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MODEL IMF-600A
MANUAL/AUTORANGING
IMPEDANCE METER

OPERATION MANUAL

EFFECTIVITY: Serial numbers prefixed A2
IET-IM-IMF-600A-A2/IMFARIM/11

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.

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WARNING

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

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

- USE MAXIMUM INSULATION AND MINIMIZE THE USE OF BARE CONDUCTORS.
- REMOVE POWER WHEN HANDLING THE UNIT.
- POST WARNING SIGNS AND KEEP PERSONNEL SAFELY AWAY.

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CAUTION

DISCHARGE ALL CAPACITORS BEFORE MEASURING.

DO NOT APPLY ANY VOLTAGES OR CURRENTS TO THE
TERMINALS OF THIS INSTRUMENT.

Chapter 1

INTRODUCTION

1.1 Description

The Model IMF-600A Impedance Meter, shown in Figure 1.1, is a versatile automatic instrument for the **simultaneous** measurement of the real and imaginary components of any impedance. In particular, it provides the following quantities:

- Capacitance
  Conductance
  Dissipation Factor (D)
- Inductance
  Resistance
  Quality Factor (Q=1/D)

This versatile instrument can serve as a convenient "unknown" measuring device. Virtually any passive component may be categorized in terms of simple or complex impedance.

All that is required to measure an unknown quantity, is to connect the 4-terminal Kelvin leads, to press the appropriate push button, and to select a range. The quantity, the decimal point, and the units are all indicated with an unambiguous 3-1/2 digit liquid crystal display and associated annunciators.

The 4-terminal Kelvin leads permit the measurement of very small impedances such as the resistance of wires and connectors. It can also serve as a convenient tool for locating shorts by leading to the point of lowest resistance.

Capacitors and inductors may be selected by considering their lossy component (**D** or **1/Q**); this can be useful in discriminating between seemingly equivalent components. Components may, in many cases, be measured in circuit without the necessity of removing them.

Analog outputs corresponds 1) to the displayed quantity, capacitance, inductance, resistance, or conductance and 2) to the dissipation factor **D**, are simultaneously available at the rear panel.

Options available with the IMF-600A include:

1. Autoranging – Option R.
2. Digital output – Option DO.

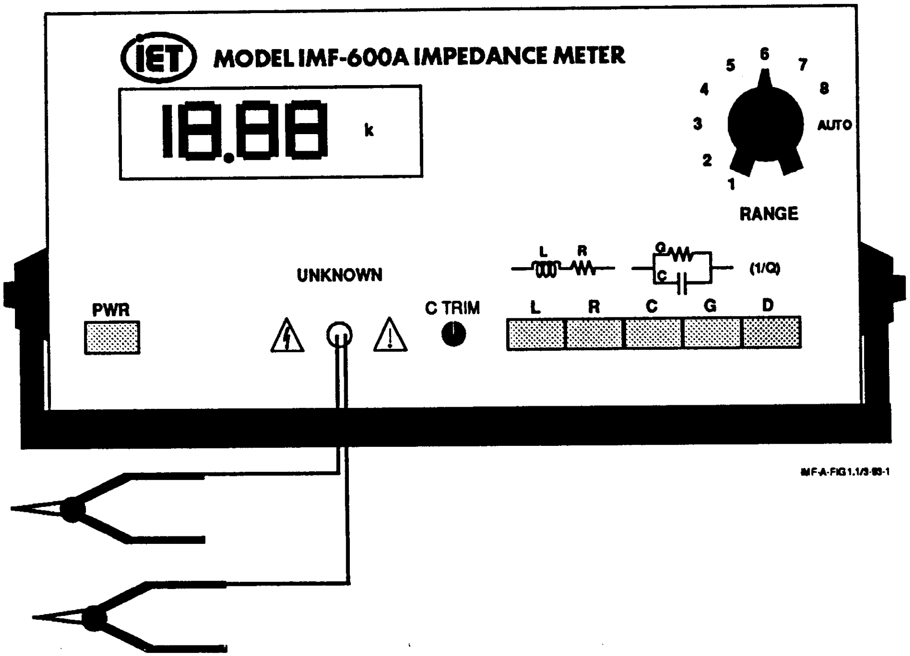


Figure 1.1 IMF-600A Impedance Meter

3. 4-20 mA output, corresponding to 0 –2000 counts of display, suitable for chart recorders – Option I.
4. High sensitivity capacitance, 20 pF range – HSC Option.
5. High sensitivity inductance, 20 µH range – HSL Option.
6. Companion comparator and sorting unit – Model LC-603.

1.2 Principle of Operation

The impedance Z_x of an unknown component X is defined as:

$$Z_x=V_x/I_x$$

where V_x is the voltage across the unknown and I_x is the current through the unknown. The IMF-600A implements this computation as shown conceptually in Figure 1.2. A sine wave generator drives current I_x through unknown Z_x and standard resistor R_s in series with it. Two ac coupled differential amplifiers measure the voltages V_x an V_r across the unknown and the resistor respectively. The impedance Z_x may then be computed as follows:

$$Z_x=V_x/I_x$$

$$Z_x=R_sV_x/V_s$$

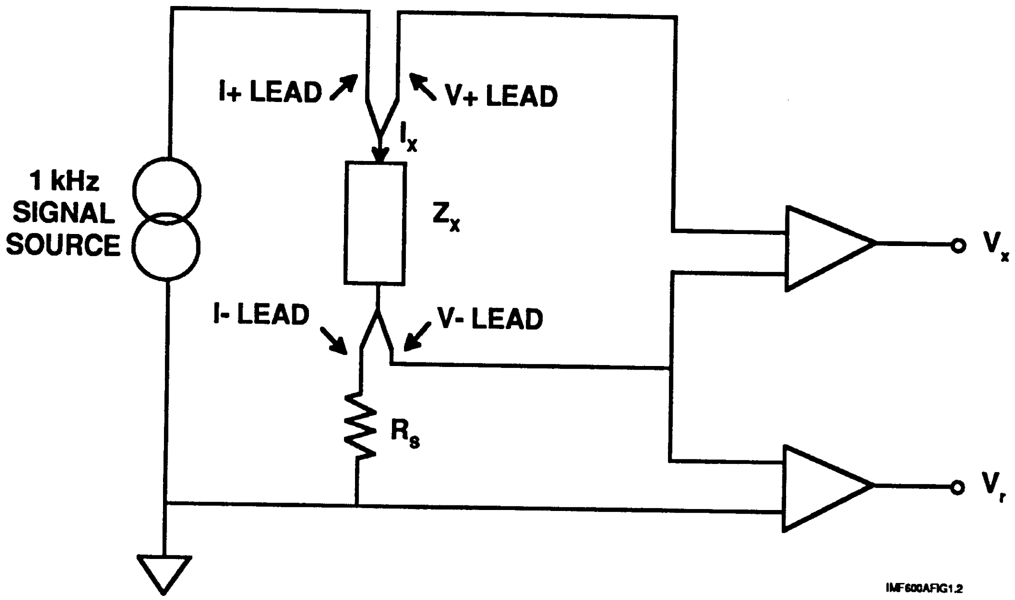


Figure 1.2 Impedance Computation Scheme

Except for pure resistance and conductance, Z_x is a complex ratio with real and imaginary components which must be separately computed.

In order not to introduce any errors from the computation of a ratio, a feedback control circuit is employed to maintain either V_x or V_s constant. For capacitance and conductance, V_x is maintained fixed, and the value of the unknown is determined as follows:

$$(C \text{ or } G)=a/Z_x=bV_s$$

where C and G are the capacitance or the conductance respectively, and a and b are constants of proportionality (different for C and G).

For inductance and resistance measurements, V_s is kept constant by the feedback control circuit, and the computation is performed as follows:

$$(L \text{ or } R)=cZ_x=dV_x$$

where **L** and **R** are the inductance or the resistance respectively, and c and d are constants of proportionality (different for L and **R**).

The voltage being measured, e.g. V_x is broken down into the "in phase or 0°" and the "quadrature or 90°" components with respect to the test signal. These are used to provide the real and imaginary portions of the complex impedance. A pure resistance, for example, will produce only an "in phase" component, whereas an ideal capacitor will result in only a "quadrature" signal.

1.3 Kelvin, 4-terminal, Measurement

As may be seen in Figure 1.2, four physical conductors are actually brought out to connect to the component under test. Each two conductors are in electrical contact with each other as well as with one end of the device under test **DUT**. They are each, therefore, nominally equivalent to a single test lead. The difference becomes clear when the resistances of the test leads and of contacts are taken into consideration.

The test current is delivered to the device by leads **I+** and **I-**. The lead pair **V+** and **V-** are the voltage sensors which are brought directly to the component. If these voltages were sensed within the instrument, they would include the potentials developed across the current carrying leads due to their inherent resistance. Clearly this could be very significant when measuring small impedances. Measuring the voltages right at the **(DUT)** eliminates this problem. The IMF-600A is therefore suitable for measuring the resistance of wire, connectors, switches, relays or other "short circuits". It is also useful for finding the location of circuit board shorts.

Chapter 2

SPECIFICATIONS

For convenience to the user, the pertinent specifications are given in an **OPERATING GUIDE**, shown in Figure 2.1, affixed to the case of the instrument.

Range, Resolution, Accuracy, and Test Signals:

CAPACITANCE (C)

RANGE	1	2	3	4	5	6	7	8
FULL SCALE	200 pF	2 nF	20 nF	200 nF	2 µF	20 µF	200 µF	2000 µF[1]
RESOLUTION	0.1 pF	1 pF	10 pF	100 pF	1 nF	0.01 µF	0.1 µF	1 µF
TEST SIGNAL	1.0 Vrms		100 mVrms					10 mVrms
ACCURACY	±(0.25% + 1 LSD +0.5% G*reading)	±(0.25% + 1 LSD + 0.5% G*reading)					±(0.25% + 1 LSD +0.2%G*reading)	±(5% + 1 LSD +1%G*reading)

CONDUCTANCE (G)

RANGE	1	2	3	4	5	6	7	8
FULL SCALE	2 µS	20 µS	200 µS	2 mS	20 mS	200 mS	2000 mS	20 S
RESOLUTION	0.001 µS	0.01 µS	0.1 µS	1 µS	10 µS	0.1 mS	1 mS	10 mS
TEST SIGNAL	1.0 Vrms		100 mVrms					10 mVrms
ACCURACY	±(0.25% + 1 LSD +0.5% C*reading)	±(0.25% + 1 LSD + 0.5% C*reading)					±(0.25% + 1 LSD +0.2% C*reading)	±(5% + 1 LSD +1% C*reading)

INDUCTANCE (L)

RANGE	1	2	3	4	5	6	7	8
FULL SCALE	200 µH	2 mH	20 mH	200 mH	2 H	20 H	200 H	200 H
RESOLUTION	0.1 µH	1 µH	10 µH	0.1 mH	1 mH	10 mH	0.1 H	0.1 H
TEST SIGNAL	100 mA	10 mA	1 mA	100 µA	10 µA		1 µA	
ACCURACY	±(0.25% + 1 LSD +0.5% R*reading)	±(0.25% + 1 LSD + 0.5% R*reading)					±(0.25% +1 LSD +0.5% R*reading)	

RESISTANCE (R)

RANGE	1	2	3	4	5	6	7	8
FULL SCALE	2 Ω	20 Ω	200 Ω	2 kΩ	20 kΩ	200 kΩ	2 MΩ	2 MΩ[2]
RESOLUTION	1 mΩ	10 mΩ	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	1 kΩ
TEST SIGNAL	100 mA	10 mA	1 mA	100 µA	10 µA		1 µA	
ACCURACY	±(0.25% + 1 LSD +0.5% L*reading)	±(0.25% + 1 LSD + 0.5% L*reading)					±(0.25% + 1 LSD +0.5% L*reading)	

DISSIPATION FACTOR (D)

RANGE	1	2	3	4	5	6	7	8
FULL SCALE	1.999[3]							
RESOLUTION	0.001							
ACCURACY	±(1% + 0.002) for L or C > 200 counts ±(2% + 0.01) for L or C 50 to 199 counts							±(5% + 0.01)

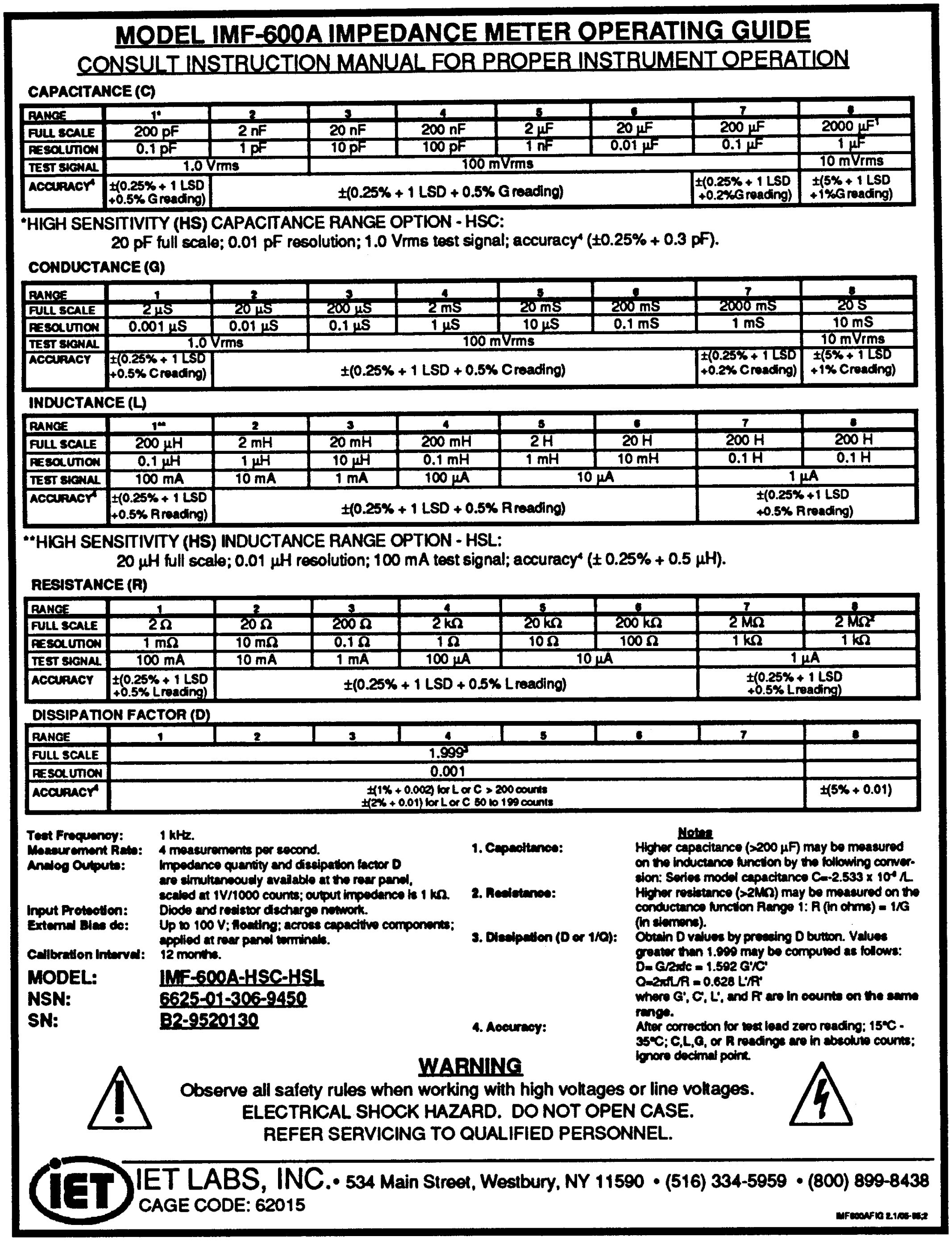
* in absolute counts – ignore decimal point.

IMF-600ASPECS/12-90-5

[1] Maximum capacitance range may be extended; see section 3.5.3.

[2] Maximum resistance range may be extended; see section 3.4.3.

[3] Maximum dissipation factor may be extended; see section 3.8 or 3.9.



MODEL IMF-600A IMPEDANCE METER OPERATING GUIDE

CONSULT INSTRUCTION MANUAL FOR PROPER INSTRUMENT OPERATION

CAPACITANCE (C)

RANGE	1*	2	3	4	5	6	7	8
FULL SCALE	200 pF	2 nF	20 nF	200 nF	2 µF	20 µF	200 µF	2000 µF[1]
RESOLUTION	0.1 pF	1 pF	10 pF	100 pF	1 nF	0.01 µF	0.1 µF	1 µF
TEST SIGNAL	1.0 Vrms		100 mVrms					10 mVrms
ACCURACY[4]	±(0.25% + 1 LSD +0.5% G reading)	±(0.25% + 1 LSD + 0.5% G reading)					±(0.25% + 1 LSD +0.2%G reading)	±(5% + 1 LSD +1%G reading)

*HIGH SENSITIVITY (HS) CAPACITANCE RANGE OPTION - HSC:
20 pF full scale; 0.01 pF resolution; 1.0 Vrms test signal; accuracy[4] (±0.25% + 0.3 pF).

CONDUCTANCE (G)

RANGE	1	2	3	4	5	6	7	8
FULL SCALE	2 µS	20 µS	200 µS	2 mS	20 mS	200 mS	2000 mS	20 S
RESOLUTION	0.001 µS	0.01 µS	0.1 µS	1 µS	10 µS	0.1 mS	1 mS	10 mS
TEST SIGNAL	1.0 Vrms		100 mVrms					10 mVrms
ACCURACY	±(0.25% + 1 LSD +0.5% C reading)	±(0.25% + 1 LSD + 0.5% C reading)					±(0.25% + 1 LSD +0.2% C reading)	±(5% + 1 LSD +1% C reading)

INDUCTANCE (L)

RANGE	1**	2	3	4	5	6	7	8
FULL SCALE	200 µH	2 mH	20 mH	200 mH	2 H	20 H	200 H	200 H
RESOLUTION	0.1 µH	1 µH	10 µH	0.1 mH	1 mH	10 mH	0.1 H	0.1 H
TEST SIGNAL	100 mA	10 mA	1 mA	100 µA	10 µA		1 µA	
ACCURACY[4]	±(0.25% + 1 LSD +0.5% R reading)	±(0.25% + 1 LSD + 0.5% R reading)					±(0.25% +1 LSD +0.5% R reading)	

**HIGH SENSITIVITY (HS) INDUCTANCE RANGE OPTION - HSL:
20 µH full scale; 0.01 µH resolution; 100 mA test signal; accuracy[4] (± 0.25% + 0.5 µH).

RESISTANCE (R)

RANGE	1	2	3	4	5	6	7	8
FULL SCALE	2 Ω	20 Ω	200 Ω	2 kΩ	20 kΩ	200 kΩ	2 MΩ	2 MΩ[2]
RESOLUTION	1 mΩ	10 mΩ	0.1 Ω	1 Ω	10 Ω	100 Ω	1 kΩ	1 kΩ
TEST SIGNAL	100 mA	10 mA	1 mA	100 µA	10 µA		1 µA	
ACCURACY	±(0.25% + 1 LSD +0.5% L reading)	±(0.25% + 1 LSD + 0.5% L reading)					±(0.25% + 1 LSD +0.5% L reading)	

DISSIPATION FACTOR (D)

RANGE	1	2	3	4	5	6	7	8
FULL SCALE	1.999[3]							
RESOLUTION	0.001							
ACCURACY[4]	±(1% + 0.002) for L or C > 200 counts ±(2% + 0.01) for L or C 50 to 199 counts							±(5% + 0.01)

Test Frequency: 1 kHz.
Measurement Rate: 4 measurements per second.
Analog Outputs: Impedance quantity and dissipation factor D are simultaneously available at the rear panel, scaled at 1V/1000 counts; output impedance is 1 kΩ.
Input Protection: Diode and resistor discharge network.
External Bias dc: Up to 100 V; floating; across capacitive components; applied at rear panel terminals.
Calibration Interval: 12 months.

MODEL: IMF-600A-HSC-HSL
NSN: 6625-01-306-9450
SN: B2-9520130

Notes

1. Capacitance: Higher capacitance (>200 µF) may be measured on the inductance function by the following conversion: Series model capacitance $C = -2.533 \times 10^{-4} / L$.
2. Resistance: Higher resistance (>2MΩ) may be measured on the conductance function Range 1: R (in ohms) = 1/G (in siemens).
3. Dissipation (D or 1/Q): Obtain D values by pressing D button. Values greater than 1.999 may be computed as follows:
$D = G/2\pi fC = 1.592\ G'/C'$
$Q = 2\pi fL/R = 0.628\ L'/R'$
where G', C', L', and R' are in counts on the same range.
4. Accuracy: After correction for test lead zero reading; 15°C - 35°C; C,L,G, or R readings are in absolute counts; ignore decimal point.

WARNING

Observe all safety rules when working with high voltages or line voltages.
ELECTRICAL SHOCK HAZARD. DO NOT OPEN CASE.
REFER SERVICING TO QUALIFIED PERSONNEL.

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CAGE CODE: 62015

IMF600AFIG 2.1/05-95;2

Figure 2.1 OPERATION GUIDE Affixed to Unit

Impedance Models: Parallel for **C** and **G**:

Series for **L** and **R**:

Test Conditions: Performance specifications apply:

1. After correction for test lead zero reading.
2. After 10 minute warm up.
3. Between 15°C and 35°C.

Test Frequency: 1 kHz ±1%.

Trim: Front panel trimming of lead capacitance

Measurement Rate: 2.5 measurements per second.

Display: 3-1/2 digit liquid crystal display (LCD) with corresponding annunciators showing units and other conditions; all decimal points on along with **OR** annunciator indicate overrange or illegal condition.

Analog Outputs: Impedance quantity and dissipation **D** are simultaneously available at the rear panel, scaled at 1V/1000 counts;
output impedance: 1 kΩ;
accuracy: ±(0.25% of display + 1 mV)

Test Terminals: 4-terminal shielded Kelvin test leads.

Operating Controls: Push button **PWR** and function select switches; **RANGE** select rotary switch.

Input Protection: Diode and resistor discharge network.

External dc Bias: Up to 100V, floating, may be applied across a capacitive component through screw terminals on the rear panel; 0.1 A maximum.

Power Requirements:
105-125 V or 210-250 V; 5W.

Calibration Interval: 12 months.

Dimensions: 21.6 cm W x 11.4 cm H x 30.5 cm D (8.5" x 4.5" x 12.0");

Weight: 6.8 kg (15 lb).

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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** is attached to the case of the instrument to provide ready reference to specifications and operation. Connect the IMF-600A to a grounded power source. Operation is at 110 or 220 Vac as indicated on the rear panel. Press the **PWR** switch which is a push-on push-release button; the display will come on. To adjust the tilt handle, press in on the pivot buttons and set the handle to provide a convenient viewing angle.

3.2 General Operating Procedure

Operation of the IMF-600A is straightforward:

1. Select the desired function with the front panel push button. The front panel shows the impedance model used by the instrument for each function, in particular a series model for **L** and **R**, and a parallel model for **C** and **G**. If no button is pressed, the **L** function is selected by default.

2. Connect the Kelvin terminals to the unknown component. The polarity of the leads has no significance except for the application of a bias voltage.

3. Turn the **RANGE** knob to the **A** position for autoranging. Or, for manual ranging, turn it to any one particular range to obtain the highest "in range" reading, i.e. a number between 200 and 1999 counts. The autoranging mechanism will display counts as low as 180 in order to have orderly ranging. If a higher resolution is desired in such a case, then manual ranging may be tried, or a Kelvin lead may be removed and reconnected for a possible lock in the next more sensitive range. Overrange or an illegal condition are indicated by all decimal points being displayed.

4. To obtain the dissipation factor for a capacitive or inductive component, press the **D** push button. It is a momentary switch and will display the associated value. **D** values greater than 1.999 will show overrange but may be computed as described below.

The correct measurement is displayed within one second and repetitive measurements are made at the rate of four per second. The decimal point and the unit of measure will be very clearly shown. If all the decimal points are on advance the range until a proper reading is obtained, or determine if an improper condition exists. In particular The following is a list of possible displays and their causes:

All decimal points on:

Overrange condition; advance **RANGE** knob; if ranges are exhausted on **R**, use **G** with a conversion of **R=1/G** (see Section 3.4.3); if ranges are exhausted on **C**, use **L** with a conversion of $\mathbf{C= -2.533 \times 10^{-8}/L}$ (see section 3.5.3).

The leads are shorted in the **C** or **G** function, or open in the **L** or **R** functions.

All decimal points on when D is pressed:

A dissipation value of >1.999 is obtained; **D** must be computed (see Section 3.8 or 3.9).

Negative reading:

A capacitive component (or one effectively capacitive at 1 kHz) is being measured with the **L** function.

An inductive component (or one effectively inductive at 1 kHz) is being measured with the **C** function.

A nonlinear component such as a diode is being measured; such a component may require a bias voltage.

3.3 Connection to Terminals

3.3.1 2-Terminal Measurement

In most cases, unknowns are 2-terminal components. When no bias is applied, there is no polarity consideration in connecting the leads to the unknown. The red leads are the **V+** and **I+** pair and the black leads are the **V-** and **I-** pair. The black lead is at virtual ground and may be connected to the more noise sensitive end of the unknown if there is one.

3.3.2 3-Terminal Measurement

Some unknowns are 3-terminal components. These are usually components enclosed in shields or conductive housings. In order to understand the effect of such an enclosure and the implications of a 2-terminal and a 3-terminal measurement, an example with a capacitor is presented here.

The capacitance of a shielded capacitor, schematically shown in Figure 3.1, demonstrates the need for 3-terminal measurement. It shows that a capacitor C_{HL} would be shunted by the series combination of the capacitances from the **HIGH** and **LOW** terminals to the case. The resultant capacitance becomes:

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

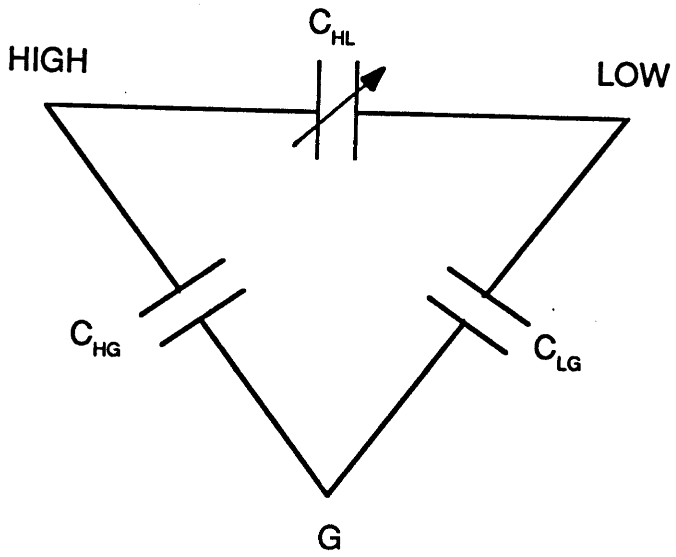

Figure 3.1 Model of Three-Terminal Capacitor

This is what a 2-terminal measurement would read. Clearly it would be difficult to get a net reading of C_{HL} in the presence the other capacitances. Shorting out the **LOW** to the **G** terminal, making a 2-terminal connection, would reduce this problem but not eliminate it.

A 3-terminal measurement scheme is implemented by connecting the **G** terminal to a guard circuit within the measuring instrument. Since the **LOW** terminal is at virtual ground, this excludes the C_{HG} and C_{LG} from the measurement. This discussion applies to any components which may have capacitance to their case or shield.

In order to implement 3-terminal measurement with the IMF-600A, connect a ground lead from the third terminal of the unknown, usually the shield, to the **COM** terminal on the rear panel of the IMF-600A.

3.4 Resistance and Conductance Measurement

3.4.1 1 kHz Resistance and Conductance Measurement Considerations

In most cases, measurement of resistance or conductance (1/resistance) with the IMF-600A is equivalent to the measurement with an ordinary ohmmeter or multimeter. Note, however, that the IMF-600A measures resistance at 1 kHz, whereas an ohmmeter determines resistance at dc. For virtually all resistors, the result is identical, but care must be taken when measuring complex components such as high value wirewound resistors or resistor-capacitor combinations as shown in Figure 3.2.

Ohmmeter reading: open circuit

IMF-600A reading: finite

Ohmmeter reading: correct

IMF-600A reading: correct, as long as **C** reading is not overrange. Range may be advanced in such a case. **G** and not **R** should be used for best ccuracy.

IMF-600AFIG 3.2

Figure 3.2 Resistance Measurements of Resistor-Capacitor Combinations

When measuring the resistance of inductive components such as transformers and inductors, the resistance computed at 1 kHz is usually different and larger than dc resistance. This is due to the fact that ac resistance will include core losses.

Another important difference between the ac resistance and dc resistance is that the former will eliminate the effects of thermal emf from the reading and will yield the equivalent of a so called "True Ω" reading found on some meters. dc meters, in the presence of emf, will give different readings depending on lead polarity; the IMF-600A will not. The user should be aware of this effect which is usually significant for small resistances.

3.4.2 Conductance Measurement

Conductance may be viewed as either a new type of measurement or another way to monitor resistance, and in particular high resistance (See Section 3.4.3). Conductance measurements are made by using the G function. The display is in conductance units, S or siemens, formerly known as mhos where:

G(in siemens)=1/R(in ohms).

As a conductance meter, the IMF-600A can directly monitor inverse-function components. For example, the resistance of a photo diode decreases as the available light increases; conductance and light level, therefore, increase or decrease together allowing for easier, more natural testing. The same is true for a number of other variable resistance transducers. It is also sometimes easier, when making computations, to multiply by conductance values than to divide by resistance values.

3.4.3 High Resistance Measurement

In the resistance function, the maximum measurement capability is 2MΩ. For higher resistances, up to 1,000MΩ, use Range 1 (2.000 µS) of the G conductance function, where **G=1/R.** Except for high voltage stress testing, this range can replace a megger for a number of applications. It can be used to check high value resistors and non-capacitive low leakage components.

High resistors should be guarded or shielded, if possible, by connecting the shield to the **COM** terminal on the rear panel of the instrument.

3.4.4 Low Resistance Measurement

The IMF-600A is capable of measuring low resistance with a resolution of 1 mΩ. The resistance of wires, switches, or connectors can therefore be precisely determined. The 4-terminal Kelvin leads allow low impedance measurement by eliminating contact and lead resistance. This is accomplished by having the test current applied through the unknown by one pair of leads and measuring the voltage across it with the second pair. See Section 1.3.

Certain care does have to be taken in making low impedance measurements. The Kelvin leads should be clean and should grip firmly, consistently, and on the **same** point on the leads of the unknown, because a change in the location of point on the lead being gripped can produce a significant change in the resistance.

3.4.5 Use of the IMF-600A for Locating Printed Circuit Board Shorts

The capability of the IMF-600A to distinguish between "short circuits" makes it a useful troubleshooting tool for the locating of shorts on PC boards.

To do this, connect one lead to one side of the short circuit. Probe a point on the other side of the short with the second lead; this would usually be a bus on the PCB. Note the resistance reading and move the second probe along the path of the short. When the minimum reading is observed, the short site is located. If a large capacitance exists between the two points of the short, as may be the case with power supply lines, the reading may appear lower than it should be, and this procedure should be used carefully.

3.5 Capacitance Measurement

3.5.1 General Procedure

Measurement of capacitance is straightforward; simply press the **C** push button and select the range providing the maximum resolution. Capacitance may be resolved to 0.1 pF (0.01 pF with the X10 option), and values as high as 2,000 µF may be measured. Higher capacitance may be measured as described in section 3.5.3.

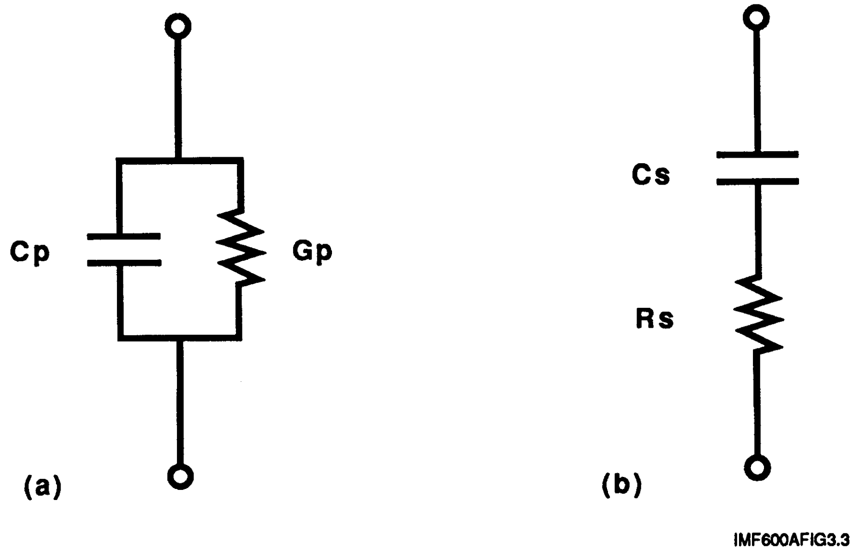

Figure 3.3 Capacitance Models

The capacitance model assumed by the IMF-600A is the parallel capacitor-conductor (or resistor) combination as shown in Figure 3.3a, where C_p and G_p are the parallel equivalent capacitance and conductance respectively. For an ideal capacitor, conductance G_p is zero, i.e. infinite resistance. For a real capacitor G_p represents the leakage or various other loss elements. Most non-electrolytic capacitors are virtually ideal.

For an in-circuit capacitor, G_p represents the conductance of the circuit across the unknown capacitor. In-circuit capacitance may be measured so long as the conductance does not overwhelm the capacitance, i.e. as long as the conductance counts displayed on the same range are not much greater than the capacitance counts.

The IMF-600A will measure both C_p and G_p simultaneously and will display one or the other as the **C** or **G** push buttons are pressed. The dissipation factor

$$D=G_p/2\pi fC_p$$

where **f** is the frequency (1,000 in this case) is displayed whenever the **D** push button is pressed. The same value is continuously available at the rear panel **D** terminal. The range chosen should be for best capacitance, not conductance resolution.

An alternative capacitor model is the series type shown in Figure 3.3b where C_s and R_s are the series equivalent capacitance and resistance respectively. The relationship between the two models is:

$$C_s=(1+D^2)C_p$$

$$R_s=D^2/(1+D^2)G_p$$

R_s is also known as the **ESR**, the Equivalent Series Resistance of a capacitor. To measure it simply press **R**, and the **ESR**, of Figure 3.3b, will be displayed. To measure the series capacitance C_s, see section 3.5.3.

3.5.2 Low Capacitance Measurement

When measuring small capacitors, particularly on the lowest capacitance range (200.0 pF) or with the X10 option, two potential problems should be carefully avoided.

First, due to their high impedance and subsequent susceptibility to noise, small capacitors should be shielded or guarded to the **COM** terminal on the rear panel. A metal case or a sheet of foil connected to that terminal may be used.

Second, cable or stray capacitance can affect the measurement. Always maintain the physical orientation and position of the Kelvin leads during a test, since capacitance may vary by as much as a few picofarads as the lead separation or orientation is changed. this is important if the zero capacitance is being subtracted from the reading. Note that although the Kelvin leads are shielded, the tips are not and do present a small capacitance between them. This residual capacitance must be kept constant, and if required arithmetically subtracted from the reading.

All four conductors of the Kelvin leads are not required for low capacitance (or other high impedance), since the currents employed are very small. The leads may therefore be lengthened, if desired, with a pair of single conductors, as long as they are shielded, or the capacitance they contribute is taken into consideration.

3.5.3 High Capacitance and Series Capacitance Measurement

The IMF-600A allows measurement beyond the 2,000 µF limit of Range 8. Higher capacitance, or series Capacitance, C_s may measured on the inductance function using the following conversion:

$$C_s = -1/(2\pi f)^2 L_s = -2.533 \times 10^8 / L_s$$

where **f** is the frequency in hertz (1,000 in this case), L_s is the series inductance in henries, and C_s is the series capacitance in farads. Note that the meter will display a negative reading and that this conversion yields the series, and not the parallel, equivalent capacitance.

3.6 Inductance Measurement

3.6.1 General Procedure

Measurement of inductance is straightforward; simply press the **L** push button and select the range providing the maximum resolution. Inductance may be resolved to 0.1 µH (0.01 µH with the X10 option), and values as high as 200 H may be measured.

The inductance model assumed by the IMF-600A logic is the series inductor-resistor combination shown in Figure 3.4a where L_S and R_S are the series equivalent inductance and resistance. For a real inductor, R_S represents the dc resistance of the conductor as well as the

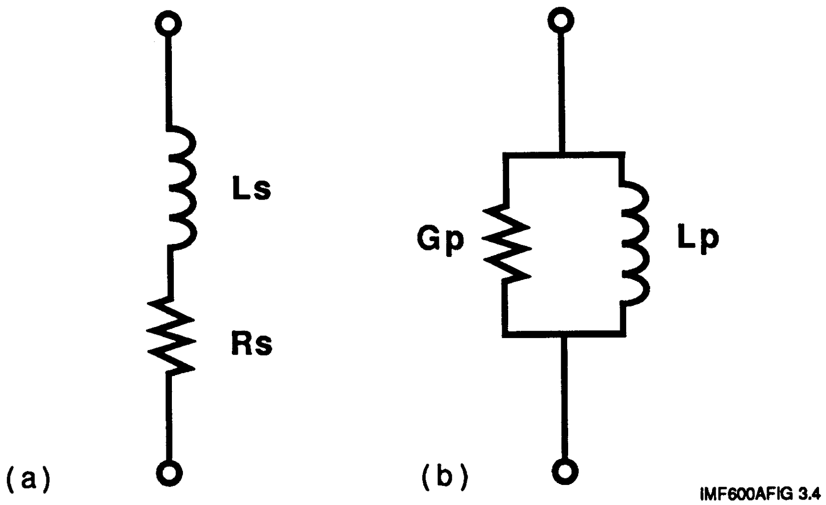

Figure 3.4 Inductance Models

various other loss elements. Unlike capacitors which are often virtually ideal, inductors will have considerable finite resistance.

The IMF-600A will measure both L_S and R_S simultaneously and will display one or the other as buttons **L** or **R** are pressed. The quality factor **Q** is available as the reciprocal of the dissipation factor **D**, i.e. **Q=1/D**. They are defined as follows:

$$Q=1/D=2\pi fL_S/R_S$$

where **f** is the frequency in hertz (1,000 in this case). The value for **D** is displayed whenever the **D** push button is pressed. The same value is continuously available at the rear panel **D** terminal. The range chosen should be for best inductance, not resistance resolution.

Because a series inductance model is employed, in-circuit inductors may be measured only as long as the impedance across them is high.

An alternative inductance model is the parallel type shown in Figure 3.4b where L_p and R_p are the parallel equivalent inductance and resistance respectively. The relationship between the two models is:

$$L_p=(1+D^2)L_s$$

$$G_p=1/(1+Q^2)R_s$$

3.6.2 High Inductance Measurement

As in the case of low capacitance or high resistance, ac pickup should be avoided. The leads should be as short as possible. The inductor under test may be shielded to the **COM** terminal on the rear panel, and hands should be kept away. Stray capacitance will be minimized by following these steps. Additionally, care should be taken to avoid external magnetic fields.

3.6.3 Low Inductance Measurement

Leads of the inductance under test may contribute some impedance on sensitive ranges. closely spaced twisted leads will minimize lead inductance and pickup. The inductance of the Kelvin leads may be determined by shorting them together and arithmetically subtracting this residual reading.

3.6.4 Mutual Inductance Measurement

The self and mutual inductances of a pair of coupled coils is given as follows:

$$V_1=L_1 dI_1/dt + M dI_2/dt$$

$$V_2=M dI_1/dt + L_2 dI_2/dt$$

where **V**, **I**, and **L** are the voltages, currents, and self inductances of the two coils, and **M** is the mutual inductance. M may be computed as follows:

1. With coil 2 open circuited, determine L_1 for coil 1 using the IMF-600A in the normal fashion.
2. With coil 1 open circuited, determine L_2 for coil 2 using the IMF-600A in the normal fashion.
3. With coil 2 short circuited, determine L_{1sc} for coil 1 using the IMF-600A in the normal fashion.
4. Using the above relationships, the mutual inductance may be computed as follows:

$$M=\sqrt{(L_2(L_1-L_{1sc}))}$$

3.7 Measurement of Complex Impedance

As described above, the IMF-600A will simultaneously discriminate and measure the reactive component (**L** or **C**) and the loss component (**R** or **G**). The IMF-600A will compute and display both components. The operative or proper range to be used will be determined by the more "significant" component, i.e. the one with greater number of counts. If, for example, a **G** reading across a capacitance is small, there is a small **G** reading and a high **C** reading. It is not possible, however to downrange to increase the G resolution since that would cause C to overrange, and the G reading would also overrange.

3.8 Determination of the Dissipation Factor (D) of Capacitors

The dissipation factor of a capacitor is defined as:

$$D=G_p/2\pi fC_p$$

Where **f** is the frequency in hertz (1,000 in this case), **C_p** is the parallel equivalent capacitance, and **G_p** is the parallel equivalent conductance. Clearly, **D** is zero for an ideal capacitor and high for a poor one.

Dissipation factor values up to 1.999 may be displayed by pressing the **D** push button which is a momentary switch. The **D** annunciator will come on without eliminating the previous operative annunciator. This value is also continuously present on the rear panel **D** terminal.

D values greater than 1.999 may be directly computed from the above relationship or more simply by:

$$D=1.592\ \mathrm{Gcount}/\mathrm{Ccount}$$

where **Gcount** and **Ccount** are the displayed **G** and **C** counts on the **same** range **without** decimal points. The range providing the maximum capacitance resolution must be used.

3.9 Determination of the Quality Factor (Q) of Inductors

The quality factor **Q** of an inductor is defined as:

$$Q=2\pi fL_s/R_s$$

Where **f** is the frequency in hertz (1,000 in this case), **L_s** is the series equivalent inductance, and **R_s** is the series equivalent resistance. Clearly, **Q** is infinite for and ideal inductor and low for a poor one.

The IMF-600A computes the dissipation factor **D=1/Q** which may be displayed by pressing the **D** push button which is a momentary switch. Dissipation factor values up to 1.999 may be displayed. The **D** annunciator will come on without eliminating the previous operative annunciator. This value is also continuously present on the rear panel **D** terminal. **Q** may then be computed as the reciprocal of **D**; this may be done so long as **Q**>0.5 (or (**D**<2). For **Q**<0.5, the value may be directly computed from the above relationship or more simply by:

$$Q=\mathrm{Lcount}/1.592\ \mathrm{Rcount}$$

where **Lcount** and **Rcount** are the displayed **L** and **R** counts on the **same** range **without** decimal points. The range providing the maximum inductance resolution must be used.

3.10 Measurement of Grounded Components

The **COM** terminal of the IMF-600A is connected internally to earth ground. If the Kelvin leads are applied to a grounded component, an erroneous reading will result. However, such a measurement may be performed; consult IET Labs Application Engineering for implementation instructions.

3.11 Application of a dc Bias Voltage Across a Capacitor

Although ideal capacitors have a constant capacitance independent of the voltage across them, many electrolytic ones and other capacitive components do not. The IMF-600A allows for the application of a dc voltage up to 100 V across the capacitor under test. Diodes and other non-linear components may also need to be biased.

WARNING

****

To minimize the danger of electric shock, limit the bias to 30 V.

Bias voltage is present at the Kelvin leads and on the capacitor under test.

When High bias voltages are used, do not leave the instrument unattended.

Capacitors remain charged after test. Discharge carefully.

Do not apply bias to non-capacitive components.

****

In order to apply a bias voltage, remove the shorting link between the **BIAS+** and the **BIAS-** terminals on the rear panel, and connect a **floating** dc supply limited to 0.1 A to these terminals. If the power supply has no current limiting, a series resistor or fuse may be used.

3.12 Analog Outputs

Two analog outputs are available at the rear panel on terminals labeled **IMPED** for the **L**, **R**, **C**, and **G** displayed value; and **D** for the dissipation factor. The analog voltage outputs are scaled at 1 V per 1,000 counts of display.

The analog outputs are effectively the inputs to the internal 3-1/2 digit A/D converter. They are both available simultaneously. They are therefore continuous and not sampled at 4 readings per second. They are also not strictly limited to 2 V maximum, but may exceed that slightly, but this feature has to be used cautiously.

These outputs are suitable for chart recorders, external voltmeters which may supply higher resolution, or limit comparators. They are useful for monitoring and recording transducers and sensors.

3.13 Digital Outputs – Optional

Unit with a **DO** option provide a connector on the rear panel with a signed BCD representation of the displayed value on any selected function. This output is the BCD equivalent of the analog to digital converter output. When the **D** button is pressed, the dissipation becomes the digital value being output.

The digital outputs may be used with the IET Labs Model CLC-502 Digital Limits Comparator for upper and lower limits selection. These comparators may be cascaded for dissipation value testing or for bin sorting.

The digital output pin assignments are given below in Figure 3.5. The digital output connector is a 26 pin header on the rear panel. It may be accessed with a “3M Company Model 3399”, “GTE Sylvania Inc. Model 6BAxx-26-1xx-xx”, “T&B/Ansley Corp. Model 609-2600M”, or equivalent socket connector. The rear panel connector pin numbering, as the connector is viewed straight on, is also shown in Figure 3.5.

The output level is 5 volt positive true logic, capable of driving CMOS or TTL loads. A strobe, an overrange indicator, and +5 volts are also brought out. The data is updated at the rate of 2.5 times per second in synchronism with the front panel display. The impedance value or the dissipation value, if selected, is output as a 3-1/2 digit BCD number. The range information corresponding to Ranges 1 through 8 corresponding to the Range knob setting or to the ranges as indicated on the Operating Guide on the bottom of the instrument, are also output are Range bit 0 to 2. There is no decimal point or annunciator output, since the information is contained in the digital data.

Figure 3.5: Digital Output Connector Pin Assignments

PIN NO.	FUNCTION
1	+5 V
2	Overrange bit, true (high) during overrange condition
3	Ground
4	Strobe pulse, true (high) in synchronism with measurements
5	10 bit
6	40 bit
7	20 bit
8	4 bit
9	Sign bit, true (high) for negative and low for positive
10	1 bit
11	Do not use
12	2 bit
13	Do not use
14	200 bit
15	Do not use
16	400 bit
17	Do not use
18	800 bit
19	Range bit 2
20	80 bit
21	Range bit 0
22	1000 bit
23	Range bit 1
24	8 bit
25	Do not use
26	100 bit

Connector Pin Numbering

```
25  23  21  19  17  15  13  11  9   7  5  3  1
26  24  22  20  18  16  14  12 10   8  6  4  2
```

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Chapter 4

MAINTENANCE

4.1 Calibration Interval

The IMF-600A Impedance Meter must be verified for performance at a calibration interval of twelve (12) months. This procedure may be carried out by the user, if a calibration capability is available, by IET Labs, or by a certified calibration laboratory.

4.2 Calibration

4.2.1 General Considerations

It is important to allow both the test instruments and the IMF-600A to stabilize 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 calibration.

Proper metrology practices should be followed in performing this verification.

4.3 Calibration Procedure

WARNING

****

Line voltages are present within the unit.

Refer servicing and calibration to qualified personnel.

****

Allow the IMF-600A to stabilize for at least 10 minutes before calibration. See Figure 4.1, for the location of the various trimmer potentiometers referred to below.

To access the calibration adjustments, remove the four screws through the feet of the case, and carefully lift off the top cover. In the instructions that follow, references such as **C5** shall mean function **C**, range **5**; and **U3/8** shall mean integrated circuit (IC) **U3** pin **8**.

Proceed as follows:

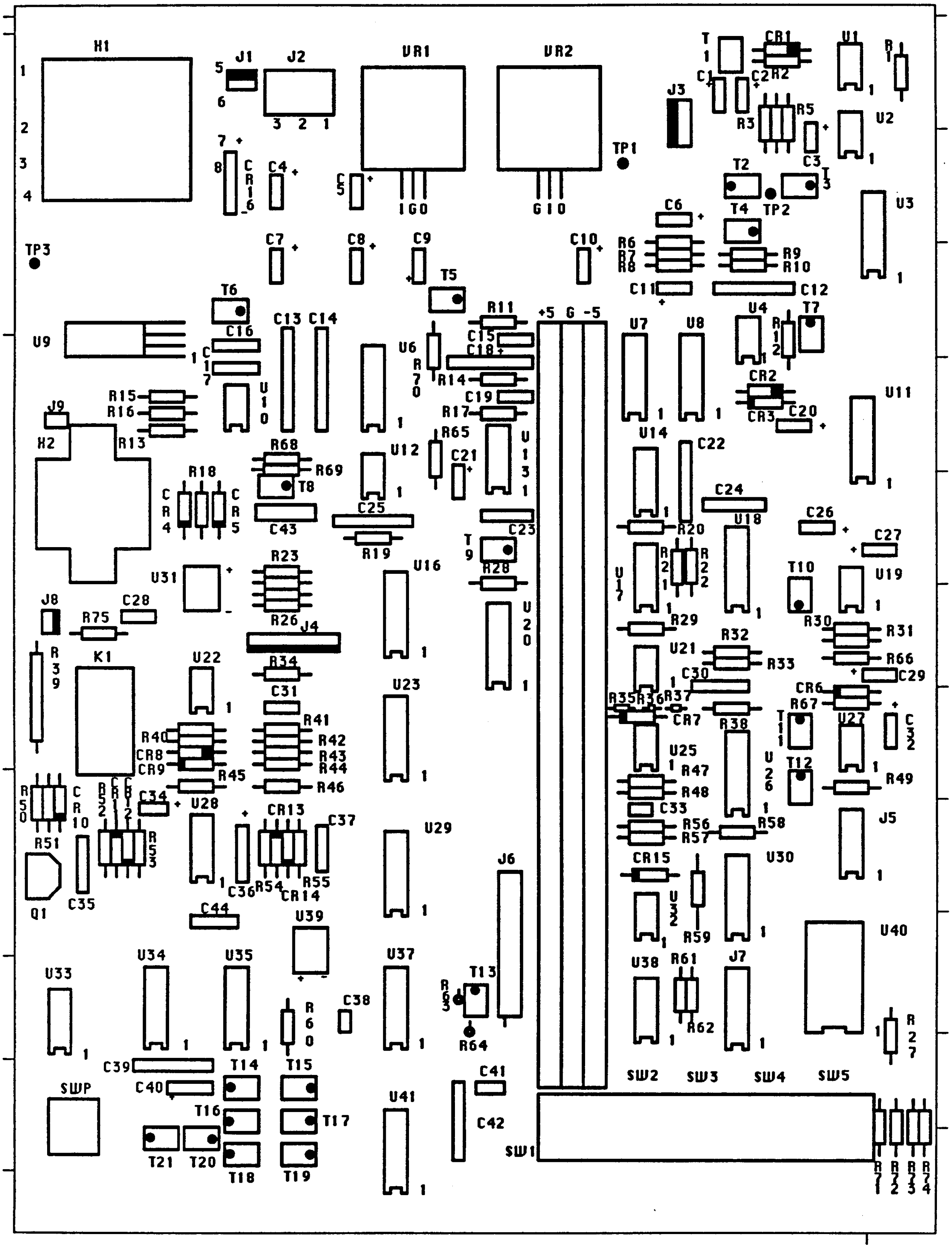

Figure 4.1 Circuit Board Layout for Calibration

IMFA600FIG4.1

1. Use a digital 4-1/2 digit voltmeter (DVM), and connect the low input to the **COM** terminal on the rear panel.

2. Set the unit to **R4** and short the Kelvin leads together. Observe J5/2 with the DVM and set to 0 ± 0.2 V with trimmer T6

3. Observe test point TP3 with a frequency counter, and confirm reading to be 1 kHz ± 10 Hz.

4. Observe J5/6 with the DVM and set to 0.3 mV ± 0.1 mV with trimmer T10.

5. Set the instrument to **R1**. Observe J5/6 with the DVM and set to 0 ± 0.3 mV with trimmer T14.

6. Set the instrument to **L4**. Observe test point TP1 with the DVM and set to 0.3 mV ± 0.1 mV with trimmer T3.

7. Set the instrument to **R1**. Observe J5/4 with the DVM and set to 0 ± 0.3 mV with trimmer T1.

8. Set the instrument to **C4**. Connect the Kelvin leads to a capacitance of 130-170 nF. Observe the voltage at J5/6. Set the instrument to **L4**, and again observe pin J5/6 with the DVM. Set both voltage readings to be the same within ± 0.3 mV with trimmer T9. Switch between **C4** and **L4** as necessary to perform this adjustment.

9. Set the instrument to **L4**. Observe the voltage at J5/6. Set the instrument to **C4**, and again observe pin J5/6 with the DVM. Set both voltage readings to 0 ± 0.3 mV with trimmer T17. Switch between **C4** and **L4** as necessary to perform this adjustment.

10. Set the instrument to **R4**. Connect the Kelvin leads to a standard resistance of 1 kΩ, with an accuracy of ± 0.05%. Observe test point TP1 with the DVM and set to 0 ± 0.3 mV with trimmer T7.

11. Observe the **IMPED** terminal on the rear panel with the DVM and set to 1.0 V ± 0.5 mV with trimmer T5.

12. Set the front panel reading to 1000 with trimmer T4.

13. Set the instrument to **C4**. Connect the Kelvin leads to a standard capacitance of 100 nF, with an accuracy of ± 0.05%. Set the front panel reading to 1000 with trimmer T2.

14. For this and some following steps, various low loss capacitors, with dissipation factor < 0.0002, are required. The needed values may be assembled from discrete low loss capacitors such as silvered mica or polystyrene, or, more conveniently using a capacitance decade unit.

15. Connect the Kelvin leads to a low loss capacitance of 105 nF. Observe the voltage at the **D** terminal on the rear panel. Set the low loss capacitance to 5 nF, and again observe **D** with the DVM. Set both voltage readings to be the same within ± 1 mV with trimmer T8. Switch between the two capacitance values as necessary to perform this adjustment.

16. Set the low loss capacitance to 100 nF. Observe the voltage at the **D** terminal on the rear panel with the DVM and set to 0 ± 0.3 mV with trimmer T12.

17. Connect the Kelvin leads to a low loss capacitance to produce a front panel reading of 159.2 nF. Connect the standard 1 kΩ resistor in parallel with the capacitor. Observe the front panel reading, with the **D** button pressed, and set to 1.000 with trimmer T11.

18. Set the instrument to **C1**. Connect the Kelvin leads to a low loss capacitance of 100 pF. Observe the voltage at the **D** terminal. Set to 0 ± 0.3 mV with trimmer T18.

19. Set the instrument to **C2**. Connect the Kelvin leads to a low loss capacitance of 1 nF. Observe the voltage at the **D** terminal. Set to 0 ± 0.3 mV with trimmer T15.

20. Set the instrument to **C3**. Connect the Kelvin leads to a low loss capacitance of 10 nF. Observe the voltage at the **D** terminal. Set to 0 ± 0.3 mV with trimmer T16.

21. Set the instrument to **C5**. Connect the Kelvin leads to a low loss capacitance of 1 µF. Observe the voltage at the **D** terminal. Set to 0 ± 0.3 mV with trimmer T21.

22. Set the instrument to **C6**. Connect the Kelvin leads to a capacitance of 10 µF, with known dissipation factor. Observe the front panel display reading, with the **D** button pressed, and Set to the known dissipation value with trimmer T20.

23. Set the instrument to **C7**. Connect the Kelvin leads to a capacitance of 10 µF, with known dissipation factor. Observe the front panel display reading, with the **D** button pressed, and Set to the known dissipation value with trimmer T19.