MM2
RLC Meter

OPERATING INSTRUCTIONS

982-707, 409A

RADIOMETER
COPENHAGEN

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RLC Meter
Type MM2

Section A. Introduction

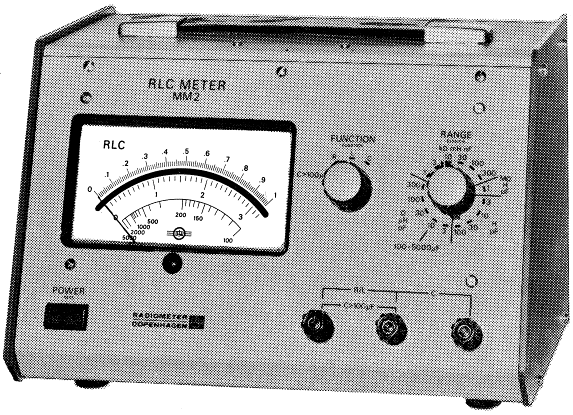


Fig.A1. The RLC Meter, type MM2.

The RLC Meter, type MM2, is a direct-reading, line-operated component tester. It is designed for making direct measurements of resistance, inductance and capacitance with a minimum of adjustment during operation. The component under test is connected to the appropriate binding posts on the front panel, whereafter it is only necessary to select the mode (R, L or C) and to turn the range knob until maximum meter deflection is obtained.

Two pairs of terminals are provided on the rear panel of the instrument:

A recorder output offering a 1 V signal at full-scale deflection and at a source impedance of approx. 50 kΩ.

An input used for biasing, for example, varicaps in the range -60 V to +60 V.

Resistance measurements are performed directly within the range 0.1 Ω to 1 MΩ at a frequency of 160 Hz. Inductance is measured directly within the range 0.1 µH to 100 H at five decade-selected frequencies between 1.6 MHz and 160 Hz. For both resistance and inductance measurements, the accuracy is 2% of reading + 1% of f.s.d., $(Q_L > 10)$. In both cases the test voltage is proportional to the meter deflection and varies between 0 and 10 mV. Capacitance measurements are made in two ranges: In the range 0.1 pF to 100 µF, measurements are performed at five decade-selected fixed frequencies between 1.6 MHz and 160 Hz, with an accuracy of 2% of reading

+ 1% of f.s.d. $(Q_C>10)$. The test voltage in the range from 0.1 pF to 10 μF is 316 mV, and in the range from 10 μF to 100 μF it is 100 mV. In the second range, from 100 μF to 5000 μF, the capacitance to be tested is placed between the terminals normally used for resistance measurements. The scale used in this case is the reciprocal scale, 100 μF to 1000 μF with 2000 μF and 5000 μF marked on it.

The test frequency is fixed and is the same as for the resistance measurements, i.e., 160 Hz. The test voltage is 10 mV at 100 μF and it is inversely proportional to the meter deflection. Finally, the accuracy is ±3% of reading at 100 μF, ±8% of reading at 500 μF and ±11% of reading at 1000 μF, $(Q_C>10)$.

Section B. Specifications

RESISTANCE

Range: 3 Ω to 1 MΩ f.s.d. in 12 ranges in a 1-3-10 sequence. First division at 0.1 Ω

Frequency: 160 Hz

Test voltage: 0-10 mV, proportional to meter deflection

Accuracy: ±2% of reading ±1% of f.s.d.

INDUCTANCE

Range: 3 µH to 100 H f.s.d. in 16 ranges in a 1-3-10 sequence. First division at 0.1 µH.

Frequency:

3 - 10 µH: 1.6 MHz

30 - 300 µH: 160 kHz

1 - 30 mH: 16 kHz

100 mH - 1 H: 1.6 kHz

3 - 100 H: 160 Hz

Test voltage 0-10 mV, proportional to meter deflection

Accuracy ($Q_L > 10$): ±2% of reading ±1% of f.s.d.

CAPACITANCE

Range: 3 pF to 100 µF f.s.d. in 16 ranges in a 1-3-10 sequence. First division at 0.1 pF. 100 µF to 1000 µF in one range, 2000 µF and 5000 µF marked on meter scale (reciprocal scale).

Frequency:

3 - 10 pF	1.6 MHz
30 - 300 pF:	160 kHz
1 - 30 nF:	16 kHz
100 nF - 1 µF:	1.6 kHz
3 - 100 µF:	160 Hz
100 - 1000 µF (2000 µF, 5000 µF)	160 Hz

Test voltage:

3 pF - 10 µF:	316 mV
30 - 100 µF:	100 mV
100 - 5000 µF:	10 mV at 100 µF, inversely proportional to meter deflection.

Accuracy ($Q_C > 10$):

3 pF - 100 µF	±2% of reading ±1% of f.s.d.
At 100 µF	±3% of reading
At 500 µF	±8% of reading
At 1000 µF	±11% of reading
DC BIAS	±60 V
RECORDER OUTPUT	-1 V at f.s.d., approx. 50 kΩ

POWER SUPPLY

Voltage:	110/220 V ±10%
Frequency:	50/60 Hz

DIMENSIONS

Height:	165 mm (6 1/2")
Width:	250 mm (10")
Depth:	190 mm (7 3/4")
WEIGHT:	3.2 kg (7 lbs.)

Section C. General Description

CIRCUIT FUNCTION

As can be seen on the simplified block diagram, the circuit of the RLC Meter, type MM2, can be divided essentially into five sections, as follows:

A Wien-bridge oscillator and an output amplifier.

A range section including the terminals for the connection of the component under test.

A regulating section consisting of a regulating amplifier, a rectifier and a dc amplifier.

A meter section including the meter amplifier and a rectifier bridge in which the meter is connected.

A reference section.

The Wien-bridge oscillator generates a test voltage the frequency of which is selected by the FUNCTION and RANGE switches. The test voltage from the oscillator is amplified by the output amplifier and fed into the range section and the component under test.

The design of the RLC Meter requires that the amplitude of the oscillator output (the test voltage) must be held constant. This is achieved by applying feedback to the oscillator in the form of a regulating voltage. The regulating voltage is derived from the oscillator output amplifier, amplified by the regulating amplifier, and passed to the rectifier. The rectified regulating voltage is again amplified in the dc amplifier and finally passed to the gate of a FET in the oscillator circuit. The choice of a FET at this point was made as it satisfies the requirements for instantaneous response and a continuous linear control of any variations in the oscillator output amplitude.

The test voltage is applied to the components of the range section and the component under test. The voltage present at the junction of the component under test and the components of the range section is fed to the meter amplifier which amplifies the voltage and passes it to a rectifier bridge circuit in which the meter is connected. A heavy degree of feedback is applied to the meter amplifier to ensure good stability and response. Included in the feedback network is a protection circuit which functions as a voltage limiter and guards against the effects of excess voltages in the meter circuit when, for example, the components under test are being changed out.

To compensate for the input impedance when measuring resistance, a compensation circuit is provided. This is formed

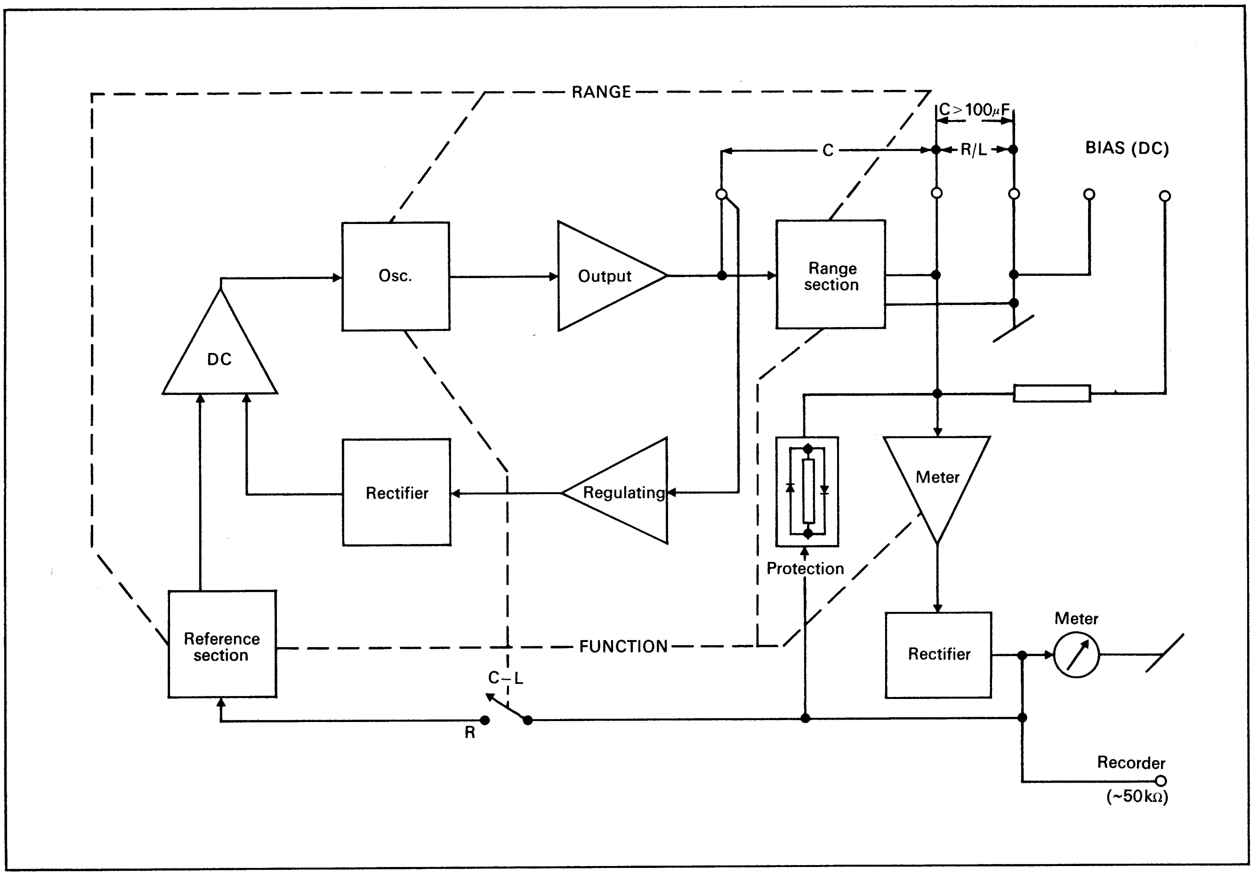


Fig.C1. Block Diagram of the RLC Meter, type MM2.

by taking an output from the meter circuit and passing it, via the reference section, to the dc amplifier following the regulating amplifier.

The reference section provides a stabilized reference voltage in a network of resistors and potentiometers whose circuit configurations are selected by the settings of both the RANGE and FUNCTION switches. The magnitude of the feedback to the dc amplifier is determined by combination of the reference voltages and, when measuring resistance, by the additional voltage from the meter circuit output.

Finally, provision is made for two external connections, as follows:

A termination for a recorder, the jacks of which are connected to the output of the meter circuit.

Bias jacks, provided for use when it is necessary to apply a dc bias to a component under test.

CONTROLS, TERMINALS AND METER

General

The RLC Meter, type MM2, is provided with the following controls, terminals and meter.

Controls, Front Terminals and Meter (See Fig.C2)

POWER Switch (1)

The switch POWER has a built-in indicator lamp, and is depressed to turn the instrument on or off.

FUNCTION Selector (2)

The selector FUNCTION is a three-position rotary switch for selection of the type of measurement to be made:

Position R, C >100 µF:

Resistance measurements
Capacitance measurements from 100 µF to 5000 µF

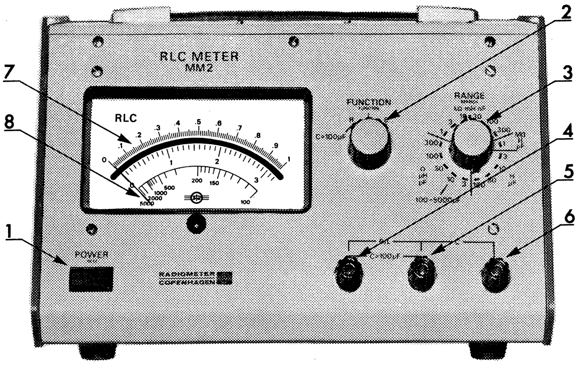


Fig.C2. Front Panel.

Position L:

Inductance measurements

Position C:

Capacitance measurements up to 100 µF

RANGE Selector (3)

The selector RANGE is a sixteen-position rotary switch for selection of the range within which measurements are to be performed.

R/L, C > 100 µF and C terminals (4, 5 and 6)

The R/L, C >100 µF and C terminals are binding posts. They are provided for the connection of the component under test to the instrument. Resistors, inductors, and capacitors >100 µF, are connected between the black binding post (4) and the red binding post (5). Capacitors up to 100 µF are connected between the two red binding posts (5) and (6).

Meter

The meter of the RLC Meter, type MM2, is of the taut-band suspension type. It is provided with three calibrated scales:

The upper scale (7) is calibrated from 0 to 1 and is used in the ranges where the full-scale deflection value is 1, 10 or 100. The centre scale is calibrated from 0 to 3 and is used in the ranges where the full-scale deflection value is 3, 30 or 300. The lower scale (8) is calibrated as a reciprocal scale from 100 to 5000 and is used for capacitance values between 100 µF and 5000 µF.

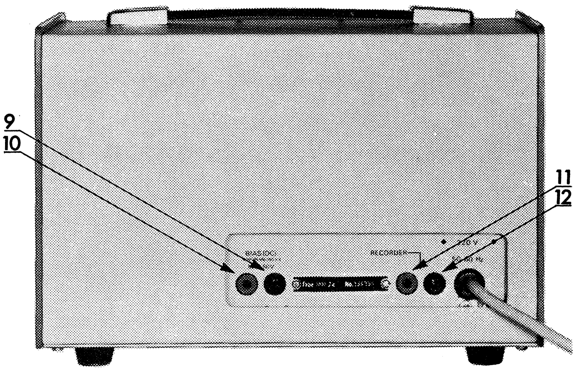


Fig.C3. Rear Panel.

Rear Terminals (See Fig.C3)

BIAS (DC) Terminals (9 and 10)

The terminals BIAS (DC) are two jacks for use when it is necessary to apply a dc bias voltage within the range -60 V to +60 V to the component under test. The black jack (9) is grounded.

RECORDER Terminals (11 and 12)

The terminals RECORDER are two jacks used to connect the instrument to a recorder. The black jack (12) is grounded.

Top Panel (See Fig.C4)

For convenience, two scales (13) are printed on the top panel of the instrument. They show the oscillator frequencies corresponding to the different positions of the FUNCTION and RANGE switches.

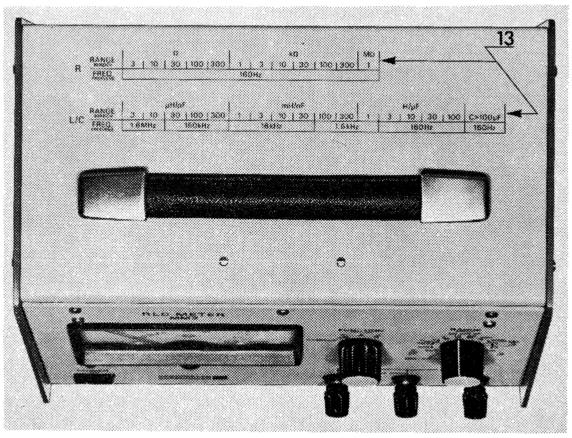


Fig.C4. Top Panel.

Section D. Operating Instructions

STEP-BY-STEP INSTRUCTIONS

1) Check that the instrument is connected for the line voltage available. (Printed one the line panel above the line cord grommet.) If not, connection should be made in accordance with the instructions printed on the printed circuit board, or reference made to the circuit diagram at the end of this manual.

2) Depress the POWER switch to switch on. The built-in lamp should light.

3) Set the FUNCTION switch to the type of measurement to be performed.

Note: As the MM2 performs impedance measurements, it is necessary to make sure that Q_L and Q_C are greater than 10.

4) Connect the component to be tested to the binding posts as follows:

a) Resistors between the black binding post (4) and the red binding post (5).

b) Inductors as for resistors.

c) Capacitors up to 100 µF in value, between the red binding posts (5) and (6).

d) Capacitors greater than 100 µF in value, between the binding posts (4) and (5), as for resistors.

5) Turn the RANGE switch until a deflection giving the best reading accuracy on the meter is obtained.

6) If it is necessary to apply a bias voltage to a capacitor under test, for example, when measuring varicaps, this should be applied to the BIAS (DC) jacks on the rear of the instrument. The bias voltage should not exceed ±60 V dc.

7) If long-term measurements are to be performed, a recorder may be connected to the RLC Meter. The RECORDER terminals on the rear of the instrument are provided for this purpose. The output is -1 V dc at full-scale deflection of the meter.

Note: When measurements on large-value resistors are to be made, it may be necessary to ground the black RECORDER jack on the rear of the instrument, or the black binding post on the front panel. If long connecting leads are used, these must be carefully shielded, the screen being connected at one point only - the black binding post on the front panel.

EXAMPLES AND CORRECTIONS

Resistance

The measurement of pure resistance presents no special problems, except perhaps at the higher values where it may be found necessary to ground the instrument. Where relatively long leads are to be used, careful screening of the leads is advisable. The screen should be grounded at the end nearest the RLC Meter (black binding post on the front panel).

Measurements of resistance in self-inductors is not generally recommended, but it can nevertheless be carried out with reasonable accuracy on high frequency coils.

The percentage error of the measurements can be found from the expression:

$$\Delta R_s \% = 1/2 \left(\frac{L}{R_s}\right)^2 \times 100$$

where: L is the self-inductance of the coil in mH

and R_s is the resistance of the coil winding in Ω.

Capacitance

Capacitance measurements in all ranges should present no difficulties.

In the 3 pF range care should be taken to reduce any stray capacitance between the component under test (including the test leads, etc.) and the instrument chassis.

Determination of the voltage/capacitance characteristics of variable capacity diodes may be made with the RLC meter in the following manner:

Connect the diode to be tested between the C-binding posts (5) and (6) on the front panel and apply the reversing voltage (V_R) to the BIAS (dc) jacks on the rear of the instrument.

The measurement of capacitance in a circuit (for example, the input capacitance of an instrument) can be made as shown in Fig.D1. The screen of the cable should be grounded at one point only, preferably at the end of the cable nearest to the RLC Meter (black binding post (4)). The self-capacitance of the cable should not be greater than 100 pF in the 3 pF and 10 pF ranges, and not greater than 1 nF in the remaining ranges.

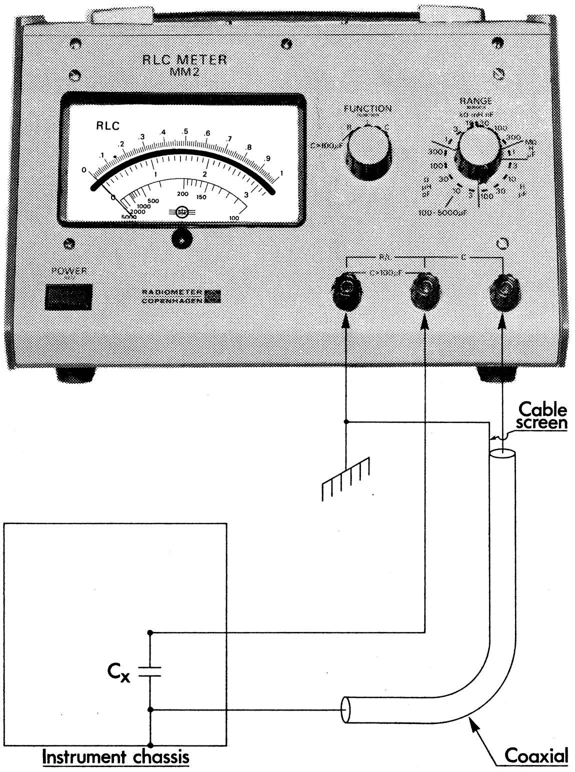


Fig.D1. Arrangement for the measurement of, for example, the input capacitance of an instrument.

Inductance

If the inductance to be measured has to be connected to the RLC Meter by means of a screened cable, it should be borne in mind that the inductance is paralleled by the cable capacitance. This results in a loss in measuring accuracy. To maintain the stated accuracy of the MM2, it is necessary to keep the cable capacitance under about 10 pF.

Section E. Circuit Description

GENERAL

A circuit diagram, No.1230A1, of the RLC Meter, type MM2, to which this description refers, is included at the end of this manual.

OPERATING PRINCIPLE

Oscillator

The oscillator in the RLC Meter is based on an R/C circuit of the Wien-bridge type and built-up around the three transistors Q107, Q108 and Q109. The frequency of the oscillator is determined by the R/C components forming the arms of the Wien-bridge in the oscillator section.

The configuration of these components is selected by the settings of the FUNCTION and RANGE switches.

Table E1 shows the operating frequencies in relation to the FUNCTION and RANGE switch settings.

A FET, Q106, is connected in the feedback circuit of the oscillator and forms a voltage divider with R133. It is connected in parallel with the components of the oscillator section and functions, in effect, as a potentiometer to provide an instantaneous and linear regulation of the oscillator output amplitude in response to the feedback from the regulating amplifier. To prevent swamping effects on the oscillator, due to excessive feedback levels when the instrument is switched on or when the RANGE switch is operated, a limiter consisting of CR120 and CR121 is connected across R133. During normal operation the diodes will be non-conducting, but when excess feedback appears across R133, they will conduct and limit the value of the feedback, ensuring that the oscillator recovery time is kept extremely short.

The zener diode, CR111, and R137 provide stabilization for the oscillator and reduce the effects of line voltage variation on the oscillator frequency.

The oscillator output is passed from the emitter circuit of Q109 to the oscillator output amplifier Q110. This amplifier acts as a buffer, isolating the effects of the component under test on the oscillator frequency.

The diode CR112 is included in the output circuit of Q110 and functions as a voltage limiter to protect Q110 against the effects of excess voltage, when, for example, the component under test is changed out.

Regulation

The circuit design of the RLC Meter, type MM2, requires that the amplitude of the oscillator output (the test voltage) shall be held constant to within

<table>
<tr><th rowspan="3">FUNCTION
SELECTED</th><th colspan="17">RANGE SELECTED</th></tr>
<tr><th colspan="5">Ω, μH, pF</th><th colspan="6">kΩ, mH, nF</th><th colspan="6">MΩ, H, μF</th></tr>
<tr><th>3</th><th>10</th><th>30</th><th>100</th><th>300</th><th>1</th><th>3</th><th>10</th><th>30</th><th>100</th><th>300</th><th>1</th><th>3</th><th>10</th><th>30</th><th>100</th><th>C>100μF</th></tr>
<tr><td>R</td><td colspan="12">$F^{(1)}$=160Hz $V^{(2)}$=316mV</td><td colspan="5"></td></tr>
<tr><td rowspan="2">L</td><td colspan="2">$F^{(1)}$=
1.6MHz</td><td colspan="3">160kHz</td><td colspan="4">16kHz</td><td colspan="3">1.6kHz</td><td colspan="4">160Hz</td><td rowspan="2"></td></tr>
<tr><td colspan="16">$V^{(2)}$=316mV</td></tr>
<tr><td rowspan="2">C</td><td colspan="2">$F^{(1)}$=
1.6MHz</td><td colspan="3">160kHz</td><td colspan="4">16kHz</td><td colspan="3">1.6kHz</td><td colspan="5">160Hz</td></tr>
<tr><td colspan="14">$V^{(2)}$=316mV</td><td colspan="2">$V^{(2)}$=100mV</td><td>$V^{(2)}$=10mV$^{(3)}$</td></tr>
</table>

(1) F is the oscillator frequency

(2) V is the amplitude value of the oscillator output delivered to the component and held constant by the regulating circuit.

(3) At 100 μF, decreasing in value towards the higher capacitance values.

TABLE E1.

close limits. This is achieved by passing a feedback from the oscillator output via a regulating circuit back to the FET, Q106, in the oscillator feedback circuit.

The regulating circuit consists of an amplifier (regulating amplifier), a rectifier and a dc amplifier, which includes a "quick-recovery" diode network in its output circuit.

The feedback to the input of the regulating amplifier is taken from a point in the circuit (J3 - the red binding post (6) on the front panel) to which the component under test and the range selection components are connected. This results in high stability of the oscillator output amplitude and assists appreciably in the accuracy of the instrument.

The input stage of the regulating amplifier consists of the complementary pair of transistors Q100 and Q101. Diodes CR100 and CR101, which are biased by CR102 and R114, provide a voltage limiter for the protection of Q100 against the effects of excess voltage, when, for example, the component under test is changed out.

Q101 is dc coupled from its emitter to the base of Q102. Q102 passes the amplified feedback into the rectifer circuit of CR105/CR106, which includes the transistor Q103. Q103 is an integral part of the rectifier circuit, providing it with an active and stable load. CR104 is included to balance out the impedance effects of Q103 in the rectifier circuit. The rectified output is then fed from the collector of Q103 across R122 to the base of the dc amplifier Q104. The base of Q104 is connected at the junction of two opposite currents. The first derived from Q103 (feedback current), and the second from the reference section (reference current). The base circuit of Q104 functions in such a way that when the two currents are equal it will be in a 0-volt condition, and no regulation will be passed to the FET, Q106, in the oscillator circuit. The amplitude of the oscillator output may then be said to be quiescent.

In practice, the probability of this state of perfect balance at the base of Q104 is likely to be rare, and there will always be some feedback, however small. Any out-of-balance of the dc currents at the base of Q104 is amplified by the dc coupled complementary pair of transistors Q104 and Q105. The output from this dc amplifier appears across R124 and is then fed into the four-diode "quick-recovery" network (CR107 through CR110). R127 connected across this circuit provides a high-resistance connection for signals of values below that of the conducting point of the diodes CR107 and CR110. The conducting point of these diodes is determined by the amount to which they are biased. This bias is derived from the other two diodes, CR108 and CR109. Should the oscillator output undergo a large variation, for example when switching ranges, a correspondingly large feedback will occur, producing a large out-of-balance condition at the base of Q104. This will, in turn, cause the feedback voltage across the diodes CR107 and CR110 to exceed the bias voltage. They will then conduct and provide a low impedance path for the feedback by shunting R127. The result will be a relatively large feedback potential at the gate of the FET, Q106. When the restoration of the oscillator output amplitude has been partly completed, the feedback potential across the diodes CR107 and CR110 will fall until it is less than their bias voltage, and they will then cease to conduct. The final restoration of the oscillator output amplitude will then continue at a lower level of feedback potential, due to the higher impedance of R127.

Reference section

The reference section provides a reference voltage for the base of Q104 in the regulating amplifier circuit. The reference voltage is derived from a stabilized source consisting of the zener diode CR103 and R108. The voltage is taken from the junction of CR103 and R108 and fed into a network of resistors and potentiometers which forms the reference section.

The configurations of the reference section network are determined by the settings of the FUNCTION and RANGE switches. The potentiometers make it possible to preset the reference voltage levels required by the settings of the RANGE and FUNCTION switches so that an appropriate reference voltage level is available at the base of Q104 for each combination of the RANGE and FUNCTION switch settings.

When switched to the resistance ranges, an additional feedback voltage is connected to the reference section from the meter circuit. It is taken from R167 and passed to the reference section via the stand-off resistor R169. This arrangement compensates for the input impedance of the RLC Meter when measuring resistance.

Range and Meter sections

The range section components, which are selected by the settings of the FUNCTION and RANGE switches, form a voltage divider with the component under test. The RLC Meter, in fact, measures the impedance of the component under test. With the exception of some special cases, this method does not influence the accuracy of the measurements. The special circumstances are dealt with in the section Operating Instructions under the heading Examples and Corrections.

The voltage present at the junction of the component under test and the components of the range section is fed to the meter amplifier. The input circuit of the meter amplifier consists of a unity-gain amplifier Q111 and Q113. Q111 is dc coupled from its drain circuit to the base of Q113 and functions as an input potentiometer providing an instantaneous and stable response with the feedback applied to its gate from the meter circuit. Q112 connected in the emitter circuit of Q113 functions as a complementary and active emitter load. The base potential of Q112 is set by the voltage divider R149 and R150 and decoupled by C112. The amplified voltage is then passed from the collector of Q113 to the amplifier consisting of Q114, Q115 and Q116. This amplifier provides further amplifications and feeds the output into the rectifier bridge circuit in which the meter is connected. Feedback to the FET Q111 and the amplifier (Q114, Q115 and Q116) is taken from the low impedance side of the rectifier bridge and fed across R152 to the gate of Q111. R152 is shunted by two reverse connected diodes CR113 and CR114. These diodes function as a voltage limiter and protect both the FET and the meter against the effects of excess voltage, when, for example, the component under test is changed out. The rectified output from the bridge circuit is fed to the meter in series with the resistors R164 and R167. The voltage developed across R167 provides the feedback to the reference section when measuring resistance. A connection for a recorder is also taken from R167 and is fed via R168 to the RECORDER jacks.

Power supply

The power supply circuit consists of a conventional full-wave rectifier. The output is connected to form a split potential supply of +24 V, 0, - 24 V. Either half of the supply is stabilized separately by the series transistors Q117 and Q118. The base potentials of these transistors are regulated by the zener diodes, CR117 and CR118, respectively.

The line transformer is protected against overheating, etc., by a thermal cut-out connected in the primary circuit.

The lamp I1, built into the POWER switch, provides an indication that the instrument is switched on.

Section F. Parts List

In the following parts list a group code prefix number is used. To facilitate the use of this code, the different types of parts and their corresponding group code prefix are listed below:

Standard resistors	100- to 139-
Precision resistors	140- to 152-
Non-linear resistors	160-
UHF resistors	170- to 172-
Carbon potentiometers	180- to 185-
Wire-wound potentiometers	190- to 195-
Mica capacitors	200- to 208-
Ceramic capacitors	210- to 214-
Paper capacitors	220- to 222-
Metal-paper capacitors	224- to 229-
Plastic capacitors	240- to 245-
Electrolytic capacitors	260- to 267-
Variable capacitors	280- to 286-
Special tubes	310-
Rectifiers	340- to 341-
Diodes	350-
Transistors	360-
Integrated circuits	364-
Lamps, batteries, fuses	400- to 486-
Switches	500- to 580-
Coils, coil material and transformers	700- to 785-

As we are continually improving our instruments, it is important, when ordering spare parts, that you include the following information:

The code number and description of the part.

The circuit reference from the wiring diagram.

The complete type designation of your instrument.

The serial number of your instrument.

Please note that the position of any part can easily be found by referring to the last column of the parts list. This indicates on which figure the part can be located.

$^+$Indicates special parts made by Radiometer.

MAIN PARTS LIST

LAMPS

Designation	Type	Code No.
I1	lamp, 24 V 0.02 A	400-902

TERMINALS

Designation	Type	Code No.
J1	terminal, insulated, black	807-031
J2	terminal, insulated, red	807-032
J3	terminal, insulated, red	807-032
J102	telephone jack, insulated, red	803-205
J103	telephone jack, insulated, black	803-205
J104	telephone jack, insulated, black	803-205
J105	telephone jack, insulated, yellow	803-207

METER

Designation	Type	Code No.
M1	meter with scale	482-146

RESISTORS

Designation	Type	Value	Code No.
R1	carbon film	4.7 kΩ 5% 0.2 W	106-447

SWITCHES

Designation	Type	Code No.
S1	rotary switch, "FUNCTION"	551-018
S2	press switch, 2-pole with lamp, "POWER"	501-000
S200	rotary switch, "RANGE"	551-017

CABLES

Designation	Type	Code No.
W1	coaxial cable, 50 Ω RG196/U	600-014
W2	coaxial cable, 50 Ω RG196/U	600-014
W3	coaxial cable, 50 Ω RG196/U	600-014
	(total length of W1 through W3 = 0.81 m)	
W100	line cord with plug for 220 V	615-005
W100	line cord with plug for 115 V	615-101

MISCELLANEOUS

Type	Code No.
knob, ϕ21 mm, black	852-613
knob with pointer, ϕ21 mm, black	852-619
plastic cap for ϕ21 mm knob, grey	852-602
rubber foot	855-001

MAIN PRINTED CIRCUIT BOARD

CAPACITORS

Designation	Type	Value	Code No.	Shown in Fig.
C100	polyester	1 µF 10% 63 V	241-027	F-1
C101	tantalum	100 µF -20 +50% 3 V	267-011	F-1
C102	tantalum	10 µF -20 +50% 15 V	267-000	F-1
C103	polystyrene	400 pF 5% 160 V	243-040	F-1
C104	tantalum	22 µF ±20% 15 V	266-006	F-1
C105	polystyrene	200 pF 5% 160 V	243-001	F-1
C106	ceramic	47 nF -20 +80% 30 V	213-016	F-1
C107	polyester	2.2 µF ±10% 63 V	241-031	F-1
C108	polycarbonate	10 µF ±20% 63 V	242-003	F-1
C109	ceramic	220 pF 5%	211-322	F-1
C110	ceramic	2.2 nF -20 +80% 25 V	213-012	F-1

C111	polyester	2.2 μF ±10% 63V	241-031	F-1
C112	tantalum	10 μF -20 +50% 15 V	207-000	F-1
C113	tantalum	100 μF -20 +50% 3 V	267-011	F-1
C114	ceramic	1 pF ±0.25 pF	210-110	F-1
C115	tantalum	10 μF -20 +50% 15 V	267-000	F-1
C116	tantalum	47 μF -20 +50% 6 V	267-012	F-1
C117	tantalum	10 μF -20 +50% 15 V	267-000	F-1
C118	polycarbonate	10 μF ±20% 63 V	242-003	F-1
C119	tantalum	10 μF -20 +50% 15 V	267-000	F-1
C120	polyester	0.1 μF ±10% 100 V	241-025	F-1
C121	ceramic	2.2 pF ±10%	211-122	F-1
C122	tantalum	47 μF -20 +50% 6 V	267-012	F-1
C123	tantalum	10 μF -20 +50% 15 V	267-000	F-1
C124	tantalum	10 μF -20 +50% 15 V	267-000	F-1
C125	tantalum	100 μF -20 +50% 3 V	267-011	F-1
C126	ceramic	10 pF 5%	210-210	F-1
C127	tantalum	22 μF ±20% 15 V	266-006	F-1
C128	tantalum	10 μF -20 +50% 15 V	267-000	F-1
C129	tantalum	20 μF -20 +50% 6 V	267-001	F-1
C130	tantalum	10 μF -20 +50% 15 V	267-000	F-1
C131	ceramic	0.1 μF -20 +80% 30 V	213-009	F-1
C132	electrolytic	250 μF 35 V	261-041	F-1
C133	electrolytic	250 μF 35 V	261-041	F-1
C134	ceramic	0.1 μF -20 +80% 12 V	213-017	F-1
C135	tantalum	1 μF -20 +50% 15 V	267-006	F-1

DIODES

Designation	Type	Code No.	Shown in Fig.
CR100	diode BAV10	350-022	F-1
CR101	diode BAV10	350-022	F-1
CR102	diode BAX16	350-023	F-1
CR103	zener diode BZY88 C5 V6	350-629	F-1
CR104	diode BAX16	350-023	F-1
CR105	diode IN5220	350-028	F-1
CR106	diode IN5220	350-028	F-1

CR107	diode BAX16	350-023	F-1
CR108	diode BAX16	350-023	F-1
CR109	diode BAX16	350-023	F-1
CR110	diode BAX16	350-023	F-1
CR111	zener diode BZY88 C3V6	350-626	F-1
CR112	diode BAX16	350-023	F-1
CR113	diode BAV10	350-022	F-1
CR114	diode BAV10	350-022	F-1
CR115	diode HD5004	350-017	F-1
CR116	diode HD5004	350-017	F-1
CR117	zener diode BZY94 C12	350-605	F-1
CR118	zener diode BZY94 C12	350-605	F-1
CR119	rectifier B280 C700	340-204	F-1
CR120	diode BAV10	350-022	F-1
CR121	diode BAV10	350-022	F-1

TRANSISTORS

Designation	Type	Code No.	Shown in Fig.
Q100	transistor IN4126	360-082	F-1
Q101	transistor BC149	360-072	F-1
Q102	transistor BC149	360-072	F-1
Q103	transistor BC159	360-085	F-1
Q104	transistor 2N930	360-038	F-1
Q105	transistor BC159	360-085	F-1
Q106	transistor SI236N	360-096	F-1
Q107	transistor 2N5087	360-087	F-1
Q108	transistor BF173	360-095	F-1
Q109	transistor BC149	360-072	F-1
Q110	transistor 2N1711	360-047	F-1
Q111	transistor 2N4303	360-089	F-1
Q112	transistor BC149	360-072	F-1
Q113	transistor 2N4126	360-082	F-1
Q114	transistor BC149	360-072	F-1
Q115	transistor BC149	360-072	F-1

Q116	transistor 2N4126		360-082	F-1
Q117	transistor 2N1711		360-047	F-1
Q118	transistor 2N2905A		360-073	F-1

RESISTORS

Designation	Type	Value	Code No.	Shown in Fig.
R100	carbon pot	5 kΩ 0.1 W	182-032	F-1
R101	carbon film	3.9 kΩ 5% 0.2 W	106-439	F-1
R102	metal film	31.6 kΩ 1% 0.1 W	140-484	F-1
R103	metal film	110 kΩ 1% 0.125 W	140-509	F-1
R104	carbon pot	5 kΩ 0.1 W	182-032	F-1
R105	carbon pot	10 kΩ 0.1 W	182-033	F-1
R106	carbon pot	5 kΩ 0.1 W	182-032	F-1
R107	metal film	34.8 kΩ 1% 0.125 W	140-486	F-1
R108	carbon film	1 kΩ 5% 0.2 W	106-410	F-1
R109	carbon film	1.5 kΩ 5% 0.2 W	106-415	F-1
R110	carbon film	3.3 kΩ 5% 0.2 W	106-433	F-1
R111	carbon film	22 kΩ 5% 0.2 W	106-522	F-1
R112	carbon film	150 Ω 5% 0.2 W	106-315	F-1
R113	carbon film	114 Ω 5% 0.2 W	106-310	F-1
R114	carbon film	15 kΩ 5% 0.2 W	106-515	F-1
R115	carbon film	22 kΩ 5% 0.2 W	106-522	F-1
R116	carbon film	3.3 kΩ 5% 0.2 W	106-433	F-1
R117	metal film	1 kΩ 1% 0.1 W	140-477	F-1
R118	carbon film	10 kΩ 5% 0.2 W	106-510	F-1
R119	carbon film	5.6 kΩ 5% 0.2 W	106-422	F-1
R120	carbon film	2.2 kΩ 5% 0.2 W	106-422	F-1
R121	carbon film	10 Ω 5% 0.2 W	106-210	F-1
R122	carbon film	3.9 kΩ 5% 0.2 W	106-439	F-1
R123	carbon film	220 kΩ 5% 0.2 W	106-622	F-1
R124	carbon film	5.6 kΩ 5% 0.2 W	106-456	F-1
R125	carbon film	470 Ω 5% 0.2 W	106-347	F-1
R126	carbon film	4.7 kΩ 5% 0.2 W	106-447	F-1
R127	carbon film	5.6 MΩ 5% 0.2 W	100-756	F-1
R128	carbon film	100 kΩ 5% 0.2 W	106-610	F-1

R129	carbon film	39 Ω 5% 0.2 W	106-239	F-1
R130	carbon film	560 kΩ 5% 0.2 W	106-656	F-1
R131	carbon film	39 Ω 5% 0.2 W	106-239	F-1
R132	metal film	1.02 kΩ 1% 0.1 W	140-482	F-1
R133	carbon film	3.3 kΩ 5% 0.2 W	106-433	F-1
R134	carbon film	3.3 kΩ 5% 0.2 W	106-433	F-1
R135	carbon film	1 kΩ 5% 0.2 W	106-410	F-1
R137	carbon film	2.7 kΩ 5% 0.2 W	106-427	F-1
R138	carbon film	8.2 kΩ 5% 0.2 W	106-482	F-1
R139	carbon film	5.6 kΩ 5% 0.2 W	106-456	F-1
R140	carbon film	8.2 kΩ 5% 0.2 W	106-482	F-1
R141	carbon film	39 Ω 5% 0.2 W	106-239	F-1
R142	carbon film	470 Ω 5% 0.2 W	106-347	F-1
R143	carbon film	1.8 kΩ 5% 0.2 W	106-418	F-1
R144	carbon film	330 Ω 5% 0.2 W	106-333	F-1
R145	carbon film	56 Ω 5% 0.2 W	106-256	F-1
R146	carbon film	39 Ω 5% 0.2 W	106-239	F-1
R147	carbon film	47 kΩ 5% 0.2 W	106-447	F-1
R148	carbon film	1.2 kΩ 5% 0.2 W	106-412	F-1
R149	carbon film	680 Ω 5% 0.2 W	106-368	F-1
R150	carbon film	2.7 kΩ 5% 0.2 W	106-427	F-1
R151	carbon film	2.2 kΩ 5% 0.2 W	106-422	F-1
R152	carbon film	5.6 MΩ 5% 0.2 W	100-756	F-1
R153	carbon film	10 kΩ 5% 0.2 W	106-510	F-1
R154	carbon film	330 Ω 5% 0.2 W	106-333	F-1
R155	carbon film	22 kΩ 5% 0.2 W	106-522	F-1
R156	carbon film	1.8 kΩ 5% 0.2 W	106-418	F-1
R157	carbon film	10 Ω 5% 0.2 W	106-210	F-1
R158	carbon film	39 kΩ 5% 0.2 W	106-539	F-1
R159	carbon film	18 kΩ 5% 0.2 W	106-518	F-1
R160	carbon film	2.7 kΩ 5% 0.2 W	106-427	F-1
R161	carbon film	39 kΩ 5% 0.2 W	106-239	F-1
R162	metal film	10 Ω 5% 0.1 W	140-478	F-1
R163	carbon film	82 Ω 5% 0.2 W	106-282	F-1
R164	carbon film	680 Ω 5% 0.2 W	106-368	F-1
R165	carbon film	39 Ω 5% 0.2 W	106-239	F-1

R166	carbon film	5.6 kΩ 5% 0.2 W	106-456	F-1
R167	carbon film	2.7 kΩ 5% 0.2 W	106-427	F-1
R168	carbon film	47 kΩ 5% 0.2 W	106-547	F-1
R169	carbon film	220 kΩ 5% 0.2 W	106-622	F-1
R170	carbon film	5.6 kΩ 5% 0.2 W	106-456	F-1
R171	carbon film	10 kΩ 5% 0.2 W	106-510	F-1
R172	carbon film	18 kΩ 5% 0.2 W	106-518	F-1

SWITCH PRINTED CIRCUIT BOARD

CAPACITORS

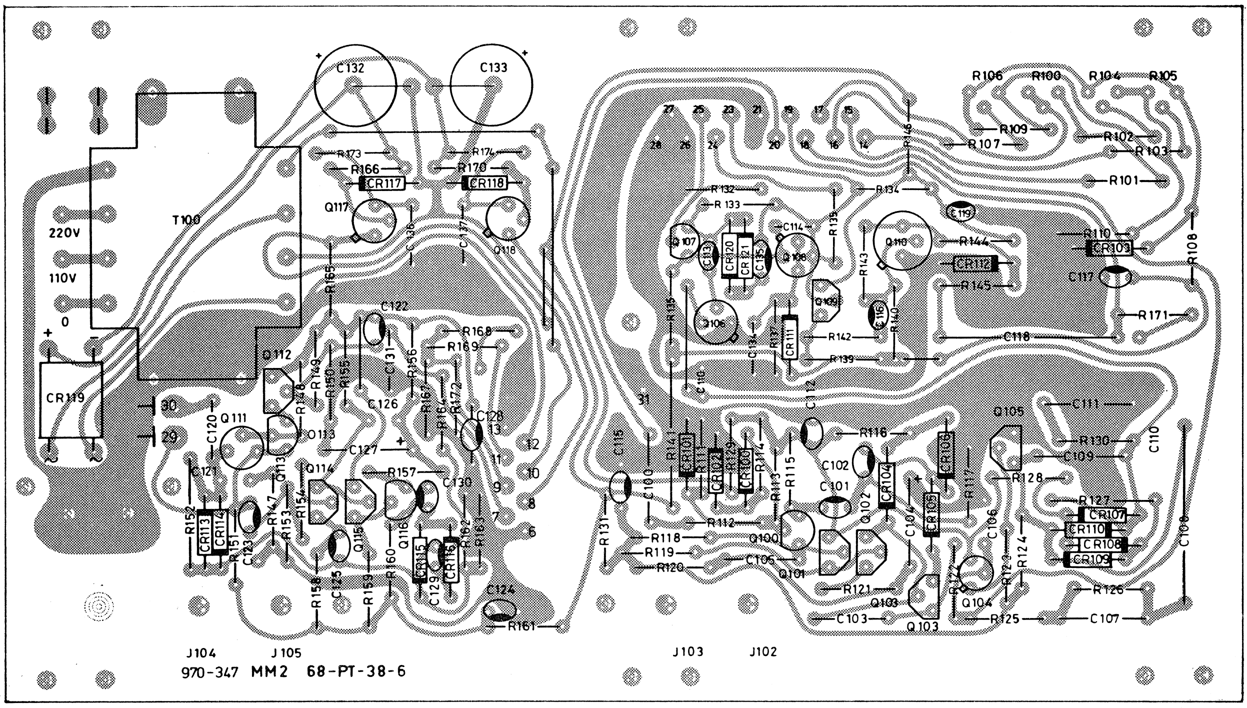
Designation	Type	Value	Code No.	Shown in Fig.
C200	ceramic	47 pF ±5%	210-247	F-2
C202	polystyrene	50 pF ±5% 630 V	243-023	F-2
C203	polystyrene	935 pF ±2% 630 V	243-055	F-2
C204	polystyrene	10 nF ±1% 63 V	243-020	F-2
C205	polycarbonate	0.1 μF ±1% 63 V	242-006	F-2
C206	polycarbonate	1 μF ±1% 63 V	242-007	F-2
C207	ceramic	68 pF ±5%	210-268	F-2
C208	ceramic	6.8 pF ±0.5 pF	210-168	F-2
C209	polystyrene	50 pF ±5% 630 V	243-023	F-2
C210	polystyrene	935 pF ±2% 630 V	243-055	F-2
C211	polystyrene	10 nF ±1% 63 V	243-020	F-2
C212	polycarbonate	0.1 μF ±1% 63 V	242-006	F-2
C213	polycarbonate	1 μF ±1% 63 V	242-007	F-2
C214	ceramic	10 pF ±5%	211-210	

INDUCTORS

Designation	Type	Value	Code No.	Shown in Fig.
L200	HF choke	22 μH ±10%	703-012	

RESISTORS

Designation	Type	Value	Code No.	Shown in Fig.
R200	carbon pot	1 kΩ 0.1 W	182-030	F-2
R201	carbon pot	250 Ω 0.1 W	182-039	F-2
R202	carbon pot	250 Ω 0.1 W	182-039	F-2
R203	carbon pot	250 Ω 0. 1 W	182-039	F-2
R204	carbon pot	250 Ω 0.1 W	182-039	F-2
R205	metal film	100 Ω 0.5% 0.125 W	140-551	
R206	metal film	316 Ω 0.5% 0.125 W	140-552	
R207	metal film	1 kΩ 0.5% 0.125 W	140-444	
R208	metal film	3.16 kΩ 0.5% 0.125 W	140-448	
R209	metal film	10 kΩ 0.5% 0.125 W	140-450	
R210	metal film	31.6 kΩ 0.5% 0.125 W	140-484	
R211	metal film	100 kΩ 0.5% 0.125 W	140-553	
R212	carbon film	316 kΩ 0.5% 0.25 W	143-036	
R213	carbon film	1 MΩ 0.5% 0.25 W	143-037	
R214	carbon film	3.16 MΩ 1% 0.25 W	143-034	
R215	carbon film	10 MΩ 1% 0.5 W	143-008	F-2
R216	carbon film	10 MΩ 1% 0.5 W	143-008	F-2
R217	carbon film	10 MΩ 1% 0.5 W	143-008	F-2
R218	carbon film	1.5 MΩ 1% 0.5 W	100-715	F-2
R219	metal film	1 kΩ 0.5% 0.15 W	140-444	F-2
R220	metal film	3.16 kΩ 0.5% 0.125 W	140-448	
R221	metal film	10 kΩ 0.5% 0.125 W	140-450	
R222	metal film	31.6 kΩ 0.5% 0.125 W	140-484	
R223	metal film	100 kΩ 0.5% 0.125 W	140-553	F-2
R224	carbon film	316 kΩ 0.5% 0.25 W	143-036	
R225	carbon film	1 MΩ 0.5% 0.25 W	143-037	
R226	metal film	1 kΩ 0.5% 0.125 W	140-444	
R227	metal film	316 Ω 0.5% 0.125 W	140-552	
R228	metal film	100 Ω 0.5% 0.125 W	140-551	
R229	metal film	31.6 Ω 0.5% 0.125 W	140-479	
R230	metal film	10 Ω 0.5% 0.125 W	140-478	
R231	wire-wound	3.16 Ω 0.5% 0.5 W	135-002	
R232	wire-wound	1 Ω 0.5% 0.5 W	135-001	
R233	metal film	1 kΩ 1% 0.1 W	140-477	


C132
C133
T100
220V
110V
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CR119
CR117
CR118
Q117
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Q111
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Q116
Q100
Q101
Q102
Q103
Q104
Q105
Q106
Q107
Q108
Q109
Q110
CR100
CR101
CR102
CR103
CR104
CR105
CR106
CR107
CR108
CR109
CR110
CR111
CR112
CR113
CR114
CR115
CR116
CR120
CR121
R100
R101
R102
R103
R104
R105
R106
R107
R108
R109
R110
C118
C111
C110
C109
C108
C107
C103
C105
C124
C127
R161
J104
J105
J103
J102
970-347 MM2 68-PT-38-6

Fig. F1

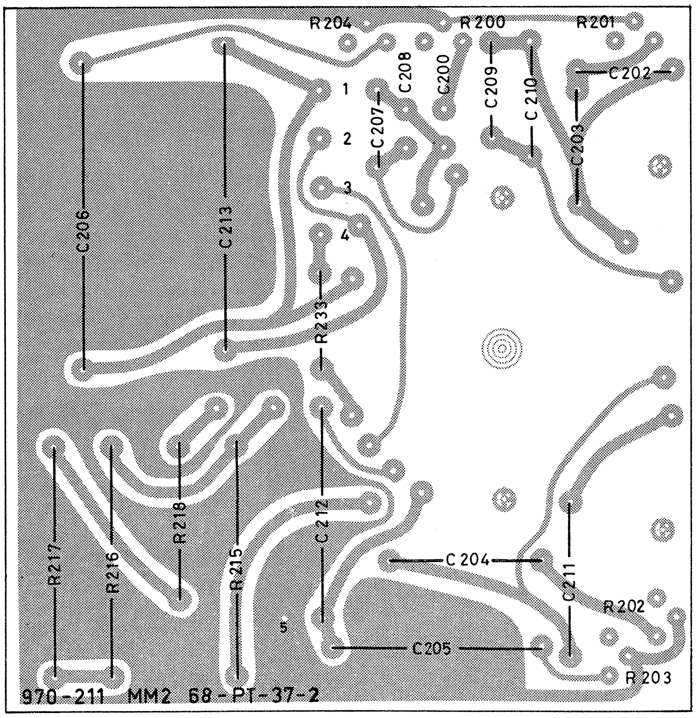
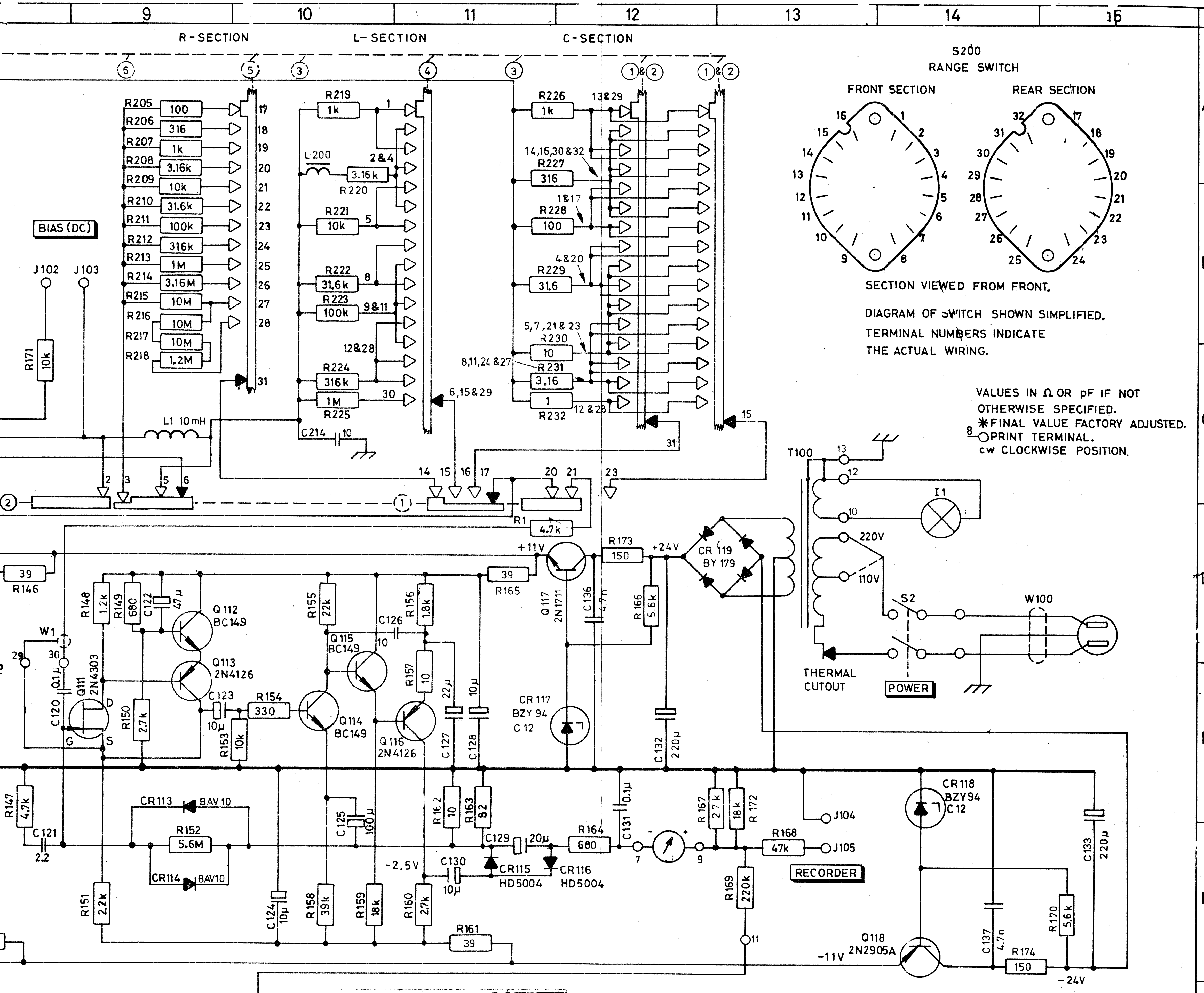

R204
R200
R201
C202
C203
C208
C200
C209
C210
C207
C206
C213
R233
1
2
3
4
5
C212
R217
R216
R218
R215
C204
C211
R202
C205
R203
970-211 MM2 68-PT-37-2

Fig. F2



SECTION VIEWED FROM FRONT.

DIAGRAM OF SWITCH SHOWN SIMPLIFIED.
TERMINAL NUMBERS INDICATE
THE ACTUAL WIRING.

VALUES IN Ω OR pF IF NOT
OTHERWISE SPECIFIED.
✱FINAL VALUE FACTORY ADJUSTED.
8○PRINT TERMINAL.
cw CLOCKWISE POSITION.

METER AMPLIFIER

RADIOMETER COPENHAGEN

This drawing [illegible] ary person [illegible] ceive it, [illegible] use of by [illegible]

12		10.3.72	MSø		PL
11	185046	12.8.71	SHM		PK
15	235164	1-10-74	BLØ		
14	213298	1.8.73	OH		
13	189181	3.1.73	BG.		
Ut.Nr.	Fra Fab. Nr.	Dato	Rt. af	Kont.	Norm.

RADIOMETER COPENHAGEN
72 EMDRUPVEJ NV

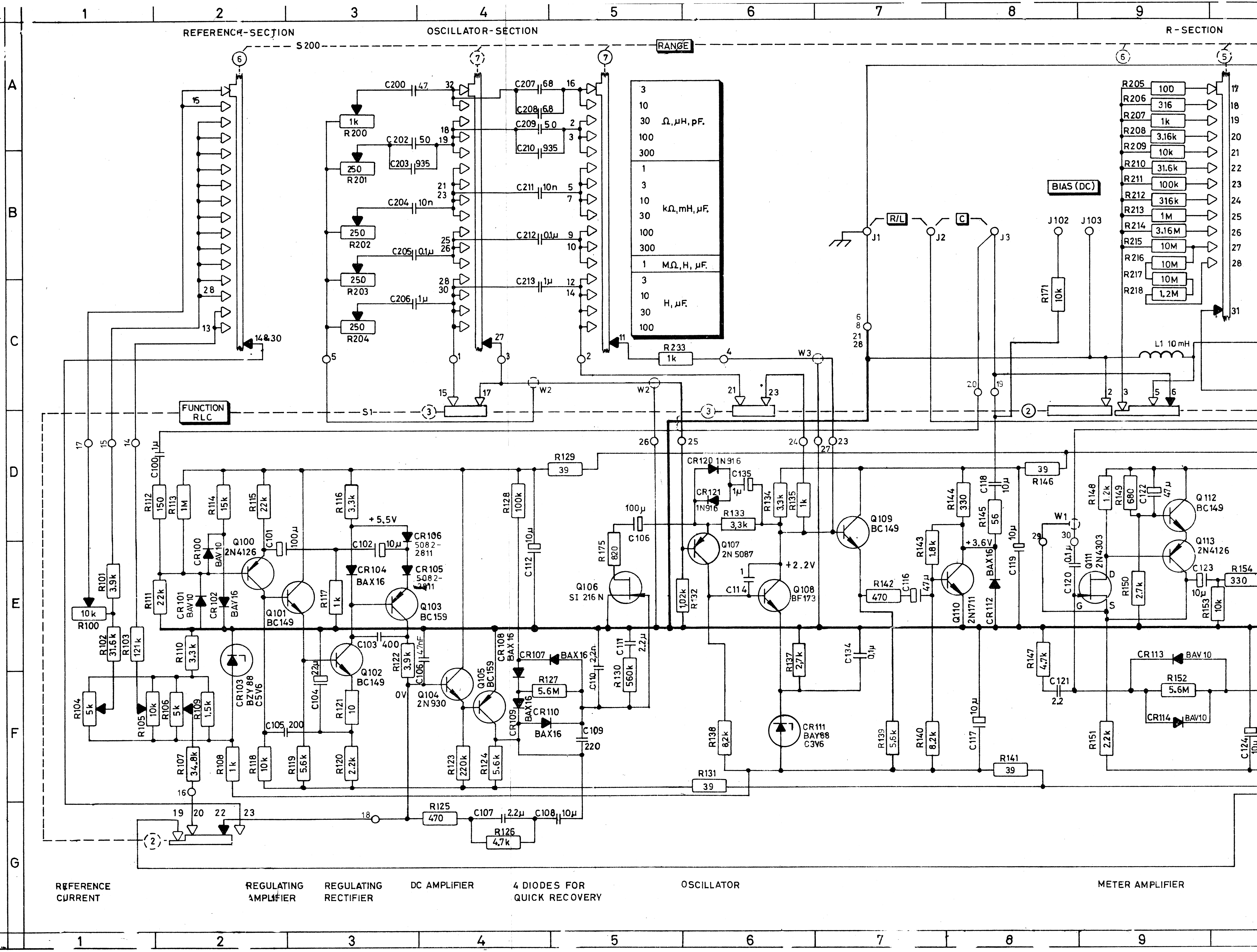
RLC-METER
TYPE TYPE MM2a
From no. to no.

Malestok	Tegn.	AT	17.10.68
	Konf.		
	Norm.		

Erstatter

1230-A1

Erstattes af


1
2
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A
B
C
D
E
F
G
REFERENCE-SECTION
OSCILLATOR-SECTION
R-SECTION
S 200
RANGE
3
10
30
100
300
Ω, μH, pF.
1
3
10
30
100
300
kΩ, mH, μF.
1
MΩ, H, μF.
3
10
30
100
H, μF.
C200 47
R200 1k
C202 50
C203 935
R201 250
C204 10n
R202 250
C205 0,1μ
R203 250
C206 1μ
R204 250
C207 68
C208 68
C209 50
C210 935
C211 10n
C212 0,1μ
C213 1μ
R233 1k
W3
W2
R/L
C
J1
J2
J3
J102
J103
BIAS (DC)
R171 10k
L1 10 mH
R205 100
R206 316
R207 1k
R208 3,16k
R209 10k
R210 31,6k
R211 100k
R212 316k
R213 1M
R214 3,16M
R215 10M
R216 10M
R217 10M
R218 1,2M
FUNCTION RLC
S1
C100 1μ
R112 150
R113 1M
R114 15k
R115 22k
R116 3,3k
+5,5V
Q100 2N4126
C101 100μ
C102 10μ
CR106 5082-2811
CR104 BAX16
CR105 5082-2811
CR100 BAV10
CR101 BAV10
CR102 BAY16
R111 22k
Q101 BC149
R117 1k
Q103 BC159
R101 3,9k
R100 10k
R102 31,6k
R103 121k
R110 3,3k
CR103 BZY88 C5V6
C103 400
Q102 BC149
R122 3,9k
C106 4,7nF
C104 22μ
R121 10
0V
C105 200
R104 5k
R105 10k
R106 5k
R109 1,5k
R107 34,8k
R108 1k
R118 10k
R119 5,6k
R120 2,2k
R123 220k
R124 5,6k
Q104 2N930
Q105 BC159
R128 100k
C112 10μ
R129 39
CR108 BAX16
CR107 BAX16
R127 5.6M
CR109 BAX16
CR110 BAX16
C110 2,2n
R130 560k
C111 2,2μ
C109 220
R125 470
C107 2,2μ
C108 10μ
R126 4,7k
R175 820
C106 100μ
Q106 SI 216 N
CR120 1N916
CR121 1N916
C135 1μ
R133 3,3k
R134 3,3k
R135 1k
Q107 2N5087
R132 1,02k
+2.2V
C114
Q108 BF173
Q109 BC149
R137 2,7k
CR111 BAY88 C3V6
R138 8,2k
C134 0,1μ
R131 39
R139 5,6k
R142 470
C116 47μ
R144 330
C118 10μ
R145 56
R143 1,8k
+3,6V
CR112 BAX16
Q110 2N1711
C119 10μ
R140 8,2k
C117 10μ
R141 39
R146 39
W1
R148 1,2k
R149 680
C122 47μ
Q112 BC149
Q113 2N4126
C120 0,1μ
Q111 2N4303
R150 2,7k
C123 10μ
R154 330
R153 10k
R147 4,7k
C121 2,2
CR113 BAV10
R152 5,6M
CR114 BAV10
R151 2,2k
C124 10μ
REFERENCE CURRENT
REGULATING AMPLIFIER
REGULATING RECTIFIER
DC AMPLIFIER
4 DIODES FOR QUICK RECOVERY
OSCILLATOR
METER AMPLIFIER