend the use of any of its products or the incorporation of any of its products by second parties in their products in (a) life support applications where failure or malfunction of the product can be reasonably expected to cause failure of the life support device or to significantly affect its safety or effectiveness, (b) any nuclear facility applications which including nuclear reactors and devices designed or used in connection with the handling, processing packaging, preparation, utilization, fabricating, alloying, storing, or disposal of fissionable material or waste products, (c) consumer applications where failure or malfunction of the product can be reasonably expected to cause injury, and (d) applications where failure or malfunction of the product can reasonably be expected to place the health and safety of the general public in jeopardy. GLK Instruments will not knowingly sell its products for use in such applications unless GLK Instruments receives in writing satisfactory assurances that (a) the risks of injury or damage have been minimized, (b) the customer assumes all such risks, and (c) the liability of GLK Instruments is adequately protected under the circumstances.

## III. RETURN MATERIAL AUTHORIZATION

In the unlikely event that any of the products of GLK Instruments need repair, contact [GLK Instruments](#) for a return material authorization (RMA) number.

## IV. SPECIFICATIONS

(25 °C unless specified otherwise)

### **Electrical**

Capacitance range:	2.000 pF to 200.0 nF
Resolution:	0.001 pF to 0.1 nF
Display:	3 1/2 digit liquid crystal display (LCD)
Accuracy with or without probes:	± (0.1% of reading + 2 digits)
Measurement frequencies:	24 kHz (2 pF, 20 pF, 200 pF, 2 nF) 2.4 kHz (20 nF) 240 Hz (200 nF)
Charging voltage:	5 V (all ranges)
Offset adjustment:	1.5 pF
Analog output voltage:	0 - 200 mV DC
Analog bandwidth <sup>(1)</sup> :	1.2 Hz (2 pF), 2.8 Hz (20 pF), 15 Hz (200 pF), 64 Hz (2 nF, 20 nF, 200 nF)
Source resistance:	1000 ohms (1%)
Reference output voltage:	5.000 V DC
Source resistance:	1000 ohms (1%)
Digital I/O:	USB Port 1.1 compliant, optically isolated
Battery:	9 V alkaline (NEDA 1604A)
Auxiliary power:	9 - 28 V DC, 50 mA supply with 2.1 mm DC power jack
USB port power:	Isolated, 4.5V to 5.5V, 300mA

### **Environmental**

Operating Temperature:	0 °C to +50 °C
Storage Temperature:	-20 °C to +70 °C
Operating relative humidity:	80% (noncondensing)

### **Mechanical**

Package:	Bench top, portable instrument case with tilt bail
Dimensions:	8.50 x 9.52 x 2.44 inches
Net Weight:	2 lbs

### **Accessories Supplied**

Two miniature shielded probes and probe accessories (PN 2110112)  
9 V battery (NEDA 1604A)  
Operation and Calibration Manual  
100 nF Chip Capacitor  
Battery eliminator (PN 4001200): input 120 VAC, 60 Hz, 6 W; output 9 VDC, 200 mA; 2.1 mm Plug  
Application CD and USB cable

### **Optional Accessories**

International battery eliminator (PN 4001201): input 90 to 264 VAC, 47 to 63 Hz, 18 W, IEC 320 connector; output 12 VDC, 1.5 A, 2.1 mm Plug. Customer supplies AC cord set, 3-prong IEC 320 to local connection.

<sup>(1)</sup> Note: wideband option 001 increases bandwidth to ~70 Hz on each range. Wideband option must be specified at time of order. Bandwidth of each range can be customized at time order.

## V. DESCRIPTION

The Model 3000 Digital Capacitance Meter is the first commercially available low cost, high accuracy instrument designed exclusively for the measurement of very small value capacitors and capacitors whose size and shape are not conveniently handled by conventional sockets, clamp fixtures, or alligator clip leads. This instrument is particularly useful for the measurement chip capacitors whose small size precludes the use of identifying marks.

The Model 3000 employs a unique and patented (U.S. Patent No. 4806846) switched capacitor circuit and a ratio metric measurement technique that eliminates errors due to stray capacitance to ground. The patented circuit has high common-mode rejection and eliminates errors due to changes in the reference voltage from temperature, aging, etc. This unique circuit allows the capacitor under measurement to be remotely connected to the meter via two, miniature, shielded probes or coaxial cables without affecting the accuracy or resolution of the instrument.

The convenience of using miniature probes solves the costly problem of constructing special test fixtures and shielded boxes for the determination of the capacitance of a variety of objects. For example, the Model 3000 with its standard probes can easily determine the capacitance between the pins of a connector, the large signal gate capacitance of power MOSFETs, the depletion capacitance of diodes, the capacitance between the traces on a printed circuit board, or even the static capacitance of microstrip or stripline microwave circuits. Using ultra-miniature, shielded probes, very accurate wafer level, large signal measurements of MOS capacitors are easily obtained.

Miniature, shielded probes are normally supplied with the instrument; however, the Model 3000, due to its unique circuitry, can accommodate a large variety of custom built shielded probes, special shielded connectors, or test fixtures. Coarse and fine offset adjustment potentiometers are provided on the front panel of the instrument to compensate for any unshielded test fixture capacitance up to 1.5 pF. Capacitors can be remotely connected to the Model 3000 using standard coaxial cables such as RG-223. The Model 3000 maintains its accuracy and resolution with or without probes.

Auxiliary analog outputs of the meter reading (0-200mV) and reference voltage (5.000V) are available on the back panel. These outputs can be connected to digital voltmeters, plotters, data loggers, computer data acquisition systems, etc. using standard banana jacks and shielded coaxial cables.

Fully isolated digital I/O is available at the USB port on all new instruments starting at serial numbers 30024 and up. Older instruments can be upgraded to support digital I/O for a nominal charge. Contact [GLK Instruments](#) for details. The USB port provides access to the instrument's 24-bit ADC and range switches.

Digital I/O support extends the resolution and range of the instrument as shown in Table I.

A standard 9 V alkaline or lithium battery powers the Model 3000. Battery life is approximately 200 hours. An auxiliary DC power jack is provided for powering the instrument from the battery eliminator (US version PN 4001200 or optional, international version PN 4001201). The USB port supplies isolated power to the Model 3000 whenever a USB cable is connected to a compliant USB port (powered port) on the host computer. When powered by the USB port, the Model 3000 is always on, independent of the ON/OFF switch position. Due to the optical and magnetic isolation of the USB port from the Model 3000 circuitry, the USB port is active only when powered from the host computer.

Table I. Extended Range and Resolution at USB Port

Front Panel		USB Port	
Range Switch	3 ½ Digit LCD Meter	Extended Range	Extended Resolution
2 pF	1.999 pF	3.0000 pF	0.1 fF
20 pF	19.99 pF	30.000 pF	1 fF
200 pF	199.9 pF	300.00 pF	10 fF
2 nF	1.999 nF	3.0000 nF	0.1 pF
20 nF	19.99 nF	30.000 nF	1 pF
200 nF	199.9 nF	300.00 nF	10 pF

## VI. INITIAL PREPARATION

The Model 3000 (PN 2903000-0) is supplied ready for use with a battery, battery eliminator, two probes with accessories, USB cable, and application CD with USB port drivers and LabVIEW7 demonstration programs. If the 9 V battery is not installed, open the battery compartment cover on the back of the instrument by removing the two thumbscrews. Connect a 9 V battery to the polarized snap lead, clamp the battery to the cover, replace cover, and secure with thumb screws. If the instrument is to be stored for an extended period, remove the battery to prevent damage from leakage.

\*\*\*\*\*

***ALWAYS DISCONNECT THE BATTERY ELIMINATOR AND ANY TEST FIXTURES OR PROBES FROM THE INSTRUMENT WHEN REPLACING THE BATTERY. BEWARE OF STATIC ELECTRICITY***

\*\*\*\*\*

The instrument is now ready for use; however, it is recommended to perform the following initial checkout to become more familiar with the instrument. Select the 2.000 pF range by depressing the respective front panel switch. Turn on the instrument by pressing the ON switch. The liquid crystal display should appear and settle to a stable reading of  $\pm 0.002$  within a few seconds. The instrument was adjusted at the factory to read  $\pm 0.002$  pF. If the display is not within  $\pm 0.002$  pF, then adjust the OFFSET COARSE or FINE potentiometers on the front panel of the instrument. Unpack the two probes, and connect each probe to the front panel BNC connectors. Hold probes at least 6 inches apart and observe the display. The display should read  $\pm 0.002$  pF provided the probes are held stationary. If necessary, adjust the OFFSET FINE potentiometer to zero the display. Hold the probes tips about 1/10 inch apart. You should observe a reading of approximately 0.015 pF or 15 femtofarads. Place the probes at least 6 inches apart again and check the zero on the other ranges by depressing each range switch while observing the display. Next, measure a 100 nF chip capacitor supplied with the unit. First select the 200 nF range; second touch each of the metalized ends of the chip capacitor with the probe tips; and third, read the display. The 100 nF chip capacitor has tolerance of  $\pm 20\%$ .

\*\*\*\*\*

***CAUTION - ALWAYS DISCHARGE HIGH VOLTAGE CAPACITORS BEFORE MEASURING TO AVOID DAMAGE TO INSTRUMENT***

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You should now be familiar with the general use of the Model 3000 Digital Capacitance Meter. For a more detailed discussion of the operation of the Model 3000, refer to the following section.

## VII. OPERATING INSTRUCTIONS

A detailed description of each function of the instrument is given in this section. The basic functions of the Model 3000 are listed below.

### **Front Panel:**

- 1) Display, 3 1/2 digit LCD
- 2) Range switch, 2 pF to 200 nF, push-to-select
- 3) Power switch, push-ON, push-OFF
- 4) Cx HIGH input BNC (positive connection, drive)
- 5) Cx LOW input BNC (negative connection, sense)
- 6) OFFSET COARSE and FINE potentiometers

### **Rear panel:**

- 7) 9 V battery compartment
- 8) Auxiliary DC power jack
- 9) Analog output jacks, 0 - 200 mV DC
- 10) Reference voltage output jacks, 5.000 V DC
- 11) USB port

1) The display is a self-contained 3 1/2 digit LCD digital voltmeter with polarity and decimal point indication. The decimal point is automatically selected when the desired range switch is pushed.

2) The range switch is a push-to-select interlocking assembly. Ranges are 2 pF, 20 pF, 200 pF, 2 nF, 20 nF, and 200 nF. A resolution of 0.001 pF or 1 femofarad can be achieved on the 2 pF range.

3) The power switch is a push-ON and push-OFF type. Note that the Model 3000 is always on, independent of the ON/OFF switch position, when powered by the USB port.

4 & 5) Connection to the Model 3000 is via the BNC's on the front panel. Normally the probes supplied with the instrument will be connected to these terminals. However, custom-built shielded probes, connectors, or other special test fixtures can be connected to these terminals without affecting the accuracy of the instrument. The terminal marked (+) or HIGH is the positive drive or charging terminal and should be connected to the positive terminal of polarized capacitors. Likewise, the negative sense terminal (-) or LOW input should be connected to the negative terminal of polarized capacitors. The HIGH terminal should always be connected to the outer foil, plate, or larger electrode of the capacitor under measurement and the LOW terminal to its other electrode to minimize noise pickup. In the case of 3-terminal capacitors, such as calibration standards, the shield of the capacitor (i.e. its third electrode) should be connected to the ground shield of the probes. An alternative is to connect a 3-terminal capacitor to the instrument using coaxial

cables. In electrically noisy environments the capacitor under test may require shielding to obtain a stable reading. To maintain accuracy and obtain low noise readings, connect external shielding to both probe shields.

The Model 3000 uses a combination of CMOS and JFET devices to charge and discharge the capacitor under test; consequently, voltage transients can damage these devices and will cause the instrument to malfunction. All capacitors, but specifically high voltage and high capacitance capacitors, must be discharged first before measurement to avoid damage to the instrument.

\*\*\*\*\*

**DISCHARGE ALL CAPACITORS BEFORE MEASUREMENT TO PREVENT  
DAMAGE TO THE INSTRUMENT AND TO PREVENT PERSONAL INJURY**

\*\*\*\*\*

The drive level that is presented to the capacitor under test from the (+) or HIGH connection is +5.0 V peak with respect to the (-) or LOW connection or to ground (shields); thus, a wide range of capacitors that have breakdown voltages as low as 5 V can be measured with the Model 3000 without damaging the capacitor under test. Avoid capacitors that have leaky dielectric or high conductance. The Model 3000 cannot measure conductance. Depending on the range, leaky dielectric capacitors can produce erroneous readings. Likewise, the depletion capacitance of diodes must be measured under reverse bias conditions, i.e. HIGH terminal is connected to the cathode, and the LOW terminal is connected to the anode to reverse bias the diode.

6) The OFFSET COARSE and FINE potentiometers on the front panel of the instrument are used primarily to compensate for the capacitance between the unshielded terminals of test fixtures used to measure axial and radial leaded capacitors. The OFFSET potentiometers can subtract up to 1.5 pF of test fixture capacitance. The OFFSET potentiometers are used also to zero the instrument on the 2 pF scale and may be required occasionally due to amplifier drift, component replacement, or operation at elevated temperatures.

7) The 9 V battery is housed in a compartment on the rear of the instrument. The Model 3000 will operate for approximately 200 hours on a 9 V alkaline battery. A low dropout voltage regulator allows extended use of the battery down to a voltage of about 5.2 V before replacement.

8) The auxiliary DC power jack provides the capability of operating the instrument continuously from an external power source such as the battery eliminator (PN 4001200). The internal 9 V battery is automatically disconnected from the instrument when the battery eliminator is connected.

9) The analog output jacks provide a 0 - 200 mV DC signal proportional to the capacitor value under test. The bandwidth of the analog output signal is range

dependent as shown in Table II. The source resistance of the analog output is 1000 ohms.

Table II. Analog Bandwidth

Range	Measurement Frequency (Hz)	Bandwidth (Hz) (Standard)	Bandwidth (Hz) (Option 001)
2 pF	24,000	1.2	67
20 pF	24,000	2.8	71
200 pF	24,000	15	78
2 nF	24,000	64	79
20 nF	2400	64	79
200 nF	240	64	79

10) The instrument's internal 5.000 V DC reference voltage is available at the reference output jacks. Its source resistance is 1000 ohms. The reference output voltage is used to provide external ratio metric capability to remove errors in the analog output signal due to changes in the reference voltage from temperature and long term drift. For ratio metric measurements, connect the 5 V reference output to the external reference input on digital voltmeters, data loggers, etc. that provide for this option. Alternatively, errors from variations in the reference voltage can be removed from the analog output signal by calculating the ratio of analog output to the 5 V reference output and multiplying by the appropriate scale factor. Using the external outputs of the Model 3000 with precision digital voltmeters or data acquisition systems, capacitors can be measured to 0.05% accuracy and to a resolution of 10 ppm.

11) USB port provides fully isolated digital I/O and power, extended resolution and range as shown in Table I, and powers the Model 3000 from the host computer. To access the USB port, the appropriate drivers must be installed on the host computer. The drivers are available on the application CD-ROM or can be down loaded from our website: [www.glkinst.com/cmeterssoftware](http://www.glkinst.com/cmeterssoftware). To install the USB drivers on the host computer, follow the instructions in the file: [ReadmeUSBDriverInstall](#)

To demonstrate the basic features of the Model 3000 digital I/O, load and run the LabVIEW® demonstration program. This program is available as a standalone application or VI. The demonstration program is written in LabVIEW® 7 and complied with National Instruments' ([www.ni.com](http://www.ni.com)) Application Builder. Users without LabVIEW® 7 can run the application by installing the LabVIEW® 7 runtime engine included on the Model 3000 application CD-ROM.

Note: All software and drivers for the Model 3000 have been tested only on computers running Microsoft's Windows XP® Professional and Home editions. To completely install all USB drivers, "found new hardware" will run four times. All of the

Model 3000 and USB communication VI's were written in LabVIEW® 7 and will not run in earlier versions of LabVIEW®. Contact National Instruments, [www.ni.com](http://www.ni.com), to upgrade to version 7 or later, or install the runtime engine and run the executable version of the demonstration program.

## VIII. SERVICING INFORMATION

For service and calibration of the Model 3000 Digital Capacitance Meter, contact [GLK Instruments](#) directly. Complete repair and calibration services are maintained by GLK Instruments; however, minor repair and calibration can generally be performed in the field if you have access to a precision 3-terminal capacitor standard. Location of parts, test points, and adjustments are shown in Figure 1.

The switched capacitor circuit in the Model 3000 uses two JFET transistors driven by CMOS logic and an opamp to convert current to voltage. Circuit protection from voltage transients is built-in to the switched capacitor circuit; however, failure to discharge high voltage capacitors or static discharge can damage the circuitry. The switched capacitor circuit includes these replaceable parts Q3 and Q4 (2N5116 JFETS), U3, U4, and U6 (4049 CMOS hex buffers), and U10 (TL061 opamp).

In the event that the switched capacitor circuit is damaged, spare parts are located inside the Model 3000 on the main board, A0, below the ADC-digital I/O board (USB interface), A3, if present. The spare parts include 2-each, 2N5116 JFETS (Q3 and Q4), 2-each 4049 CMOS hex buffers (U3, U4, or U6), 1-each TL061 opamp (U10), and 1-each 0.125 A fuse (F1) for the external power supply or battery eliminator. All critical parts are socketed for easy replacement. JFETS, Q3 and Q4, should be replaced in pairs.

### Basic Diagnostics:

If the Model 3000 fails to power on under battery power, replace the 9 V battery through the compartment on the back of the instrument. Remove the two thumbscrews to gain access to the battery. If the Model 3000 fails to power up when connected to the battery eliminator but operates normally on battery power, check the battery eliminator for approximately 12 V between the center pin and outer conductor and fuse, F1. Replace battery eliminator if defective. To check fuse, open the Model 3000 by removing the four screws on bottom of the instrument and remove the top cover. Check fuse with an ohmmeter and replace if open using the spare fuse. If the Model 3000 still fails to power on, contact [GLK Instruments](#).

If you suspect that the input circuitry is damaged, first check regulated power supply voltage between TP2 and GND for a voltage of  $5.000 \pm 0.002$  V. If proper reading is obtained, proceed to the next step. Check that a 0 to 5 V square wave is present at the "HIGH" BNC terminal on the front panel. If there is no signal, replace U3 and U4; recheck for square wave. JFETS, Q3 and Q4, are located inside the rectangular metal shield. To gain access to Q3 and Q4, remove the two, 2-56 nuts on the top of the metal shield. Replace both Q3 and Q4, and zero the LCD meter using the coarse and fine adjustments. If unable to zero, replace U10 adjacent to Q3 and Q4. Repeat zero adjustment. Attach a 1 nF standard capacitor, and note the LCD reading. If the reading is 1.00 nF, the Model 3000 is working correctly. Replace

the metal shield and calibrate instrument. If the above repair is unsuccessful, the instrument will need factory service. Contact [GLK Instruments](http://www.glk.com) for RMA and shipping instructions.

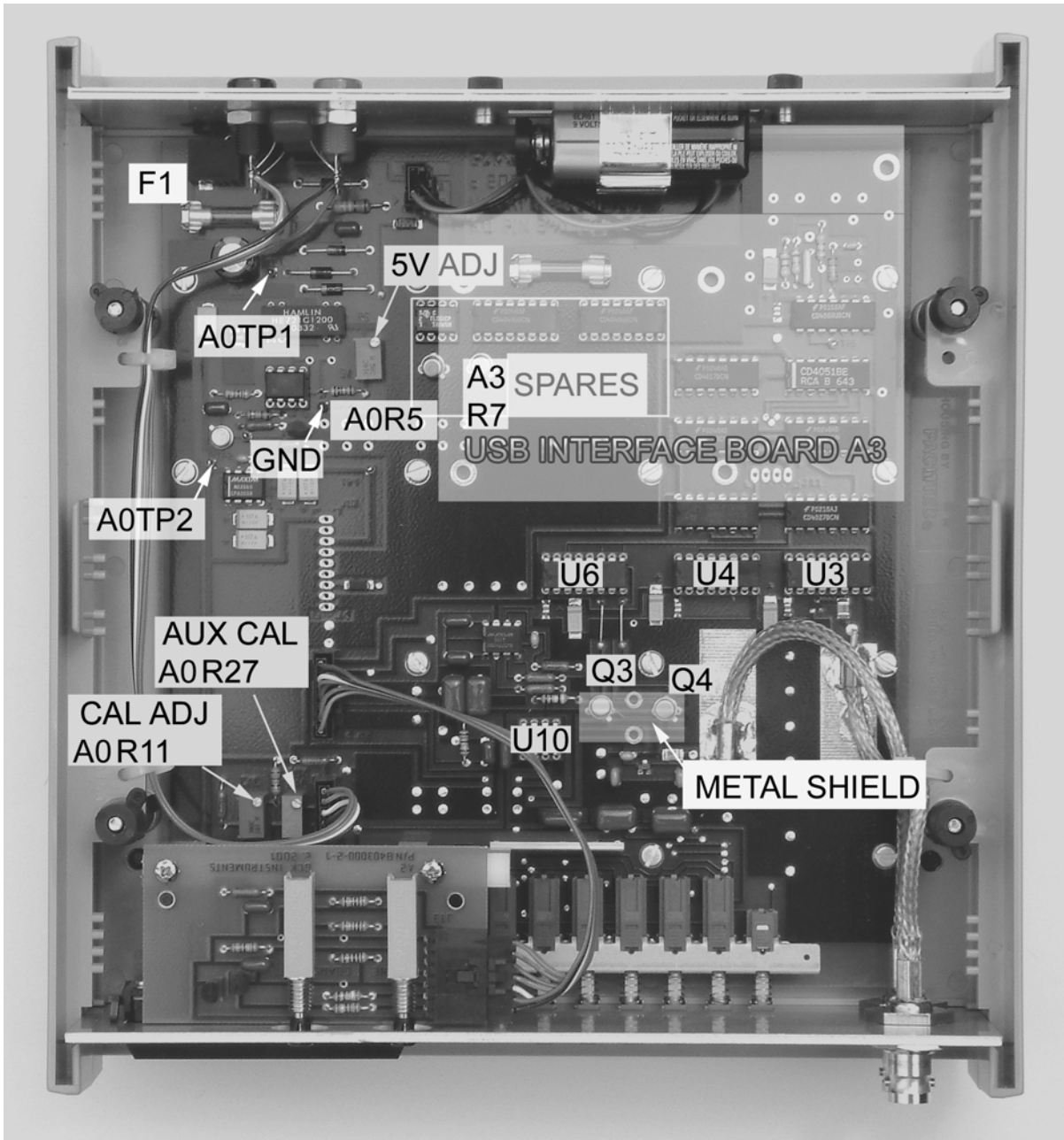


Figure 1. Location of parts, test points, and adjustments. Spares are located on the main board, A0, and under the ADC-digital I/O USB interface board, A3, if present.

## IX. CALIBRATION

Field calibration of the Model 3000 Digital Capacitance Meter can be accomplished using only a single 1.000 nF (1000 pF), 3-terminal standard capacitor such as General Radio or IET Labs ([www.ietlabs.com](http://www.ietlabs.com)) Model 1404-A standard reference capacitor. Refer to main circuit board, A0, and ADC-digital I/O board (USB interface), A3, for the location of test points and calibration adjustments. Adjustments and test points are labeled on the printed circuit boards (see Figure 1).

To calibrate the Model 3000, first remove the top half of the instrument case by removing the four screws located in the bottom half of the case. If operating in battery mode, check the battery voltage at A0TP1. If its voltage is below 7 V, replace the battery with a fresh 9 V alkaline or lithium cell. The Model 3000 will function correctly down to a battery voltage of approximately 5.2 V. Note, in the following procedure, the calibration standard is assumed to  $1.0000 \text{ nF} \pm 0.0001 \text{ nF}$ . Your standard may differ slightly in value; in that case, adjust the Model 3000 meter reading to agree with your standard.

Turn on the instrument, measure the voltage at A0TP2, and adjust the 5 V potentiometer, A0R5, to set the voltage at A0TP2 to  $+5.000 \pm 0.002 \text{ V}$ . Select the 2.000 pF range and adjust the OFFSET COARSE and FINE potentiometers to zero the display. The display should read  $\pm 0.000 \text{ pF}$  after zero adjustment. Select the 2.000 nF range and connect the 1000 pF (1.000 nF) standard capacitor to the instrument using coaxial cables. Adjust the CAL potentiometer, A0R11, for a display reading of  $1.000 \text{ nF} \pm 0.000 \text{ nF}$ .

Connect a calibrated, high impedance voltmeter, such as the Agilent 34401A, to the ANALOG OUTPUT terminals on the back of the instrument. The 34401A should be set as follows: range to 200 mV, resolution to fast 6 digit, and input resistance to  $>10 \text{ Gohm}$ . Adjust the AUX CAL potentiometer, A0R27, for a reading of  $0.1000 \text{ V} \pm 0.0001 \text{ V}$ .

Connect the Model 3000 USB port to the host computer and run the Model 3000 LabVIEW® demonstration program. Adjust AD CAL potentiometer, A3R7, for a software display reading of  $1.0000 \text{ nF} \pm 0.0001 \text{ nF}$ . A3R7 is located on the AD-digital I/O USB interface board in the approximate position shown in Figure1.

This completes the basic calibration of the instrument. All of the other ranges will track the calibration on the 2.000 nF range to within  $\pm (0.1\% \text{ of reading} + 2 \text{ digits})$ . Remove the standard capacitor and replace the cover. The Model 3000 is now ready for use as precision capacitance meter.

## X. REVISIONS

The following changes are effective for instruments with serial numbers 30000 and up (PCB Assembly 8503000-0-3 Rev 3).

No revisions at this time. This manual and any future revisions will be posted on our website: [www.glkinst.com](http://www.glkinst.com)