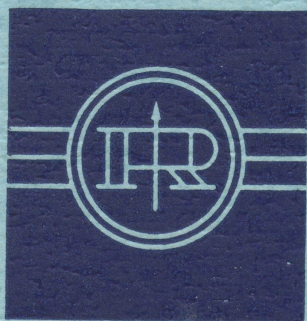


# INSTRUCTION MANUAL

Impedance Meter  
Type GB11c  
and  
Admittance Adapter  
Type GB11/AA11



# RADIOMETER

ELECTRONIC MEASURING INSTRUMENTS  
FOR SCIENTIFIC AND INDUSTRIAL USE



**Instruction Manual  
for**

**Impedance Meter  
Type GB11c  
and  
Admittance Adapter  
Type GB11/AA11**

## Table of Contents

	page
SECTION A - INTRODUCTION	A1
SECTION B - SPECIFICATIONS	B1
SECTION C - ACCESSORIES	C1
1. Component Adapter, type IM501	C1
2. 1 kHz Plug-in Filter, type GB11/F-1 kHz	C1
3. Admittance Adapter, type GB11/AA1	C1
SECTION D - GENERAL DESCRIPTION	D1
1. General	D1
2. Controls, Terminals and Meter	D2
SECTION E - OPERATING INSTRUCTIONS	E1
1. Initial Operations	E1
2. Preparing the Instrument	E1
3. How to Measure	E5
SECTION F - TECHNICAL DESCRIPTION	F1
1. General	F1
2. Oscillator Section	F1
3. Measuring Circuit	F2
4. Meter Circuit	F2
5. Power Supply	F3
SECTION G - MAINTENANCE	G1
1. General	G1
2. Removing the Instrument from the Cabinet	G1
3. Cleaning the Contacts	G1
4. DC Potentials	G1
5. Oscillator Amplitude Adjustment	G1
6. Ammeter Calibration	G2
7. Adjusting the Instrument to 100-125 Volt Line Voltage	G2
8. Replacing the Pilot Lamp	G2

SECTION H - PERIODICAL CHECKS	H1
1. General	H1
2. Checking the Frequency	H1
3. Checking the Selector Switch "MAGNITUDE OF Z" and the Resistor Decades	H3
4. Checking the Measuring Current Switch	H3
5. Checking the Stability, Adjustment of Amplification	H5
SECTION J - ADMITTANCE ADAPTER, TYPE GB11/AA1	J1
1. General Description	J1
2. Operating Instructions	J2



# **Impedance Meter Type GB11c and Admittance Adapter Type GB11/AA11**

## **Section A. Introduction**

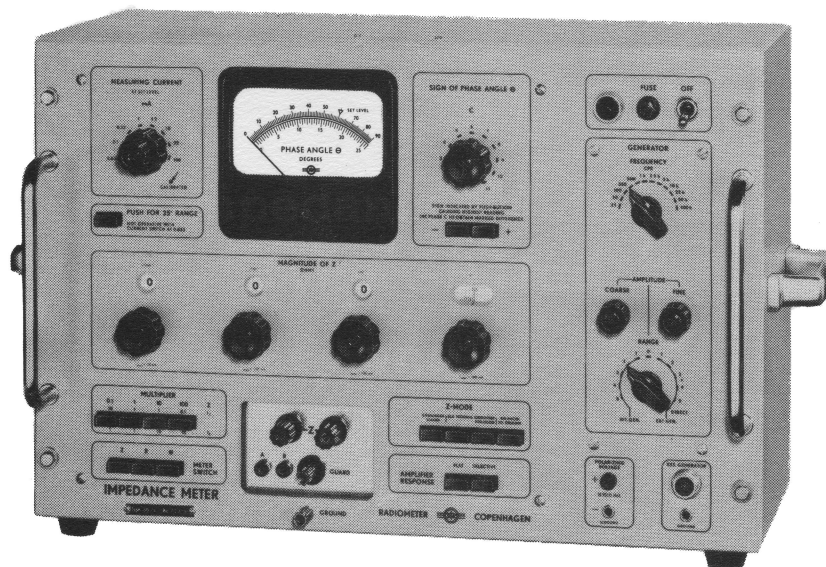


Fig.A1 The Impedance Meter, type GB11

The Impedance Meter, type GB11, which is fully transistorized and line-operated, is designed for measurements of impedances in terms of magnitude and phase angle.

Measurements can be performed on components in the impedance range from  $1\ \Omega$  to  $1.1\ \text{M}\Omega$  and with phase angles from  $0^\circ$  to  $\pm 90^\circ$  with a basic accuracy of 1% of

magnitude and  $0.5^\circ$  on phase angle. By a modified operating technique, negative impedances in the range  $1\ \Omega$  to  $111\ \text{k}\Omega$  and with phase angles from  $180^\circ$  to  $180^\circ \pm 90^\circ$  can be measured.

A built-in guard circuit enables measurements to be carried out independently on any of the three impedances in a three-terminal network. Measurements can be made on impedances which are floating, grounded, or balanced to ground.

A built-in generator provides for test currents at 12 spot frequencies from 25 Hz to 100 kHz; external generators can be used to 1 MHz. The test currents, monitored by a meter, can be varied from 3.2 mA to 1 A.

Provision is made for measuring incremental impedances by using an external polarization voltage; for measuring non-linear impedances by means of optimal plug-in filters; and for connecting an external generator.



## Section B. Specifications

### MEASURING RANGE

<u>Magnitude</u>	1 $\Omega$ to 1.1 M $\Omega$
<u>Phase Angle</u>	0° to $\pm 25^\circ$ and 0° to $\pm 90^\circ$ , direct reading.
<u>Frequency Range and Accuracy</u>	See Fig.B1

When negative impedances are measured, the measuring range is modified as follows:

<u>Magnitude</u>	1 $\Omega$ to 111 k $\Omega$ .
<u>Phase Angle</u>	180° to 180° $\pm 25^\circ$ and 180° to 180° $\pm 90^\circ$ .
<u>Frequency Range and Accuracy</u>	See Fig.B1.

### TEST CURRENT

<u>Range</u>	3.2 $\mu$ A to 1A.  The test currents with the meter at SET LEVEL are 0.032, 0.1, 0.32, 1, 3.2, 10, 32, and 100 mA with the impedance multiplier in position $\times 1$ or $\times 10$ . When the multiplier is set to $\times 0.1$ , the test currents are 10 times larger and when the multiplier is set to $\times 100$ , the test currents are 10 times smaller.
<u>Accuracy of Test Current</u>	3% from 100 Hz to 100 kHz.
<u>Frequency Response</u>	$\pm 0.5$ dB from 50 Hz to 500 kHz $\pm 1$ dB from 25 Hz to 1 MHz.

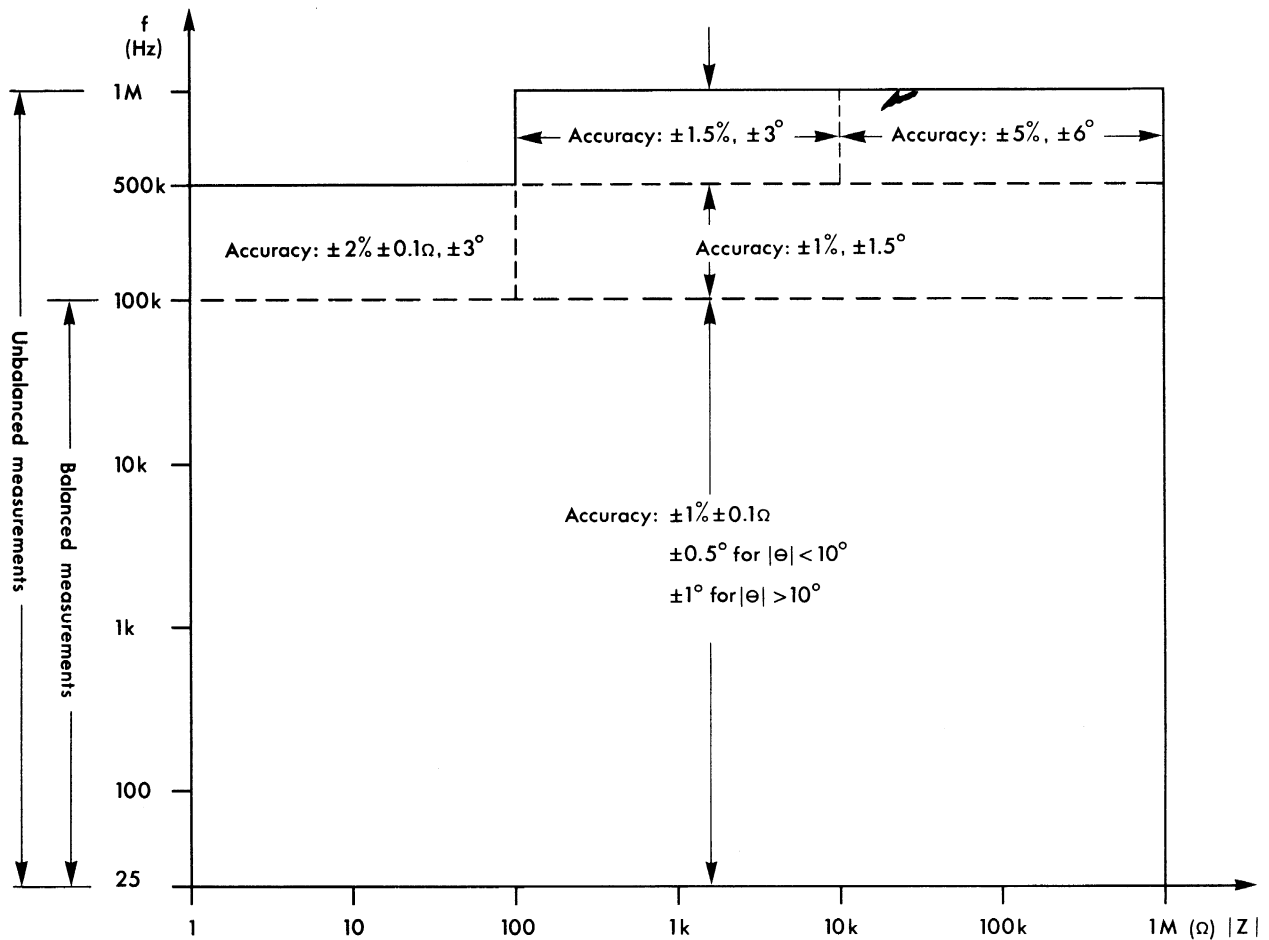


Fig.B1 Frequency Range and Accuracy. For negative impedances  $|\theta|$  corresponds to  $180^\circ \pm |\theta|$ . Upper limit of  $|Z|$  is 110 kilohms.

## INTERNAL GENERATOR

### Frequency

25, 50, 100, 250, and 500 Hz, 1, 2.5, 5, 10, 25, 50, and 100 kHz.

### Accuracy of Frequency

$\pm 1\% \pm 0.5$  Hz.

### Waveform Distortion

Less than 1% harmonic distortion above 50 Hz.  
Less than 2% harmonic distortion at 25 Hz.

### Power Output

0 to 125 mW supplied via a multitap matching transformer. The output voltage is continuously variable from 0 to 0.1, 0.35, 1, 3.5, or 10 V maximum.

## TERMINALS

### Z, Guard, and Ground Terminals

Binding posts which accommodate 4 mm banana plugs.



Auxiliary jacks for the measurement of negative impedances

Banana jacks.

Ext. Generator Input

UHF-type coaxial socket.

dc Polarizing Input

Banana jacks.

## STANDARD RESISTOR

1  $\Omega$  to 11000  $\Omega$  in four decades of 1 to 10  $\Omega$  continuously variable,  $9 \times 10 \Omega$ ,  $9 \times 100 \Omega$ , and  $10 \times 1000 \Omega$ . Convenient in-line read-out.

The accuracy is better than  $0.5\% + 0.1 \Omega$ , and the phase angle is less than  $2^\circ$  per megahertz.

The maximum current in the standard resistor is 100 mA except for the  $10 \times 1000 \Omega$  decade for which it is 32 mA.

## MAX. INPUT VOLTAGE FROM EXTERNAL GENERATOR

75 V peak

## dc POLARIZATION

Measurements are made with one terminal grounded. Maximum polarizing current is 200 mA; actual limit value depends on frequency and test current. The voltage should not exceed 50 volts dc.

When the instrument is operated with polarization, a measuring error, which easily can be corrected, is introduced at low frequencies and low impedance values (below  $2000 \Omega \times \text{Hz}$ ).

## TRANSISTORS

1 AU Y 10 8 AF116

## POWER SUPPLY

Voltages

100 to 125 and 200 to 240 volts.

Line Frequencies

50 to 60 Hz.

Consumption

3 watts.

## DIMENSIONS

Height

340 mm (13 1/2 in.)

Width

560 mm (22 in.)

Depth

240 mm (9 1/2 in.)

## MOUNTING AND FINISH

Steel cabinet finished in grey enamel.

## WEIGHT

21 kilos net (45 lbs.).

## ACCESSORIES SUPPLIED

1 Power Cord, code 615-300

1 Terminal Shield, type GB11/M65.

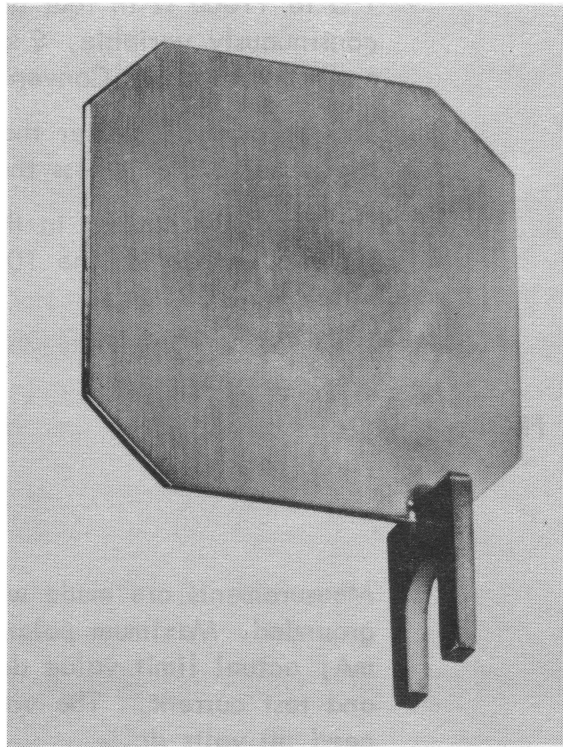


Fig.B2 The Terminal Shield, type  
GB11/M65

## ACCESSORIES AVAILABLE

Admittance Adapter,  
type GB11/AA1

The Admittance Adapter, which fits on the Z and Guard terminals, converts the Impedance Meter into an Admittance Meter. (See SECTION C.)

Component Adapter,  
type IM501

The guarded Component Adapter which fits on the Z and Guard terminals, makes possible a rapid testing of components. (See SECTION C.)

Plug-in Filters

The Plug-in Filters adapt the Impedance Meter for selective measurements. (See SECTION C.)



Wide Range Oscillator,  
type RCO11

The Wide-Range Oscillator, type RCO11, is a transistorized, line-operated RC oscillator delivering a sine wave or a square wave ( with a 50 ns fall and rise time), with low distortion and fine resolution in the frequency range from 10 Hz to 1 MHz.

It is provided with 3 outputs: A direct output (specially designed for use with the Impedance Meter) with an impedance of 10  $\Omega$  in series with 1000  $\mu$ F delivering a voltage continuously variable from 0 to 5 V at max. 100 mA, and two outputs with impedance of 50  $\Omega$  and 600  $\Omega$ .

For further details, please order separate brochure.

## Section C. Accessories

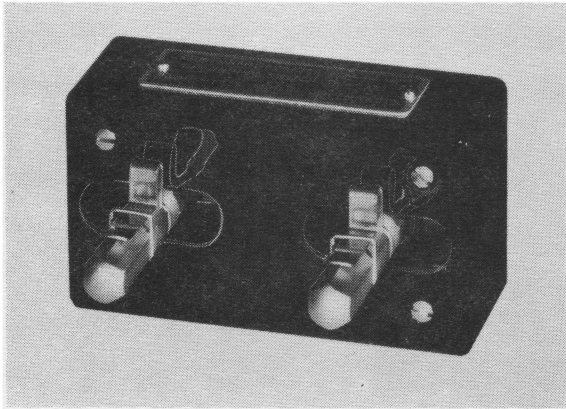


Fig.C1 The Component Adapter, type IM501

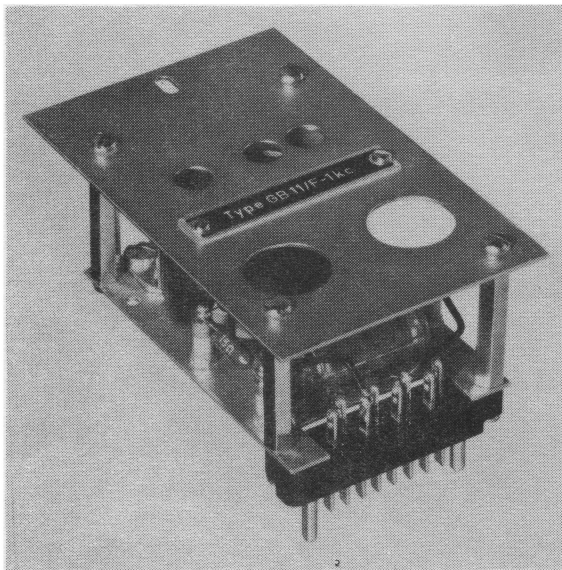


Fig.C2 The 1 kHz Plug-in Filter, type GB11/F 1 kHz

### ACCESSORIES AVAILABLE

#### Component Adapter, type IM501

The Component Adapter, type IM501, is a small unit that fits directly on the binding posts of the Impedance Meter. The Component Adapter has two movable terminals for adjustable spacing and spring-loaded clips for easy insertion of components.

#### 1 kHz Plug-in Filter, type GB11/F-1 kHz

The 1 kHz Plug-in Filter adapts the Impedance Meter for selective measurements. The filter is plugged into the Impedance Meter from the rear.

The 1 kHz Plug-in Filter is stocked, but filters for the remaining 11 spot-frequencies of the built-in oscillator can be supplied to order.

#### Admittance Adapter, type GB11/AA1

##### General:

The Admittance Adapter, which fits on the Z and Guard terminals, converts the Impedance Meter into an Admittance Meter. (For further information, see SECTION J.)



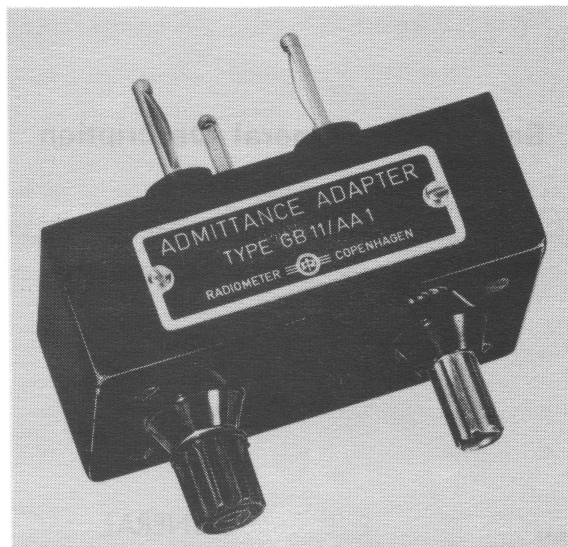


Fig. C3 The Admittance Adapter, type GB11/AA1

#### Specifications:

##### 1) Measuring Range

- a) Magnitude: 1 mho to 11 mhos
- b) Phase Angle: 0 to  $\pm 90^\circ$

##### 2) Accuracy

- a) Magnitude:  $\pm 2\%$
- b) Phase Angle:  $3^\circ$

##### 3) Test Current

3.2 mA at 1 mho to 35 mA at 11 mhos, with the RANGE SWITCH at 0.032 mA, the test current interpolator in the CALIBRATED position, and the meter at SET LEVEL.

(See also SECTION J.)

##### 4) Frequency Range

25 Hz to 10 kHz

##### 5) dc Polarization

Max: 25 V dc

##### 6) Over-all Dimensions

- a) Height: 53 mm
- b) Width: 90 mm
- c) Depth: 85 mm

##### 7) Weight

0.265 kilos (0.6 lbs.)

## Section D. General Description

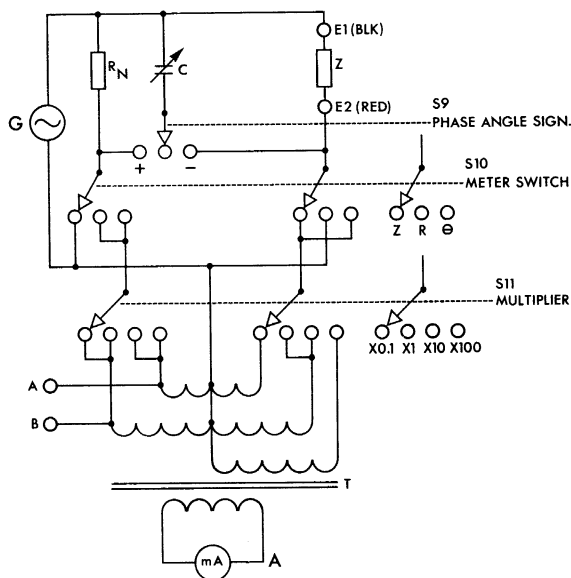


Fig.D1 Simplified block diagram of the Impedance Meter, type GB11

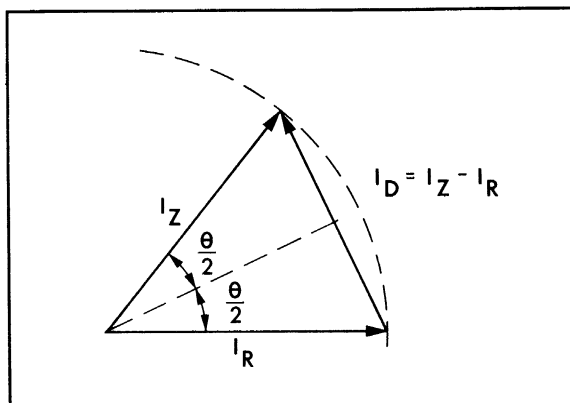


Fig.D2 Vector diagram for phase angle determination

### GENERAL

The Impedance Meter, type GB11, is based on the principle of a modified Grützmacher bridge.\* The operating principle of the Impedance Meter is shown in Fig. D1.

The impedance  $Z$  to be tested and the variable standard resistor  $R_N$  are both connected to the generator  $G$ , either directly or through a current-measuring circuit which consists of a differential current transformer  $T$  and a transistorized ammeter  $A$ . Assuming that the impedance of the current-measuring circuit is zero with the switch  $S10$  in the positions  $Z$ ,  $R$ , and  $\theta$ , the ammeter  $A$  will indicate the current  $I_Z$  through  $Z$ , the current  $I_R$  through  $R_N$ , and the vector difference  $I_D = I_Z - I_R$  of the two currents.

When  $R_N$  is adjusted so that  $I_Z = I_R$  it follows immediately that  $Z = R_N$  and the magnitude can be directly read from the standard resistor dials.

The phase angle of the impedance can then, in accordance with the vector diagram in Fig. D2, be determined from

$$\sin \frac{\theta}{2} = 0.5 \frac{I_D}{I_Z} .$$

\* See: Direct-Reading Meter Gives Impedance and Phase Angle, by P. Lund, Electronics, Jan.3.1964.

The meter can conveniently be calibrated to read  $I_d$  directly in terms of phase angle  $\theta$  between  $0$  and  $90^\circ$  by adjusting the generator voltage or the current sensitivity. This is done so that the current  $I_z$  brings the meter needle to a set-level mark, which is at  $0.5 \sqrt{2}$  of full scale.

While reading  $I_d$ , the sign of the phase angle is finally determined by alternately connecting the variable capacitance  $C$  across  $R_n$  and  $Z$  by means of the push-buttons  $S9_+$  and  $S9_-$ . Noting the corresponding current differences of  $I_{d+} - I_{d-}$ , the sign of the phase angle is determined by the sign of  $I_{d+} - I_{d-}$ , or simply by the sign of the pushbutton,  $S9_+$  or  $S9_-$ , that gives the higher reading.

If the phase angle  $\theta$  is greater than  $-90^\circ$ , the angle cannot be read directly on the meter. It is, however, possible to read  $\varphi = \theta - 180^\circ$  by moving one end of the impedance under test from E2 (RED) to the A or B terminals. (See SECTION E under "Measuring Impedances with Phase Angles of  $180^\circ$  to  $180^\circ \pm 90^\circ$ ".) The phase angle minus  $180^\circ$ , can then in accordance with the vector diagram shown in Fig. D3 be determined from

$$\sin \frac{\varphi}{2} = 0.5 \frac{I_s}{I_z} \text{ where } \varphi, \text{ as described}$$

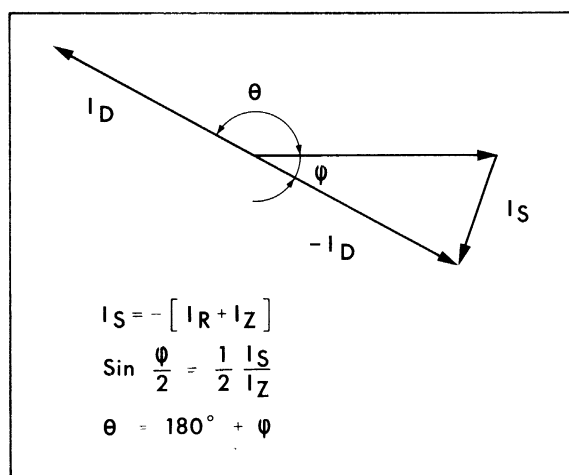


Fig.D3 Vector diagram for phase angle determination of phase angles from  $180^\circ$  to  $+90^\circ$

above, can be read directly on the meter. The phase angle is then  $\theta = \varphi + 180^\circ$ .

The impedance range is extended over the range covered by the standard resistor  $R_n$  by multiplication. This extension is obtained by choosing different turn ratios  $m:n$  for the windings on the current transformer  $T$  (see Fig.D4). Note that phase angles from  $180^\circ$  to  $180^\circ \pm 90^\circ$  cannot be determined with the turn ratio  $1:100$  of the current transformer.

The sensitivity of the transistorized ammeter can be varied over a wide range, which makes it possible to measure impedance at different currents.

For polarizing purposes, a blocking choke  $L3$  and blocking capacitors  $C18$  and  $C19$  are added to the circuit as shown in Fig. D4. The dc current through the impedance  $Z$  under test must be supplied and monitored externally.

The common point of transformer windings is brought out to the front panel and serves as a terminal for the guard system.

The mode switch  $S4$  connects the ground either to the guard terminal (for direct impedance measurement of floating impedances) or to the black  $Z$  terminal (for

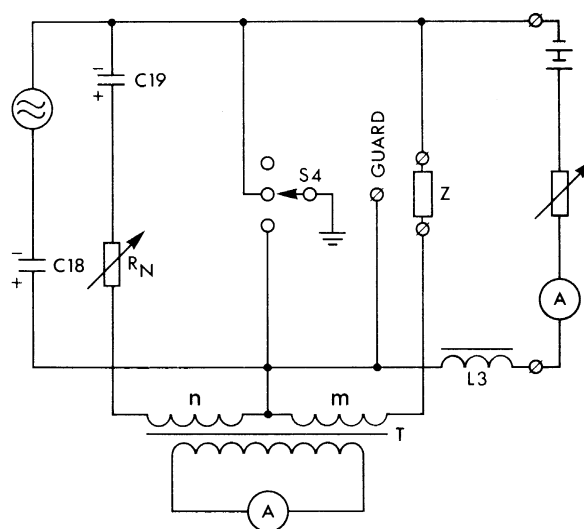


Fig.D4 Polarization by dc current, and mode switching

the measurement of grounded impedances), or it leaves the circuit floating for the measurement of the compound impedance of balanced-to-ground circuits.

The internal generator is connected to the bridge via a multi-tap, balanced matching transformer. An external generator can be connected directly or through the matching transformer. When measuring balanced-to-ground circuits, the matching transformer operates as a balancing transformer.

## CONTROLS, TERMINALS AND METER

### Controls and Terminals

As can be seen in Fig.D5, the Impedance Meter, type GB11, is provided with the following controls and terminals:

#### Power Switch ON-OFF (1)

The power switch is used to turn the instrument on or off.

#### Monitoring Lamp (2)

The lamp (2) monitors the power switch.

#### Fuse (3)

The fuse holder holds the line fuse (see SECTION E OPERATING INSTRUCTIONS).

#### GENERATOR FREQUENCY Switch (4)

The 12-position rotary switch FREQUENCY is used to select the frequency of the internal generator from 25 Hz to 100 kHz in a 25-50-100 sequence.

#### AMPLITUDE RANGE Switch (5)

The rotary switch AMPLITUDE RANGE is used to adjust the generator voltage in steps by changing taps on the input transformer. It is operative both with the internal and an external generator, and is provided with a position DIRECT, for direct coupling of an external generator.

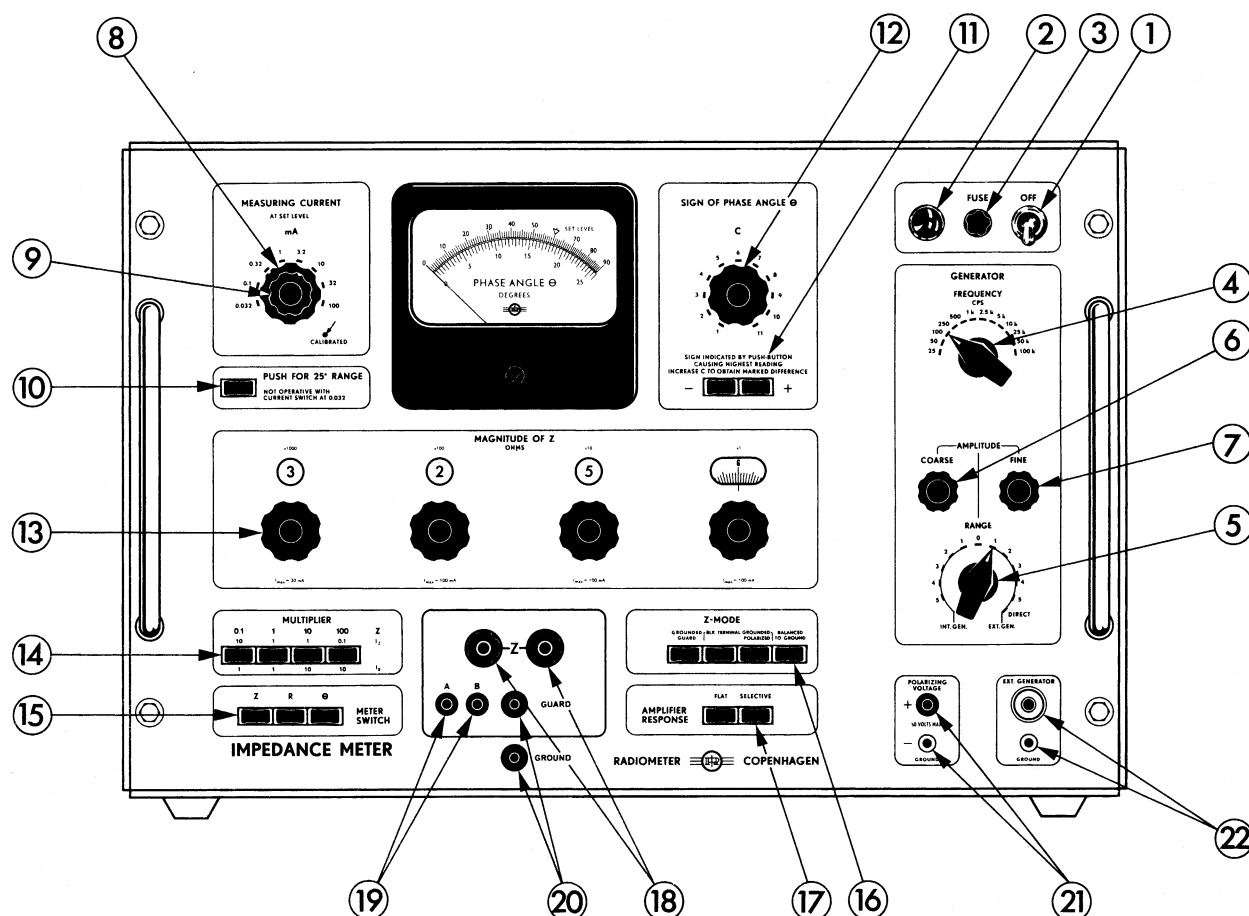


Fig.D5 The front panel of the Impedance Meter, type GB11



**AMPLITUDE COARSE Potentiometer (6)**

The potentiometer AMPLITUDE COARSE is used to adjust the delivered voltage of the internal generator.

**AMPLITUDE FINE Potentiometer (7)**

The potentiometer AMPLITUDE FINE is used for fine adjustment of the voltage of the internal generator.

**MEASURING CURRENT (COARSE) (8)**

The 8-position rotary switch MEASURING CURRENT (coarse) is used to adjust the ammeter sensitivity in 10 dB steps (0 dB = 0.032 mA) from 0.032 to 100 mA.

**MEASURING CURRENT (FINE) (9)**

The potentiometer MEASURING CURRENT (fine) is used for interpolation between the 10 dB steps of the coarse adjustment.

**PUSH FOR 25° RANGE (10)**

The self-releasing pushbutton PUSH for 25° RANGE is used to expand the meter scale to 25° when measuring phase-angles smaller than 25°. Note that it is not operative in the lowest range of the MEASURING CURRENT switch (0.032 mA).

**SIGN OF PHASE ANGLE (+ AND -) (11)**

The two self-releasing pushbuttons SIGN OF PHASE ANGLE are used to determine the sign of the phase angle (see SECTION E OPERATING INSTRUCTIONS).

**SIGN OF PHASE ANGLE (C) (12)**

The 11-position rotary switch SIGN OF PHASE ANGLE is used to control the capacitive current component during phase-angle sign determinations.

**MAGNITUDE OF Z Selectors (13)**

The 4-decade standard resistor selectors MAGNITUDE OF Z are used during the balancing operation (see SECTION E OPERATING INSTRUCTIONS).

**MULTIPLIER Pushbuttons (14)**

The 4-section pushbutton switch MULTI-

PLIER is used to bring the impedance under test into the range of the standard resistor (see SECTION E OPERATING INSTRUCTIONS).

**METER SWITCH Pushbutton (15)**

The 3-section pushbutton METER SWITCH is used to switch the measuring circuit into the unknown branch of the impedance under test when the pushbutton Z is pressed. When the pushbutton R is pressed, the standard resistor is connected to the measuring circuit for comparison purposes. The pushbutton  $\theta$  must be pressed when the value of the phase-angle is desired, this value being read directly on the meter.

**Z MODE Pushbuttons (16)**

The Z MODE switch is a 4-section pushbutton switch. In position GROUNDED GUARD, the Z MODE switch connects the ground to the inner shield. In position BLK TERMINAL GROUNDED, it connects the ground to the black terminal, and in position POLARIZED, it introduces a blocking capacitor in series with the standard resistor and closes the connection to the + POLARIZING VOLTAGE terminal. In position BALANCED TO GROUND, the ground is disconnected from the measuring circuit and the DIRECT generator connection is disconnected.

**AMPLIFIER RESPONSE Pushbuttons (17)**

The pushbutton switch AMPLIFIER RESPONSE consists of two sections and is used as follows: In position SELECTIVE, a filter is coupled to the measuring circuit, thus enabling selective measurements. In position FLAT, the filter is disconnected.

**Z-Terminals (18)**

The two Z-terminals are regular banana jacks. They are used to connect the impedance to be tested to the instrument. The black terminal is connected directly to the voltage source, and the red terminal is connected through the current-measuring transformer.

### A and B Terminals (19)

The two terminals A and B are regular banana jacks. The A terminal is used instead of the red Z-terminal with the  $Z \times 0.1$  MULTIPLIER when measuring phase angles in the range  $180^\circ \pm 90^\circ$ . The terminal B is used instead of the red Z-terminal with the  $Z \times 1$  and  $Z \times 10$  MULTIPLIER when measuring phase angles in the range  $180^\circ$  to  $180^\circ \pm 90^\circ$ .

### GUARD and GROUND Terminals (20)

The GUARD and GROUND terminals are regular banana jacks, and are respectively used to connect guarded circuits and to connect external ground to the instrument, or as third terminal for balanced-to-ground impedance measurements.

### POLARIZING VOLTAGE Terminals (21)

The POLARIZING VOLTAGE terminals are regular banana jacks. They are used to connect a dc polarizing supply. The upper terminal should be positive with respect to the lower one, which is grounded.

### EXTERNAL GENERATOR Terminals (22)

The EXTERNAL GENERATOR terminals consist of a UHF connector and a banana jack, thus enabling the use of either UHF coaxial cables, or banana-plug-terminated cables. These terminals are used to connect an external generator. Note that the banana jack is grounded.

### Plug-in Filter Terminals (See Fig.D6)

The Plug-in Filter terminals are located on the rear of the cabinet and are used to connect Plug-in Filters for selective measurements.

### Meter (See Fig.D5)

The meter of the Impedance Meter, type GB11, is provided with a knife-edge pointer, and two scales for phase-angle measurements. The upper scale is calibrated from 0 to 90, and is provided with a SET LEVEL mark ( $\nabla$ ). (See SECTION E OPERATING INSTRUCTIONS.) The lower scale is calibrated from 0 to 25.

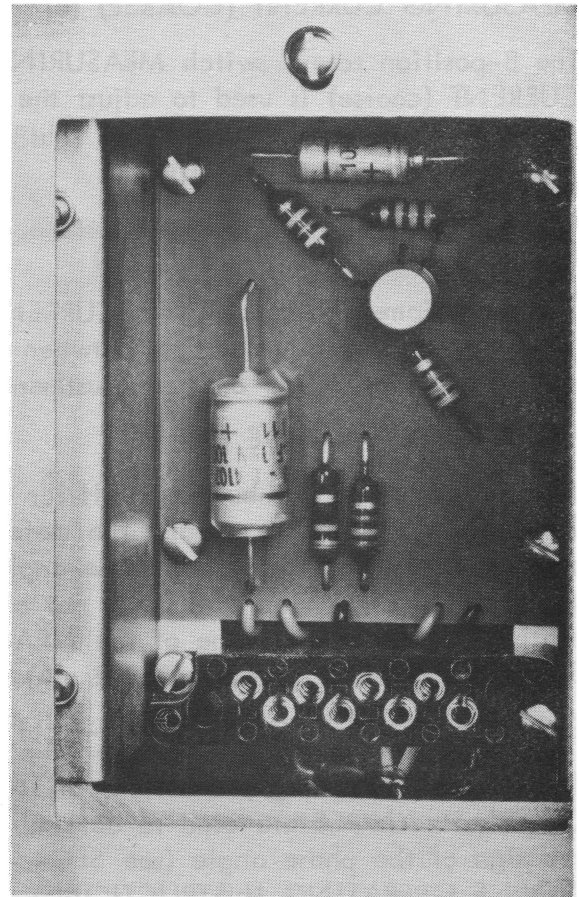


Fig.D6 The Plug-in Filter terminals of the Impedance Meter, type GB11

## Section E. Operating Instructions

### INITIAL OPERATIONS

- (1) Make sure that the wiring is correct for the line voltage to be used, and that the corresponding fuse is installed. All instruments are wired for 200-240 volts and equipped with a 50 mA slow-blow fuse when leaving the factory. See SECTION G MAINTENANCE, if the instrument is to operate on 100-125 volts.
- (2) Check the mechanical zero-setting of the meter and reset, if necessary.

### PREPARING THE INSTRUMENT

#### General

Connect the instrument to the power line with the line cord supplied. Set power switch to ON.

#### Selecting the proper Z-MODE

The mode is usually determined by the nature of the impedance under test. It depends on whether the impedance is balanced, polarized, grounded or floating.

Whenever possible, the GROUNDED GUARD mode should be chosen, since in

this mode only the direct impedance between the terminals is measured, while stray capacitances and leakages to ground are prevented from affecting the measurement.

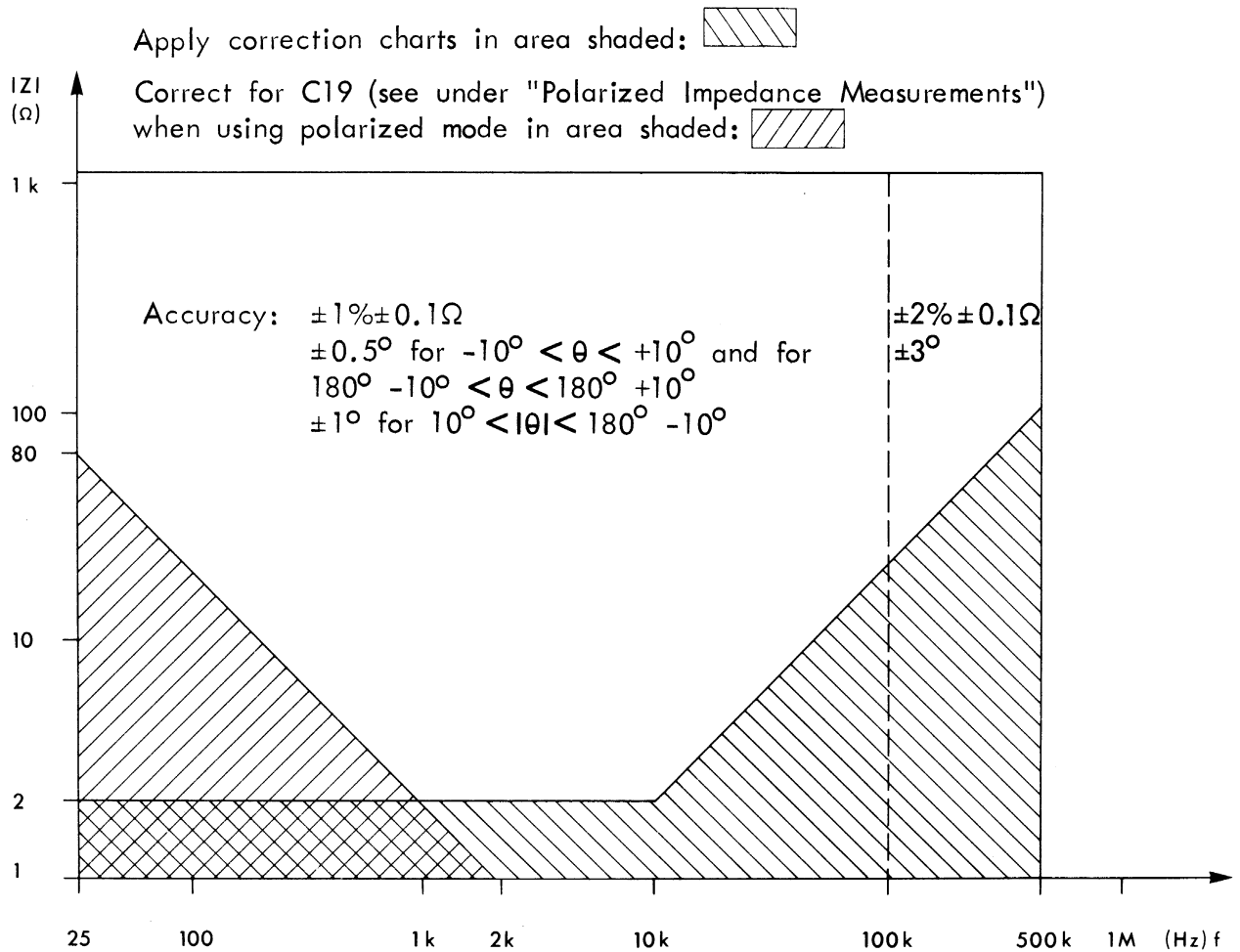
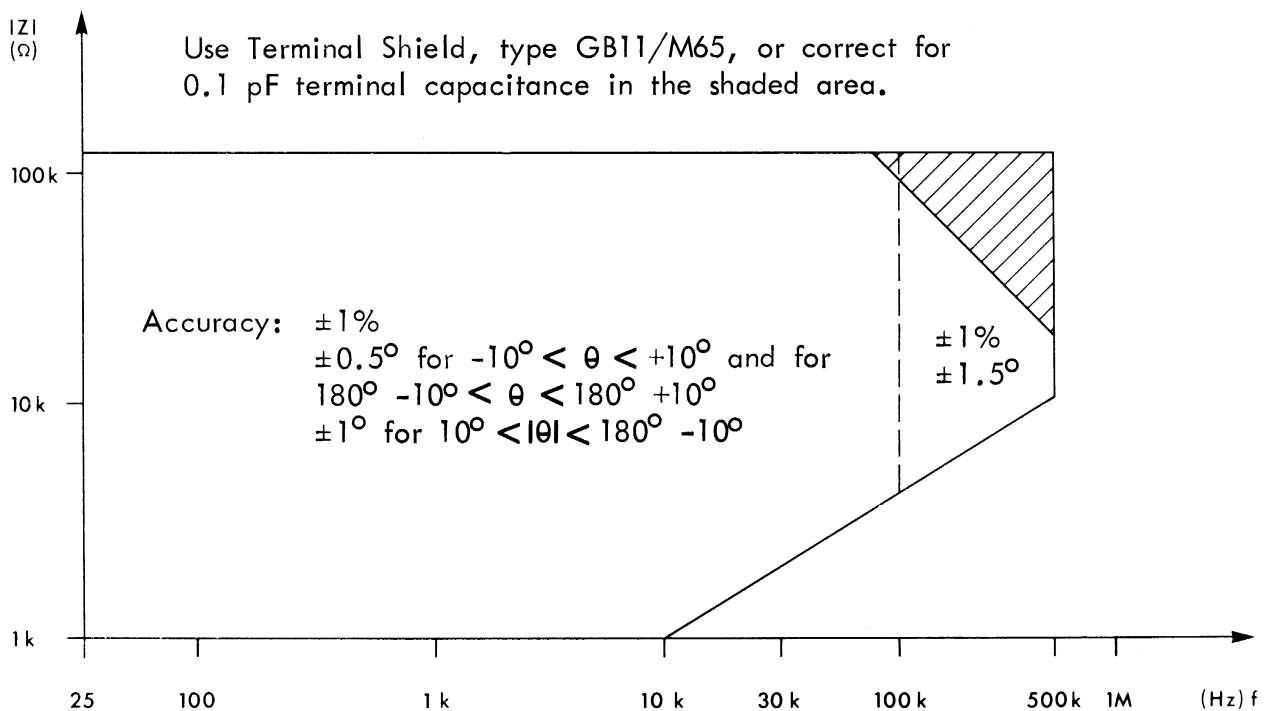
#### Selecting the proper AMPLIFIER RESPONSE

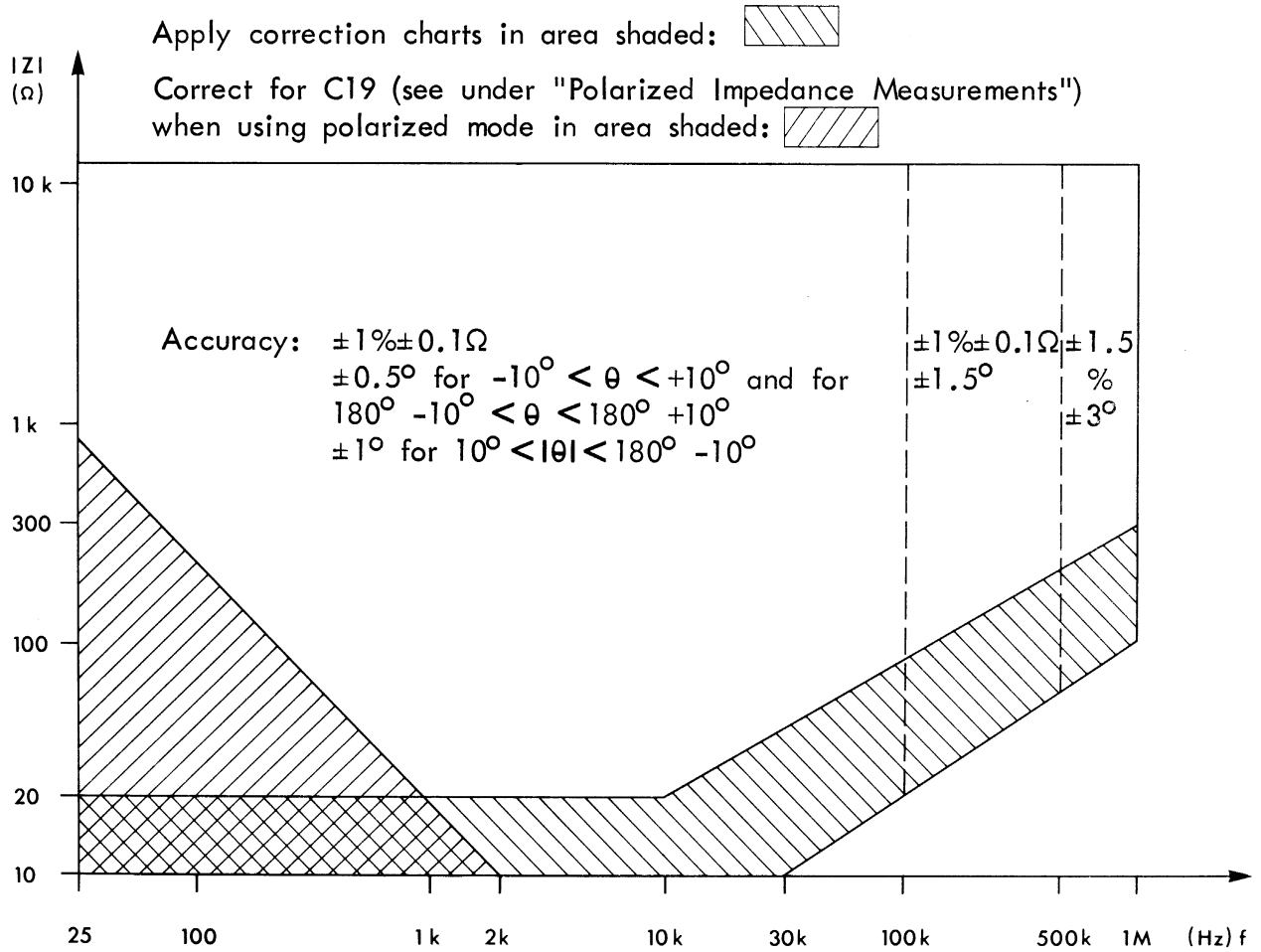
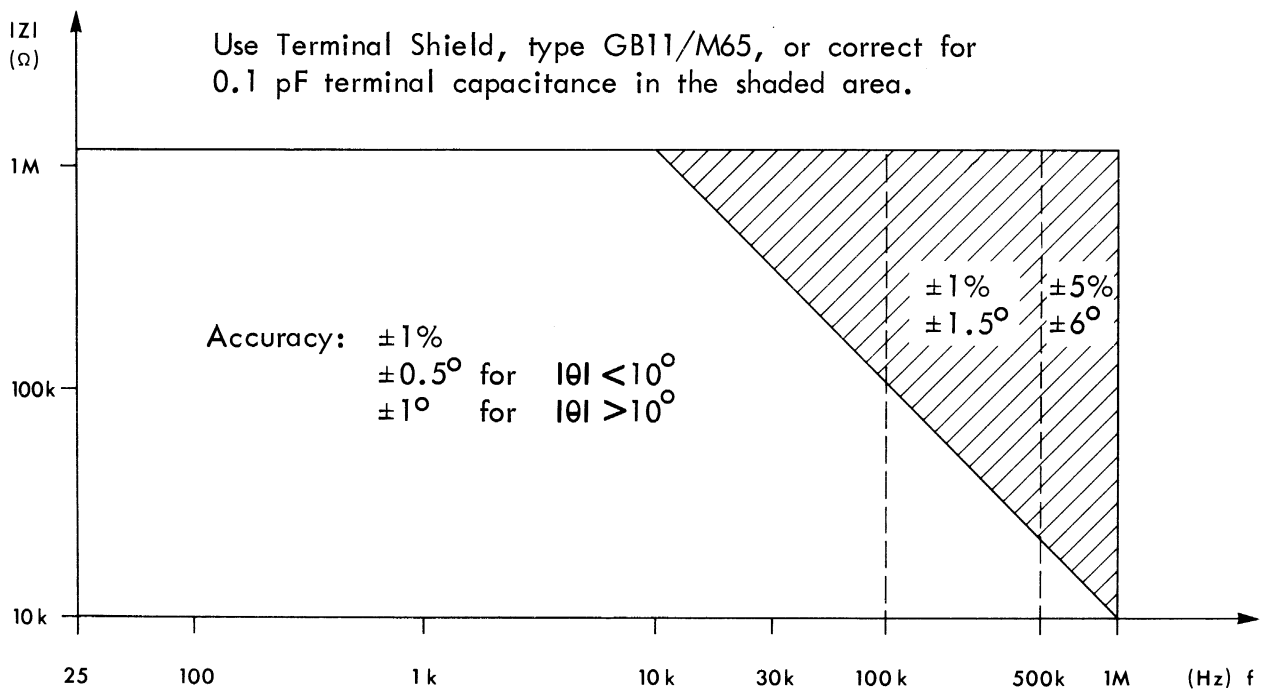
Normally the FLAT response should be used to measure all linear impedances. The SELECTIVE response requires that the instruments be equipped with a Plug-in Filter Unit, type GB11/F, and it is recommended for measuring non-linear impedance, when the current wave-form distortion caused by the non-linearity may affect the measurement.

#### Selecting the proper MULTIPLIER

Multipliers must be used to extend the range of the instrument beyond 11 k $\Omega$  covered by the standard resistor, and to obtain a higher accuracy for impedances below 100  $\Omega$ .

When there is any doubt about the proper multiplier settings, consult Figs. E1, E2, E3, E4 to find out which range gives the

Fig.E1  $Z \times 0.1$  MULTIPLIER (1  $\Omega$  to 1.1 k $\Omega$ ) selection chartFig. E2  $Z \times 10$  MULTIPLIER (100  $\Omega$  to 110 k $\Omega$ ) selection chart

Fig.E3 Z x 1 MULTIPLIER (10  $\Omega$  to 11 k $\Omega$ ) selection chartFig.E4 Z x 100 MULTIPLIER (1 k $\Omega$  to 1.1 M $\Omega$ ) selection chart



highest accuracy and whether corrections must be applied.

### Selecting the desired MEASURING CURRENT

The test current is determined by the MEASURING CURRENT setting multiplied by the  $I_z$  factor of the MULTIPLIER.

The impedance of linear devices is independent of the test current, which may be chosen arbitrarily. However, low test currents are preferred in order to obtain a favourable matching between the generator and the measuring circuit, with a quicker balance as a result.

For non-linear impedances, the test current has to be specified and the instrument set accordingly.

In case the test voltage is specified, connect an external voltmeter across the black Z and GUARD terminals to monitor the test voltage, and adjust the MEASURING CURRENT controls to a set-level meter reading.

### Using an external generator

If frequencies other than, or test currents higher than, those obtainable from the internal generator are desired, connect an external generator to the EXTERNAL GENERATOR connector.

The external generator can be connected to the measuring circuit either directly or through the internal multi-tap matching transformer, depending on the position of the AMPLITUDE-COARSE selector.

The transformer (EXT.GEN.) connection must be used to measure balanced circuits. The DIRECT connection must be used at frequencies above 11 kHz and powers above 125 mW, which are the upper fre-

quency and power-handling limits of the matching transformer.

The output impedance and the harmonic distortion of the external generator should be as low as possible (below 200  $\Omega$ ). (See SECTION B under "Wide-Range Oscillator, type RCO11".) The first is desirable to obtain a rapid balance. The second is necessary to obtain a rapid balance and to minimize measuring errors due to harmonics, especially when measuring at frequencies close to the resonant frequency of parallel-tuned circuits. The errors caused by harmonics depend on the nature of the impedance and on the phase relationship between the harmonic and fundamental frequencies. In the case of magnitude measurements, 10% of the second harmonic may produce errors up to 1%, and 10% of the third harmonic may cause errors up to 4%.

In the case of phase-angle measurements, the errors caused by harmonics may be severe, especially when measuring on tuned circuits. This inaccuracy may be overcome by using the Plug-in Filter Units, type GB11/F, or by inserting an adequate filter between the generator and the instrument.

When using an external generator, care should be taken not to exceed the current rating of the standard resistors. The current through the standard resistor is determined by the MEASURING CURRENT setting multiplied by the  $I_r$  factor of the MULTIPLIER. The current rating of the standard resistors is 100 mA, except for the x1000 decade, in which it is only 32 mA.

### Inserting a Plug-in Filter Unit, type GB11/F

Remove the thumb-screw and cover from the back of the instrument. The Filter can then be plugged in (see Fig.D6) and

kept in place by a fixing screw. The cover should be replaced when the Filter Unit has been inserted.

## HOW TO MEASURE

### General

1) When the instrument has been set up, connect the impedance to be measured to the Z terminals and select the desired generator frequency.

2) Press the Z button of the METER SWITCH and adjust AMPLITUDE so that the pointer of the meter deflects to the SET-LEVEL mark.

3) Press the R button of the METER SWITCH and adjust the MAGNITUDE decades so that the pointer again deflects to SET-LEVEL.

4) Check the Z reading and, if necessary, repeat operations (2) and (3) until the R and Z readings coincide with the SET-LEVEL mark.

The magnitude of the impedance, Z, is now obtained by reading the MAGNITUDE dials and multiplying the reading by the Z factor of the MULTIPLIER.

5) Press the  $\theta$  button and read directly (from the upper meter scale) the phase angle in degrees. If the phase angle is less than  $25^\circ$ , the meter scale must be expanded by pressing the button  $25^\circ$  RANGE. Phase angles above  $90^\circ$  can be measured as described below under "Measuring Impedance with Phase Angles of  $180^\circ$  to  $180^\circ \pm 90^\circ$ ".

Note: In the case of very small phase angles, i.e. below  $10^\circ$ , a more accurate measurement of  $\theta$  may be obtained by slightly readjusting the MAGNITUDE setting to reach a minimum reading for  $\theta$ .

6) While measuring  $\theta$ , alternately press the Plus and Minus pushbuttons. Increase C only enough to obtain a pronounced difference between the reading obtained with the Plus button and that obtained with the Minus button. The sign of the phase angle is now determined by the sign of the button that gives the higher reading.

### Measuring Low Impedances

When the impedance is too low to be measured with the accuracy specified, because of inevitable imperfections in the measuring circuits, corrections must be applied to obtain the accuracy specified.

#### 1) Correction charts:

The correction charts shown in Fig.E5 and E6 are to be used with the  $Z \times 0.1$  MULTIPLIER, whilst those shown in Fig. E7 and Fig.E8 are to be used with the  $Z \times 1$  MULTIPLIER.

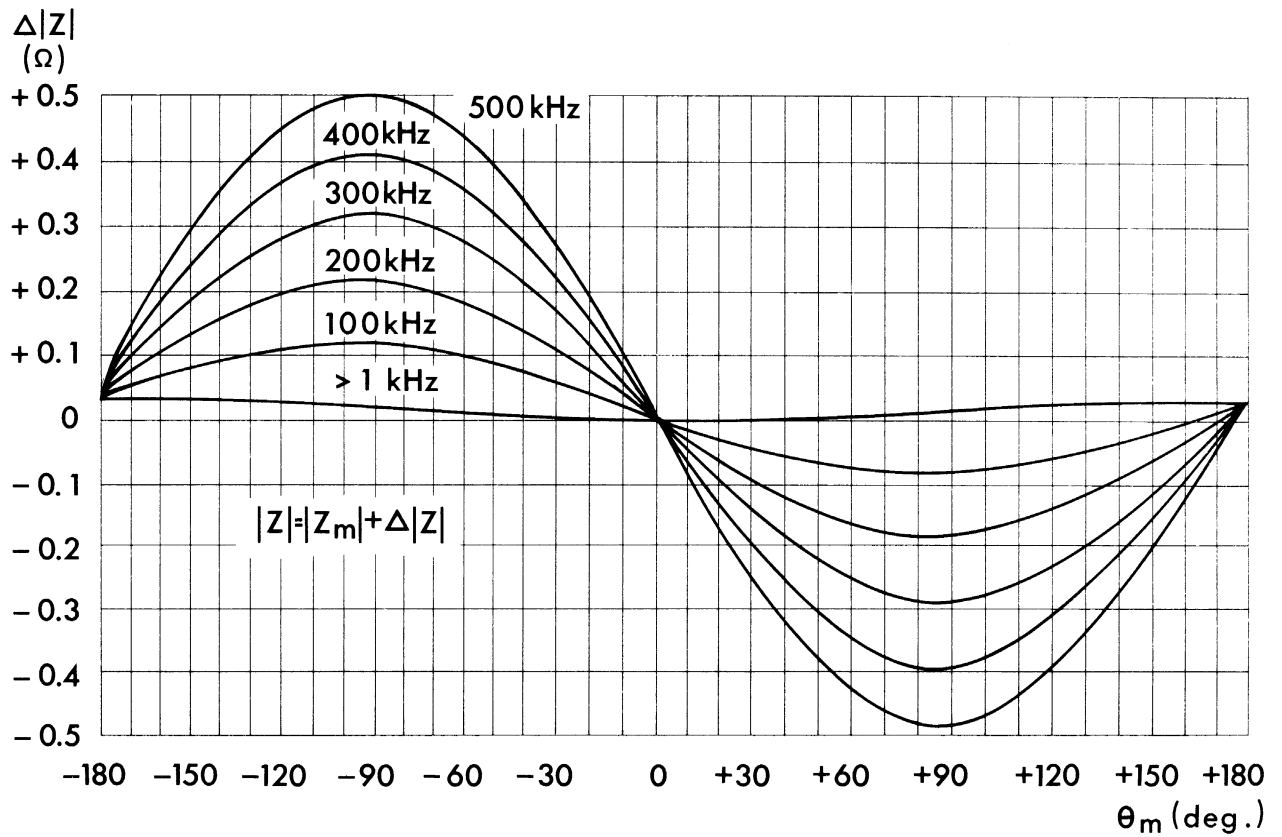
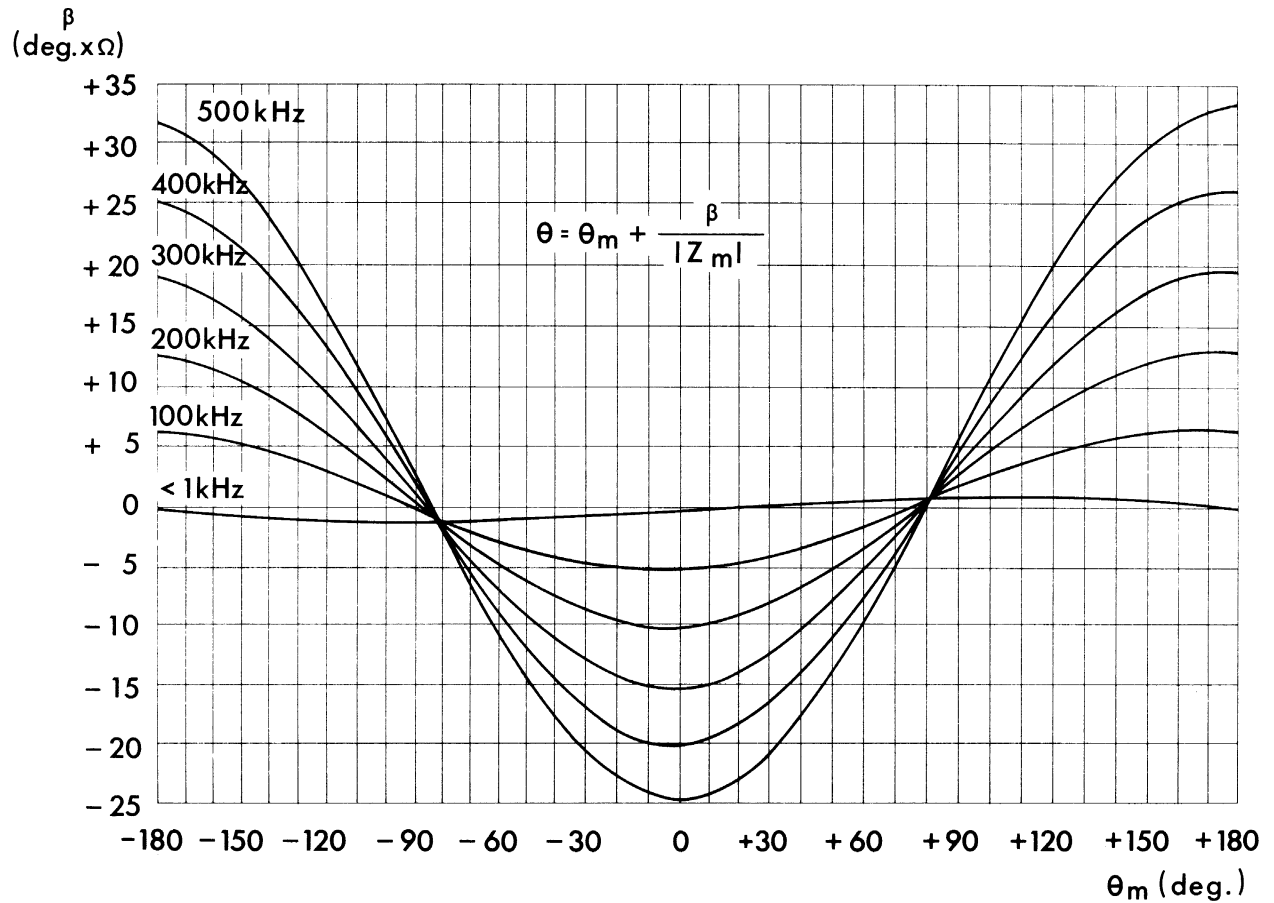
The correction charts give the quantities  $\Delta |Z|$  and  $\Delta \theta$ .

$$|Z| \text{ and } \theta \text{ are found from } |Z| = |Z_m| + \Delta |Z| \text{ and } \theta = \theta_m + \frac{\beta}{|Z_m|}$$

where  $|Z_m|$  and  $\theta_m$  are the measured values of  $|Z|$  and  $\theta$ .

#### 2) Correction formulae:

It is necessary to apply the correction formulae instead of correction charts only when using the  $Z \times 0.1$  MULTIPLIER, and only when both  $|Z_m| < 2\Omega$  and  $f > 0.3$  MHz. The correction formulae are shown in Table 1, page E10.

Fig.E5 Magnitude correction chart for  $Z \times 1$  MULTIPLIERFig.E6 Phase angle correction chart for  $Z \times 1$  MULTIPLIER

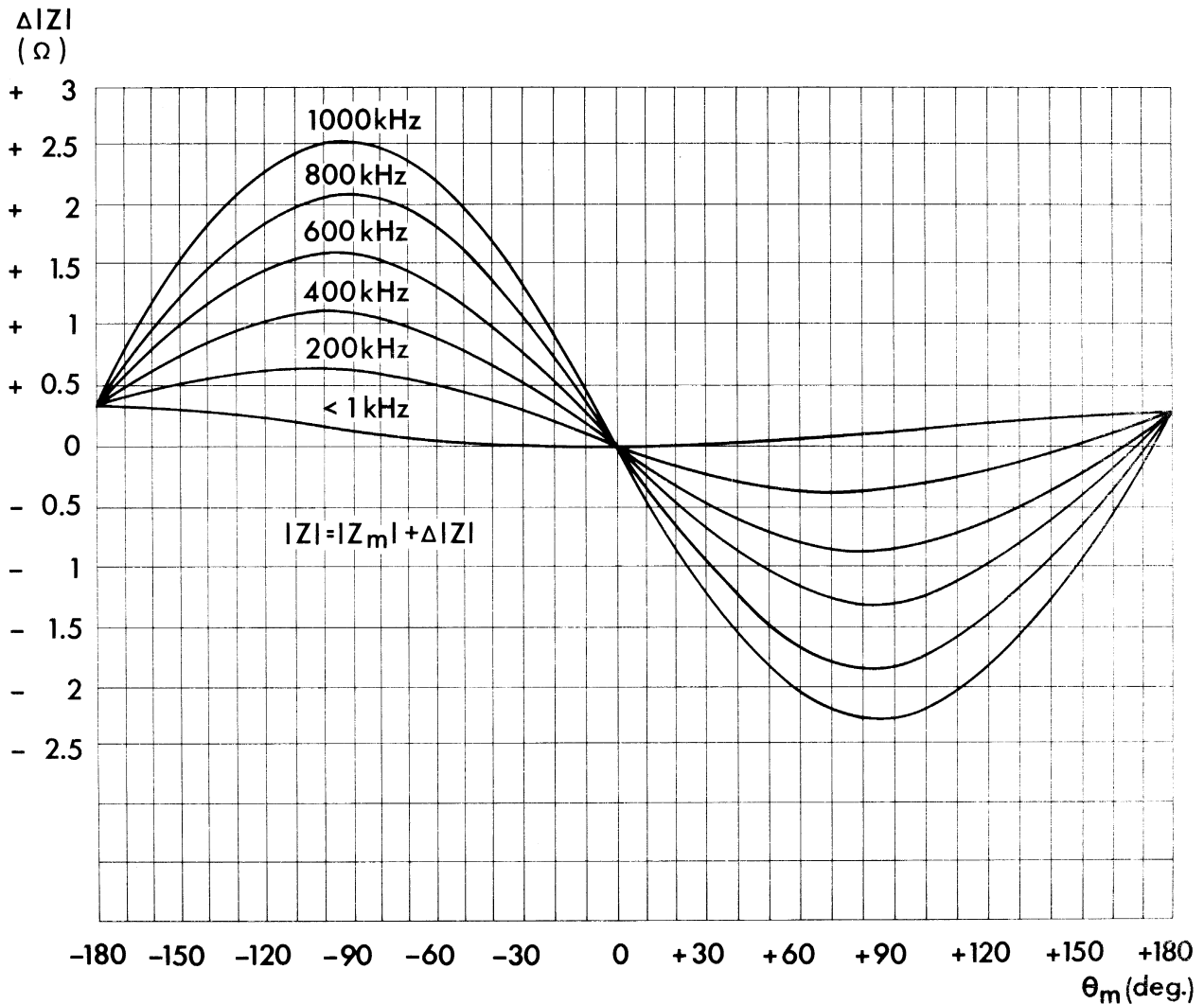


Fig.E7 Magnitude correction chart for  $Z \times 0.1$  MULTIPLIER

### Measuring High Impedances at High Frequencies

Stray capacitances that shunt the impedance  $Z$  may affect the measurement of high impedance at high frequencies.

Choose the GROUNDED GUARD mode in case these capacitances are not considered part of the impedance  $Z$ . The influence of wire capacitances may be avoided by connecting the impedance either directly to the terminals or with two short shielded cables.

Above 10 k $\Omega$  and above 10 kHz it is necessary to use the Terminal Screen, type GB11/M65, or to make small corrections because of the 0.1 pF residual capacitance across the terminals of the instrument.

The correct magnitude  $Z$  and phase-angle  $\theta$  are then computed from the correction formulae shown in Table 2, page E10.

### Polarized Impedance Measurement

The polarizing current or voltage must be supplied and monitored externally via the POLARIZATION VOLTAGE jacks on the front panel. Be sure that the polarity of the applied dc voltage is correct, and that the latter is not higher than 50 volts, to prevent damaging the blocking capacitors. The specified current limits must be observed to prevent saturation of the matching transformer. Otherwise an error in measurement will result. When polarized, the red  $Z$  terminal is positive, and the black  $Z$  terminal is negative.

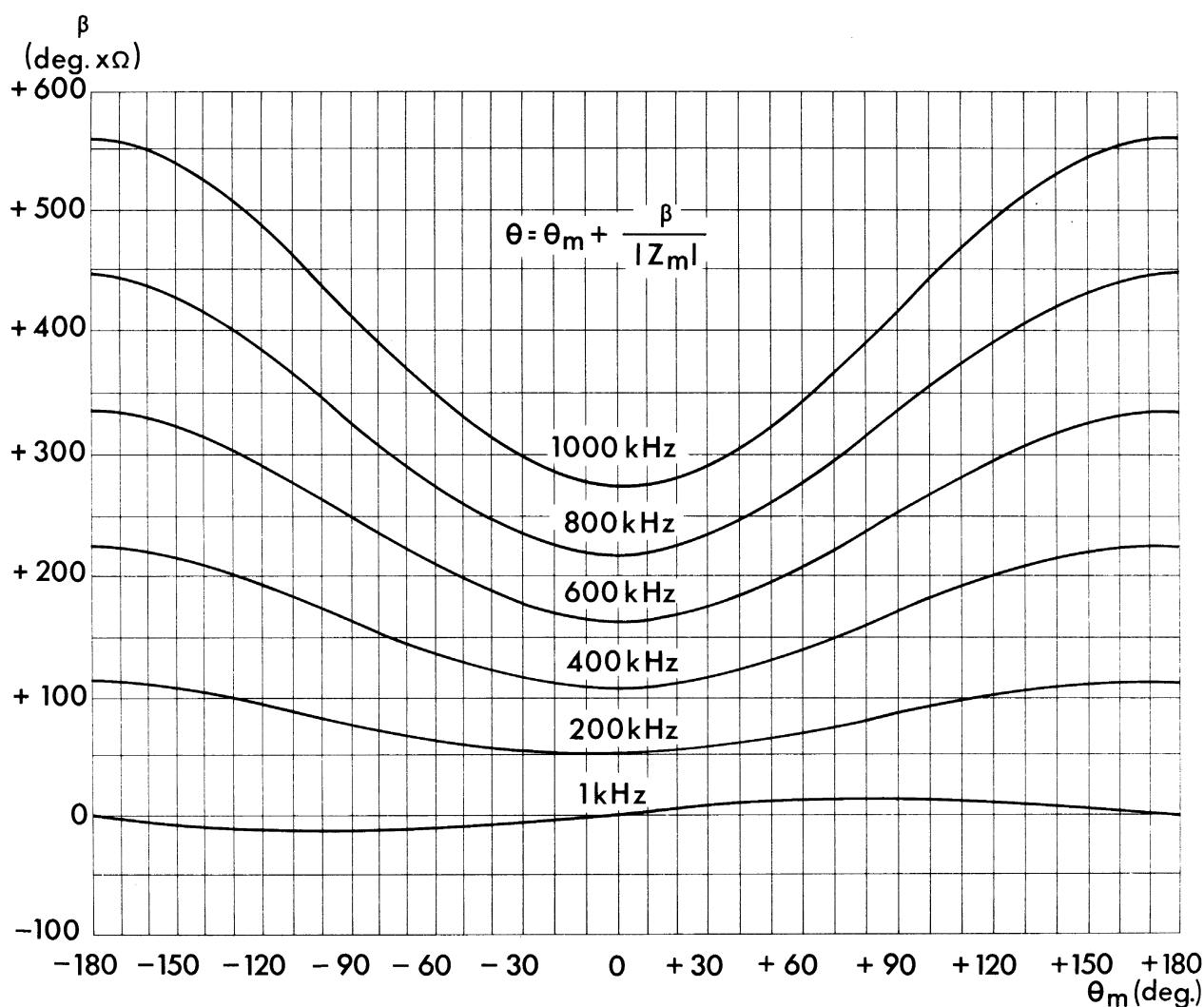


Fig.E8 Phase angle correction chart for  $Z \times 0.1$  MULTIPLIER

At low frequencies and at low settings of the MAGNITUDE standard resistor, the blocking capacitor in series with the standard resistor, C19, may cause an error in measurement. Fig. E1, E2, E3, E4 illustrate the limit within which this error may become noticeable. The magnitude and phase angle errors are not dependent on the impedance  $Z$ , but only on the frequency and magnitude settings.

Generally applicable correction data cannot be given because of the wide tolerance of the blocking capacitors used ( $1000 \mu\text{F} \pm 50\%, -20\%$ ). If it becomes necessary to correct for the errors introduced by the blocking capacitor, it is easy to find the  $|Z|$  and  $\theta$  corrections

by measuring a pure resistor of value  $|Z|$ , both in the polarized and non-polarized modes, at the test frequency.

It should be noted that all polarized impedances are essentially non-linear elements. As long as the test current (or voltage) is low compared with the polarizing current (or voltage), the incremental impedance is measured. When the test current (or voltage) is high compared with the polarizing current (or voltage), the effective impedance is measured. In the latter case, phase angle measurements are of no use unless a Plug-in Filter Unit, type GB11/F, is used (see above). In this case, the relationship of the fun-



damental voltage and fundamental current is measured.

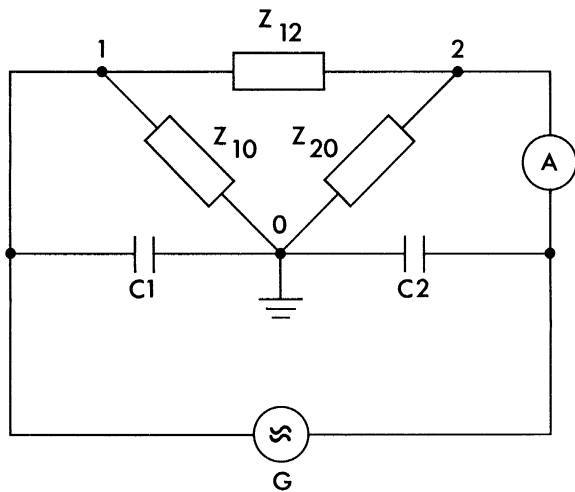


Fig.E9 Simplified block diagram for balanced mode measurements

#### Balanced Impedance Measurement

Fig.E9 shows a simplified schematic diagram of the instrument in the BALANCED mode during the Z measurement.

The generator is floating except for the capacitances C1 and C2, which are balanced. With a perfectly balanced network, where  $Z_{10} = Z_{20}$ , the instrument will measure the total impedance between the Z terminals 1 and 2, which is defined as

$$Z = \frac{Z_{12} (Z_{10} + Z_{20})}{Z_{12} + Z_{10} + Z_{20}}$$

If the impedance network to be tested is not perfectly balanced-to-ground, the presence of C1 and C2 may produce an error in measurement.

An indication of any imbalance in the network, and of whether the imbalance

affects the measurement to any noticeable degree, is easily obtained by taking a measurement and then measuring again with the connections to the Z terminals (1 and 2) reversed. If the two measurements differ by more than the specified errors, the imbalance of the network is too large. In this case Z can be computed only from the two-terminal impedances  $Z_{12}$ ,  $Z_{10}$ , and  $Z_{20}$  measured separately.  $Z_{12}$  is measured directly in the GROUNDED GUARD mode.  $Z_{10}$  is measured in the BLACK TERMINAL GROUNDED mode when terminal 2 is connected to the GUARD terminal.  $Z_{20}$  is found in a similar way with terminal 1 connected to the GUARD terminal.

#### Measuring Impedances with Phase Angles of $180^\circ$ to $180^\circ \pm 90^\circ$

1) Measuring Z is done as described above.

2) Measuring  $\theta$  where  $90^\circ < \theta < 270^\circ$  is done as follows:

a) Multiplier  $Z \times 0.1$

If Z is measured with MULTIPLIER in position  $Z \times 0.1$ , move one end of Z from the red Z terminal (E2) to the banana jack marked A. Press the  $\theta$  button and determine the angle as described under HOW TO MEASURE.

The phase angle  $\theta$  is given by  $\theta = \varphi + 180^\circ$ , where the positive or negative sign of  $\varphi$  must be taken into account.

b) Multiplier  $Z \times 1$  and  $Z \times 10$

Proceed as described in a, except for the fact that Z must be connected to the banana jack marked B.

$$|Z| = |Z_m| + 0.01 - 0.015 \cos \theta_m - 0.98 f \sin \theta_m + \frac{f^2}{|Z_m|} \cos \theta_m$$

$$\left[ (0.481 \cos \theta_m - 0.132 \frac{f}{|Z_m|} \sin \theta_m) (1 + 0.98 \frac{f}{|Z_m|} \sin \theta_m) - 0.135 \right]$$

$$\theta = \theta_m + \tan^{-1} \frac{1}{|Z_m|} \left[ \sin \theta_m (0.015 + 0.135 \frac{f^2}{|Z_m|}) - 0.98 f \cos \theta_m \right] \times$$

$$(1 + 0.98 \frac{f}{|Z_m|} \sin \theta_m) + \tan^{-1} 0.138 \frac{f}{|Z_m|}$$

Where

$|Z|$  = the true value of the impedance in  $\Omega$ .

$|Z_m|$  = the measured value of the impedance in  $\Omega$ .

$\theta$  = the true value of the phase angle.

$\theta_m$  = the measured value of the phase angle.

$f$  = the measuring frequency in MHz.

Table 1

$$Z = |Z_m| \cos \theta \sec \theta$$

$$\theta = \theta_m + \tan^{-1} |Z_m| 0.628 \cdot 10^{-12} f \sec \theta$$

Where  $|Z_m|$  = the measured magnitude in ohms

$\theta_m$  = the phase angle measured

$f$  = the frequency in hertz.

Table 2

## Section F. Technical Description

### GENERAL

The Impedance Meter, type GB11, consists of 4 sub-units, i.e. Oscillator, Measuring Circuit, Ammeter Circuit, and Power Supply.

### OSCILLATOR SECTION

The Oscillator is of the Wien-bridge type and consists of an amplifier (Q1, Q2, Q3, and associated components on print board Z1), a frequency-determining, positive feedback network (S2 and associated components), a negative feedback, amplitude-stabilizing network (RT1 and associated components), and a matching network (T3, S3).

The amplifier is three-staged, dc coupled, and has a stabilized working point (R16, R17, and R28), which results in stable operation over a wide temperature range and allows for great variations in the supply voltage.

The positive feedback frequency-determining network is a conventional RC-series-parallel type. The 12 spot-frequencies are selected with S2, which switches 3 different resistance values to the network to obtain frequencies in a ratio 2.5:5:10, and 4 capacitances to multiply the frequencies in decade steps.

The negative feedback is controlled by the termistor RT1, operating in the con-

stant voltage region, thus stabilizing the amplitude to within 0.5% (at constant ambient temperature).

By connecting C9 between the junction of R16 and R17 and the emitter of Q1, a high ac input impedance is obtained, thus increasing the frequency stability.

The voltage transformer, T3, is a shielded, balanced multi-tap transformer. A wide bandwidth is obtained by using a Mumetal core and a special technique. The amplitude is controlled by switch S3, which switches taps on the secondary of the transformer which has open-circuit voltage ratios of 3.2 to 0.1: 0.35 : 1 : 3.5 : 10, and by R29, with which the voltage can be continuously varied from zero to maximum.

The COARSE AMPLITUDE control, S3, can also select between internal and external generator, switching off the power-supply connection DIRECT. The external generator is connected to the measuring circuit, by-passing T3.

The maximum undistorted voltage and power available from T3 is 10 V and 125 mW at 25 Hz. At higher frequencies, the power-handling capacity increases considerably. At 50 Hz the maximum undistorted voltage is 25 V and the power available with an external generator is 300 mW.

## MEASURING CIRCUIT

The Measuring Circuit consists of:

The current transformer, T4, the MULTIPLIER switch S11, the Z MODE switch S4, the standard-resistor decades R32, S5, S6, and S7, the METER SWITCH S10, the variable capacitor switch S8, and the SIGN OF PHASE ANGLE switch S9. It is mounted inside the inner shield, which is isolated from the grounded chassis.

The current transformer, T4, is made of a high-permeability ring core on which are wound the secondary (connected to the ammeter) and the differential primaries, consisting of multi-tap R and Z windings.

The MULTIPLIER switch, S11, selects the proper taps on the R and Z windings of the current transformer. The taps selected are:

Multiplier	R winding	Z winding
Z $\times$ 0.1	10	1
Z $\times$ 1	10	10
Z $\times$ 10	1	10
Z $\times$ 100	1	100

The METER switch, S10, passes the current into the unknown impedance through the Z winding of the current transformer T4, when Z is pressed, and into the standard resistance loop through the R winding of the current transformer T4, when R is pressed. It passes current through both windings when  $\theta$  is pressed.

When the SIGN OF PHASE-ANGLE switch, S9, is operated, an additional current, leading by  $90^\circ$ , is superimposed on the 10-turn R or Z winding by S9A or S9B. The magnitude of the additional current is controlled by the capacitor selector S8.

In position GROUNDED GUARD, the MODE switch connects the ground to the inner shield. In position BLK TERMINAL GROUNDED, it connects the ground to the black terminal, and in position POLARIZED, it introduces the blocking ca-

pacitor C19 in series with the standard resistor and closes the connection of choke L2 to the + POLARIZING VOLTAGE terminal. In position BALANCED TO GROUND, the ground is disconnected from the measuring circuit and a DIRECT generator connection is disconnected.

The standard resistance decades are made of resistors of the close-tolerance, high-stability, metal-film type, which are mounted in a special way on switches S5, S6, and S7, to obtain minimum phase shift at high frequencies. R32 is a specially designed  $10\ \Omega$  continuously-variable resistor of infinite resolution and low inductance.

## METER CIRCUIT

The Meter Circuit is enclosed in the inner, insulated shield of the instrument together with the measuring circuit.

The current to be measured is amplified, first by a pre-amplifier (Z2), followed by an emitter follower (Z3) for matching to a filter, and finally by the main amplifier (Z4). The ammeter sensitivity is varied on the three most sensitive ranges by a divider (S12B) connected to the pre-amplifier output and on all the subsequent ranges by a universal shunt at the pre-amplifier input (S12A). In addition the sensitivity is made continuously variable by R91 at the input of the main amplifier. The  $25^\circ$  scale-expansion is obtained by increasing the meter sensitivity by 10 dB when pressing S13, which is connected to the divider (S12B).

The pre-amplifier consists of the dc coupled transistors Q4, Q5, Q6, and associated components. Negative feedback (R69) and stabilization of the working point (R74, R78) are utilized to obtain a low input impedance and a constant gain over wide temperature and supply-voltage ranges.

The emitter-follower, Q7, permits a low impedance filter to be inserted between the divider and the main amplifier. When the FLAT switch of the AMPLIFIER RESPONSE control is pressed, the filter is

disconnected, and a 3-dB attenuator (R89, R90) introduced to simulate the filter insertion loss.

The main amplifier consists of the dc coupled transistors Q8 and Q9 and their associated components. The meter is connected to a rectifier bridge placed in the feedback loop of the amplifier. The dc working point is stabilized by connecting the base resistor R93 to R101 in the emitter path of the output transistor.

The feedback applied, both in the pre-amplifier and in the main amplifier, gives a practically constant gain. The instrument is calibrated at the factory by the selection of the resistor R94, which determines the feedback factor of the main amplifier stage.

#### POWER SUPPLY

The Power Supply consists of the transformers T1 and T2 and their associated components. The transformers are connected

back to back and mounted in a shielded compartment.

The transformer, T1, has a split primary winding which permits connection to either a 200-240 volt line (series) or a 100-125 volt line (parallel). The transformer, T2, is a double-shielded transformer fed from the low-voltage secondary of T1. Furthermore, the transformers are mounted close to each other to minimize stray magnetic fields.

The rectifier, CR1, which is connected to T1, supplies the Oscillator or a dummy load (R15) when the internal generator is disconnected. The pilot lamp I1 serves as fuse and filter-dropping resistor of this Power Supply.

The rectifier CR2, which supplies the Amplifier through a filter (C31, C32, L2), is placed in the inner, insulated shield and connected to T1 with double-shielded wires that prevent leakage and capacitive coupling between the measuring circuit and the power line.



## Section G. Maintenance

### GENERAL

The Impedance Meter, type GB11, is a precision instrument which can be used both in the laboratory and in the field. It will operate under widely different climatic conditions and stand rough handling. Long trouble-free operation has been ensured by the use of transistors, high-quality components, and print-boards, and by thorough testing of the instrument during and after the manufacture. If, however, repairs are necessary, they should be made only by skilled persons provided with the necessary test equipment.

### REMOVING THE INSTRUMENT FROM THE CABINET

The instrument can be taken out of the cabinet after the four hexagonal screws at the corners of the front panel have been removed.

The Power Supply and the Oscillator are accessible when the cover of the right-hand compartment has been removed.

The Measuring Circuit and the ammeter circuit are accessible when the cover of the left compartment has been removed. If a Plug-in Filter Unit GB11/F has been inserted, it must be removed before the cover is taken off.

### CLEANING THE CONTACTS

The contacts of the various switches may need cleaning if unstable readings are obtained, especially when very low impedances are measured.

The switch contacts should be cleaned with a non-corroding cleaner and subsequently lubricated with a thin film of acid-free vaseline.

### DC POTENTIALS

The potentials listed at the end of the manual in Table 7 can be used to locate faults, if any. The potentials are referred to GROUND and measured with a vacuum-tube voltmeter with the controls of the Impedance Meter set to GROUNDED GUARD, INTERNAL GENERATOR, 0 AMPLITUDE, and at nominal line voltage. Deviations up to 20% of the listed potentials are permissible.

### OSCILLATOR AMPLITUDE ADJUSTMENT

The oscillator amplitude should be constant to within 0.5 dB for all frequencies and between 3.1 and 3.3 volts, measured at room temperature on the C15-

R29 junction. The amplitude is adjusted with R21 in series with thermistor R22. Readjustment may be necessary after replacement of RT1 or R19.

#### AMMETER CALIBRATION

After replacing components in the amplifier section, the meter calibration should be checked and, if necessary, corrected by selecting a proper R94 resistor. To check the calibration, connect an ac voltmeter between the black terminal and the GROUND terminal. Set the controls as follows:

MEASURING CURRENT:	1 mA
AMPLIFIER RESPONSE:	FLAT
MAGNITUDE OF Z:	1000
METER SWITCH:	R
Z-MODE	GROUND
	GUARD
MULTIPLIER:	Z x 1
FREQUENCY:	1 kHz

Adjust the amplitude to obtain SET-LEVEL readings on the meter of the instrument.

The voltage indicated by the voltmeter should be 1 volt  $\pm 3\%$ .

#### ADJUSTING THE INSTRUMENT TO 100-125 VOLT LINE VOLTAGE

The instrument is supplied for operation on a line voltage of 200-240 volts. If the line voltage is 100-125 volts, take the instrument out of the cabinet and remove the cover from the power supply section. Disconnect the wire jumper between the terminals marked "220" on the T1 terminal board and mount two wire jumpers between the terminals marked "110".

Replace the fuse by a 250 volt, 0.1 A slow-blow fuse.

#### REPLACING THE PILOT LAMP

The oscillator becomes inoperative when the pilot lamp burns out. If it must be replaced, use only type 8007D, 10 volt, 0.2 A.

## Section H. Periodical Checks

### GENERAL

Checking the Impedance Meter, type GB11, in the manner described below will ensure that the apparatus is in working order. Just how frequently such checks should be made will depend on the number of hours that the Impedance Meter has been operating, but intervals of from 6 to 12 months will in most cases be suitable.

### CHECKING THE FREQUENCY

Connect a frequency counter between the Black and Guard terminals. Switch on the Impedance Meter, and set AMPLITUDE RANGE to INTERNAL GENERATOR 4. Set Z-MODE to GROUNDED GUARD, and MAGNITUDE to 10 k $\Omega$ . Now turn the FREQUENCY switch through the entire range and check that the frequencies lie within the limits specified. In case one or more should fall beyond the assigned values, correct according to the adjustment procedure described in the following items.

#### Adjusting 25, 50 and 100 Hz

1) Shunt C1a or C2a with a capacitor or resistor until one of the frequency deviations almost equals zero, while all three frequencies lie below their nominal values. (When C1a or C2a is shunted with a capacitor, the percentage of decrease will be equal for all three frequencies,

and when shunted with a resistor, they will increase by equal numbers of hertz).

2) Adjust 25 Hz to minimum deviation by means of shunt resistors R1 or R4.

3) Adjust 50 Hz to minimum deviation by means of shunt resistors R2 or R5.

4) Adjust 100 Hz to minimum deviation by means of shunt resistors R3 or R6.

The matching components produce the same effect on the frequency, whether they shunt C1a or C2a, R1 or R4, etc. However, the appropriate point of connection depends on the amplitude which must be within  $\pm 3\%$  as compared with the level at 1 kHz.

5) Ascertain (at least 5 minutes after the last component has been soldered on) that the frequency lies within  $\pm 1\% \pm 0.5$  Hz.

#### Adjusting 250 Hz - 50 kHz

1) Measure the frequencies by means of a counter, determine both percentage and sign or errors obtained, and enter your observations in Table 3.

2) Adjust the B-frequencies to the correct ratio 1:2:4, i.e. to equal percentage of error of identical sign, by means of shunt resistors across R7 or R14, R8 or R13, R9 or R12 (see Table 3).

	I	II	III
A FREQUENCIES (C1b, C2b)	(R7, R14) (250 Hz) %	(R8, R13) (500 Hz) %	(R9, R12) (1 kHz) %
B FREQUENCIES (C1c, C2c)	(2.5 kHz) %	(5 kHz) %	(10 kHz) %
C FREQUENCIES (C1d, C2d)	(25 kHz) %	(50 kHz) %	100 kHz not to be measured

Table 3

Shunt resistance	Shunt on R7 or R14 will shift I-frequencies:	Shunt on R8 or R13 will shift II-frequencies:	Shunt on R9 or R12 will shift III-frequencies:
1.2 M $\Omega$	0.5 % up	0.25 % up	0.13 % up
1 M $\Omega$	0.6 % up	0.3 % up	0.16 % up
820 k $\Omega$	0.8 % up	0.4 % up	0.19 % up
680 k $\Omega$	0.9 % up	0.45 % up	0.23 % up
560 k $\Omega$	1.1 % up	0.55 % up	0.28 % up
470 k $\Omega$	1.3 % up	0.7 % up	0.33 % up
390 k $\Omega$	1.6 % up	0.8 % up	0.4 % up
330 k $\Omega$	1.9 % up	1 % up	0.5 % up
270 k $\Omega$	2.3 % up	1.2 % up	0.6 % up
220 k $\Omega$	3 % up	1.4 % up	0.7 % up
etc.	etc.	etc.	etc.

Table 4

3) Make sure that all 8 frequencies lie above their nominal values. Select appropriate resistors in accordance with Table 4.

4) Solder the resistor into position, check the results obtained, and enter these in table as before.

5) Adjust the A-frequencies so that 500 Hz and 1 kHz give the smallest possible errors, using a capacitive shunt across C1b or C2b.

6) Select the shunt capacitor according to the rule that A-frequencies shall be shifted 0.1% downwards for every 100 pF.

7) Adjust the B-frequencies to give the smallest possible errors, using a capacitive shunt across C1c or C2c.

8) Select the shunt capacitor according to the rule that B-frequencies shall be shifted 0.1% down for every 10 pF.

9) Adjust the C-frequencies so that 25 kHz and 50 kHz give the smallest possible errors, using a capacitive shunt across C1d or C2d. (100 kHz is left out of consideration, since other means are provided for adjusting this frequency (see below).)

10) Select the shunt capacitor according to the rule that C-frequencies shall be shifted 0.1% downwards for every pF.

11) Solder the capacitor into position, check the results obtained, and - if necessary - exchange for the nearest lower value to compensate for stray capacitances.

12) Check (at least 5 minutes after the last component has been soldered on) that the frequency falls within  $\pm 1\% \pm 0.5$  Hz.

#### Adjusting 100 kHz

1) Measure the frequency by means of a frequency counter and determine percentage and sign of the error. In case the frequency is too low, R10 or R11 must be shunted with a resistor, or R10 with a capacitor.

2) Select the appropriate resistor in accordance with the right hand column of Table 1, or choose the capacitor to accord with the rule that the frequency shall be shifted 0.1% upwards for every pF. If the frequency is too high, R11 must be shunted with a capacitor.

3) Choose the capacitor according to the rule that the frequency shall be shifted 0.1% downwards for every pF.

4) Solder the capacitor in position, check the result, and - if needed - exchange with the nearest lower value to compensate for stray capacitances.

5) Check (at least 5 minutes after the last component has been soldered on) that the frequency falls within  $\pm 1\%$ .

#### CHECKING THE SELECTOR SWITCH "MAGNITUDE OF Z" AND THE RESISTOR DECADES

1) Connect a precision ohmmeter or measuring bridge across the terminals BLACK and GUARD. Set AMPLITUDE RANGE to EXT. GEN. DIRECT, Z-MODE to Balanced to Ground, and METER SWITCH to Z.

2) Ascertain that the ohmmeter indicates the same value as the MAGNITUDE of Z scales.

3) Check all scale positions. Permissible deviation  $0.5\% + 0.1 \Omega$ .

4) Depress the switch Z-MODE Polarized and check that the ohmmeter indication is above  $0.1 M\Omega$ .

5) Disconnect the ohmmeter.

6) In case the check measurement discloses that the resistor decade exceeds the limits stipulated in one or more positions, the defective resistor(s) must be replaced.

#### CHECKING THE MEASURING CURRENT SWITCH

1) Set the various controls and switches as follows:

a) AMPLITUDE RANGE to INT. GEN. - 1, 2 or 3.

b) FREQUENCY to 1 kHz.

c) AMPLITUDE COARSE to zero.

d) Z-MODE to Grounded Guard.

e) METER to Z.

f) AMPLIFIER RESPONSE to FLAT.

g) MULTIPLIER to  $\times 1$ .

h) MAGNITUDE to  $10 k\Omega$ .

Range mA	Setting of Resistance Box	Comments
1	100 $\Omega$	Adjust voltage to SET LEVEL and read VTVM
0.32	316 $\Omega$	Maintain constant voltage on VTVM for all readings
0.1	1000 $\Omega$	
0.032	3160 $\Omega$	
3.2	31.6 $\Omega$	Make allowance for resistance in measuring leads !
10	10 $\Omega$	
32	3.16 $\Omega$	
100	1 $\Omega$	

Table 5

i) MEASURING CURRENT FINE to CALIBRATED.

2) Connect a 1  $\Omega$  resistance box to the Z terminals.

3) Turn the MEASURING CURRENT range switch from 1000 mA down to 0.032 mA. If the built-in meter does not indicate zero (except for approx. 5 divisions in the 0.032 mA range), C36 on the PRE-AMPLIFIER printboard Z2 will require adjustment in order to prevent the pre-amplifier from oscillating.

4) Connect a vacuum-tube voltmeter across the terminals BLACK and GUARD.

If the switch is in working order, the built-in meter will indicate SET-LEVEL  $\pm 1$  division for the measurements recorded in Table 5.

NOTE : For 100 mA, use an external generator. Switch S3 to EXT: GEN. - 1, 2 or 3.

Limits for 100 mA only:  $\pm 3$  divisions.

If the above-mentioned deflection cannot be obtained, measure the potentials on printboards Z<sub>2</sub>, Z<sub>3</sub>, and Z<sub>4</sub>.

Compare with the values stated on the circuit diagram.



## CHECKING THE STABILITY, ADJUSTMENT OF AMPLIFICATION

### Checking the Stability

- 1) Connect an ac VTVM across the terminals BLACK and GUARD.
- 2) Set as follows:
  - a) MULTIPLIER to  $\times 1$
  - b) Z-MODE to Grounded Guard
  - c) MEASURING CURRENT to 10 mA
  - d) MAGNITUDE to 350  $\Omega$
  - e) METER to R
  - f) MAGNITUDE RANGE to INT.GEN.-4.5
  - g) FREQUENCY to 1 kHz
- 3) Adjust AMPLITUDE COARSE and FINE until the ac voltmeter indicates 3.5 V  $\pm 0.2\%$ , and also check that the reading on M1 equals SET LEVEL  $\pm 2$  divisions.
- 4) Check the calibration of SET LEVEL in the following ranges for the above-mentioned voltage (3.5 V) held constant.

Measuring Current: mA	Magnitude $\Omega$	Multiplier Z $\times$
0.1	3500	100
1	3500	1
10	350	1

Table 6

### Adjusting the Amplification

- 1) Set controls of the Impedance Meter as described above.
- 2) Connect a resistance box instead of R94 (printboard Z4 at the rear of the instrument), and adjust the resistance box until the reading on M1 equals SET LEVEL  $\pm$  divisions.
- 3) Observe resistance value and solder a resistor of the same magnitude in R94's former position.
- 4) Check as above.

## Section J. Admittance Adapter, Type GB11/AA1

### GENERAL DESCRIPTION

Re specifications, please refer to section C.

The Admittance Adapter, type GB11/AA1, will, when used in connection with the Impedance Meter, type GB11, and an external oscillator, extend the lower limit of the measuring range of the Impedance Meter from  $1\Omega$  to  $0.09\Omega$  (11 mhos).

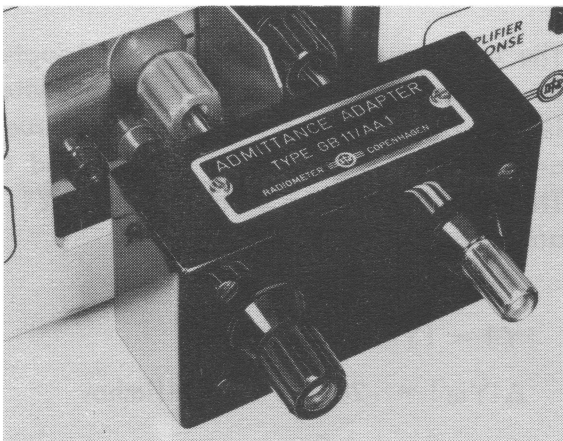


Fig. J1 The Admittance Adapter, type GB11/AA1, mounted on the Impedance Meter, type GB11

The operating principle is shown in Fig. J2

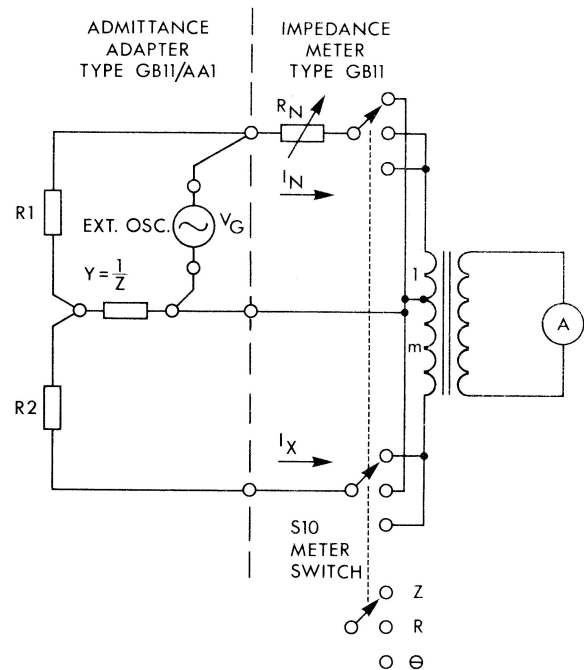


Fig. J2 Operation principle of the Admittance Adapter, type GB11/AA1

When  $R_n$  is adjusted so that  $|I_n| = m |I_x|$  it follows that:

$$|I_x| \approx \frac{V_G}{R_1} \cdot \frac{1}{Y} \cdot \frac{1}{R_2}$$

$$|I_n| = \frac{V_G}{R_n}$$

$$|Y| \approx m \frac{R_n}{R_1 R_2} \text{ mhos;}$$

hence  $R_n$  is proportional to  $|Y|$ .

## OPERATING INSTRUCTIONS

Plug in the Admittance Adapter and turn the power switch to ON. Connect a suitable oscillator, i.e. an oscillator that can deliver at least 35 mA into 100  $\Omega$  (for example a RADIOMETER Wide-Range Oscillator, type RCO11 (see SECTION C), to the two telephone jacks on the right side of the adapter.

### 1) Operating the IMPEDANCE METER

The Impedance Meter, type GB11, is operated as described in SECTION E, except for the reservations made in the following items.

### 2) Selecting the proper MULTIPLIER

The Admittance Adapter, type GB11/AA1, must be used with the MULTIPLIER  $Z \times 10$ . See above.

### 3) Selecting the MEASURING CURRENT SWITCH

The measuring current, i.e. the current through the Z-windings of the current transformer T4, is between 1% and 0.1% of the current through Y, depending on the value of Y, as can be seen above.

The maximum permissible measuring current is limited by the power that can be safely dissipated by R1, and can be found from the equation:

$$I_m (\text{max}) = \frac{1}{Y} \text{ mA}$$

It is recommended only to use the ranges of 0.032 mA and 0.1 mA of the MEASURING CURRENT switch, and preferably the range 0.1 mA.

### 4) Selecting the FREQUENCY

The Admittance Adapter, type GB11/AA1, can be used in the frequency range 25 Hz to 10 kHz.

Important. Always remember to switch the RANGE switch of the Impedance Meter to EXT.GEN.DIRECT.

### 5) Selecting DC POLARIZING Voltage

Selecting DC POLARIZING voltage on J4 of the Impedance Meter is dependent on the ac voltage that is used, and can be determined from:

$$U_{\text{max}} (\text{dc}) = 2.5 \sqrt{100 - (1/2)U_{\text{max}}^2 (\text{ac})}$$

where

$U_{\text{max}} (\text{ac})$  is the maximum amplitude 0 to peak of the ac signal.

#### How to Measure

Connect the admittance to be measured to the terminals of the Admittance Adapter; Preferably directly to the terminals, as the accuracy will be affected if long leads are used.

Adjust the Impedance Meter as described above in this manual, and read the magnitude and the phase angle.

The magnitude read on the Impedance Meter is  $|Y|$  in millimhos,

(1 mho =  $\frac{1}{1 \text{ ohm}}$ ), and the phase angle

is the phase angle  $\theta$  of  $|Y| < \theta$  in degrees.

#### Correction Formulae

The accuracy of the Admittance Adapter in connection with the Impedance Meter is basically 2% and 3°. To this accrues an error that is dependent on  $|Y|$  and  $\theta$ . The error is between 0 and 2% for  $|Y|$ , and 0 and 1°, 15' for  $\theta$ .

$$|Y| = |Y_m| + \Delta |Y_m|,$$

$$\Delta |Y_m| = -20 \cos \theta_m \text{ millimhos}$$

$$\theta = \theta_m + \Delta \theta_m$$

$$\Delta \theta_m = \frac{1^\circ 15'}{|Y_m|} \cdot 10^3 \sin \theta_m$$

where

$|Y_m|$  = the measured magnitude in millimhos

$\Delta |Y_m|$  = the correction in millimhos

$|Y|$  = the true magnitude in millimhos

$\theta_m$  = the measured phase angle in degrees

$\Delta \theta_m$  = the correction in degrees

$\theta$  = the true phase angle in degrees

#### Maintenance

see SECTION G MAINTENANCE under  
"CLEANING THE CONTACTS".

Transistor                      dc Potential,       volts			
Circuit Designation	Emitter	Base	Collector
Q1	-1.2	-1.5	-4.3
Q2	-4.1	-4.3	-9.7
Q3	-3.8	-4.1	-13.8
Q4	-0.5	-0.8	-2.0
Q5	-1.7	-2.0	-6.1
Q6	-5.8	-6.1	-10.8
Q7	-8.3	-8.7	-21.5
Q8	-1.4	-1.7	-6.0
Q9	-5.7	-6.0	-12.5

dc potential of pilot-lamp terminals: -19.2 V, -15.2 V

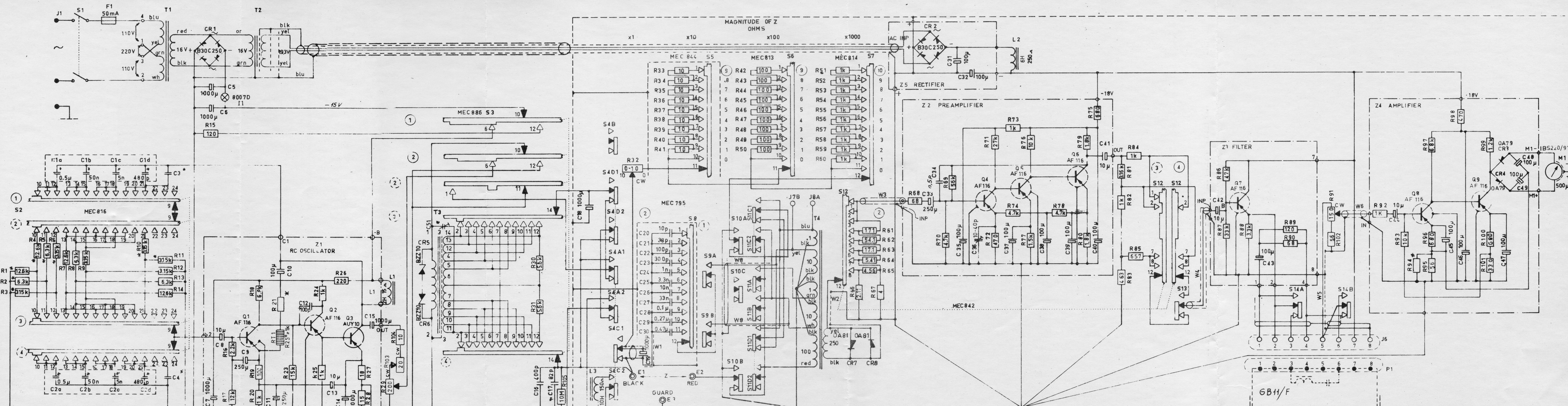
ac ripple on -15.2 V pilot-lamp terminal: less than 15 mV

dc potentials of choke L2 terminals: -24.2 V, -21.5 V

ac ripple on -21.5 V choke terminal: less than 3 mV

Table 7  
dc potentials





**S2**  
MEC 816  
FREQUENCY

CPS	
25	
50	
100	
250	
500	
1K	
2.5K	
5K	
10K	
25K	
50K	
100K	

FREQUENCY DETERMINING NETWORK

**INT. OSCILLATOR**

Q1 AF 116  
Q2 AF 116  
Q3 AU110

R18 100K  
R19 100K  
R20 100K  
R21 100K  
R22 100K  
R23 100K  
R24 100K  
R25 100K  
R26 220K  
R27 100K  
R28 100K  
R29 100K  
R30 100K  
R31 100K  
R32 100K  
R33 100K  
R34 100K  
R35 100K  
R36 100K  
R37 100K  
R38 100K  
R39 100K  
R40 100K  
R41 100K  
R42 100K  
R43 100K  
R44 100K  
R45 100K  
R46 100K  
R47 100K  
R48 100K  
R49 100K  
R50 100K  
R51 100K  
R52 100K  
R53 100K  
R54 100K  
R55 100K  
R56 100K  
R57 100K  
R58 100K  
R59 100K  
R60 100K  
R61 100K  
R62 100K  
R63 100K  
R64 100K  
R65 100K  
R66 100K  
R67 100K  
R68 100K  
R69 100K  
R70 100K  
R71 100K  
R72 100K  
R73 100K  
R74 100K  
R75 100K  
R76 100K  
R77 100K  
R78 100K  
R79 100K  
R80 100K  
R81 100K  
R82 100K  
R83 100K  
R84 100K  
R85 100K  
R86 100K  
R87 100K  
R88 100K  
R89 100K  
R90 100K  
R91 100K  
R92 100K  
R93 100K  
R94 100K  
R95 100K  
R96 100K  
R97 100K  
R98 100K  
R99 100K  
R100 100K

**AMPLITUDE CONTROL**

S3  
MEC 886  
AMPLITUDE RANGE

INT. GEN.	5
	4
	3
	2
	1
	0
EXT. GEN.	1
	2
	3
	4
	5
DIRECT	

EXT. GEN. J2  
EXT. GEN. J3

R103 AMPLITUDE FINE  
R29 AMPLITUDE COARSE

**MODE SELECTOR**

S8  
MEC 795  
C

1
2
3
4
5
6
7
8
9
10
11

J4 + 50 VOLTS MAX  
POLARIZING VOLTAGE  
J5 - GROUND

MEC 809  
Z-MODE  
S4A - Grounded Guard  
S4B - Blk Terminal Grounded  
S4C - Polarized  
S4D - Balanced to Ground

**MEASURING CIRCUIT**

S9  
MEC 811  
PHASE ANGLE SIGN

S9A - +
S9B - -

MEC 807  
METER SWITCH

S10A - Z
S10B - R
S10C - 0

MEC 808  
MULTIPLIER

S11A - x0.1
S11B - x1
S11C - x10
S11D - x100

S12  
MEC 842  
MEASURING CURRENT

mA
0.032
0.1
0.32
1
3.2
10
32
100

CALIBRATED F.91

**PREAMPLIFIER**

Z2  
PREAMPLIFIER

Q4 AF 116  
Q5 AF 116  
Q6 AF 116  
Q7 AF 116  
Q8 AF 116  
Q9 AF 116

R71 100K  
R72 100K  
R73 100K  
R74 100K  
R75 100K  
R76 100K  
R77 100K  
R78 100K  
R79 100K  
R80 100K  
R81 100K  
R82 100K  
R83 100K  
R84 100K  
R85 100K  
R86 100K  
R87 100K  
R88 100K  
R89 100K  
R90 100K  
R91 100K  
R92 100K  
R93 100K  
R94 100K  
R95 100K  
R96 100K  
R97 100K  
R98 100K  
R99 100K  
R100 100K

**AMPLIFIER**

Z4  
AMPLIFIER

Q8 AF 116  
Q9 AF 116

R91 100K  
R92 100K  
R93 100K  
R94 100K  
R95 100K  
R96 100K  
R97 100K  
R98 100K  
R99 100K  
R100 100K

**GB11/F**

1 2 3 4 5 6 7 8

**FINAL VALUE FACTORY ADJUSTED**  
ALL VALUES IN  $\Omega$  OR pF ( $\mu$ pF)  
IF NOT OTHERWISE MARKED  
ALL SWITCHES ARE SHOWN IN CCW POSITION  
ALL PUSHBUTTONS ARE SHOWN NOT OPERATED

**RADIOMETER COPENHAGEN**  
72 EMDRUPVEJ NV  
Impedance Meter  
TYPE GB11c  
From no. 65218

**1033 A1**