INSTRUCTION MANUAL

Type GB11

IMPEDANCE METER

RADIOMETER

ELECTRONIC MEASURING INSTRUMENTS
FOR SCIENTIFIC AND INDUSTRIAL USE

CONTENTS

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INTRODUCTION

The type GB11 Impedance Meter measures impedances in terms of magnitude and phase angle. The range is from 1 ohm to 1.1 megohms, $-90°$ to $+90°$.

Only one balancing operation is necessary. The magnitude is indicated by the in-line read-out of a four-decade standard resistor. The phase angle is indicated directly by a built-in meter.

An internal generator supplies test currents at 12 spot frequencies, from 25 c/s to 100 kc/s. With an external generator the instrument can be used at up to 1 Mc/s. In this case the impedance range and the accuracy are reduced somewhat.

The instrument measures either floating impedances (free from ground), grounded impedances, or balanced-to ground-networks. Grounded impedances can be polarized by a d-c current or voltage, requiring only an external d-c source. The instrument has a terminal for the connection of a guard circuit.

The test current can be chosen arbitrarily over a wide range, so the instrument is useful for non-linear impedance measurements. Plug-in filters are available for obtaining greater accuracy in these measurements.

The instrument is fully transistorized and line-operated. The consumption is approximately 3 watts.

SECTION 1
SPECIFICATIONS

MEASURING RANGE

Magnitude: 1 ohm to 1.1 megohm
Phase Angle: $0°$ to $±25°$ and $0°$ to $±90°$, direct reading.

TEST CURRENT

Range: 3.2 μA to 1A.

The test currents, with the meter at SET LEVEL and the test current interpolator in the CALIBRATED position, are 0.032, 0.1, 0.32, 1, 3.2, 10, 32, and 100 mA with the impedance multiplier in position x1 or x10. When the multiplier is set to x0.1, the test currents are 10 times larger and when the multiplier is set to x100, the test currents are 10 times smaller.

Accuracy of test current
3% from 100 cps to 100 kc.

Frequency response: $±0.5$ db from 50 cps to 500 kc, $±1$ db from 25 cps to 1 Mc.

INTERNAL GENERATOR

Frequency
25, 50, 100, 250, and 500 cps, 1, 2.5, 5, 10, 25, 50, and 100 kc.

Accuracy of frequency
$±1\%$ $±0.5$ cps.

Waveform Distortion
Less than 1% harmonic distortion above 50 cps.
Less than 2% harmonic distortion at 25 cps.

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

Terminals

Z, GUARD and GROUND terminals:	Binding posts with banana jacks.
EXTERNAL GENERATOR input:	UHF type coaxial socket.
D-C POLARIZING input:	Banana jacks.

Standard resistor

1 ohm to 11.000 ohms in four decades of 1 to 10 ohms continuously variable, 9 x 10 ohms, 9 x 100 ohms, and 10 x 1000 ohms. Convenient in-line read-out. The accuracy is better than 0.5% + 0.1 ohm and the phase angle is less than 2° per megacycle. The maximum current in the standard resistor is 100 mA except for the 10 x 1000 ohms decade for which it is 32 mA.

DC POLARIZATION

Measurements are made with one terminal grounded. Absolute maximum polarizing current is 200 mA and maximum polarizing voltage 50 volts. The actual limit value of the current depends on the MEASURING CURRENT range setting, is subject to the same multiplication as the measuring current, and is proportional to the frequency. At 25 cps and at Z x 1 the limits are:

Measuring current range mA	Maximum polarizing current mA
0.032	20
0.1	20
0.32	20
1	20
3.2	50
10	150
32	200
100	200

When the instrument is operated with polarization, a measuring error, which can easily be corrected, is introduced at low frequencies and low impedances (below 2000 ohm x cps).
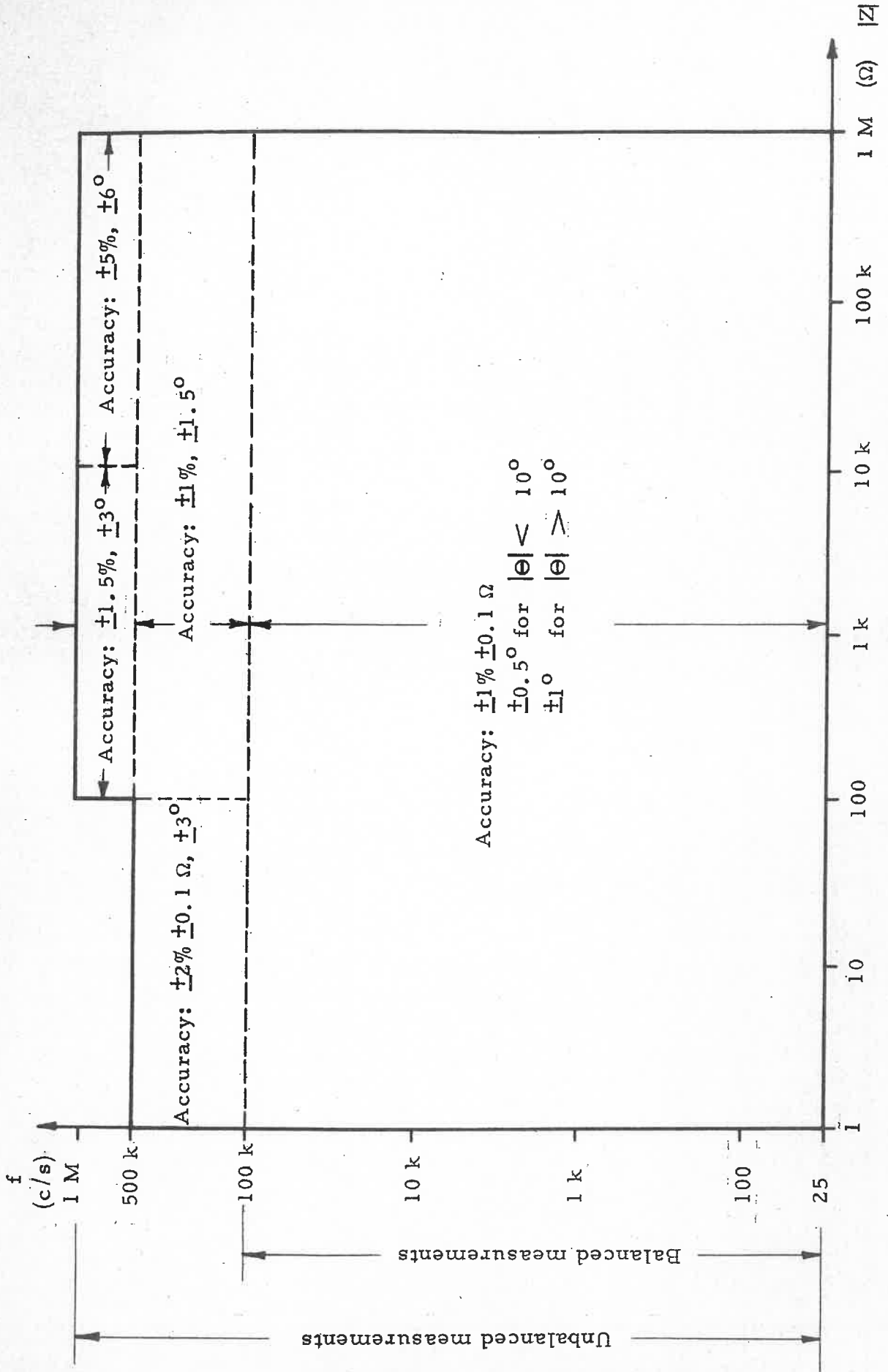
Fig. 1-1 Measuring range and accuracy

TERMINAL SHUNTING CAPACITANCE

Grounded guard mode, with terminal shield: <0.003 pF
Grounded guard mode, without shield: 0.1 pF
Grounded terminal mode: 0.6 pF
Balanced mode, Z terminals 0.2 pF
        from each Z terminal to ground: 600 pF approximately.

OPEN CIRCUIT VOLTAGE UNBALANCE

At balanced mode: Less than 2% at 1 kc.
                 Less than 5% at 100 kc.

TRANSISTORS

1 0C24   8 0C170

POWER SUPPLY

Voltage: 100 to 125 and 200 to 240 volts.
Line frequency: 50 to 60 cps.
Consumption: Approximately 3 watts.

OVER-ALL DIMENSIONS

Height	Width	Depth	
340	560	240	mm
$13\frac{1}{2}$	22	$9\frac{1}{2}$	inches

WEIGHT

21 kilos net (46 lbs).

ACCESSORIES SUPPLIED

1 type 12G19-1.5 power cord
1 type GB11/M65 terminal shield.
1 operating and servicing manual.

ACCESSORIES AVAILABLE

Component Adapter, type IM501. A guarded adapter for rapid testing of components.

Plug-in Filter Units. A 1 kc filter, type GB11/F1K, is stocked, other filters supplied to order.

DC/AC Converter, type KVT1, for operation of the Impedance Meter from 6 volt storage-batteries.

SECTION 2
GENERAL DESCRIPTION

Type GB11 Impedance Meter is based on the principle of a modified Grütz-macher bridge. The operating principle is shown in fig. 1 below.
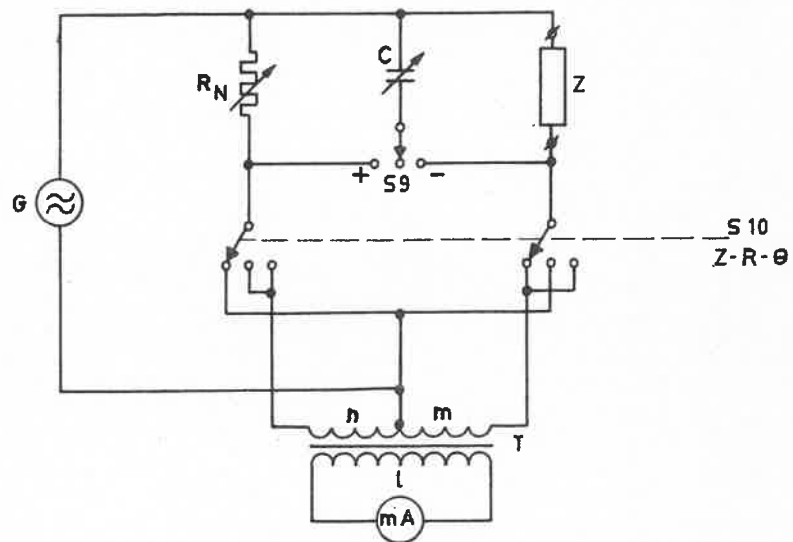
Fig. 1 Simplified schematic diagram

The impedance Z to be tested and the variable standard resistance 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 θ, 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. 2, be determined from
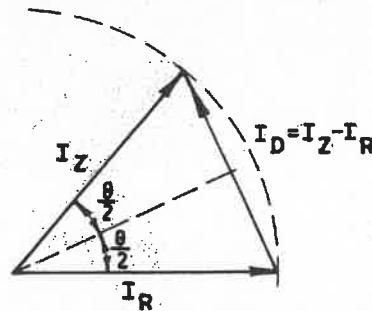
$$\sin \frac{\theta}{2} = \frac{1}{2} \frac{I_D}{I_Z}$$

Fig. 2 Vector diagram for phase-angle determination

The meter can conveniently be calibrated to read I_D directly in terms of phase angle θ between 0 and 90° by adjusting the generator voltage or the current sensitivity. This is done so that the current I_Z brings the meter needle to the SET-LEVEL mark, which is at $1 / \sqrt{2}$ of full scale.

While reading I_D, the sign of the phase angle is finally determined by connecting the variable capacitance C across R_N and Z with $S9_+$ and $S9_-$. Noting the corresponding current differences of I_D, being I_{D_+} and 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 push button $S9_+$ or $S9_-$, whichever gives the higher reading.

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.

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. 3 below. The d-c current through the impedance Z must be supplied and monitored externally.
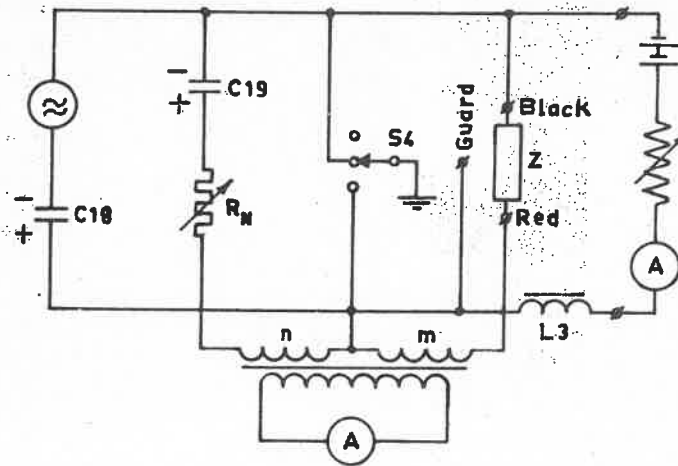
Fig. 3 Polarization by d-c and mode switching

The common point of transformer windings, n and m, 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 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.

SECTION 3

OPERATION

3.1 CONTROLS AND TERMINALS

The following controls and terminals are located on the front panel of
the instrument:

Name:	Description:	Designation in circuit diagram:
ON-OFF	Power switch	S1
FREQUENCY	12-position rotary switch Used to select the frequency of the internal generator.	S2
AMPLITUDE-COARSE	Rotary switch. Used to adjust the generator voltage in steps by changing taps on the input transformer. Operative with internal and external generator.	S3
AMPLITUDE-FINE	Potentiometer. Used to adjust voltage of internal generator.	R29
MEASURING CURRENT (coarse)	8-position rotary switch. Used to adjust ammeter sensitivity in 10 db steps.	S12
MEASURING CURRENT (fine)	Potentiometer. Used for interpolation between the 10 db steps.	R91
PUSH FOR 25° RANGE	Self-releasing push-button. Used to expand meter scale to 25°. Not operative in lowest range of MEASURING CURRENT.	S13
SIGN OF PHASE ANGLE (1) + and −	Self-releasing push buttons. Used to determine the sign of the phase angle.	S9
(2) C	11-position rotary switch. Used to control the capacitive-current component during phase-angle sign determinations.	S8
MAGNITUDE OF Z	4-decade standard resistor. Used during the balancing operation.	R32, S5-S7

Name:	Description:	Designation in circuit diagram:
MULTIPLIER	4-section push-button switch. Used to bring impedance during test into range of standard resistor.	S11
METER SWITCH (1) Z (2) R (3) ⊖	3-section push-button switch. Used to switch the measuring circuit into the un-known branch or the standard resistor branch or both.	S10
Z-MODE (1) Grounded Guard (2) Blk Terminal Grounded (3) Blk Terminal Grounded-Polarized (4) Balanced to Ground	4-section push-button switch. Used to switch the ground connection to the mea-suring circuit, and for the in-sertion of a d-c blocking net-work for polarized impedance measurements.	S4
AMPLIFIER RESPONSE (1) Flat (2) Selective	2-section push-button switch. Used to switch the filter unit in or out.	S14
Z	Terminals. Used to con-nect impedance under test. The black terminal is con-nected directly to the voltage source, and the red terminal is connected through the cur-rent-measuring transformer.	E1, E2
GUARD	Terminal. Used to connect guard circuits.	E3
GROUND	Terminal. Used to connect external ground to apparatus and as third terminal for balanced-to-ground impedance measurements.	E4
POLARIZING VOLTAGE	Banana jacks. Used to con-nect d-c polarizing supply. Up-per terminal should be positive with respect to the lower one, which is grounded.	J4, J5
EXTERNAL GENERATOR	UHF connector. Used to connect an external generator.	J2

The front panel also has a power-line fuse and a pilot lamp. The power cord and receptacle are at the back of the instrument. A covered hole gives access to the plug-in filter unit.

3.2 INITIAL OPERATION AFTER UNPACKING

The following precautions should be taken before operating the instrument for the first time:

(1) Make sure that the wiring is correct for the line voltage that will be used and 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 item 5.3 if the instrument is to operate on 100-125 volts.

(2) Check the mechanical zero-setting of the meter and reset, if necessary.

The instrument is now ready for use.

3.3 OPERATING THE IMPEDANCE METER

3.31 PREPARING THE INSTRUMENT

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

3.311 Selecting the proper 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 capacities and leakages to ground are prevented from affecting the measurement.

3.312 Selecting the proper AMPLIFIER RESPONSE

Normally the FLAT response should be used to measure all linear impedances. The SELECTIVE response requires that the instrument be equipped with a plug-in filter unit type GB11/F, and it is recommended for measuring non-linear impedance, when the current waveform distortion caused by the non-linearity would affect the measurement.

3.313 Selecting the proper MULTIPLIER

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

When there is any doubt about the proper multiplier settings (taking the imperfections of the instrument into consideration), consult fig. 4 to find out which range gives the highest accuracy and whether corrections must be applied.
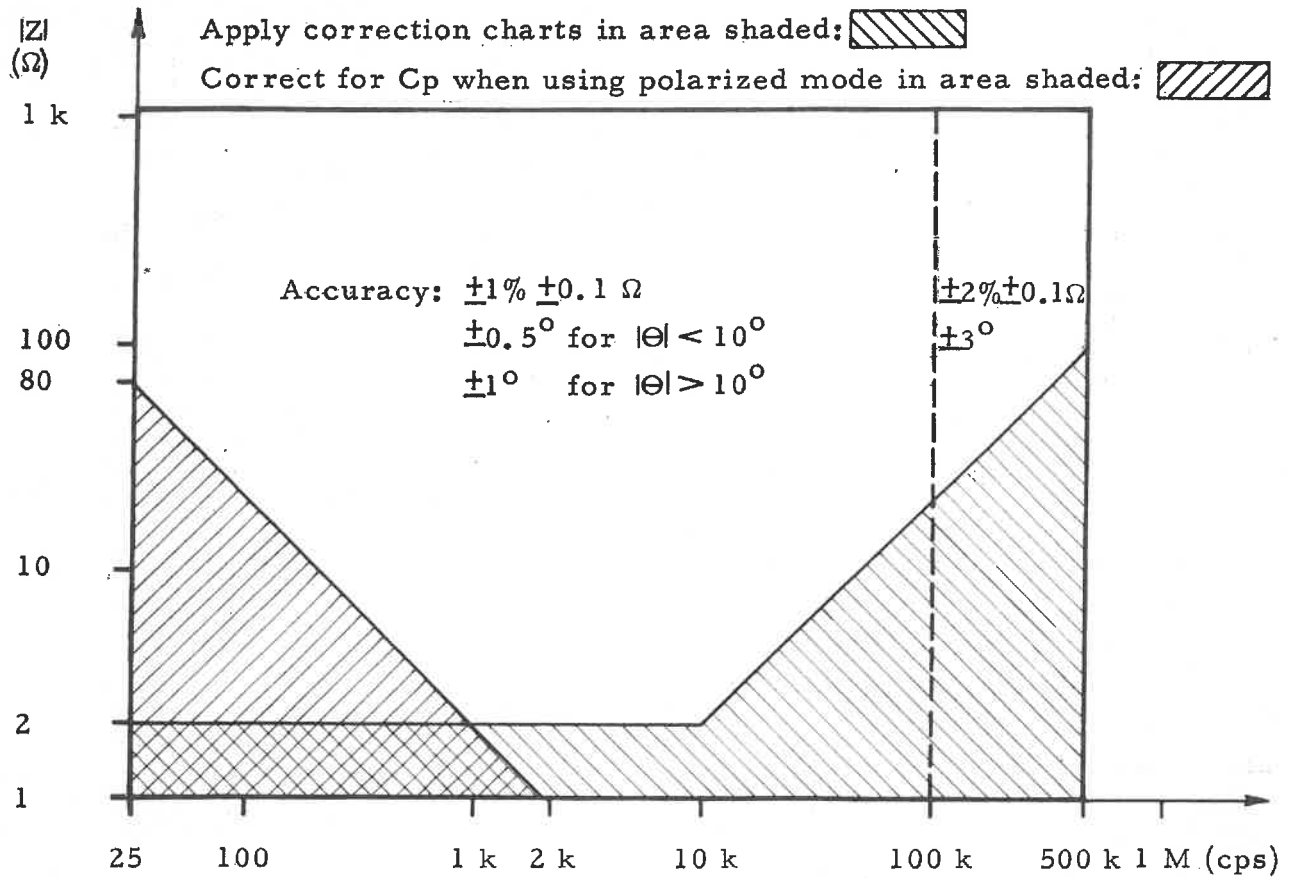
Fig. 4-a Z x 0.1 Multiplier (1 Ω to 1.1 kΩ)
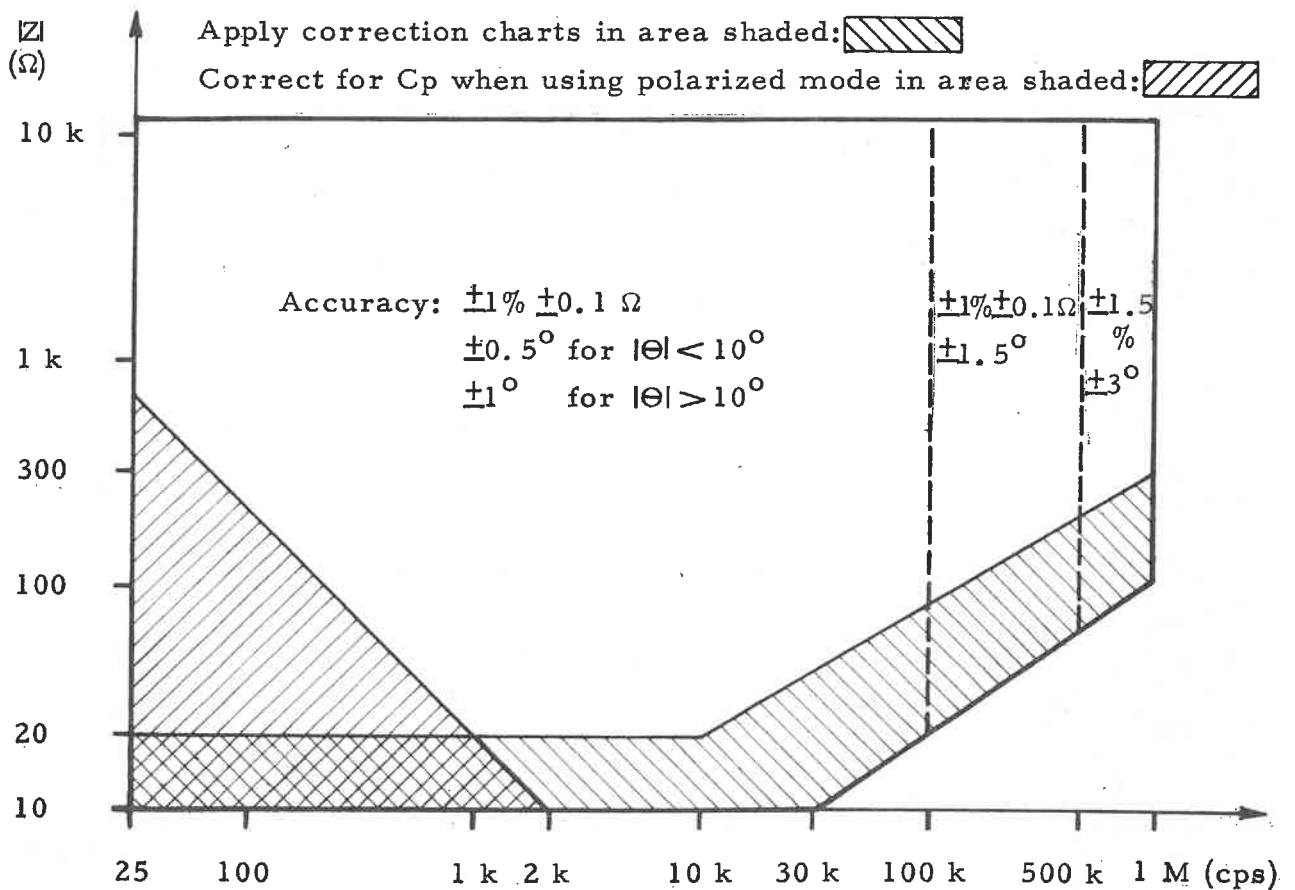
Fig. 4-b Z x 1 Multiplier (10 Ω to 11 kΩ)

MULTIPLIER SELECTION CHARTS

Use terminal shield or correct for 0.1 pF terminal capacitance in the shaded area.

Accuracy: $\pm 1\%$
$\pm 0.5^{\circ}$ for $|\Theta| < 10^{\circ}$
$\pm 1^{\circ}$ for $|\Theta| > 10^{\circ}$

$\pm 1\%$
$\pm 1.5^{\circ}$
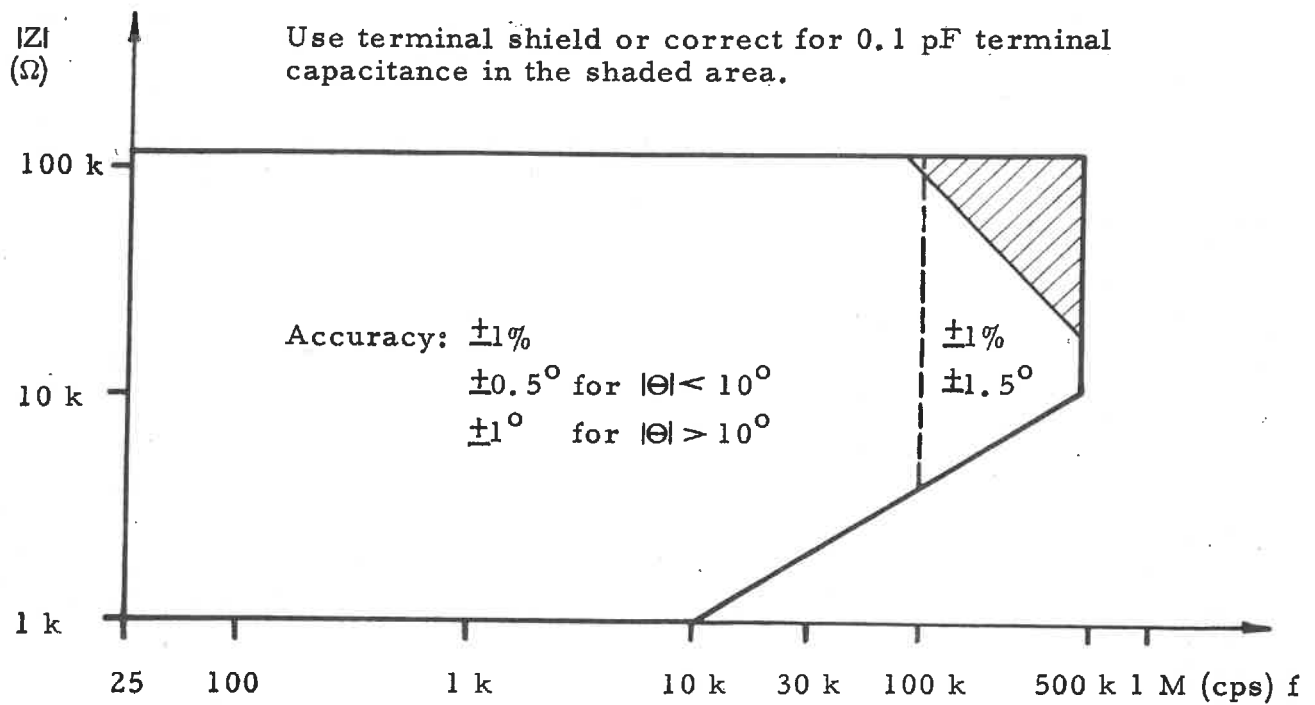
Fig. 4-c Z x 10 Multiplier (100 Ω to 110 kΩ)

Use terminal shield or correct for 0.1 pF terminal capacitance in the shaded area.

Accuracy: $\pm 1\%$
$\pm 0.5^{\circ}$ for $|\Theta| < 10^{\circ}$
$\pm 1^{\circ}$ for $|\Theta| > 10^{\circ}$

$\pm 1\%$ $\pm 5\%$
$\pm 1.5^{\circ}$ $\pm 6^{\circ}$

Fig. 4-d Z x 100 Multiplier (1 kΩ to 1.1 MΩ)

MULTIPLIER SELECTION CHARTS

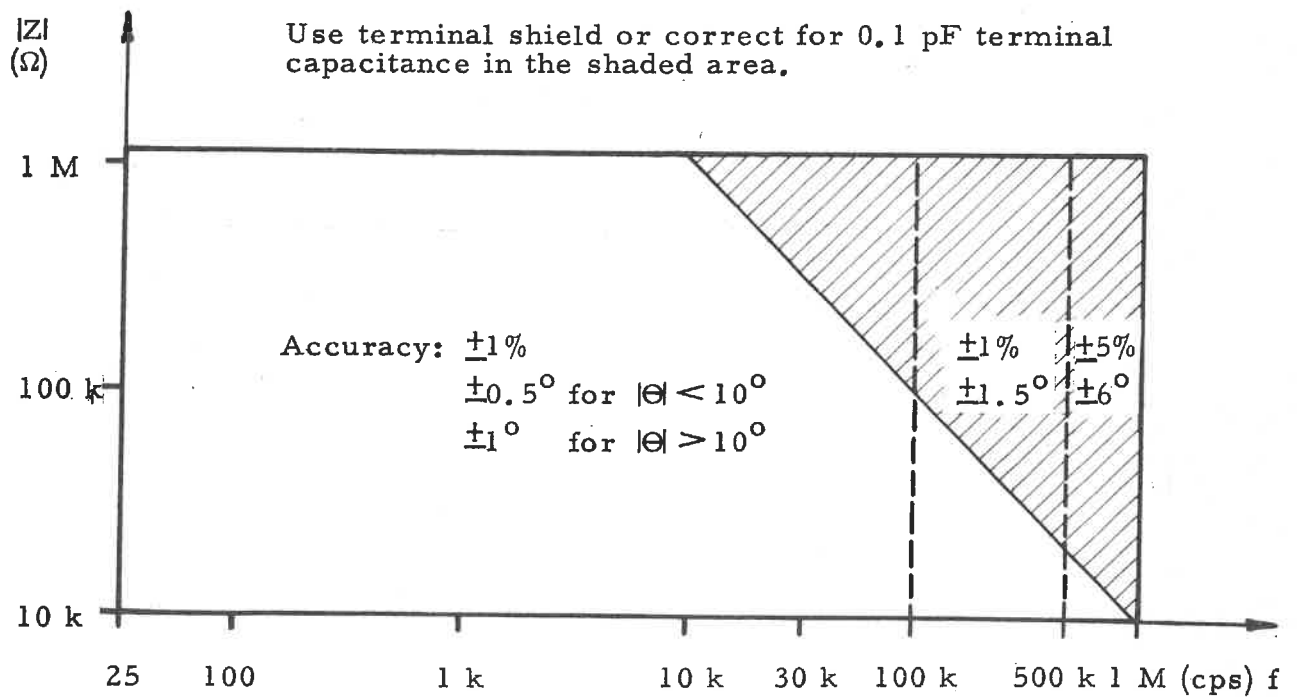3.314   Selecting the desired MEASURING CURRENT

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 favorable 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.

3.315   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 voltage transformer, depending on the position of the AMPLITUDE-COARSE selector.

The transformer connection must be used to measure balanced circuits.

The DIRECT connection must be used at frequencies above 100 kc/s and powers above 125 mV, which are the upper frequency and power-handling limits of the voltage transformer.

The output impedance and the harmonic distortion of the external generator should be as low as possible (below 200 ohms). The first is desirable to obtain a rapid balance. The second is necessary to minimize measuring errors because of 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 tuned circuits. This inaccuracy may be overcome by using type GB11/F filter units or by inserting an adequate filter between generator and 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 Ω decade in which it is only 32 mA.

3.316   Inserting a plug-in filter unit GB11/F

Remove the thumb-screw and cover from the back of the instrument. The filter can then be plugged in and kept in place by a fixing screw. The cover should be replaced when the filter has been inserted.

3.32   HOW TO MEASURE

3.321   General

When the instrument has been set up,

(1)   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 the 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 deflects to SET-LEVEL again.

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

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 θ button and read directly from the upper meter scale the phase angle in degrees. If the phase angle is less than 25°, the meter scale can be expanded (lower scale) by pressing the button 25° RANGE.

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

(6)   While measuring θ, alternately press the + and − push buttons. Increase C only enough to obtain a

pronounced difference between the reading obtained with the + button and that with the — button.

The sign of the phase angle is now determined by the sign of the button that gives the higher reading.

3.322 Measuring low impedances

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

Fig. 5 and fig. 6 are correction charts to be used with the Z x 0.1 multiplier.

Fig. 7 and fig. 8 are correction charts to be used with the Z x 1 multiplier.

Fig. 5 and fig. 7 show the magnitude correction, $\triangle Z$, in ohms. The correction depends on the frequency and the phase angle θ. The correction is independent of the magnitude. When the phase angle measured, θ_m, is entered on the ordinate and the frequency among the constant frequency lines, the correction $\triangle Z$ is found on the abscissa. The correct magnitude is:

$$ /Z/ = /Z/_m + \triangle Z $$

where $/Z/_m$ is the magnitude measured, and $\triangle Z$ is the correction.

Fig. 6 and fig. 8 show the phase-angle correction δ. As before, the phase angle measured, θ_m, is entered on the ordinate and the frequency among the constant frequency lines. The phase correction δ is found by dividing the value found on the abscissa by $/Z/$.

The correct phase-angle is given by:

$$ \theta = \theta_m + \delta $$

where θ_m is the phase-angle measured and δ the correction.

3.323 Measuring high impedance at high frequencies

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

Choose the GROUNDED GUARD mode in case these capacities 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 screened cables.

Above 10 kΩ and above 10 kc/s it is necessary to use the terminal screen or to make small corrections because of the 0.1 pF residual capacity across the terminals of

the instrument. The correct phase-angle Θ is computed from:

$$\Theta = arctg \ (tg \ \Theta_m + /Z/_m \ \frac{0.628 \times f \times 10^{-12}}{cos \ \Theta}$$

where Θ_m is the phase-angle measured, $/Z/_m$ the magnitude in ohms, and f the test frequency in cycles.

The correct magnitude is computed from

$$/Z/ = /Z/_m \ \frac{cos \ \Theta}{cos \ \Theta_m}$$

3.324 Polarized impedance measurement

The polarizing current or voltage must be supplied and monitored externally via the corresponding jacks on the panel. Be sure that the polarity of the applied d-c voltage is correct, and that it is maximum 50 volts, to prevent damaging the blocking capacitors. The specified current limits must be observed to prevent saturation of the current transformer. Otherwise an error in measurement will result. When polarized, the red Z terminal is positive, and the black Z terminal is negative.

At low frequencies and at low settings of the MAGNI-TUDE standard resistor, the blocking capacitor in series with the standard resistor, C19, may cause an error in measurement. Fig. 4 illustrates the limit within which this error may become noticeable. The magnitude and phase errors are not dependent on the impedance Z but only on the settings of frequency and magnitude.

Generally applicable correction data cannot be given because of the wide tolerance of the blocking capacitors used (1000 μF + 50%, —20%). If it becomes necessary to correct for the errors introduced by the blocking capacitor, it is easy to find the $/Z/$ and Θ corrections by measuring a pure resistor of value $/Z/$, both in the polarized and nonpolarized 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 measurements are of no use unless a plug-in filter unit type GB11/F is used. In this case, the phase relationship of the fundamental voltage and fundamental current is measured.

3.325 Balanced impedance measurement

Fig. 9 shows a simplified schematic diagram of the in-

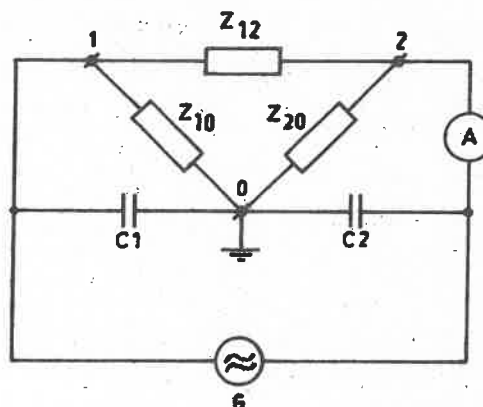strument in the BALANCED mode during the Z measurement.

Fig. 9 Simplified schematic diagram for
BALANCED mode Z measurement

The generator is floating except for the capacities C1
and C2, which are balanced and approximately 370 pF
each. 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 unbalance in the network and of
whether the unbalance affects the measurement to any
noticeable degree is easily obtained by taking a measure-
ment and then measuring again with the connections to
the Z terminals (1 and 2) reversed. If the two measure-
ments differ by more than the specified errors, the un-
balance 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 mea-
sured directly in the GROUNDED GUARD mode. Z_{10}
is measured in the BLACK TERMINAL GROUNDED
mode when terminal 2 is connected to the GUARD termi-
nal. Z_{20} is found in a similar way with terminal 1 con-
nected to the GUARD terminal.

SECTION 4

DETAILED DESCRIPTION

The Impedance Meter, type GB11, consists of 4 sub-units:

> Oscillator
> Measuring circuit
> Ammeter circuit
> Power supply

A complete circuit diagram is appended to the instructions.

4.1   OSCILLATOR SECTION

The oscillator is the Wien-bridge type and is made up of:

(1)   an amplifier (Q1, Q2, Q3 and associated components on print board Z1)

(2)   a frequency-determining positive feedback network (S2 and associated components)

(3)   a negative feedback amplitude stabilizing network (RT1 and associated components)

(4)   a matching network (T3, S3)

The amplifier is three-staged, d-c coupled, and has a stabilized working-point (R16, R17, and R28), which results in a stable operation over a wide temperature range and allows for great variations in the supply voltage. The voltage gain at 1 kc is approximately 80 dB.

The positive feedback frequency-determining network is the conventional RC-series-parallel type. The operating frequency is determined by

$$f \doteq \frac{1}{2\pi RC}$$

and the ensuing feedback factor

$$\beta_+ = \frac{1}{3}$$

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 feeback is controlled by the thermistor RT1, operating in the constant voltage region, thus stabilizing the amplitude to within 0.5% (at constant ambient temperature).

Because of the high open-loop gain and the thermistor characteristic, the output impedance of the oscillator (measured at the collector of Q3) is approximately 0.1 ohm, and the distortion is 0.5%. By connecting C9 between the junction of R16 and R17 and the emitter of Q1, a high a-c input impedance is had, thus increasing the frequency stability.

The voltage transformer T3 is a shielded, balanced multi-tap transformer. A wide bandwidth (25 c/s to 100 kc/s) is obtained by using a mumetal core and a special winding technique. The amplitude is controlled by the S3 switching 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 to the internal generator when in position EXTERNAL. In position 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 c/s. At higher frequencies, the power-handling capacity increases considerably. At 50 c/s the maximum undistorted voltage is 25 V and the power available with an external generator is 300 mW.

4.2 THE MEASURING CIRCUIT

The measuring circuit consists of:

(1) current transformer T4
(2) multiplier switch S11
(3) mode switch S4
(4) standard-resistor decades R32, S5, S6, and S7
(5) meter switch S10
(6) variable capacitor switch S8
(7) phase-angle sign-determing 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. The taps selected are:

Multiplier	R winding	Z winding
Z x 0.1	10	1
Z x 1	10	10
Z x 10	1	10
Z x 100	1	100

The meter switch, S10, passes the current

(1) into the unknown impedance through the Z winding of T4 when Z is pressed

(2) into the standard resistance loop through the R winding of T4 when R is pressed

(3) both currents through their windings when o is pressed

When the PHASE-ANGLE SIGN switch, S9, is operated, an additional current, leading by $90°$, 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 capacitor 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 $10Ω$ continuously variable resistor of infinite resolution and low inductance.

4.3 AMMETER 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 by a preamplifier (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 with a divider (S12B) connected to the preamplifier output and on all the subsequent ranges with a universal shunt at the preamplifier input (S12A). In addition the sensitivity is made continuously variable by R91 at the input of the main amplifier. The 25° scale expansion is obtained by increasing the meter sensitivity by 10 dB when pressing S13, which is connected to the divider (S12B).

The preamplifier consists of the d-c 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. With FLAT response, the filter is disconnected, and a 3-dB attenuation introduced (R89, R90) to simulate the filter insertion loss.

The main amplifier consists of the d-c 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 d-c 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 preamplifier and in the main amplifier, is approximately 30 dB and 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.

The amplifier input impedance is 10 ohms, the bandwidth is 20 c/s to 1.5 Mc/s. The equivalent noise input is 0.02 μA. The total maximum current gain is 29 dB.

4.4 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.

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). T2

is a double shielded transformer fed from the low-voltage secondary of T1. 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 supply.

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 5
MAINTENANCE

5.1 GENERAL

The Impedance Meter, type GB 11, 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 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.

5.2 REMOVING THE INSTRUMENT FROM THE CABINET

The instrument can be taken out of the cabinet after the four hexa-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 GB 11/F has been inserted, it must be removed before the cover is taken off.

5.3 CLEANING THE CONTACTS

The contacts of the various switches may need cleaning if unstable readings are had, especially when a very low impedance is measured.

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

5.4 D-C POTENTIALS

The potentials listed on the next page 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 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 may be allowed for.

Transistor		D-C Potential, volts		
Circuit Designation	Type	Emitter	Base	Collector
Q1	OC170	−1.2	−1.5	−4.3
Q2	OC170	−4.1	−4.3	−9.7
Q3	OC24	−3.8	−4.1	−13.8
Q4	OC170	−0.5	−0.8	−2.0
Q5	OC170	−1.7	−2.0	−6.1
Q6	OC170	−5.8	−6.1	−10.8
Q7	OC170	−8.3	−8.7	−21.5
Q8	OC170	−1.4	−1.7	−6.0
Q9	OC170	−5.7	−6.0	−12.5

D-C potential of pilot-lamp terminals: −19.2 V, −15.2 V.

A-C ripple on −15.2 V pilot-lamp terminal: less than 15 mV

D-C potentials of choke L2 terminals: −24.2 V, −21.5 V

A-C ripple on −21.5 V choke terminal: less than 3 mV

5.5 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.

5.6 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 a-c 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:                   GROUNDED GUARD
MULTIPLIER:               Z x 1
FREQUENCY:                1 kc
```

Adjust the amplitude to obtain SET-LEVEL readings on the meter of the instrument. The voltage indicated by the voltmeter should be 1 volt ±3%.

5.7   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 amp slow-blow fuse.

5.8   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 amp.

Example: $\theta = +52°$; $f = 475$ kc; $|Z|_m = 2.00\ \Omega$

$\triangle |Z| = -0.63\ \Omega$; $|Z| = 2.00 - 0.63 = 1.37\ \Omega$
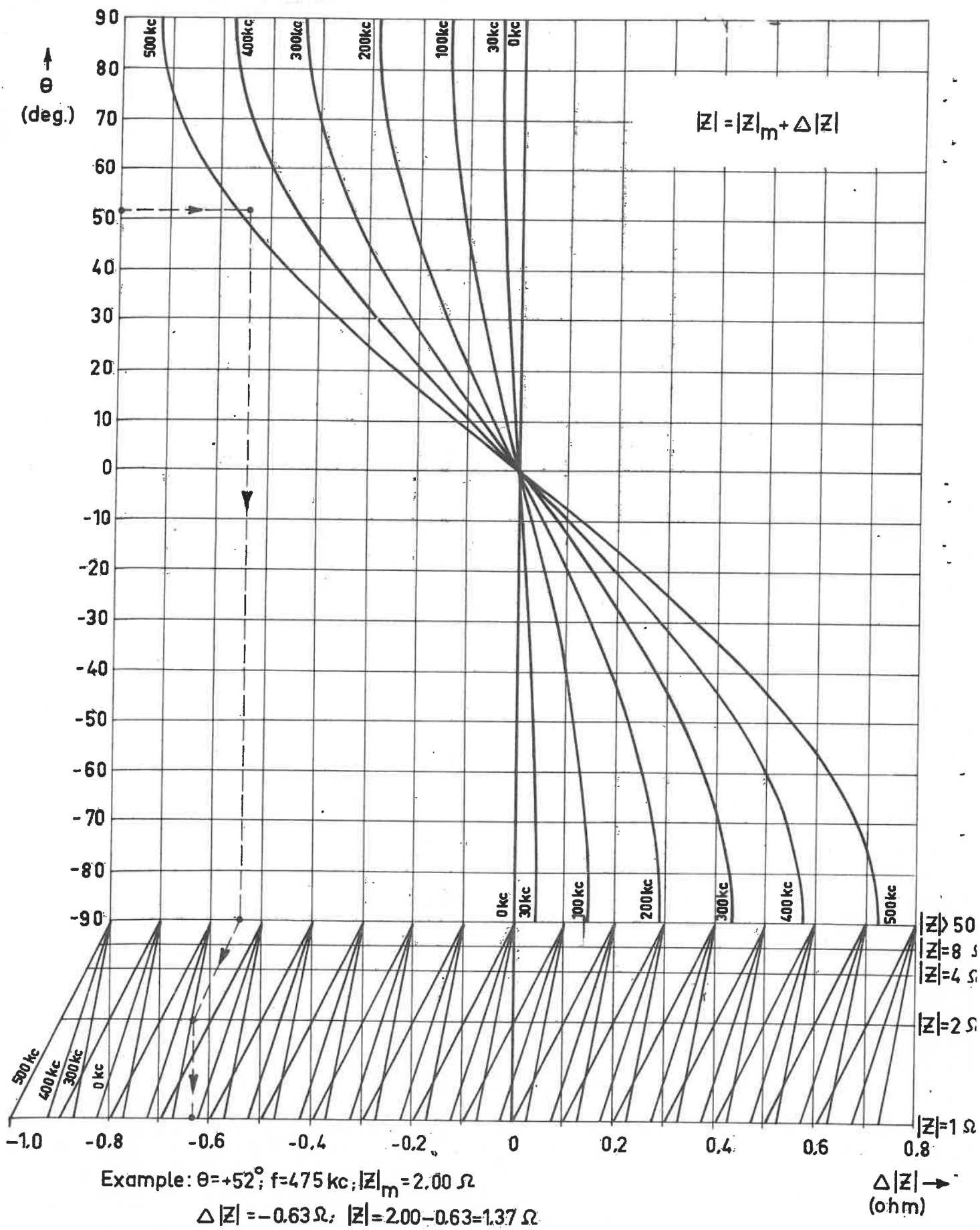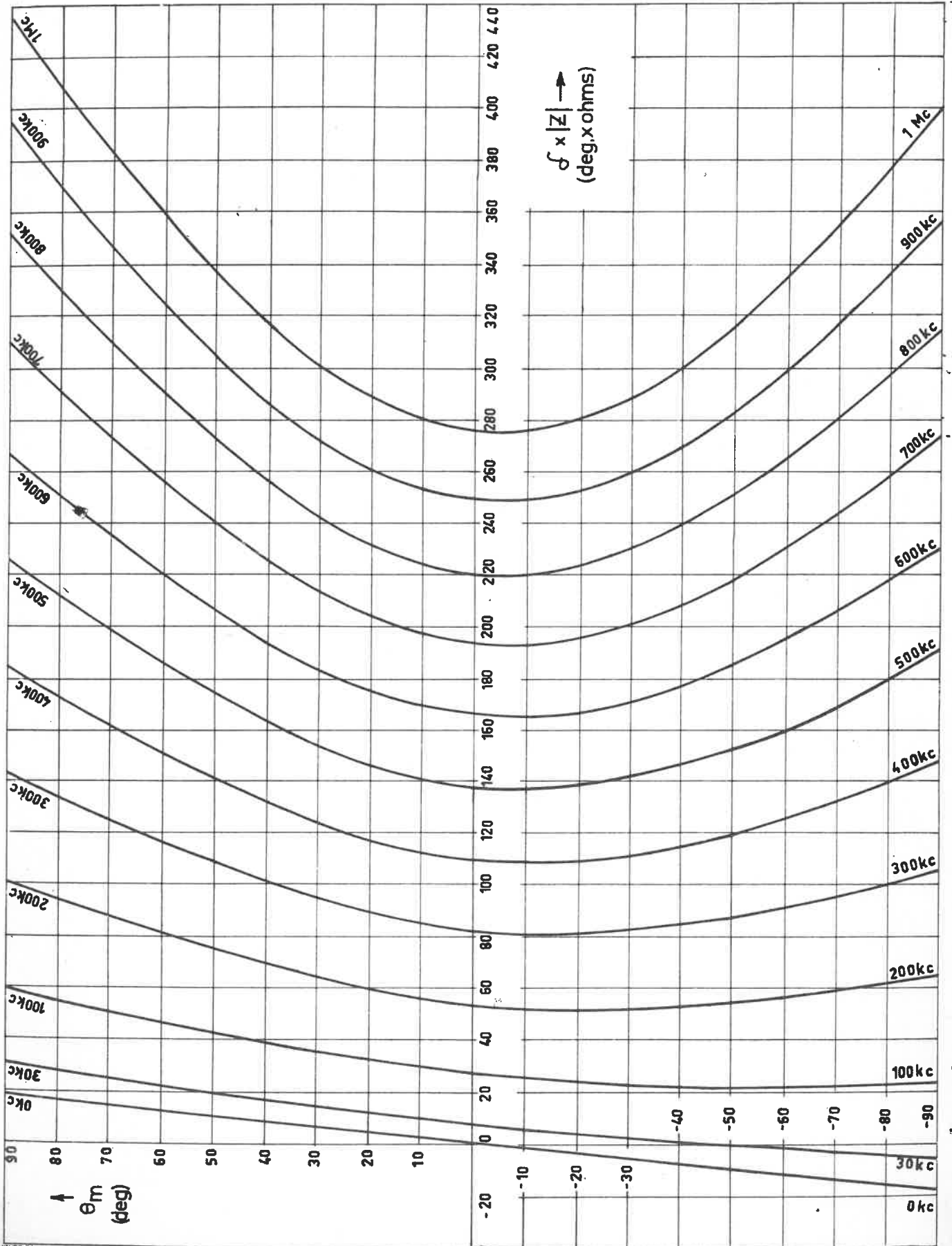
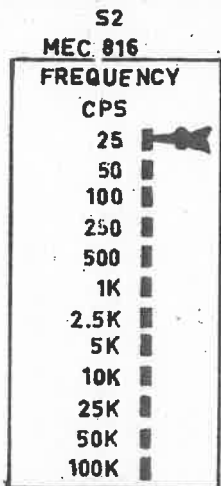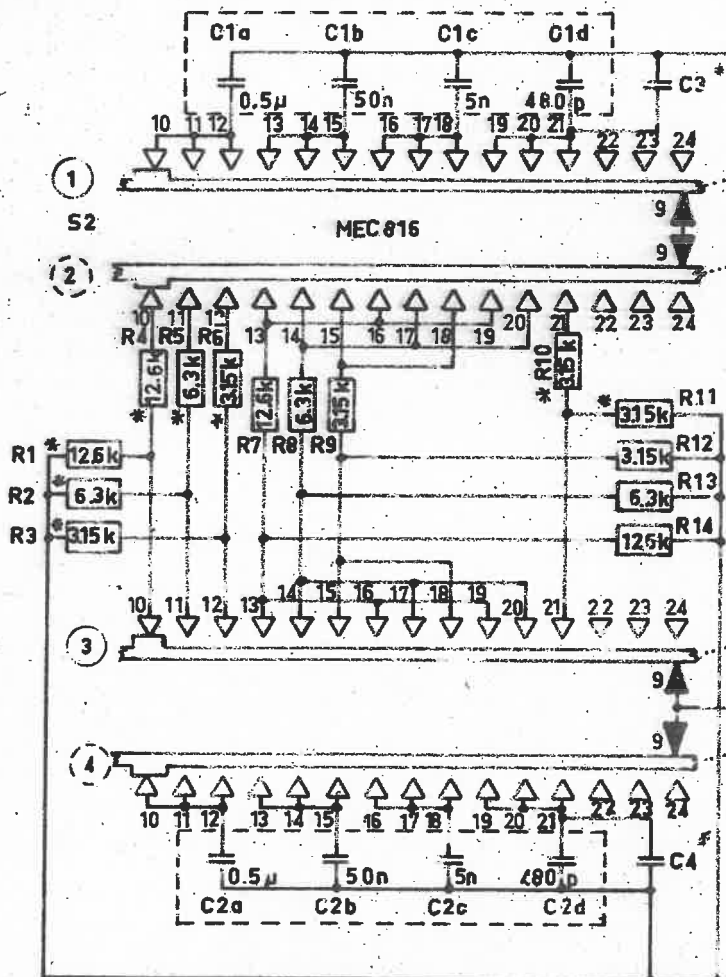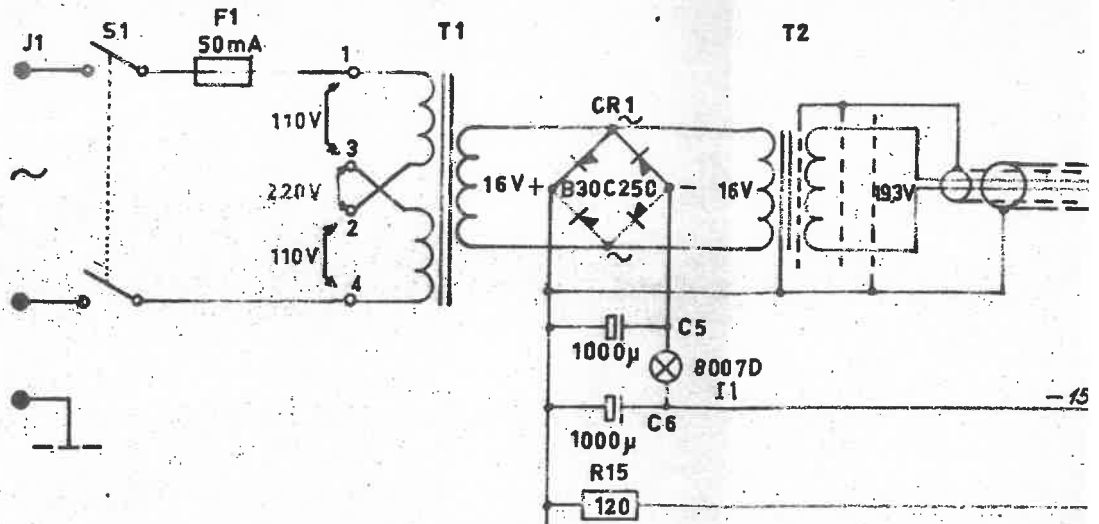Fig. 5   Magnitude correction chart for $Z \times 0.1$ multiplier

Fig.6

Phase-angle correction chart

for $Z \times 0.1$ multiplier

$\theta = \theta_m + \delta$

$\delta \times |Z| \longrightarrow$ (deg. x ohms)

θ_m (deg.)

Example: $\theta = 56°$; $f = 800$ kc; $|Z|_m = 75\,\Omega$
$\Delta|Z| = +1.85\,\Omega$
$|Z| = 75 + 1.85 = 76.85\,\Omega$
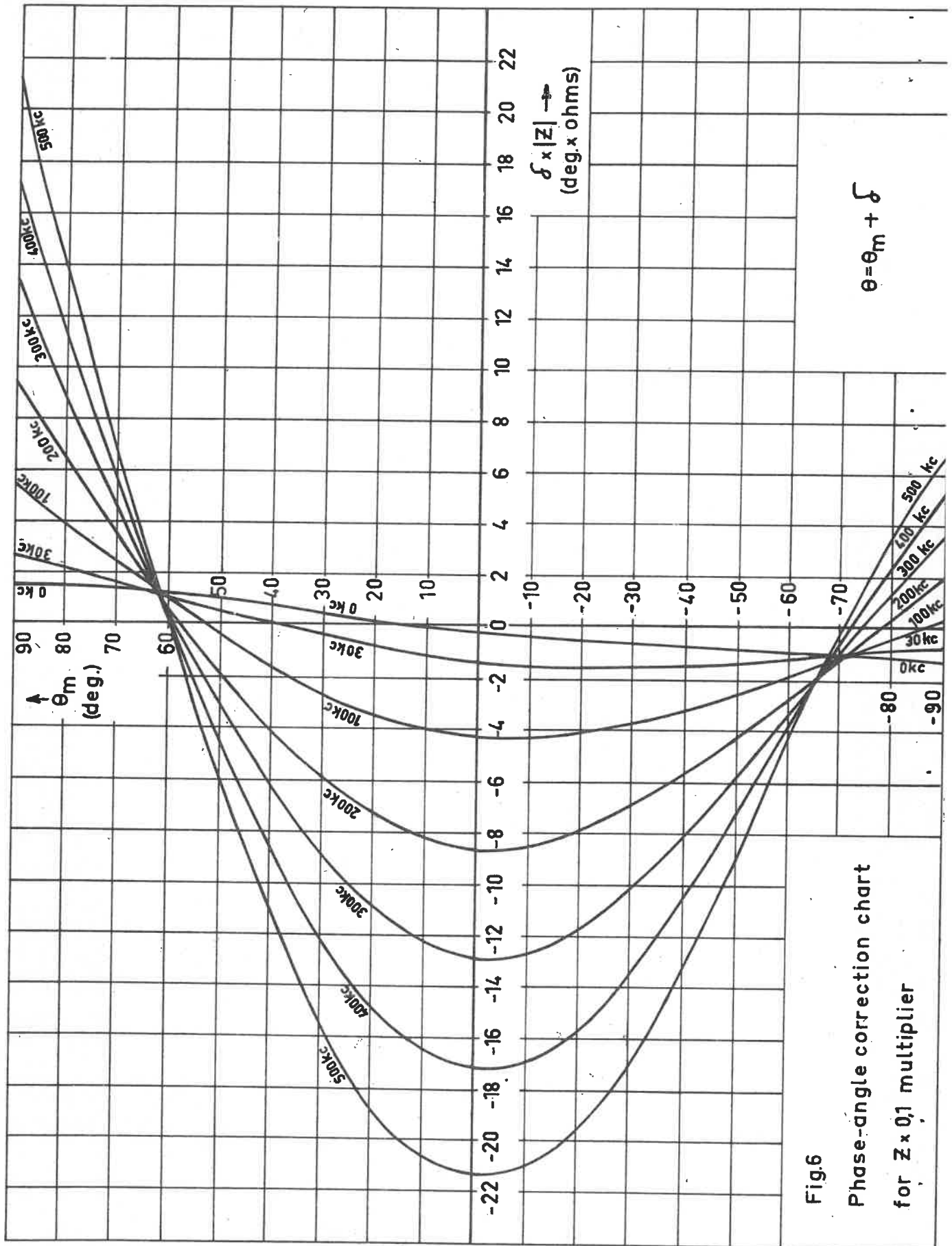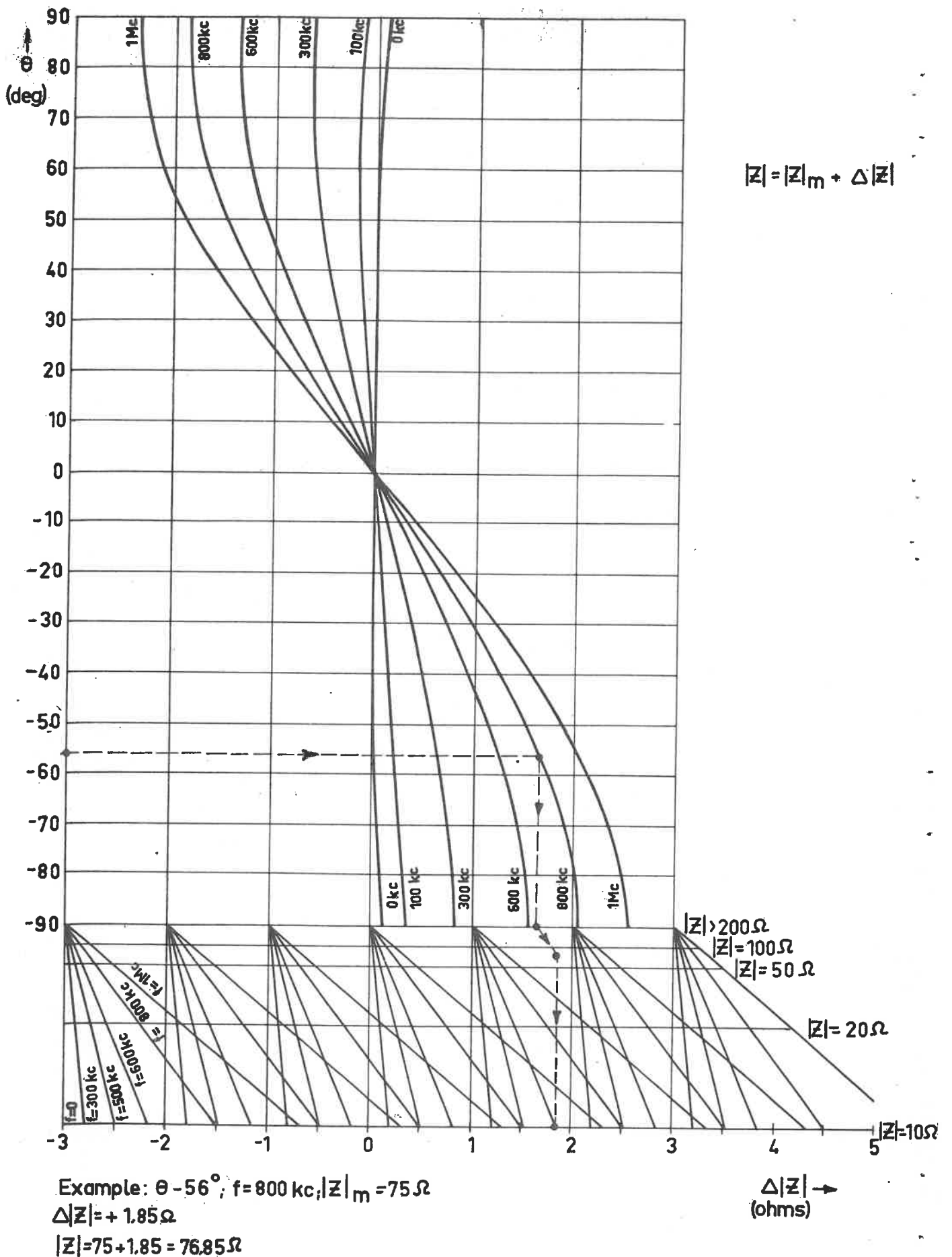
Fig.7   Magnitude correction chart for $Z \times 1$ multiplier

Phase correction chart for Z×1 multiplier

Fig. 8

$\theta = \theta_m + \delta$
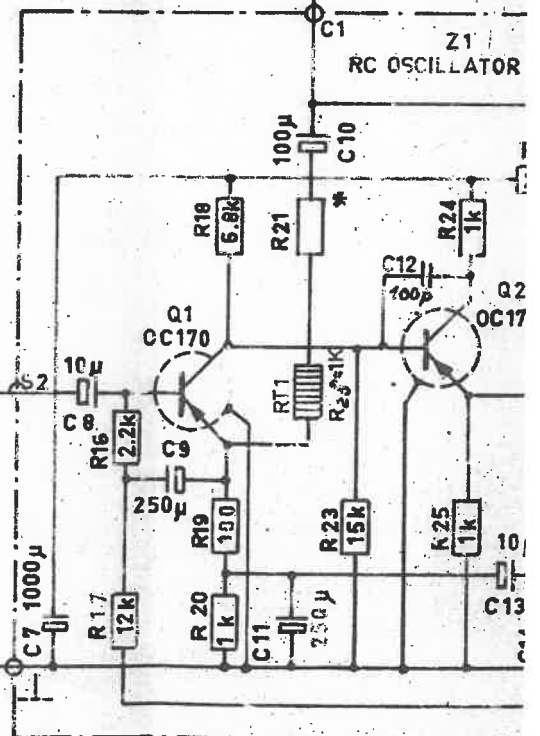
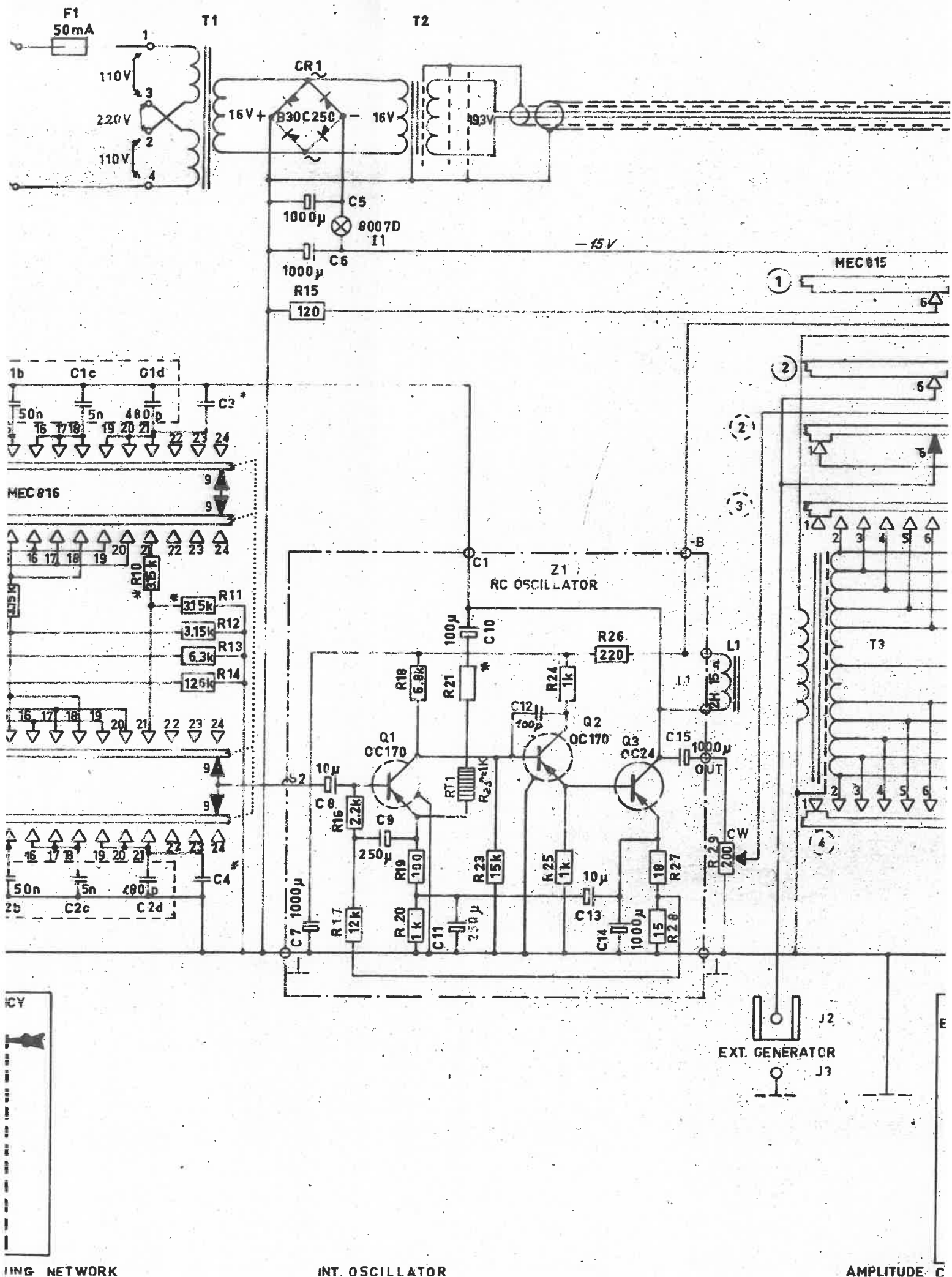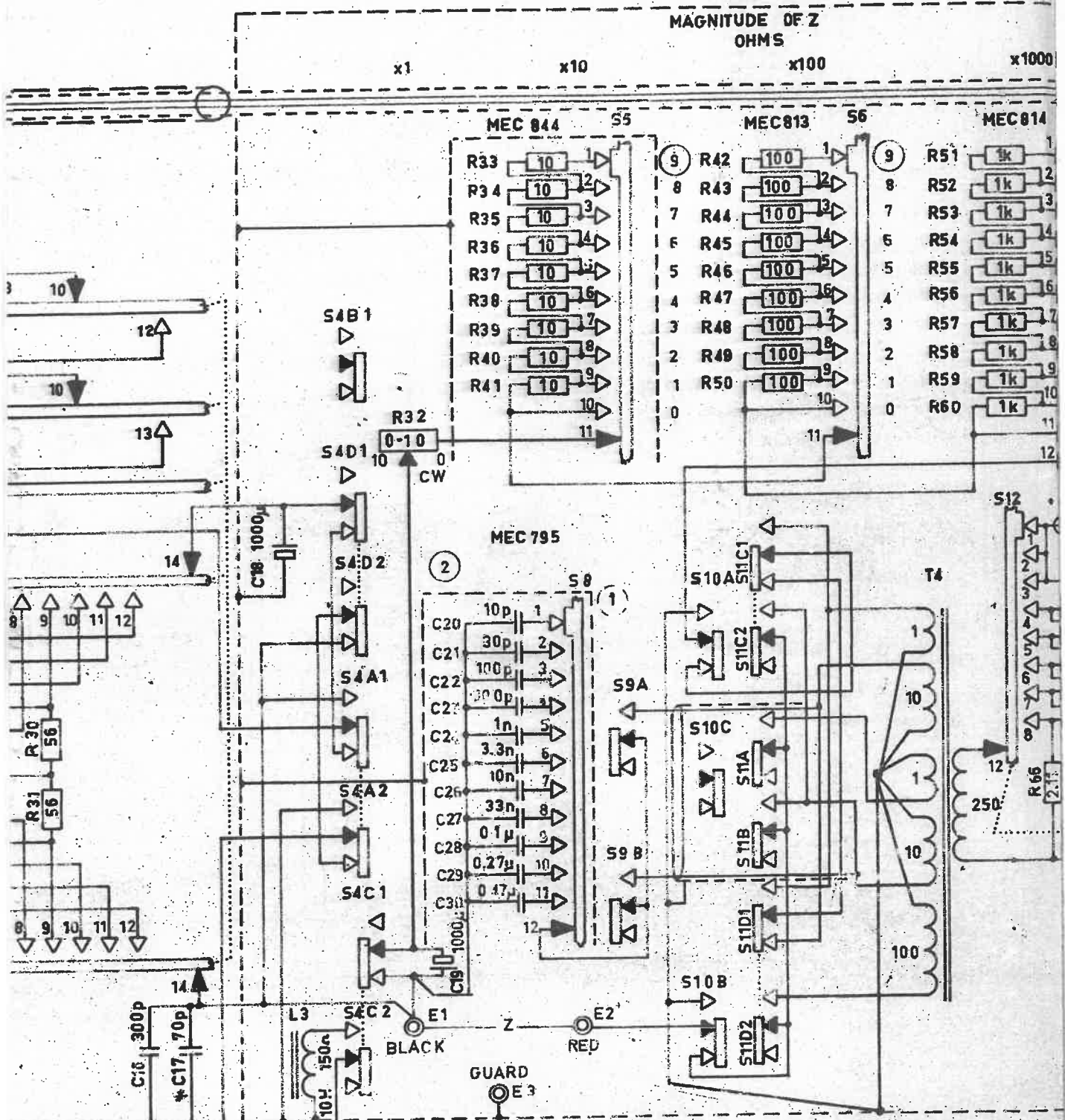FREQUENCY DETERMINING NETWORK   INT. OSCILLATOR

MAGNITUDE OF Z
OHMS

x1   x10   x100   x1000

MEC 844   S5   MEC813   S6   MEC814

MEC 795

MEC 795

S3
MEC 815

AMPLITUDE COARSE
INT GEN DIRECT

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

FINE — R29

J4 — + 50 VOLTS MAX.
POLARIZING
VOLTAGE
J5 — GROUND

GROUND
E4

MEC 809-1
Z-MODE
S4A - Grounded Guard
S4B - Blk Terminal
S4C - Grounded Polarized
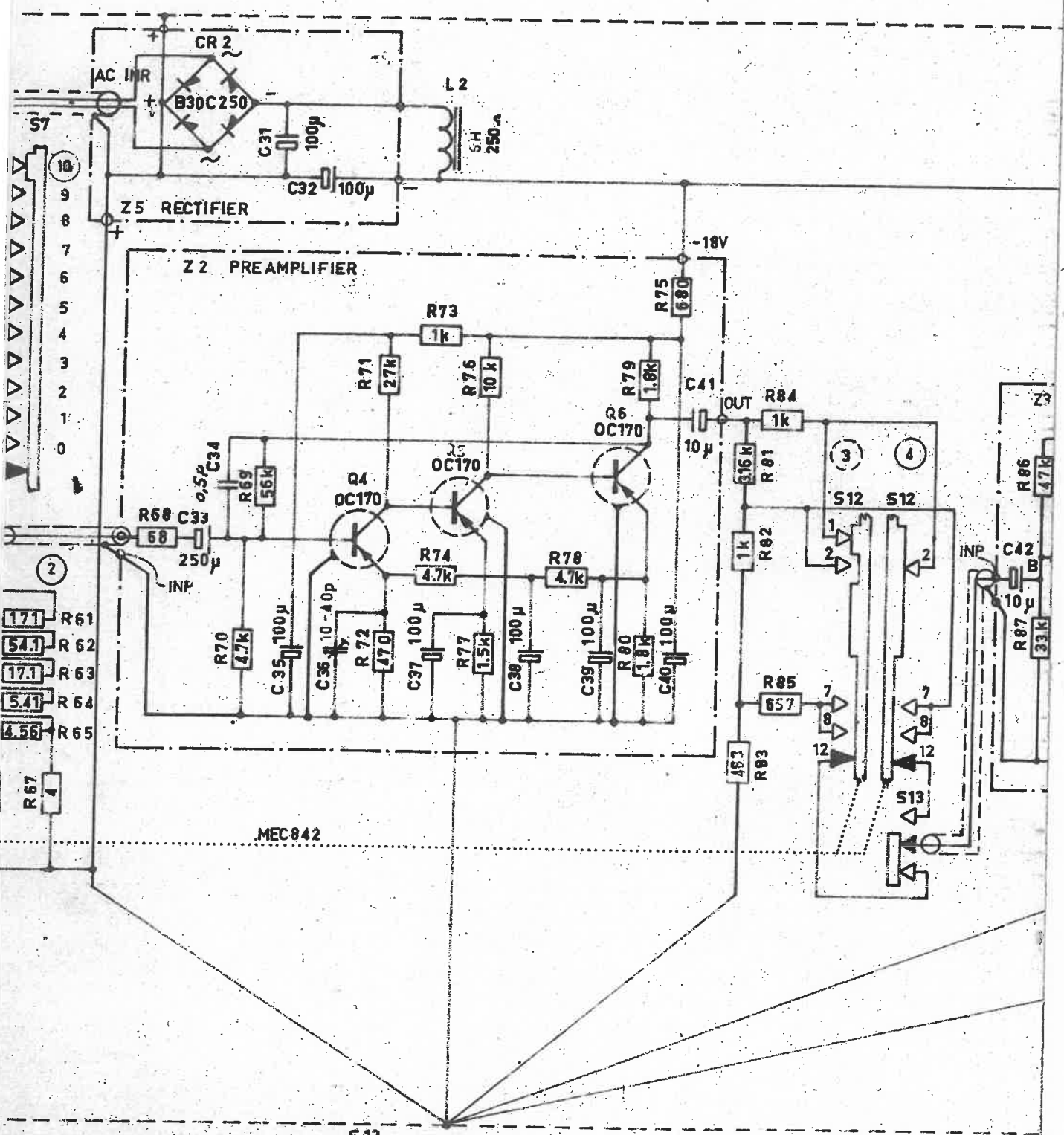S4D - Balanced to Ground

S8
MEC 795
C
1
2
3
4
5
6
7
8
9
10
11

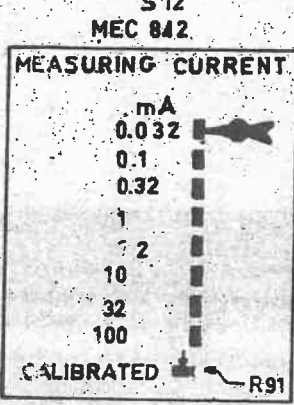MEC811
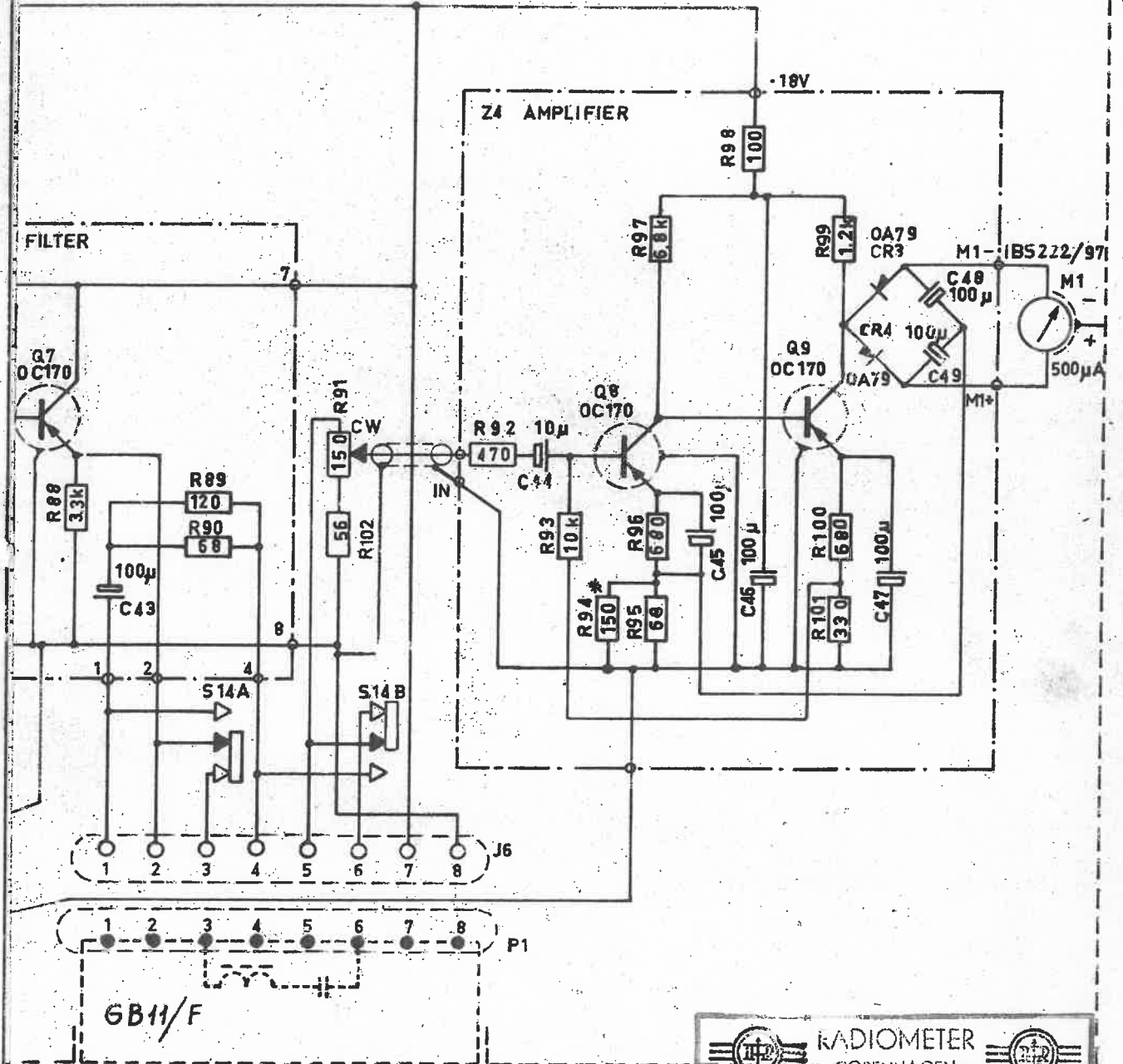PHASE ANGLE SIGN
S9A - +
S9B - -

METER
S10A
S10
S10

NTROL   MODE SELECTOR   MEASURING CIRCUIT

Z5 RECTIFIER

CR 2
B30C250
C31 100µ
C32 100µ
L 2
5 H 250

AC INP
S7
10 9 8 7 6 5 4 3 2 1 0

−18V

Z 2 PREAMPLIFIER

R75 680
R73 1k
R71 27k
R76 10k
R79 1,8k
Q6 OC170
C41 10µ
OUT
R84 1k
R81 316k
Q4 OC170
OC170
R69 56k
0,5p C34
R68 C33
68 250µ
INP
R74 4,7k
R78 4,7k
R82 1k
S12 S12
INP
C42 B 10µ
R86 47k
R70 4,7k
R72 470
R77 1,5k
R80 1,8k
R87 33k
C35 100µ
C36 10-40p
C37 100µ
C38 100µ
C39 100µ
C40 100µ
R85 657
R83 463

2
17,1 R61
54,1 R62
17,1 R63
5,41 R64
4,56 R65
R67

S13

MEC842

S 12
MEC 842

S 13
MEC 812-1
PUSH FOR 25° RANGE

C 807
SWITCH
A - 2
B - R
C - 0

MEC 808
MULTIPLIER
S11A - ×0.1
S11B - ×1
S11C - ×10
S11D - ×100

MEASURING CURRENT
mA
0.032
0.1
0.32
1
2
10
32
100
CALIBRATED — R91

Notes:
1) Components marked by */ are m
2) All resistances are in ohms unless
   indicated by k (kilohms) or M (mego
3) Capacitances are indicated by:
   p corresponding to µµF
   n ———— " µµF×10³
   µ ———— " µF

FILTER

Z4 AMPLIFIER

-18V

R98 100

R97 6.8K

R99 1.2k

0A79 CR3

M1 – IBS 222/97

C48 100 µ

CR4 100µ

0A79

C49

M1

M1+

500µA

Q7 OC170

Q9 OC170

Q8 OC170

R88 3.3k

R89 120

R90 68

R91 150 CW

R102 56

R92 470

C44 10 µ

IN

R93 10k

R96 680

C45 100 µ

C46 100 µ

R100 680

C47 100 µ

100µ C43

R94 150

R95 68

R101 33 0

S14A

S14B

1 2 3 4 5 6 7 8 J6

1 2 3 4 5 6 7 8 P1

GB11/F

MEC-810-1
AMPLIFIER RESPONSE
S14A-FLAT
S14B-SELECTIVE

FILTER

AMPLIFIER

			Rt.Nr.	Fra Fab. Nr.	Dato	Rt. af	Konf.	Norm.
4		9/7-62	dod	EH				
3		16/5-62	EP					
2		6/12-61	EP					
1		17-11-01	LTJ	MW				