

INSTRUCTION MANUAL

Component Linearity
Test Equipment
Type CLT1a



RADIOMETER

ELECTRONIC MEASURING INSTRUMENTS
FOR SCIENTIFIC AND INDUSTRIAL USE

**Instruction Manual
for**

**Component Linearity
Test Equipment
Type CLT1a**

1st edition

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Preface

Fundamentals of Non-Linearity Measurements

NON-LINEARITY MEASUREMENTS GENERAL

Of late years it has become a very important problem to procure sufficiently reliable electronic components for very demanding applications, and great efforts are being made to increase their reliability. Systematical reliability investigations are, however, a necessity for an evaluation of the improvements

gained, and such are often made as environmental test. This implies that a great number of components must be subjected to external influence in order to determine their useful life. Unfortunately this procedure suffers from several disadvantages: It is time consuming and it may destroy the components. Furthermore, the accelerated environmental tests do not give a perfect picture of the component's behaviour under normal working

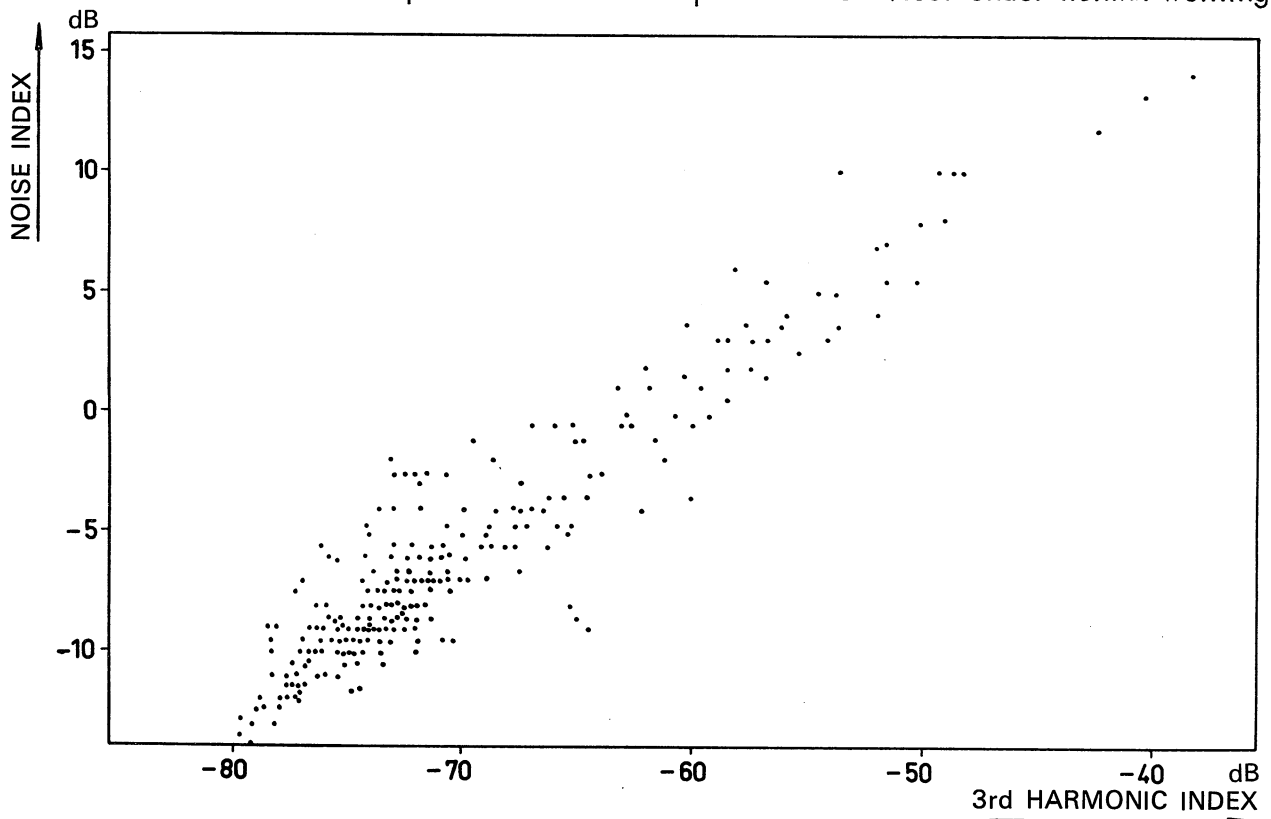


Fig.1. Correlation between noise index and third harmonic index.

conditions. And finally, it must be noted that in case of a running production test or incoming inspection, the environmental tests are out of the question.

What is needed is a fast, simple and non-destructive measuring method which will give information on the reliability of the components. This is offered by the Component Linearity Test Equipment, type CLT1. The measuring method is based on a determination of the non-linearity of nominally linear electronic components, such as resistors and capacitors, the non-linearity being taken as a measure of the reliability. Experience has shown that those components of a batch which exhibit a relatively high non-linearity are less stable and probably have a shorter lifetime than the rest of the batch. This relationship between component reliability and non-linearity corresponds very closely with the already accepted relationship between resistor current noise and reliability. Nevertheless, the new method is characterized by the fact that measurements on low resistances, as well as on other types of components, e.g. capacitors, are possible without loss of accuracy.

The non-linearity is determined by a selective measurement of the 3rd harmonic voltage generated in the component when a pure sinusoidal current is applied to it. The non-linearity is defined as the ratio between the 3rd harmonic voltage and the applied fundamental voltage, expressed in dB. Many investigations have shown that only the 3rd harmonic has practical significance. It is therefore possible to neglect the higher harmonics without appreciable loss of accuracy. As the non-linearity of some types of components can be as good as -120 dB or greater, it is obvious that only measuring equipment with a residual non-linearity better than -140 dB can be used.

As previously mentioned, the established non-linearity is taken as a measure of

the reliability of the component, and the problem is therefore to fix a reasonable rejection limit. In production testing, where the tester as a rule has had ample experience with the product, it will suffice to use a fixed rejection limit. Frequently, such limits are established within the range -80 dB to -120 dB.

Acceptance testing is carried out along the same lines, but in cases where new types and makes of components are to be tested, the rejection limit can be established by measuring a sample lot that is taken from the entire batch. The criterion for classifying a component as less reliable is then that its non-linearity shall be substantially greater than the median non-linearity of the sample lot. The results obtained by making non-linearity measurements on the sample lot are plotted on probability paper, as shown in Fig.2, where the X-axis indicates the non-linearity which here is represented by the 3rd harmonic voltage V_3 , and the Y-axis indicates the cumulative distribution of the components. In the design adopted on this occasion

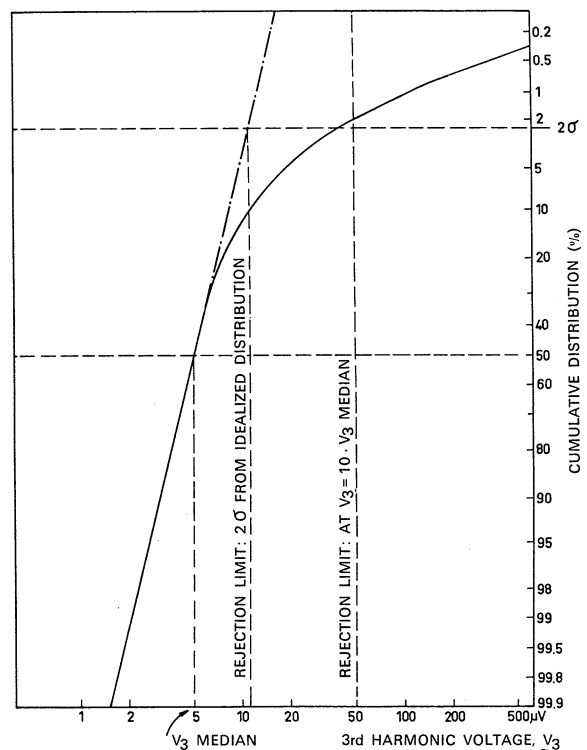


Fig.2. Determination of rejection limits.

for the probability paper, a straight line corresponds to a pure Gaussian distribution curve, i.e. an ideal batch. However, in the example shown, a bend occurs, indicating an irregularity in the batch. It is consequently in the area above the bend that the dubious components are found, and the problem is then to establish a reasonable rejection limit that can be used when testing a whole batch. Fairly often such a limit can be fixed as a 3rd harmonic voltage of e.g. $10 V_{3m}$, where V_{3m} denotes the median non-linearity of the sample expressed by the 3rd harmonic voltage. In our example this will give rise to a rejection of approx. 2%.

Where the requirements for high reliability are very stringent, the rejection limit can be fixed as the 3rd harmonic voltage that corresponds to the point of intersection between the $+2 \sigma$ line and the ideal distribution curve which results from a projection of the straight portion of the distribution curve. This is indicated by the dotted line in Fig.2. In these circumstances, the rejection will correspond to approx. 10% - in other words: a far more severe rejection than in the first example. A rejection of the dubious components will in the first place increase the overall reliability of the batch. However, as a higher reliability in principle ought not to be achieved through rejection, but rather should be a matter of ever better production technique, the rejected components will enable the manufacturer to study the defects and thereby perhaps trace their origin. A knowledge of the nature of these defects will lead to an improved production technique and thus to higher reliability.

The non-linearity is defined as the ratio between the 3rd harmonic voltage and the amplitude of the applied fundamental, expressed in dB. However, for most types of resistors, it appears that the generated 3rd harmonic voltage is proportional to the amplitude of the fundamental voltage raised to a certain power, often the third power for carbon film resistors, so that

the above non-linearity is highly dependent on the amplitude of the fundamental voltage. It is therefore common practice to perform the non-linearity measurements at a fixed power level - usually 1/4 watt dissipated in the resistor.

To overcome the problem of the dependence of the non-linearity ratio on the amplitude of the fundamental, the unit of measurement THIX), a contraction of third harmonic index, can be used. THI is defined as:

$$THI = 20 \log \frac{V_3}{V_1^3},$$

where the 3rd harmonic voltage, V_3 , is measured in microvolts, and the fundamental voltage, V_1 , is measured in volts. This unit is practically independent of the amplitude of the fundamental voltage, provided that the resistor investigated to some extent complies with a 3rd power law.

It should be stressed, however, that the 3rd harmonic index ought only to be employed if the power law applicable to the specific type of resistor be known.

Typical effects causing non-linearity, and which can be detected by non-linearity measurements are summarized below:

RESISTORS:

(Carbon, metal and oxide film resistors)

Contact instability:

Poor contact between connecting lead and cap.

Poor contact between cap and film.

Poor quality of film:

Inhomogeneous spots in film.

Inferior spiralling process:

Traces of film left in grooves.

Inferior ceramic:

Longitudinal grooves in the ceramic.

X) The Non-Linearity of Fixed Resistors.
By P.L. Kirby, Electronic Engineering,
Nov.1965, pp 722-726

CAPACITORS:

Contact instability:

Poor contact between metal electrode and terminal.

Contamination in dielectric:

Iron oxide in mica or iron particles in paper, polystyrene film, etc.

Mechanical instability:

Small movements due to electrostatic forces.

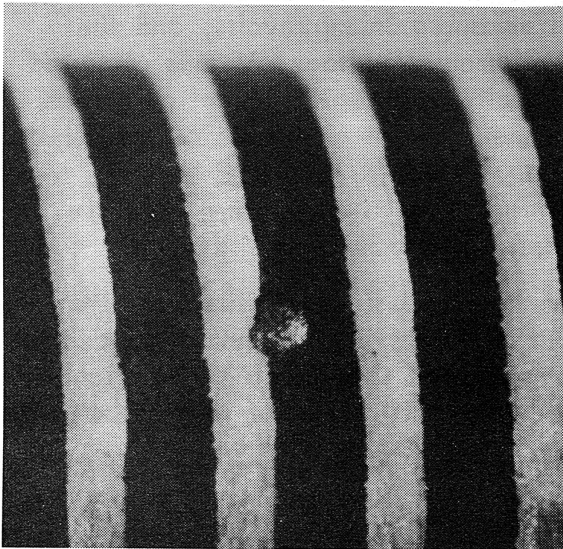


Fig.3. Defective resistor detected by having high non-linearity. A hole in the carbon film constricts the resistance path which results in excessive non-linearity because of overstraining of the carbon film.

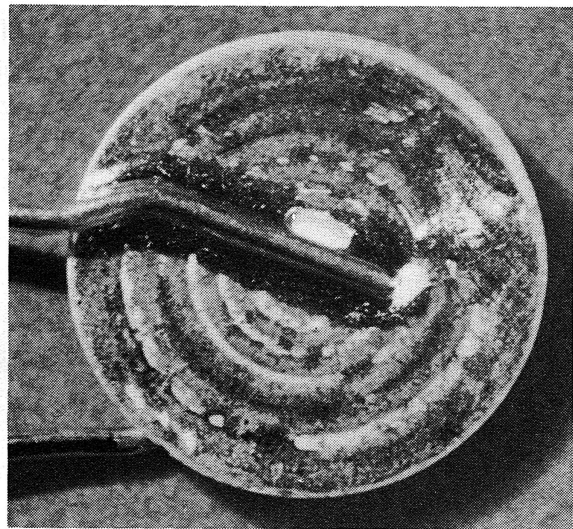


Fig.4. Defective ceramic capacitor detected by a very unstable 3rd harmonic voltage reading. The tinned surface has annular irregularities and a big hole at the terminal.

Component Linearity Test Equipment Type CLT1a

Section A. Introduction

The Component Linearity Test Equipment, type CLT1, is developed and manufactured by Radiometer A/S. It is an advanced development of the Distortion Measuring Equipment, type ZTP 1271, which originally was developed and manufactured by Telefonaktiebolaget L.M. Ericsson of Stockholm, Sweden.

A simplified block diagram of the working principle is shown in Fig.6. A very pure sinusoidal current with a frequency of 10 kHz is fed to the component under test, and the non-linearity is determined by a selective measurement of the 3rd harmonic voltage formed in the component.

Fig.7 shows an equivalence diagram. The 3rd harmonic voltage, $e_{30 \text{ kHz}}$, generated in the component, is divided between the impedance of the component at 30 kHz, $Z_{30 \text{ kHz}}$, and the input impedance, Z_i , 30 kHz, of the selective 30 kHz voltmeter. The 10 kHz generator can be disregarded, inasmuch as the loading caused by it is negligible at 30 kHz. By multiplying the 3rd harmonic voltage,

measured with the 30 kHz voltmeter, by a correction factor, F_c , the output volt-



Fig.5. The Component Linearity Test Equipment, type CLT1.

age of the "3rd harmonic generator" of the component under test is obtained. Obviously, as the impedance, $Z_{30 \text{ kHz}}$, increases, the effective voltage yield across the terminals of the 30 kHz voltmeter decreases, which seriously would affect the sensitivity of the instrument unless precautionary measures were taken.

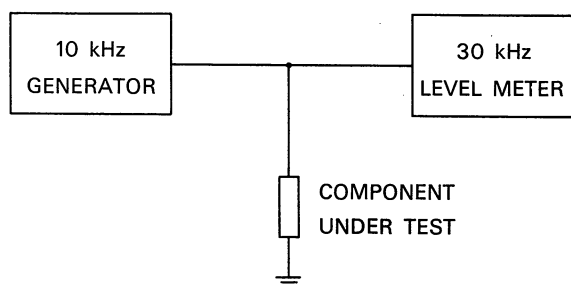


Fig.6. Simplified block diagram of the Component Linearity Test Equipment, type CLT1.

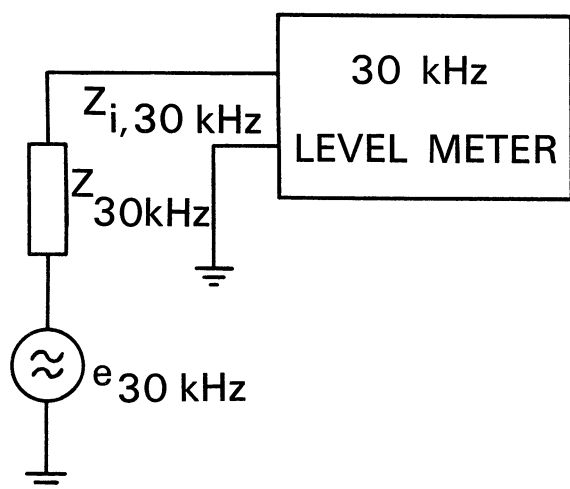


Fig.7. Equivalence diagram of the Component Linearity Test Equipment, type CLT1.

By introducing a matching transformer, the component can be matched to the 10 kHz generator and the 30 kHz voltmeter within a very wide impedance range. The Matching Transformer (patents pending) is of a very special design, inasmuch as its residual distortion must be very low in order not to impair the measurements.

The circuit design has four transformation ranges with impedance transformation ratios of 0.01, 0.1, 10 and 100. In addition, a basic range provides an imped-

ance transformation ratio of 1, so that an impedance range from 3 Ω to 300 k Ω is covered in five decades.

The afore-mentioned correction factor, F_c , is defined as

$$F_c = \left| \frac{Z_{30 \text{ kHz}}}{N} + 1 \right|,$$

where $Z_{30 \text{ kHz}}$ is the impedance in k Ω of the component at 30 kHz, and N is the impedance transformation ratio of the matching transformer, since the input impedance of the 30 kHz voltmeter is $N \times 1 \text{ k}\Omega$.

Within each impedance range, the correction factor varies between 1.3 and 4 (2 to 12 dB). It is obvious that such favourable conditions cannot be obtained when the impedance of the component under test greatly exceeds 300 k Ω . At a resistance of 100 M Ω , the correction factor is 1000 (60 dB); in other words, the relative sensitivity of the instrument is reduced. Fortunately, however, the non-linearity usually increases with increasing resistance, one of the reasons being that the resistance layer becomes thinner and thinner. This means that measurements can be made without difficulties on high-ohmic resistors.

The Residual Non-Linearity (RNL) of the instrument is of the greatest importance as a means of evaluating its performance. The RNL is expressed thus:

$$\text{RNL} = 20 \log \frac{V_{f3} + \text{noise}}{V_{f1}} \text{ dB},$$

where V_{f1} = fundamental voltage

V_{f3} = residual 3rd harmonic voltage.

"Residual 3rd harmonic voltage" denotes the reading on the 30 kHz voltmeter on the assumption that the component under test is replaced by a perfectly linear component having the same impedance.

In order to compare the RNL of the instrument with the non-linearity of the

component, it will be necessary to correct the RNL by means of the above mentioned correction factor, F_c . To make a reasonably accurate non-linearity measurement, the corrected RNL of the instrument should preferably be at least 20 dB lower than the non-linearity of the component. The Component Linearity Test Equipment is provided with two voltmeters for level measurements:

10 kHz Voltmeter

The amplitude of the 10 kHz test signal is read on the 10 kHz Voltmeter. The 10 kHz Voltmeter covers the voltage range from 10 mV to max. 550 V.

30 kHz Voltmeter

The amplitude of the 3rd harmonic voltage generated in the component can be read directly on the 30 kHz Voltmeter. It is provided with both a logarithmic and a linear indicating mode, selected alternatively by means of a locking push-button. The 30 kHz Voltmeter covers the range from 0.1 μ V to 1 V, on both indication modes.

Furthermore, a control input makes possible external, electronic control of the amplitude of the 10 kHz voltage by means of a dc control voltage. The 10 kHz voltage can be varied from 0 to 100% of the value indicated by the range switch.

The equipment also features a recorder output, with a 1 V dc output signal at full-scale deflection on the 30 kHz Voltmeter B, for registration of the 3rd harmonic at both linear and logarithmic indication.

An analyzer output permits investigations of harmonics of an order higher than the 3rd, for example by means of a Radiometer Wave Analyzer, type FRA3. It requires that the equipment is set for the 300 Ω - 3 k Ω range.

Dynamic measurements may be made by sweeping the fundamental, the external control voltage being the sawtooth voltage from an oscilloscope. By connecting the recorder output voltage to the oscilloscope, the non-linearity as a function of the fundamental voltage can conveniently be measured on the oscilloscope - especially if the logarithmic indicating mode is employed.

As the Component Linearity Test Equipment, type CLT1, offers a very high operational speed, is insensitive to external fields, and gives a high resolution, it is suited for an automatic 100% "go/no go" production testing as well as for reliability investigations on a laboratory basis.

Section B. Specifications

COMPONENT RANGE

Fundamentally, the component range comprises all types of passive impedances. The equipment is primarily adapted to impedances of magnitudes within the main range. Measurements within the supplementary ranges are encumbered with certain restrictions, which appears from the specifications.

The individual ranges are selected by means of the N-selector of the Matching Transformer. (N indicates the impedance transformation ratio of the built-in Matching Transformer), and they are indicated in ohms corresponding to the magnitude of the component's impedance at 10 kHz, $|Z_{X,10}|$.

Main Range

Basic Range:	300 Ω to 3 k Ω	N = 1
Transformation Ranges:	3 Ω to 30 Ω	N = 0.01
	30 Ω to 300 Ω	N = 0.1
	3k Ω to 30 k Ω	N = 10
	30k Ω to 300 k Ω	N = 100

Supplementary Ranges

Upper Supplementary Range:	Above 300 k Ω	N = 100
Lower Supplementary Range:	Below 3 Ω	N = 0.01

GENERATOR FREQUENCY

10 kHz (fundamental)

MEASURING FREQUENCY

30 kHz (3rd harmonic)

TOTAL MEASURING ACCURACY OF NON-LINEARITY

Approx. 1 dB (see below)

POWER AND VOLTAGE RANGE

Main Range (3 Ω to 300 k Ω)

Power:	The max. power delivered from the generator to the component under test is 1 VA.
Output Voltages:	See item 10 kHz Voltmeter. Max. output voltage limited to

$$\sqrt{|Z_{X,10}|} \text{ volts, where } |Z_{X,10}| \text{ is expressed in } \Omega.$$

Examples: 1.7 V at 3 Ω , 550 V at 300 k Ω .

Upper Supplementary Range (Above 300 k Ω)

Power:

Max. power delivered from generator to component under test is

$$\frac{0.3}{|Z_{X,10}|} \text{ VA, where } |Z_{X,10}| \text{ is expressed in M}\Omega.$$

Output Voltages:

See item 10 kHz Voltmeter. Max. output voltage limited to 550 V.

Lower Supplementary Range (Below 3 Ω)

Power:

The max. power delivered from the generator to the component under test is

$$I^2 \cdot |Z_{X,10}| \text{ VA, where } |Z_{X,10}| \text{ is expressed in } \Omega, \text{ and } I \text{ is the max. current delivered.}$$

Output Voltages:

Meter Range	I
mV	A
10	0.031
30	0.1
100	0.31
300	0.58

See item 10 kHz Voltmeter. Max. output voltage limited to

$$I^2 \cdot |Z_{X,10}| \text{ volts, where } |Z_{X,10}| \text{ is expressed in } \Omega, \text{ and } I \text{ is the max. current delivered.}$$

GENERATOR OUTPUT IMPEDANCE

Less than $N \cdot 5 \Omega$.

INPUT IMPEDANCE OF 30 kHz VOLTMETER

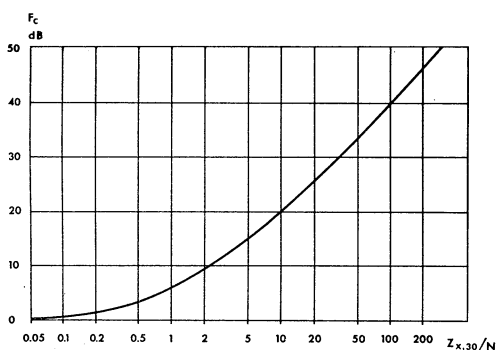
Magnitude:

$N \cdot 1 \text{ k}\Omega \pm 2\%$

Phase Angle:

Less than 5°

CORRECTION FACTOR



The correction factor is defined as

$$F_C = 20 \log \left| \frac{Z_{X,30}}{N} + 1 \right| \text{ dB}$$

where $Z_{X,30}$ indicates the component's impedance in k Ω .

By multiplying the 3rd harmonic reading by the dimensionless value of the correction factor,

$$\left(F_C = \left| \frac{Z_{X,30}}{N} + 1 \right| \right),$$

the open-circuit value of the 3rd harmonic voltage produced by the component is obtained. Typical values are stated below.

For Measurements on Resistors

Main Range: $F_C \leq 4$ (12 dB)

Lower Supplementary Range: $F_C \leq 1.3$ (2.3 dB)

Upper Supplementary Range:

$R = 10 \text{ M}\Omega$	$F_C = 100$ (40 dB)
$R = 100 \text{ M}\Omega$	$F_C = 1000$ (60 dB)

For Measurements on Capacitors

Main Range: $F_C \leq 1.4$ (3 dB)

Lower Supplementary Range: $F_C \leq 1.04$ (0.4 dB)

For Measurements on Inductors

Main Range: $F_C \leq 9$ (19 dB)

Lower Supplementary Range: $F_C \leq 1.4$ (3 dB)

RESIDUAL NON-LINEARITY

General

The residual non-linearity RNL is defined as

$$\text{RNL} = 20 \log \frac{\text{residual 3rd harm.} + \text{noise}}{\text{fundamental}} \text{ dB}$$

The corrected residual non-linearity, CRNL, which is the RNL referred to the "3rd harmonic generator" of the component under test, is defined as

$$\text{CRNL} = 20 \log \frac{\text{residual 3rd harm.} + \text{noise}}{\text{fundamental}} F_C \text{ dB}$$

where F_C is the correction factor defined above.

Note: The "residual 3rd harm. + noise" is the reading of the 30 kHz voltmeter when the component under test is replaced by a virtually linear component of the same impedance.

Noise comprises the thermal noise of the component and the noise of the instrument proper.

Measuring error originating in the RNL is max. 10% for a non-linearity of the component being 20 dB above the CRNL.

Main Range

The residual non-linearity RNL for 0.25 VA delivered to a resistive component is less than -150 dB in the basic range ($N = 1$), and less than -140 dB in the transformation ranges ($N = 0.01, 0.1, 10, \text{ and } 100$).

Typical values of the residual non-linearities are -160 dB in the basic range, and -150 dB in the transformation ranges.

Upper Supplementary Range (Above 300 k Ω)

The residual non-linearity RNL at a voltage of 275 V applied to a resistive component, R_X , is less than -140 dB.

The corrected residual non-linearity CRNL is less than $- [140 - 20 \log (1 + 10R_X)]$ dB, where R_X is in M Ω .

Note: 275 V correspond to 0.25 VA dissipated in 300 k Ω . In the M Ω range it is more reasonable to use the CRNL for a valuation of the measuring performance since the correction factor F_C may be very large.

Examples: $R_X = 10 \text{ M}\Omega$ CRNL < -100 dB

$R_X = 100 \text{ M}\Omega$ CRNL < -80 dB

Lower Supplementary Range (Below 3 Ω)

The residual non-linearity RNL at a voltage of $0.29 \cdot R_X$ V applied to a resistive component, R_X , is less than:

$$- \left[140 + 20 \log \frac{R_X}{3} \right] \text{ dB}$$

where R_X is in Ω .

Note: 0.29 A corresponds to 0.25 VA dissipated in 3 Ω . The CRNL is from 0 to 2 dB higher than the RNL, depending on the resistance value.

Example: $R_X = 0.3 \Omega$: CRNL \sim RNL < -120 dB.

10 kHz VOLTMETER

The equipment has a common range switch for the generator amplitude and the 10 kHz voltmeter sensitivity. Therefore, the voltage range indicated is valid for both the generator and the voltmeter. A fine control sets the 10 kHz voltage within the range selected. The range index is automatically switched in accordance with the selected component range. The range switch has 7 positions in a 1-3-10 sequence. Max. generator output voltage is 550 V.

Measuring Ranges

Basic Range:	300 Ω to 3 k Ω	0.1 V to 100 V f.s.d.
Transformation Ranges:	3 Ω to 30 Ω	0.01 V to 10 V f.s.d.
	30 Ω to 300 Ω	0.03 V to 30 V f.s.d.
	3 Ω to 30 k Ω	0.3 V to 300 V f.s.d.
	30 k Ω to 300 k Ω	1 V to 1000 V f.s.d.
Upper Supplementary Range:	Above 300 k Ω	1 V to 1000 V f.s.d.
Lower Supplementary Range:	Below 3 Ω	0.01 V to 10 V f.s.d.

Accuracy

2% of reading + 1% of full scale

Total dB Range

The total dB range, by utilizing the range switch, is 82 dB. dB calibration referred to 10^{-8} V.

Meter Scale

Two linear voltage scales, 0 to 1 and 0 to 3.
One dB scale -2 to 20 dB.

30 kHz VOLTMETER

The 30 kHz Voltmeter has a linear and a logarithmic indication mode. The range index is automatically switched in accordance with the selected component range. The sensitivity is given without regard to the correction factor. The range switch has 11 positions in a 1-3-10 sequence.

Linear Indication

Basic Range:	300 Ω to 3 k Ω	1 μ V to 100 mV f.s.d.
Transformation Ranges:	3 Ω to 30 Ω	0.1 μ V to 10 mV f.s.d.
	30 Ω to 300 Ω	0.3 μ V to 30 mV f.s.d.
	3 k Ω to 30 k Ω	3 μ V to 300 mV f.s.d.
	30 k Ω to 300 k Ω	10 μ V to 1 V f.s.d.
Upper Supplementary Range:	Above 300 k Ω	10 μ V to 1 V f.s.d.

Lower Supplementary Range: Below 3 Ω 0.1 μ V to 10 mV f.s.d.

Accuracy:

Basic Range: 3% of reading + 1% of full scale.

Transformation and Supplementary Ranges:

5% of reading + 1% of full scale.

Total dB Range: The total dB range, by utilizing the range switch, is 122 dB. dB calibration referred to 10^{-8} V.

Logarithmic Indication

Basic Range: 300 Ω to 3 k Ω 40 dB to 140 dB above 10^{-8} V.

Transformation Ranges:

3 Ω to 30 Ω	20 to 120 dB above 10^{-8} V
30 Ω to 300 Ω	30 to 130 dB above 10^{-8} V
3 k Ω to 30 k Ω	50 to 150 dB above 10^{-8} V
30 k Ω to 300 k Ω	60 to 160 dB above 10^{-8} V

Upper Supplementary Range: Above 300 k Ω 60 to 160 dB above 10^{-8} V

Lower Supplementary Range: Below 3 Ω 20 to 120 dB above 10^{-8} V

Accuracy:

1. Basic Range: 1 dB

2. Transformation and Supplementary Ranges: 1.2 dB

Meter Scale: One linear dB scale 20 to 80 dB.

Note: The dB ranges specified above are inclusive of the 60 dB scale range of the meter, i.e. the range switch utilizes 5 positions only.

Example: Basic Range: Range switch from 20 to 60 dB
Total dB range from 40 to 140 dB

MEASURING VOLTAGE CONTROL

Ext. ON-OFF Switch

A control input provides for remote switching of the 10 kHz voltage by means of an external switch.

Note: An additional external switch is required for the warning lamp next to the measuring terminals.

Ext. Voltage Control

A control input provides for external electronic control of the 10 kHz voltage. The 10 kHz voltage can be varied from 0 to 100% of the value indicated by the range switch.

<u>DC Control Voltage</u>	1 V for 100% of range indication. The 10 kHz voltage is proportional to the control voltage.
<u>Input Resistance</u>	Greater than 2 k Ω . Note: Remote control and remote switching are performed by means of the Component Linearity Test Equipment's controls in addition to external switches.
MEASURING SPEED	Up to 10 components per second.
DC BIAS	A bias input provides for dc bias of the component under test. It cannot be used in the transformation ranges 3 Ω to 30 Ω , and 30 Ω to 300 Ω , or in the lower supplementary range.
<u>Max. dc Voltage</u>	200 V
<u>Max. dc Current</u>	30 mA
OUTPUTS	
<u>Analyzer Output</u>	For investigation of harmonics of a higher order than the 3rd. Requires that the instrument be set for the basic range where no Matching Transformer is employed.
<u>Recorder Output</u>	For registration of the 3rd harmonic at both linear and logarithmic indication. Loading of the recorder output does not affect the meter reading.
<u>Output Voltage:</u>	1 V dc for full-scale deflection on meter.
<u>Output Resistance:</u>	4 k Ω .
TERMINALS AND CONNECTIONS	
<u>Measuring Terminals</u>	Two binding posts. Accept component clips with standard-size banana plugs (4 mm).
<u>DC Bias</u>	Two binding posts. Accept standard-size banana plugs (4 mm).
<u>Analyzer Output</u>	BNC coaxial socket, type UG-290U

12-Pole Connectors

Two 12-pole connectors - located on the rear and connected in parallel - are provided for:

Recorder Output

Measuring Voltage Control, i.e.

Ext. On-Off Switch

Ext. Warning Lamp Switch

Ext. Voltage Control

POWER SUPPLY

Voltages: 110, 115, 127, 200, 220, 240 V

Line Frequencies: 45 to 65 Hz

Consumption: 22 VA

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
630 mm	500 mm	310 mm	40 kilos net
25"	19 3/4"	12 1/4"	88 lbs net

ACCESSORIES SUPPLIED

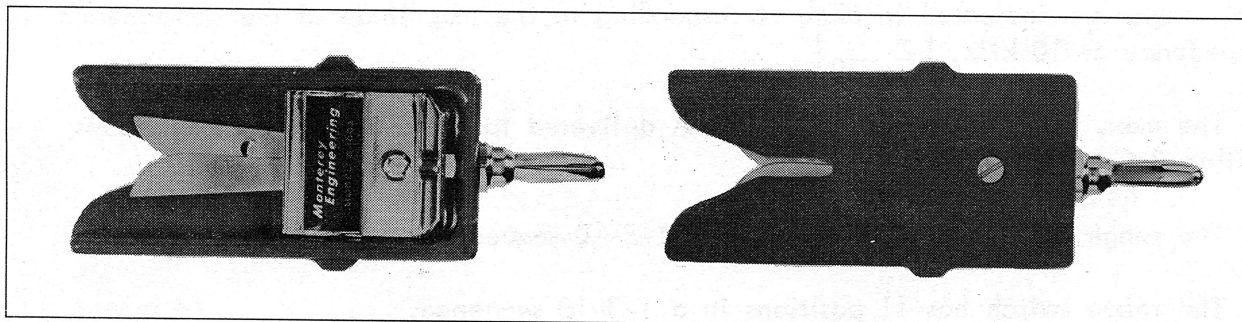
1 Cable Unit, code 900-215, extension cable terminated by 2 measuring terminals. Makes possible measurements up to 90 cm (36 in) away from the Component Linearity Test Equipment, type CLT1 (cannot be used in the range $N = 100$).

2 12-pole plugs, code 805-015/805-016, for connection of cables from external recorder and external control unit, if any.

1 power cord, code 615-300

ACCESSORIES AVAILABLE

1 pair of Component Clips, code 807-200, for easy component insertion, standard size plug mounting.



Section C. Survey of Specifications

The main specifications of the Component Linearity Test Equipment, type CLT1, are gathered in the table below, thus providing for a practical survey.

SPECIFICATIONS

GENERATOR FREQUENCY	10 kHz						
MEASURING FREQUENCY	30 kHz						
COMPONENT RANGE ¹⁾	< 3 Ω	3 Ω–30 Ω	30 Ω–300 Ω	300 Ω–3 kΩ	3 kΩ–30 kΩ	30 kΩ–300 kΩ	> 300 kΩ
TOTAL MEASURING ACCURACY (for f.s.d.) Linear indication Logarithmic indication	1.2 dB 2.0 dB			1 dB 1.5 dB	1.2 dB 2.0 dB		
MAX. POWER DELIVERED	– ⁷⁾	1 VA					$\frac{0.3}{ Z_{x,10} }$ VA
MAX. VOLTAGE APPLIED ²⁾ (10 kHz)	– ⁷⁾	1.7–5.5 V	5.5–17 V	17–55 V	55–173 V	173–550 V	550 V
10 kHz VOLTMETER RANGE ³⁾ f.s.d.	0.01–10 V		0.03–30 V	0.1–100 V	0.3–300 V	1–1000 V	
ACCURACY	2 % of reading + 1 % of f.s.d.						
30 kHz VOLTMETER RANGE ⁴⁾ f.s.d. (linear indication)	0.1 μV–10 mV		0.3 μV–30 mV	1 μV–100 mV	3 μV–300 mV	10 μV–1 V	
ACCURACY	5 % of reading + 1 % of f.s.d.			3 % of reading + 1 % of f.s.d.	5 % of reading + 1 % of f.s.d.		
30 kHz VOLTMETER RANGE ⁵⁾ (logarithmic indication)	20–120 dB		30–130 dB	40–140 dB	50–150 dB	60–160 dB	
ACCURACY	1.3 dB			1 dB	1.3 dB		
RESIDUAL NON-LINEARITY ⁶⁾	– ⁷⁾	–140 dB		–150 dB typ. –160 dB	–140 dB	–140 dB	– ⁷⁾
DC BIAS				Max. 200 V / 30 mA			
MEASURING VOLTAGE CONTROL	Inputs for remote ON-OFF switching and level control of 10 kHz voltage						
MEASURING SPEED	Up to 10 components per second						
RECORDER OUTPUT	1 V dc at full-scale deflection on 30 kHz voltmeter						

1) Fundamentally the component range comprises all passive impedances. The individual ranges are indicated in ohms corresponding to the magnitude of the component's impedance at 10 kHz, $|Z_{x,10}|$

2) The max. voltage corresponds to 1 VA delivered to components with magnitudes within 3 Ω to 300 k Ω .

3) The range switch has 7 positions in a 1–3–10 sequence.

4) The range switch has 11 positions in a 1–3–10 sequence.

5) The ranges indicated include the 60 dB range of the meter.

6) The residual non-linearity is defined as: $20 \log \frac{\text{residual 3rd harm. + noise}}{\text{fundamental}}$ dB

The "residual 3rd harm. + noise" is the reading of the 30 kHz voltmeter when the component is replaced by a virtually linear component of the same impedance. In the range 3Ω -300 k Ω , the residual non-linearity is stated for 0.25 VA delivered to the component.

7) See SECTION B - SPECIFICATIONS

Section D. General Description

GENERAL

The principle of operation is indicated in the block diagram shown in Fig.8.

The output from the 10 kHz Oscillator is fed via the Automatic Gain Control stage, AGC, and the Attenuator, AT1, to the special low-distortion Power Amplifier, A1. The third harmonic is suppressed by at least 60 dB in the 10 kHz Oscillator. The output voltage of the latter is fed to the Low-Pass Filter, LP, suppressing the 3rd harmonic by at least 110 dB, in order to obtain a very pure sinusoidal electromotive force which is applied to the component under test via the Matching Transformer. x)

The 10 kHz voltage which is applied to the component is measured by means of the voltmeter, consisting of the Attenuator, AT2, the Amplifier, A2, and the Meter, M1. The Automatic Amplitude Control stage, AAC, is connected to the voltmeter and controls the AGC stage in order to keep the input 10 kHz voltage constant and independent of variations in the impedance of the component under test. As the Attenuators, AT1 and AT2, are mechanically coupled, the sensitivity of the voltmeter is automatically set in accordance with the selected voltage range of the generator.

x) Patents pending

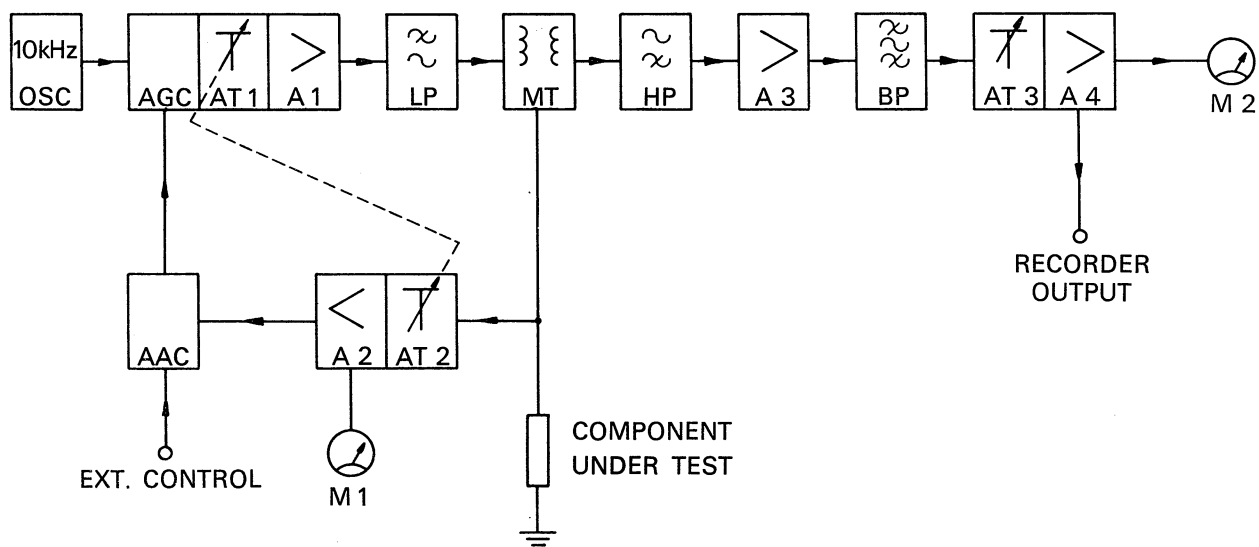


Fig.8. Block diagram of the Component Linearity Test Equipment, type CLT1.

Continuous adjustment of the 10 kHz voltage to a value within the range selected is accomplished by adjusting the AAC stage. Further, external control of the 10 kHz voltage can be introduced by applying a dc voltage to the AAC stage. Therefore, remote control of the equipment is possible.

The 3rd harmonic voltage developed in the component under test is passed via the Matching Transformer, MT, to the High-Pass Filter, HP, which suppresses the fundamental in order to avoid overloading of the subsequent amplifiers.

The 30 kHz voltage is then fed via the Preamplifier, A3, to the Band-Pass Filter, BP, which keeps the noise voltage sufficiently low. Then the filtered voltage is fed to the 30 kHz Voltmeter, which consists of the Attenuator, AT3, the Amplifier, A4 (providing for a recorder output), and the Meter, M2. The Amplifier, A4, has two operating modes. The first is linear and provides for normal linear meter indication. The second operates as a logarithmic amplifier, thus providing for logarithmic meter indication over a 60 dB range.

CONTROLS, INDICATING LAMPS, TERMINALS, AND METERS

As shown in Fig.9, the Component Linearity Test Equipment, type CLT1, is equipped with the following controls, indicating lamps, terminals and meters:

Controls and Indicating Lamps

POWER SWITCH (1) and PILOT LAMP (2)

The power switch ON-OFF is a toggle switch monitored by the pilot lamp POWER.

STANDARD (3)

The non-locking, push-button STANDARD connects, when pressed, an internal non-linearity standard to the measuring terminals. When the amplitude of the 10 kHz signal is 10 V in the basic range (300 Ω to 3 k Ω), the corresponding 30 kHz signal has an amplitude of 10 mV \pm 4%.

N-selector (4)

The N-selector selects the impedance transformation ratio of the built-in Matching Transformer, according to the following table.

N	Z
0.01	<30 Ω
0.1	30 - 300 Ω
1	300 Ω - 3 k Ω
10	3 k Ω - 30 k Ω
100	>30 k Ω

Transformation ratio as function of the impedance at 10 kHz of the component under test.

LEVEL AND METER RANGE (5)

The selector LEVEL AND METER RANGE selects the level and voltage ranges of the 10 kHz test signal from 100 to 200 dB in 10 dB steps (1-3-10 sequence), dB calibration referred to 10^{-8} V (10 mV to 1000 V). The level ranges are indicated by a selector provided with 11 sectors facing 5 index-lamps (6). The lamps are individually lit in accordance with the impedance range selected by means of the N-selector of the Matching Transformer, thus indicating the selected level range.

MEASURING VOLTAGE ON-OFF (7)

The locking push-button MEASURING VOLTAGE (ON-OFF) switches the 10 kHz test signal ON (when pressed) or OFF (when released). When the 10 kHz test signal is switched on, a control lamp (8) just above the measuring terminals is lit.

LEVEL (9)

The potentiometer LEVEL continuously adjusts the level of the 10 kHz test signal within the full-scale deflection value of the selected voltage range.

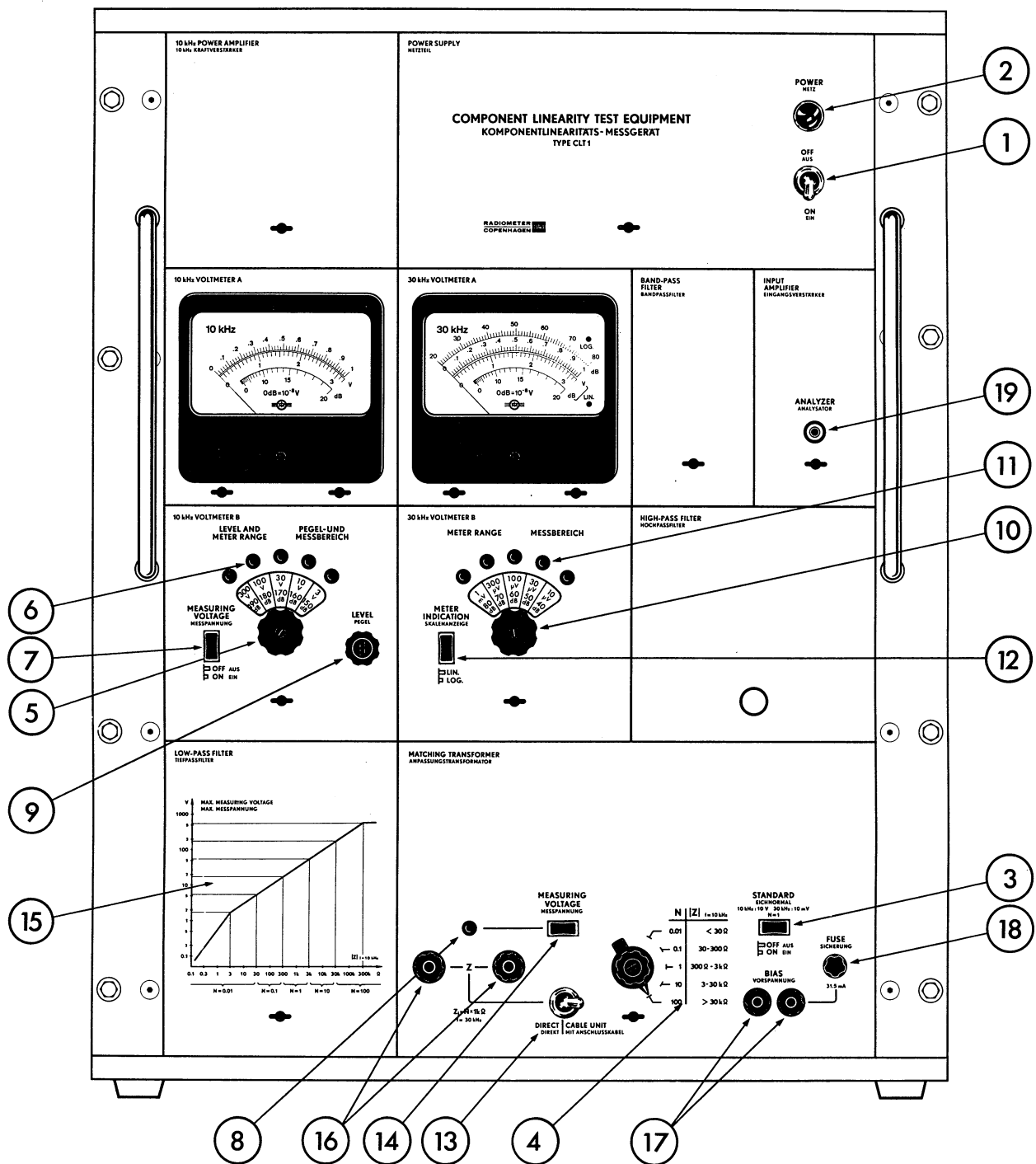


Fig.9. Front plate of the Component Linearity Test Equipment, type CLT1.

METER RANGE (10)

The selector METER RANGE selects the sensitivity range of the 30 kHz voltmeter from 0 dB to 140 dB in 10 dB steps (0.1 μ V to 1 V in a 1-3-10 sequence). The selector METER RANGE is monitored by 5 index-lamps (11). One lamp goes on at a time according to the com-

ponent range selected by means of the N-selector of the Matching Transformer, thus indicating the sensitivity range selected.

METER INDICATION (LIN-LOG) (12)

The monitoring meter of the 30 kHz signal gives both a linear indication,

covering a 22 dB range, and a logarithmic indication, covering a 60 dB range. These indications can be alternatively selected by means of the locking push-button METER INDICATION LIN.-LOG. The selected mode is indicated by one of two index-lamps (see Fig.11 (8) and (9)) located on the meter scale. The indication is linear when the push-button is released, logarithmic when it is pressed.

DIRECT/CABLE UNIT (13)

The toggle switch DIRECT/CABLE UNIT allows for direct measurements on components when in position DIRECT, whereas measurements up to 90 cm (36 in) away from the equipment can be made in position CABLE UNIT, as a series of capacitors then is connected to the measuring circuit. Nevertheless, due to an increase in capacitance in the impedance range above 30 k Ω , the use of the Cable Unit is not advised.

MEASURING VOLTAGE (14)

The non-locking push-button MEASURING VOLTAGE switches on the 10 kHz signal to the component under test, and as it is located in close proximity to the measuring terminals, it provides for fast and safe operation. It is operative only when MEASURING VOLTAGE (ON-OFF) is switched to OFF, and it is monitored by the same control lamp (8) as MEASURING VOLTAGE (ON-OFF).

Voltage Curve (15)

This curve gives the maximum available voltage that can be applied to a component with a given impedance referred to 10 kHz.

Terminals

Measuring terminals (16)

The measuring terminals consist of two binding posts that accept regular 4 mm banana plugs.

DC bias terminals (17)

A bias input provides for dc bias of the component under test. It cannot be used in the transformation ranges (3 to 30 Ω and 30 Ω to 300 Ω) and in the lower supplementary range (below 3 Ω). The max. voltage is 200 V for a current of max. 30 mA. The dc bias circuit is provided with a 31.5 mA slow-blow fuse (18).

The terminals consist of two binding posts that accept regular 4 mm banana plugs.

ANALYZER Output (19)

The BNC-type analyzer output is intended for investigation of harmonics of a higher order than the 3rd (the High-Pass Filter allows harmonics up to the 9th to pass). Its use requires that the equipment be set for the basic range (300 Ω to 3 k Ω) where no Matching Transformer is employed.

Rear Terminals

As seen in Fig.10, the Component Linearity Test Equipment, type CLT1, is

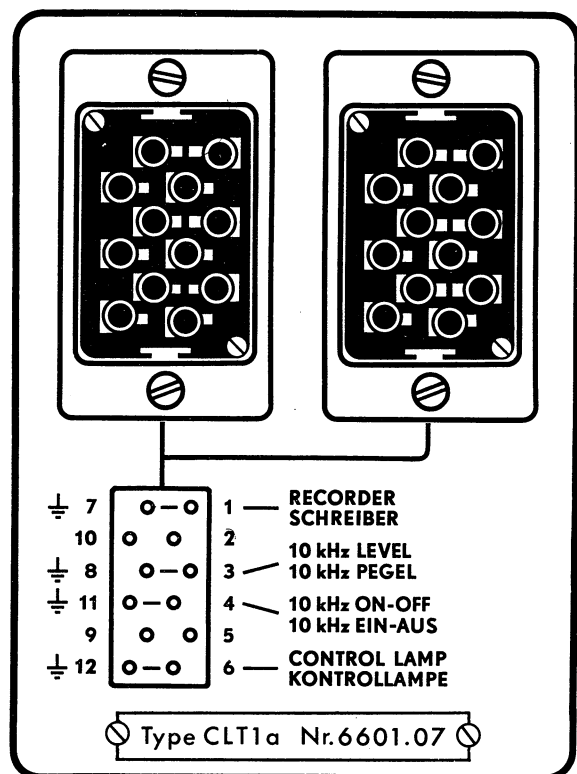


Fig.10. View of the rear terminals of the Component Linearity Test Equipment, type CLT1.

provided with the following rear terminals (all included in two 12-pole connectors coupled in parallel):

1. RECORDER Output (1 and 7)

For registration of the 3rd harmonic at both linear and logarithmic indication, the Component Linearity Test Equipment, type CLT1, is provided with a recorder output marked RECORDER. Loading of the recorder output does not affect the meter reading. The output can deliver a voltage of 1 V dc for full-scale deflection at an output resistance of 4 k Ω .

2. External Control Voltage (3 and 8)

A control input 10 kHz LEVEL provides for external control of the 10 kHz signal by means of a dc control voltage. The 10 kHz voltage can be varied from 0 to 100% of the value indicated by the range switch LEVEL AND METER RANGE.

3. External ON-OFF Switch (4 and 11)

The control input provides for remote switching (10 kHz ON-OFF) by means of an external switch.

4. External Control Lamp Switch (6 and 12)

An additional external switch is required for the control lamp above the measuring terminals during remote switching. The equipment is therefore provided with the inputs CONTROL LAMP.

Meters

As illustrated in Fig.11, the Component Linearity Test Equipment, type CLT1, is provided with the following meters:

10 kHz VOLTMETER A

The 10 kHz Voltmeter A indicates the amplitude of the 10 kHz test voltage applied to the component. It is provided with two linear voltage scales. The upper scale (1) is calibrated from 0 to 1 and the lower (2) from 0 to 3. The third scale is calibrated from -2 to +20 dB (0 dB = 10^{-8} V), and is used for level measurements.

30 kHz VOLTMETER A

1) General

The 30 kHz Voltmeter A monitors the 3rd harmonic signal generated in the component under test. Linear meter indication is normal, but logarithmic meter indication is also provided.

2) Linear Indication

The meter is provided with two voltage scales and one level scale for linear indication. The upper voltage scale (4) is calibrated from 0 to 1, whilst the lower scale (5) is calibrated from 0 to 3. The third scale (6) is calibrated from -2 to +20 dB (0 dB = 10^{-8} V). When the push-button METER INDICATION is released, the meter is switched

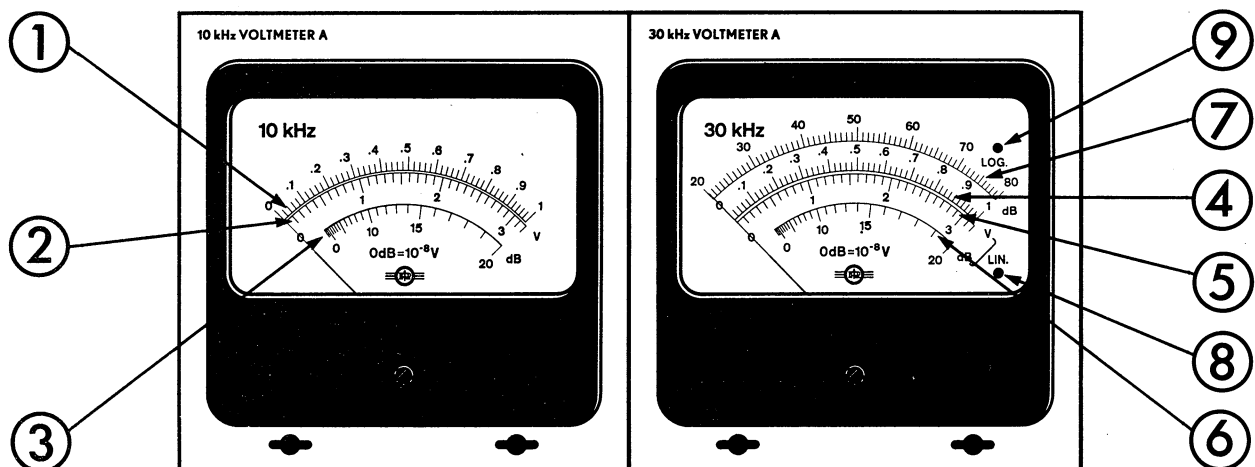


Fig.11. View of the meters of the Component Linearity Test Equipment, type CLT1.

to linear indication and the control lamp (8) is lit.

3) Logarithmic Indication

The meter is provided with one dB scale from 20 to 80 dB ($0 \text{ dB} = 10^{-8} \text{ V}$) for logarithmic indication. When the push-button METER INDICATION is pressed, the meter is switched to logarithmic indication, and the control lamp (9) is lit.

Line Voltage Receptacle, Main Fuse and Voltage Selector

The Line Voltage Receptacle, Main Fuse and Voltage Selector are all three located on the rear of the cabinet. The Component Linearity Test Equipment, type CLT1, is set to a line voltage of 220 V, unless otherwise specified, when leaving the factory, and it is furnished with two identical main fuses.

Section E. Operating Instructions

PREPARING THE LINEARITY TEST EQUIPMENT, TYPE CLT1

1. Check that the equipment is correctly switched to the line voltage to be used, as indicated by the line voltage selector on the rear of the cabinet. Switching to another line voltage is accomplished by unscrewing the main fuse, taking off the contact ring, repositioning it according to the desired line voltage value, and screwing the fuse back in, as shown in Fig.12.

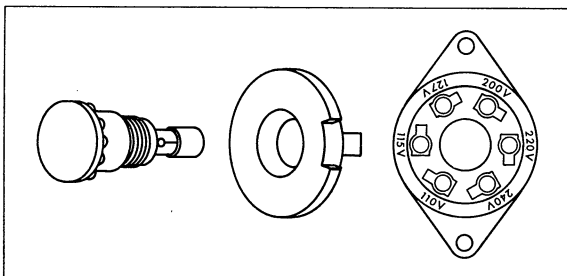


Fig.12. View of the disassembled fuse holder and voltage selector.

The Component Linearity Test Equipment is provided with one main fuse and six secondary fuses.

Main fuse:

The main fuse is located in the line voltage selector on the rear of the cabinet. Use a 0.2 A slow-blow fuse for 200 - 240 V operation, and a 0.4 A

slow-blow fuse for line voltages between 110 - 127 V.

Secondary fuses:

The secondary fuses are as follows:

24 V Power Supply: 4 fuses 0.063 A quick-blow, located in the Power Supply section.

36 V Power Supply: 1 fuse 0.4 A quick-blow, located in the Power Supply section

Bias: 1 fuse 0.0315 A quick-blow, located in the Matching Transformer section.

2. Connect the equipment to the line and switch on.

CHECKING THE EQUIPMENT

1. Set the N-selector of the Matching Transformer to the basic impedance range ($N \approx 1$).
2. Turn the LEVEL AND METER RANGE selector until the 10 V range sector faces the lit index-lamp.
3. Switch to LINEAR indication mode by releasing the METER INDICATION push-button.
4. Turn the METER RANGE selector until the 10 mV range sector faces the lit index-lamp.

5. Switch the locking push-button MEASURING VOLTAGE located on the 10 kHz VOLTMETER B section to "ON" and adjust to full-scale deflection on the 10 kHz VOLTMETER A by means of the potentiometer LEVEL.

6. Press the non-locking push-button STANDARD. The 30 kHz VOLTMETER A must read $10 \text{ mV} \pm 4\%$.

7. Switch to LOGARITHMIC indication mode by pressing the METER INDICATION push-button.

8. Read the dB value indicated on the 30 kHz VOLTMETER A. Decrease the sensitivity of the 30 kHz VOLTMETER B by steps of 10 dB and note the dB readings of the 30 kHz VOLTMETER A and the corresponding range sector of the 30 kHz VOLTMETER B. Their sum must constantly be equal to $120 \pm 1 \text{ dB}$.

9. Release the locking push-button MEASURING VOLTAGE.

STEP-BY-STEP OPERATION

1. Prepare the equipment as above.

2. By means of the N-selector of the Matching Transformer, select the transformation ratio (impedance range) corresponding to the impedance of the component to be tested, referred to 10 kHz. This impedance can be readily determined by means of the chart shown in Fig.13.

3. Determine the voltage required so as to apply the desired power to the component. This is readily accomplished by using the power chart shown at the back of this instruction manual.

4. Turn the LEVEL AND METER RANGE selector until the sector that determines the full-scale deflection range and includes the voltage found at step 3 faces the lit index-lamp.

5. Press the non-locking push-button MEASURING VOLTAGE and adjust to the required voltage by means of the potentiometer LEVEL. Note the dB value indicated on the 10 kHz VOLTMETER A. Add this to the value indicated on the range sector facing the lit index-lamp on the 10 kHz VOLTMETER B. Release MEASURING VOLTAGE.

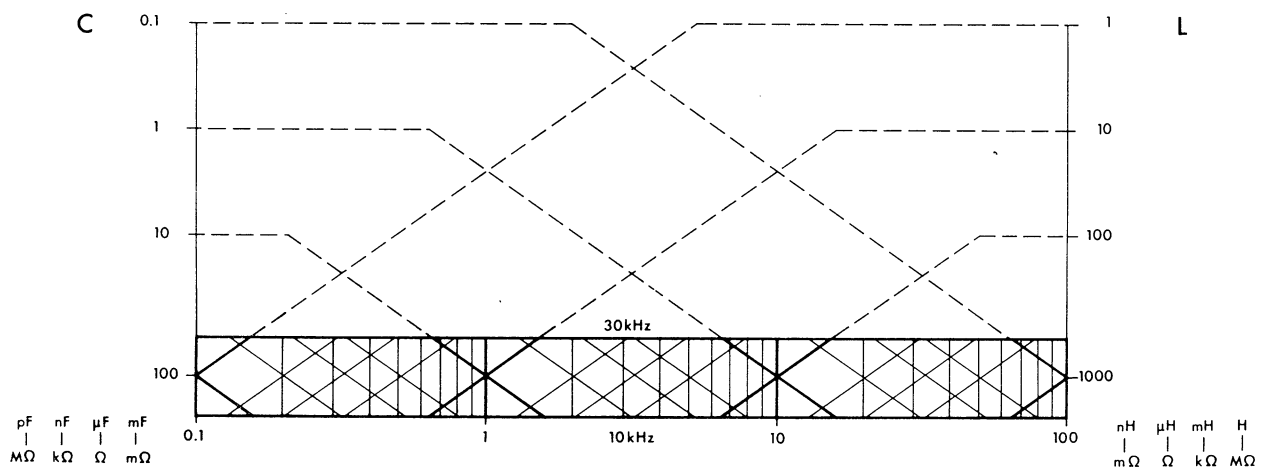


Fig.13. Impedance chart. Note that the impedance scale covers four units: viz., mΩ, Ω, kΩ, and MΩ. The correlation between these units and units of inductance and capacitance is indicated on the L and C scales.

WARNING: Under unfavourable conditions, a high measuring voltage may be hazardous. Above 42 V, the voltage should always be turned off when connecting or disconnecting the component under test.

6. Connect the component to the measuring terminals of the equipment, either directly to the equipment (in which case the switch DIRECT/CABLE UNIT must be thrown to DIRECT) or through a 90 cm (36 in.) Cable Unit (the switch DIRECT/CABLE UNIT then being thrown to CABLE UNIT). The component must always be connected to the measuring terminals before the 10 kHz voltage is applied, as it can be dangerous to reverse the procedure, and doing so also may result in erroneous measurements.

7. Apply the dc bias voltage to the input terminals BIAS, if required. The polarity of the bias terminals is the same as that of the measuring terminals. Note that dc biasing is not possible in the three lower impedance ranges, and that the max. dc voltage and current are 200 V and 30 mA, respectively.

WARNING: Remember that the dc bias voltage is always present at the measuring terminals.

8. Select the desired indicating mode of the 30 kHz VOLTMETER B by means of the push-button METER INDICATION.

9. Press the non-locking push-button MEASURING VOLTAGE, and turn METER RANGE until a suitable deflection is obtained on the 30 kHz VOLTMETER A.

10. The dB value of the 3rd harmonic on the 30 kHz VOLTMETER A is read on (6) (see Fig.11) when the linear mode is selected, and on (7) when the logarithmic mode is selected.

This reading must be added to the value indicated on the range sector facing the lit index-lamp on the 30 kHz VOLTMETER B.

11. Release MEASURING VOLTAGE.

12. Subtract the value obtained at step

6. from that obtained at step 10. The result is the 3rd harmonic distortion of the component under test, defined as the ratio between the 3rd harmonic voltage and the applied fundamental voltage expressed in dB. If it is desired to know the value of the 3rd harmonic voltage generated in the component under test, the dB value of a correction factor F_c (see page B2) must be added to the 3rd harmonic distortion value.

13. When measurements are undertaken at other power levels than that chosen at step 3 above, a decrease in residual non-linearity can be obtained. This can be accomplished by operating the equipment adjusted to an impedance-range different from the one including the actual impedance of the component.

The optimal conditions can be determined by consulting the chart shown in Fig.14.

Thus, by comparing the two curves, it will be seen that it in some cases is appropriate to make the measurements in an impedance range where the dB value of the CRNL is reduced; but this implies that the measurements must be carried out at lower power levels.

REMOTE CONTROL AND REMOTE SWITCHING

Remote Control

Remote control of the 10 kHz voltage from 0 to 100% of the value indicated by the range selector can be achieved by means of a variable dc control voltage of 0 to 1 V. The 10 kHz voltage is proportional to the control voltage.

Remote control is performed as follows:

1. Press the locking push-button MEASURING VOLTAGE and adjust the 10 kHz VOLTMETER A to zero deflection by means of the potentiometer LEVEL.

2. Apply the control voltage to the 10 kHz LEVEL terminals (8 and 3) on the rear of the cabinet.

3. The 10 kHz voltage is still monitored

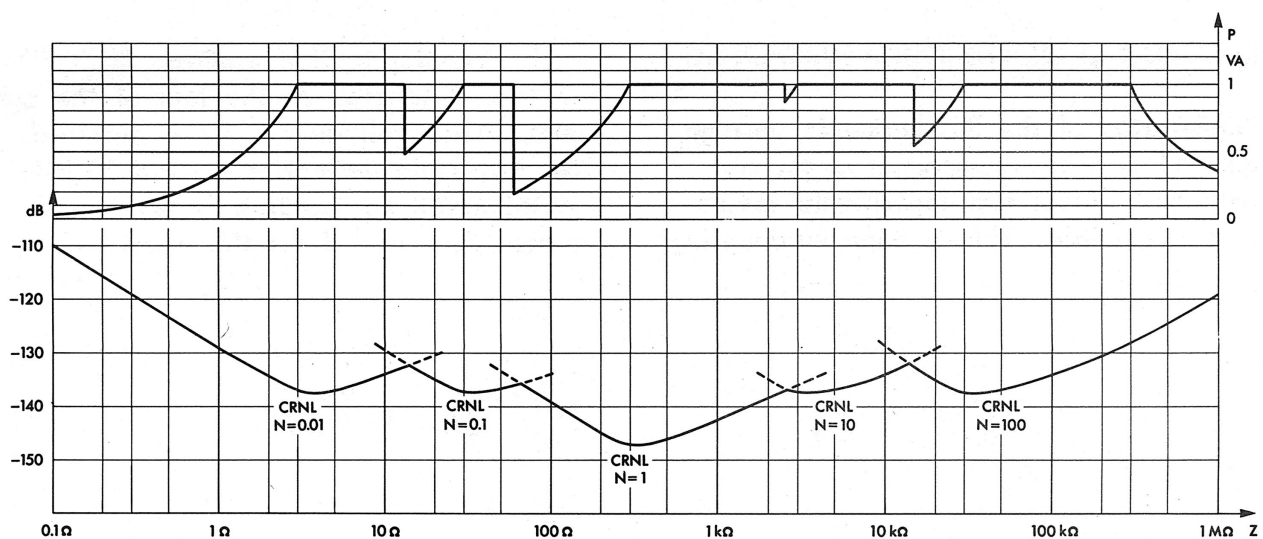


Fig.14. Comparison of available power and corrected residual non-linearity. The lower curve shows the variations of the corrected non-linearity as a function of the component's impedance. The upper curve shows the variations of the available power as a function of the component's impedance.

by the 10 kHz VOLTMEETER A and the level ranges indicated by the LEVEL AND METER RANGE SELECTOR.

Remote Switching

Remote switching of the 10 kHz voltage requires a twin-switch and can be performed as follows:

1. Press the non-locking push-button MEASURING VOLTAGE and adjust to the desired voltage by means of the potentiometer LEVEL.
2. Release MEASURING VOLTAGE.
3. Connect the CONTROL LAMP terminals (12 and 6) to the first half of a twin-switch.
4. Connect the 10 kHz ON-OFF terminals (11 and 4) to the second half of the twin-switch. When the switch is closed, the voltage selected at step 1 is present at the terminal and is monitored by the lit warning-lamp.

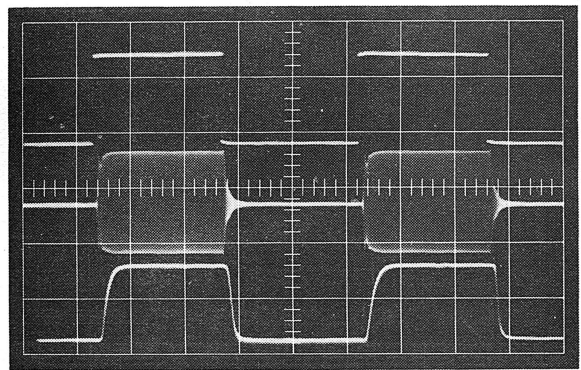


Fig.15. Oscillogram showing the 10 kHz voltage and the recorder output signal when the equipment is remote-controlled by a square wave. The horizontal calibration is 20 m sec/cm.

The upper curve shows the control square wave voltage having a frequency of 10 Hz. The vertical calibration is 0.5 V/cm.

The middle curve shows the 10 kHz voltage at the measuring terminals. Note that the 10 kHz voltage reaches its full value in 6 msec. The vertical calibration is 10 V/cm.

The lower curve shows the recorder output signal when the linear mode is selected. Note that the recorder output signal reaches its full value about 10 m sec after the rise of the control voltage.

RECORDING OF THE THIRD HARMONIC

Registration of the 3rd harmonic voltage generated in the component under test with both linear and logarithmic indication is possible. This is done by coupling

a dc recorder to the terminals RECORDER (7 and 1) located on the rear of the cabinet. A dc voltage of 1 V is obtained for full-scale deflection on the 30 kHz VOLTMETER A. Loading of the recorder output does not affect the meter reading.

Section F. Circuit Description

10 kHz VOLTMETER A

The 10 kHz VOLTMETER A comprises a 2-stage, 10 kHz Oscillator and a Buffer Stage. The 10 kHz oscillator is an LC oscillator and comprises transistors Q450 and Q451. It is amplitude-stabilized by means of the thermistor RT450. The 10 kHz Oscillator is coupled to the Buffer Stage, consisting of the two cascaded transistors Q452 and Q453. The transistor Q452 has a tuned circuit in the collector and delivers a 10 kHz sine wave. To avoid too strong a loading of the coil, the output of the tuned circuit is taken from a tap on the tuning coil. The transistor Q453, which is the emitter load of Q452, is part of the AAC stage (see page F2). The dc signal for the AAC control is fed via diode CR450, which is used as a protecting diode against possible polarity inversion of the control voltage, to transistor Q453, which regulates the amplification of the Buffer Stage, inasmuch as the higher the dc current in Q453 is, the higher is the current in the emitter of Q452, and, consequently, the greater will be the amplification of the Buffer Stage. Diode CR451 is used to limit the control voltage fed to transistor Q453.

10 kHz POWER AMPLIFIER

The pure 10 kHz sine-wave from the

Buffer Stage is fed to the Power Amplifier. Its input transistor is Q150, the collector of which is coupled to the base of Q153 and to the base of Q156. Transistor Q153 drives Q100, and transistor Q156 drives Q101. Transistors Q100 and Q101 are complementary emitter-followers and serve as output stages. The signal is then fed to a tap on the step-up autotransformer T100 and to the output. The 10 kHz Power Amplifier is provided with overall negative feedback from the output. The dc working point of Q153 and Q156 can be adjusted by the balanced stage Q151 and Q152.

In addition, transistors Q154 and Q155 work as current limiters. When the current in R169 or R170 becomes higher than a predetermined value, there is a rise in voltage across R169 or R170, causing Q154 or Q155 to start conducting and therefore blocking Q153 or Q156. The limit value is determined by the diodes CR152 or CR153. Diodes CR151 and CR154 protect transistors Q159 and Q155 against a possible polarity reversal of the applied voltages.

10 kHz VOLTMETER B

The 10 kHz VOLTMETER B consists of two amplifier stages: a meter amplifier and a balanced amplifier.

Meter Amplifier

From the 10 kHz Power Amplifier, the signal is fed through a Low-Pass Filter to the Matching Transformer (see below). From one of the secondary windings of the Matching Transformer section, the 10 kHz signal is fed to the emitter of the common base amplifier transistor Q900. From Q900, the signal goes to the meter amplifier proper via the LEVEL AND METER RANGE attenuator S800. The meter amplifier proper is a dc-coupled, 4-stage amplifier consisting of transistors Q850, Q851, Q852 and Q853. From the collector of the last stage (Q853), the signal is fed to the 10 kHz monitoring meter via R867, C851, and diode CR853, which only let pass the negative half-wave of the signal. The 10 kHz monitoring meter is in the feedback loop terminated by R850 and R851, whilst the connection to ground is made via L850 and R854.

Balanced Amplifier

The balanced amplifier stage consists of the double transistor Q854. The left base of Q854 receives via CR852 a signal proportional to the positive half-wave of the meter current. The right base of Q854 receives a dc signal from the 10 kHz LEVEL potentiometer. Through the above-mentioned feedback loop, the signal on the left base is regulated to equal the dc signal on the right base. The generator voltage and the 10 kHz monitoring meter deflection are thus controlled by setting the balance by means of the 10 kHz LEVEL which regulates the dc voltage on the right base. From the left collector of Q854 is drawn a dc control voltage output, used as AAC signal and fed to the oscillator stage.

LOW-PASS FILTER

The output voltage from the 10 kHz Power Amplifier is fed to the Low-Pass Filter in order to obtain a very

pure sinusoidal electromotive force which via the Matching Transformer is applied to the component under test. The Low-Pass Filter is an L-C filter which suppresses the 3rd harmonic by at least 110 dB. To achieve this high suppression, great care has been taken in designing and manufacturing the Low-Pass Filter.

MATCHING TRANSFORMER

A special low-distortion Matching Transformer section provides for matching of the component's impedance within a wide component range to that of the 10 kHz generator and that of the 30 kHz voltmeter. The 10 kHz signal from the Low-Pass Filter is applied to the primary windings of the Matching Transformer section, and from the secondary windings of the latter the 10 kHz signal is then fed to the component under test. The 30 kHz signal generated in the component is next via the Matching Transformer section fed to a High-Pass Filter and then via an Input Amplifier and a Band Pass Filter to the 30 kHz Voltmeter B section.

The Matching Transformer section consists of the Matching Transformer which is constructed of air-cored coils, ^{x)} the N-selector that selects the transformation ratio of the Matching Transformer proper, the push-button MEASURING VOLTAGE, that is used to apply the 10 kHz signal to the component when pressed, a non-linearity standard for testing the equipment, and the toggle switch DIRECT/CABLE UNIT.

The internal non-linearity standard consisting of the bridge CR1550, CR1551, CR1552, CR1553, and CR1554, generates a 10 mV, 3rd harmonic signal when the push-button STANDARD is pressed. When the toggle switch DIRECT/CABLE UNIT is thrown to DIRECT, the 10 kHz signal is applied to the component under test, and the 30 kHz signal generated in the component is

^{x)} Patents pending

then fed to the High-Pass Filter. Measurements up to 90 cm (36 in.) away from the equipment are possible, when using the optional Cable Unit, code 900-215. This is done by means of DIRECT/CABLE UNIT, as the 10 kHz signal is applied to the component under test when the switch is thrown to CABLE UNIT, but the series of capacitors in parallel with the measuring terminals is then disconnected.

HIGH-PASS FILTER

The 30 kHz signal generated in the component is passed via the Matching Transformer to the High-Pass Filter.

The High-Pass Filter, which is an L-C filter and which suppresses the 10 kHz voltage in order to avoid overloading of the subsequent amplifiers, must not introduce non-linearity. Therefore, it is designed and manufactured under the same conditions as are valid for the Low-Pass Filter. The High-Pass Filter allows harmonics up to the 9th to pass. However, since the Matching Transformer is ideal at 10 kHz and 30 kHz only, the measurements of the higher harmonics can be carried out only with equipment set for the basic impedance range where the Matching Transformer is not in use.

INPUT AMPLIFIER

The 30 kHz signal from the High-Pass Filter is fed to the Input Amplifier, which consists of transistors Q650, Q651, Q652 and Q653.

The input transistor is Q650 which receives the 30 kHz signal on its base. It is dc-coupled to Q651. Negative feedback is provided from the collector of Q651 to the emitter of Q650 through R662 - R663. The relay K650 is actuated by the METER RANGE attenuator in the 30 kHz VOLTMETER B section. When actuated, it short-circuits R663, whereby a 30 dB change in amplification of the Q650 - Q652 stage is achieved. This occurs in the

three most sensitive ranges of the 30 kHz VOLTMETER B. The signal is then fed to an amplifier stage Q652 and Q653. From the collector of Q653, the output signal is fed to a subsequent Band-Pass Filter and an analyzer output. The analyzer output provides for analysis of the third and higher harmonics.

BAND-PASS FILTER

From the Input Amplifier, the 30 kHz voltage is then fed to an L-C Band-Pass Filter, which provides for high selectivity of the 30 kHz level meter in order to keep the noise voltage sufficiently low.

30 kHz VOLTMETER B

From the Band-Pass Filter, the 30 kHz signal is fed to the 30 kHz VOLTMETER B section which consists of a 10 x 10 dB attenuator, a logarithmic amplifier, and the 30 kHz monitoring meter, providing for both logarithmic and linear indication.

Attenuator

From the Band-Pass Filter, the signal is fed to the common base coupled buffer transistor Q1100 and is then passed via the METER RANGE attenuator S1000 to the following stages.

The first 3 gangs of the METER RANGE attenuator selector provide for actuation of the relay in the Input Amplifier. The signal is then fed to the meter amplifier when the 30 kHz VOLTMETER B is switched to linear indication mode. When the logarithmic indication mode is used, the signal is passed to the logarithmic amplifier.

Logarithmic amplifier

Through the METER INDICATION switch S1100, the signal is fed to the base of the common emitter-coupled transistor Q1101, which is the input stage of the

3-stage logarithmic amplifier. The latter consists of the cascaded transistors Q1101, Q1102 and Q1104. From the collector of Q1101, the signal is passed to the base of Q1102 and then to that of Q1104. The logarithmic characteristic is determined by means of two diodes CR1100 and CR1101, located in the negative feedback loop. Their working point is adjusted by means of transistors Q1103A, Q1103B and Q1105. Deviation from logarithmic characteristic is compensated for by diodes CR1102, CR1103, CR1104 and CR1105. Transistor Q1054 is used for biasing the meter circuit in the logarithmic indication mode. Full scale deflection (20 dB) in the linear indication mode corresponds to zero deflection (20 dB) in the logarithmic indication mode. From the logarithmic amplifier, the signal is fed to the meter amplifier.

Meter Amplifier

The Meter Amplifier consists of transistors Q1050, Q1051, Q1052, Q1053 and Q1054. When the METER INDICATION push-button is released (linear indication), the signal from the METER RANGE attenuator is fed direct to the

base of the input stage of the meter amplifier, and transistor Q1054 is simultaneously cut off. When METER INDICATION is pressed (logarithmic indication), the signal from the logarithmic amplifier is fed to the meter amplifier, and Q1054 is conducting.

30 kHz monitoring meter

The 30 kHz signal from the Meter Amplifier is fed to the 30 kHz monitoring meter via diode CR1052. The meter deflection is proportional to the current in CR1052. A recorder output is provided for from resistor R1072 without loading of the meter.

POWER SUPPLY

The Power Supply of the Component Linearity Test Equipment, type CLT1, is a stabilized power supply delivering -36 V, -24 V, and +24 V. Its design and construction have received very careful attention so as to achieve a high degree of stability and minimize the influence of line voltage variations on the measurements.

Section G. Applications

CHECKING THE POWER LAW

General

As previously stated, the 10 kHz voltage can be controlled by means of an external dc voltage. If the sawtooth voltage from an oscilloscope is used, the 10 kHz voltage will vary linearly with the horizontal sweep on the screen. By connecting the recorder output of the 30 kHz voltmeter to the vertical sweep terminals of the oscilloscope, the 3rd harmonic voltage generated in the component will be produced on the screen as a function of the amplitude of the fundamental voltage.

In this manner it is very easy to determine which power law is applicable to a particular resistor, for example.

The measuring set-up consists of the following elements:

A Component Linearity Test Equipment, type CLT1

An attenuator (see Fig.16)

An oscilloscope with a sensitivity of $\frac{1}{d}$ V, d being the number of divisions of the graticule.

A perspex plate with one (or more) engraved theoretical power laws.

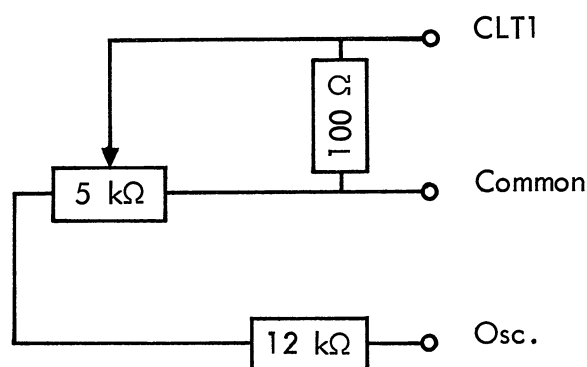


Fig.16. Circuit of the attenuator used for checking the power law of components.

Step-by-step procedure

1. Prepare the equipment as described under OPERATING INSTRUCTIONS.
2. Select the impedance range of the Matching Transformer by means of the N-Selector.
3. Connect the component to the measuring terminals.
4. Connect the sawtooth output of the oscilloscope to the 10 kHz LEVEL input terminals (located on the rear of the cabinet) via the attenuator, as shown in Fig.17.
5. Set the oscilloscope for a sweep drive of approx. 20 m sec/m (free running).

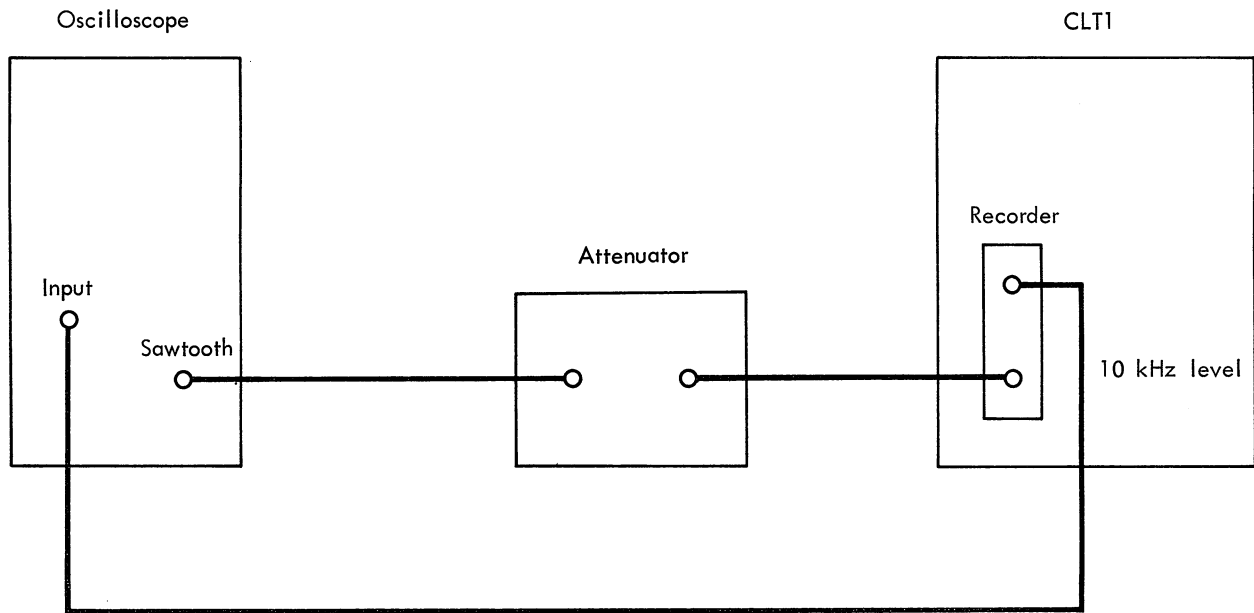


Fig.17. Set-up used for checking the power law of components.

6. Determine the voltage required to apply the desired power. (See the power chart at the back of the manual).

7. Turn the range sector of the LEVEL AND METER RANGE Selector including the voltage determined at step 6 until it faces the lit index-lamp.

8. Set the locking push-button MEASURING VOLTAGE to ON.

9. Produce the 10 kHz voltage taken from the measuring terminals on the screen of the oscilloscope.

10. Turn the potentiometer LEVEL fully counter-clockwise.

11. Set the horizontal position of the trace on the screen, and the attenuation of the attenuator, so that the amplitude of the 10 kHz voltage is zero when the horizontal sweep starts, and increases to $\sqrt{2}$ multiplied by the value determined at step 6, when the sweep is completed. See drawing of oscillogram shown in Fig.18.

To accomplish the amplitude settings, the oscilloscope sweep should be set for a very slow sweep rate so that the value of the 10 kHz voltage can be read when the sweep is completed.

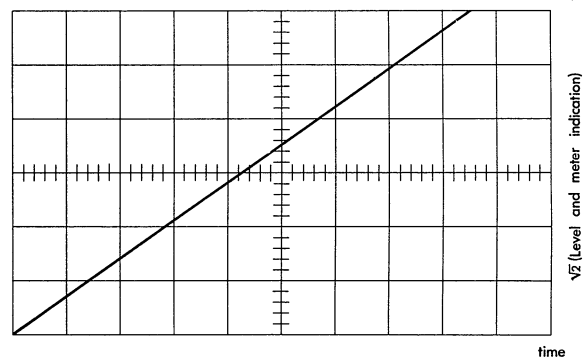


Fig.18. Oscillogram of the signal obtained at step 11.

12. Switch the 30 kHz VOLTMETER A to logarithmic indication by means of the METER INDICATION push-button.

13. Temporarily remove the lead connecting the 10 kHz LEVEL input to the sawtooth voltage.

14. Connect the RECORDER output of the equipment to the oscilloscope.

15. By means of the potentiometer LEVEL, adjust the 30 kHz VOLTMETER A reading to 20 dB.

16. Adjust the vertical position of the trace on the oscilloscope so that it appears on the 2nd horizontal line from the bottom of the graticule. The lowest line is thus the 0 dB line.

17. Select a sensitivity of the oscilloscope equal to $\frac{1}{d}$ V, where d is the number of divisions of the graticule.

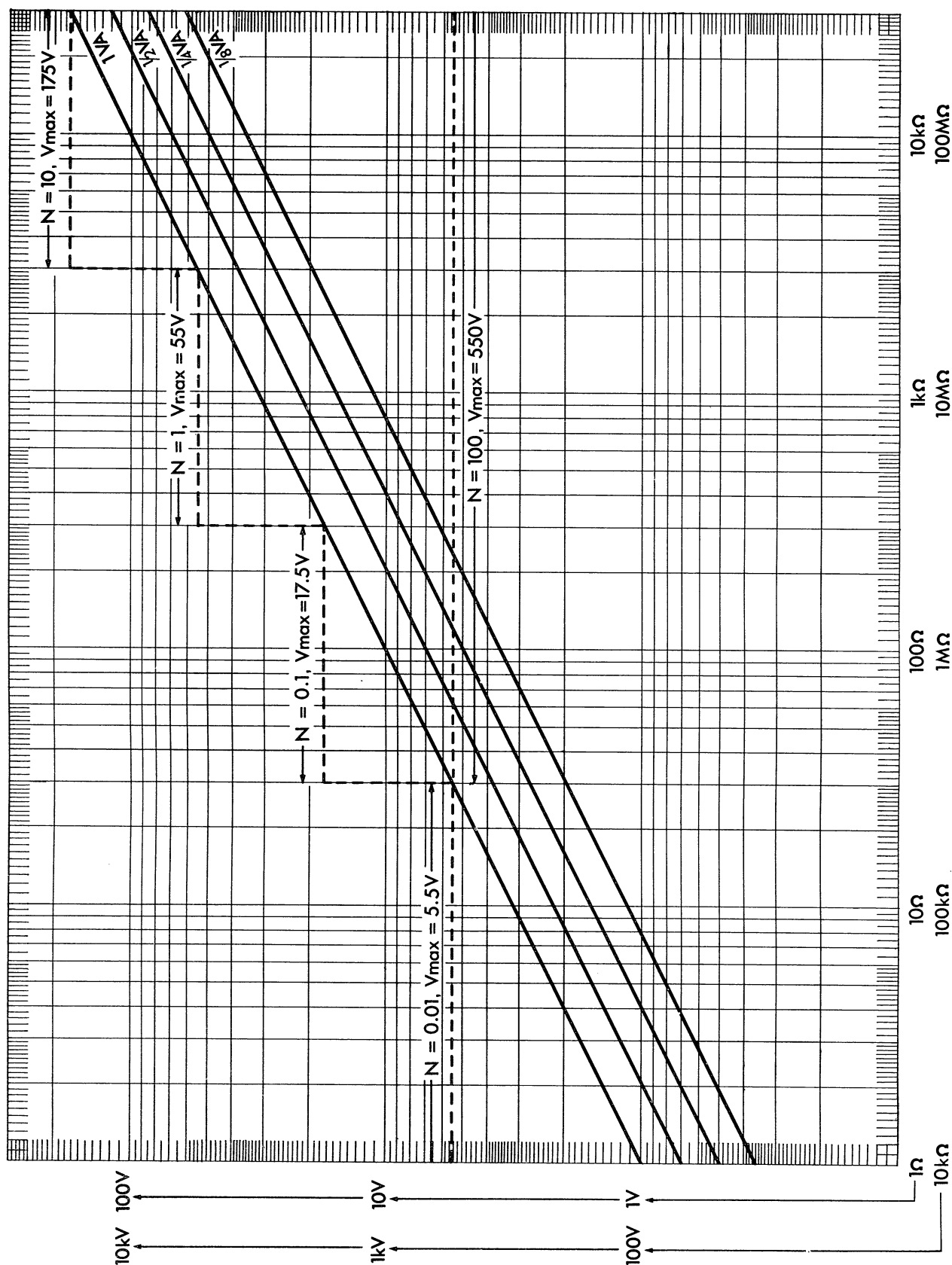
18. Calibrate the oscilloscope by increasing the reading of the 30 kHz VOLTMETER A by steps of 10 dB. This is done by turning the potentiometer LEVEL.

19. Turn the potentiometer LEVEL fully counter-clockwise.

20. Set the perspex plate before the screen.

21. Reconnect the lead to the 10 kHz LEVEL input. The result is a representation of the power law of the component which can be compared with the theoretical power law engraved on the perspex plate.

*

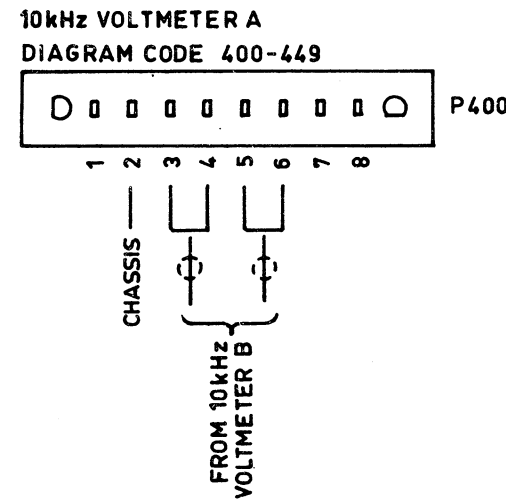
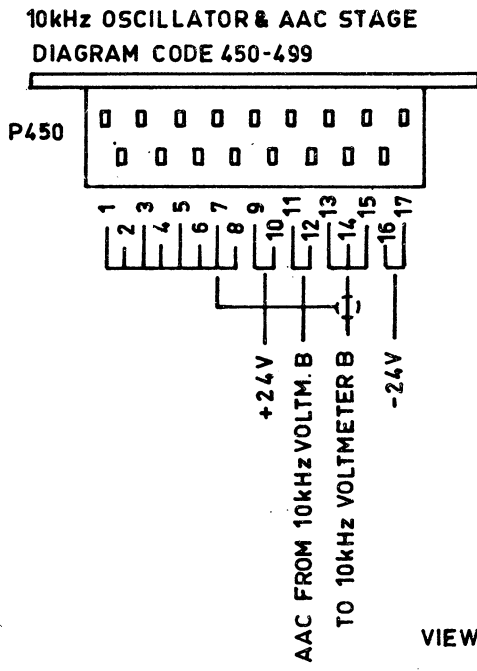
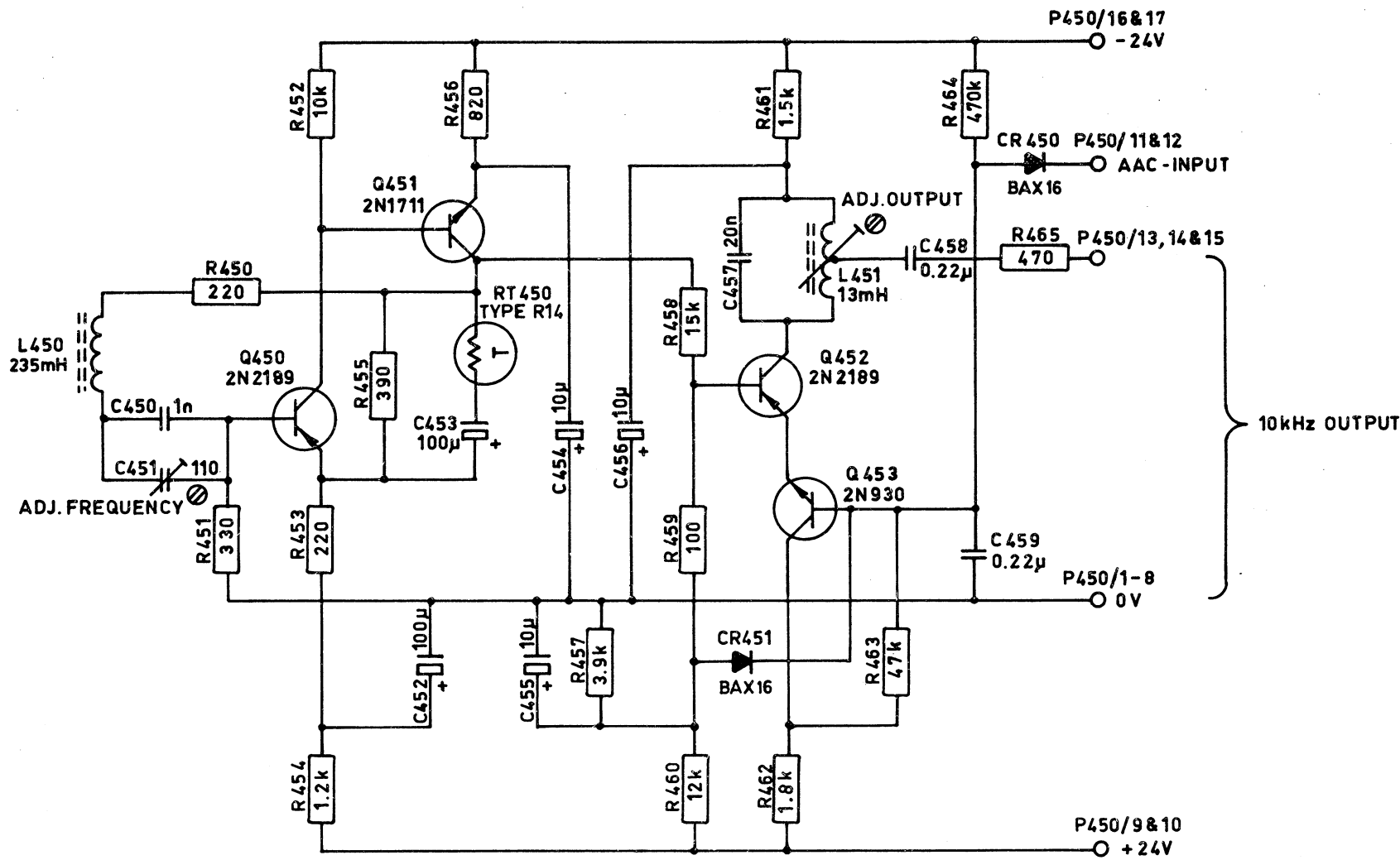
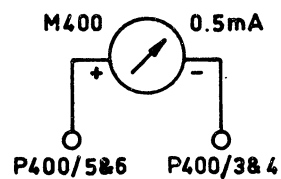


Power Chart

The power chart gives the voltage required to apply power to a component as a function of its impedance at 10 kHz. Draw a vertical line from the point corresponding to the impedance of the component. The intersection of this vertical line and the power line determines the voltage to be applied to the component.

The dotted lines represent the maximum voltage available from the equipment, and are used to check that the above determined voltage is within the available voltage range. If this does not hold true, it is then necessary to perform measurements at a lower power level. On the other hand, measurements at power levels higher than 1 VA are also possible in certain parts of the impedance range.

Note: For impedances above 30 kΩ, the maximum available voltage is 550 V.



VIEWED FROM TERMINAL END

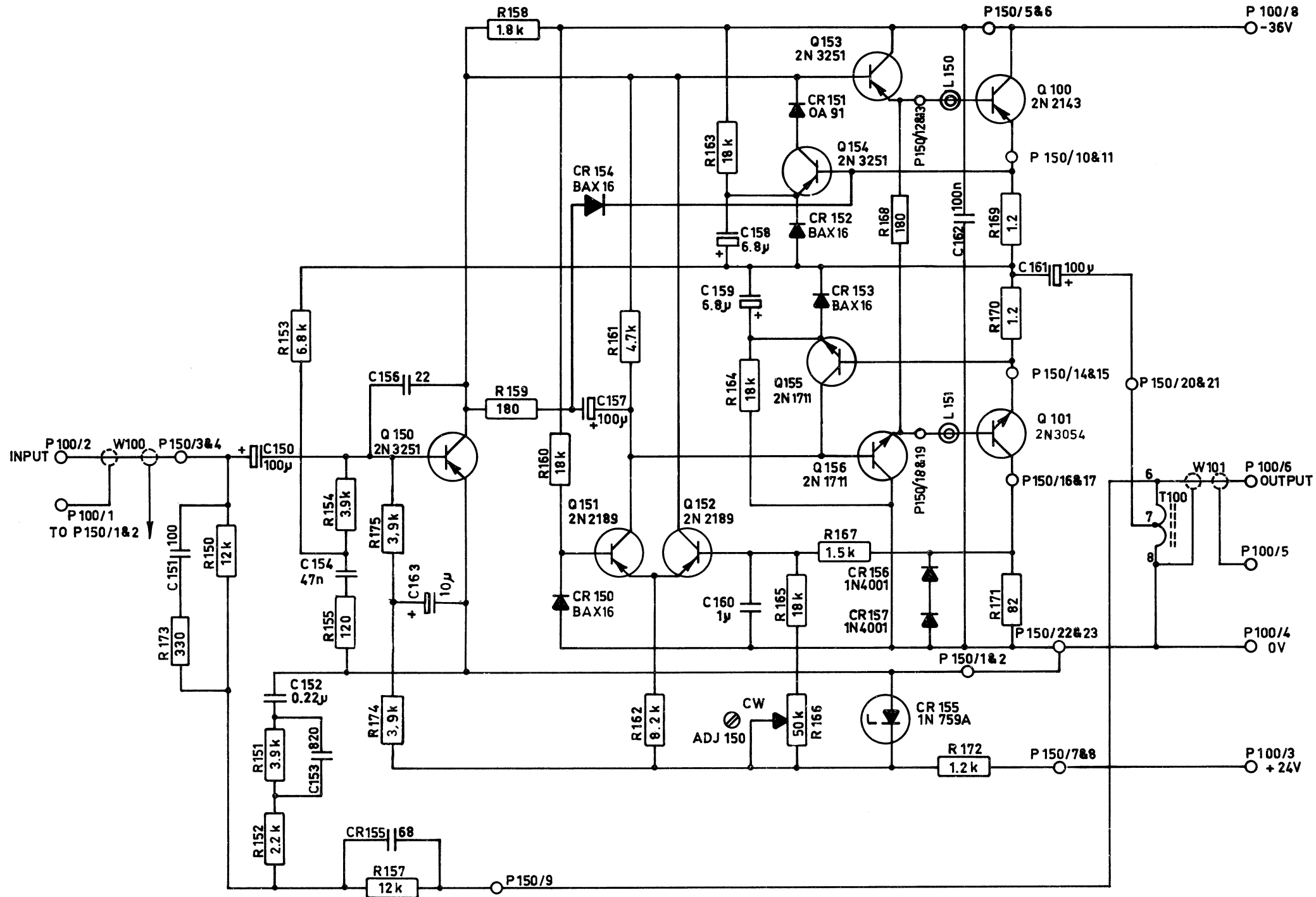
VALUES IN Ω OR pF IF
NOT OTHERWISE SPECIFIED

RADIOMETER COPENHAGEN

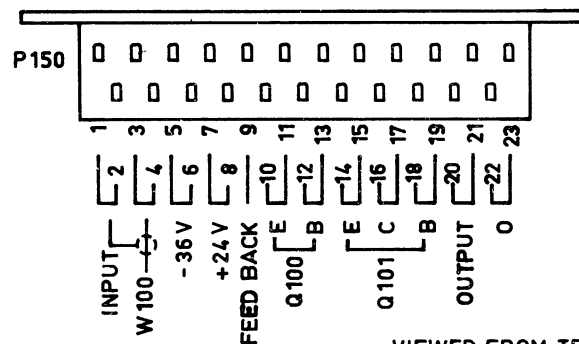
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P.N.	Rev. No.	Date	By	Cont.	Norm.
4		26-6-67	LTJ	PK	
3		5-1-67	KHK	PK	
2	102340	19-9-66	KHK	PK	
1		28.3.66	EA	PK	

RADIOMETER COPENHAGEN		Målestok	Tegn.	EA 28.3.66
72 EMDRUPVEJ NV		Kont.		
10kHz VOLT. METER A CODE 900-222		Norm.		
From no. 91487 to no.		Erstatter		
		1668-A2		
		Erstattes af		

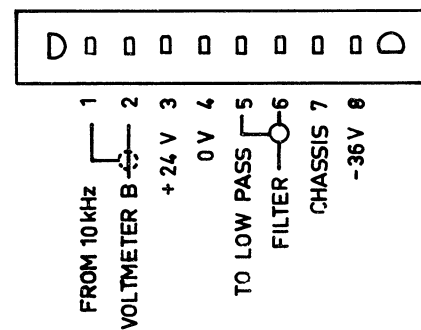


10 kHz POWER AMPLIFIER
DIAGRAM CODE: 150-199



VIEWED FROM TERMINAL END

P 100



P100/7



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CW: CLOCKWISE



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6		6-5-70	OH	PK
5	122373	20-12-67	PAB	PK
4		10-3-67	KHK	PK
3	114091	18-11-66	MH	PK
2	91487	16-9-66	KHK	PK
1		29.3.66	MH	PK
Rt. Nr.	Fra Fab. Nr.	Date	Rt. af	Kont. Norm.

RADIOMETER COPENHAGEN
72 EMDRUPVEJ NV

10 kHz POWER AMPLIFIER
CODE: 900-220

From no. 91487

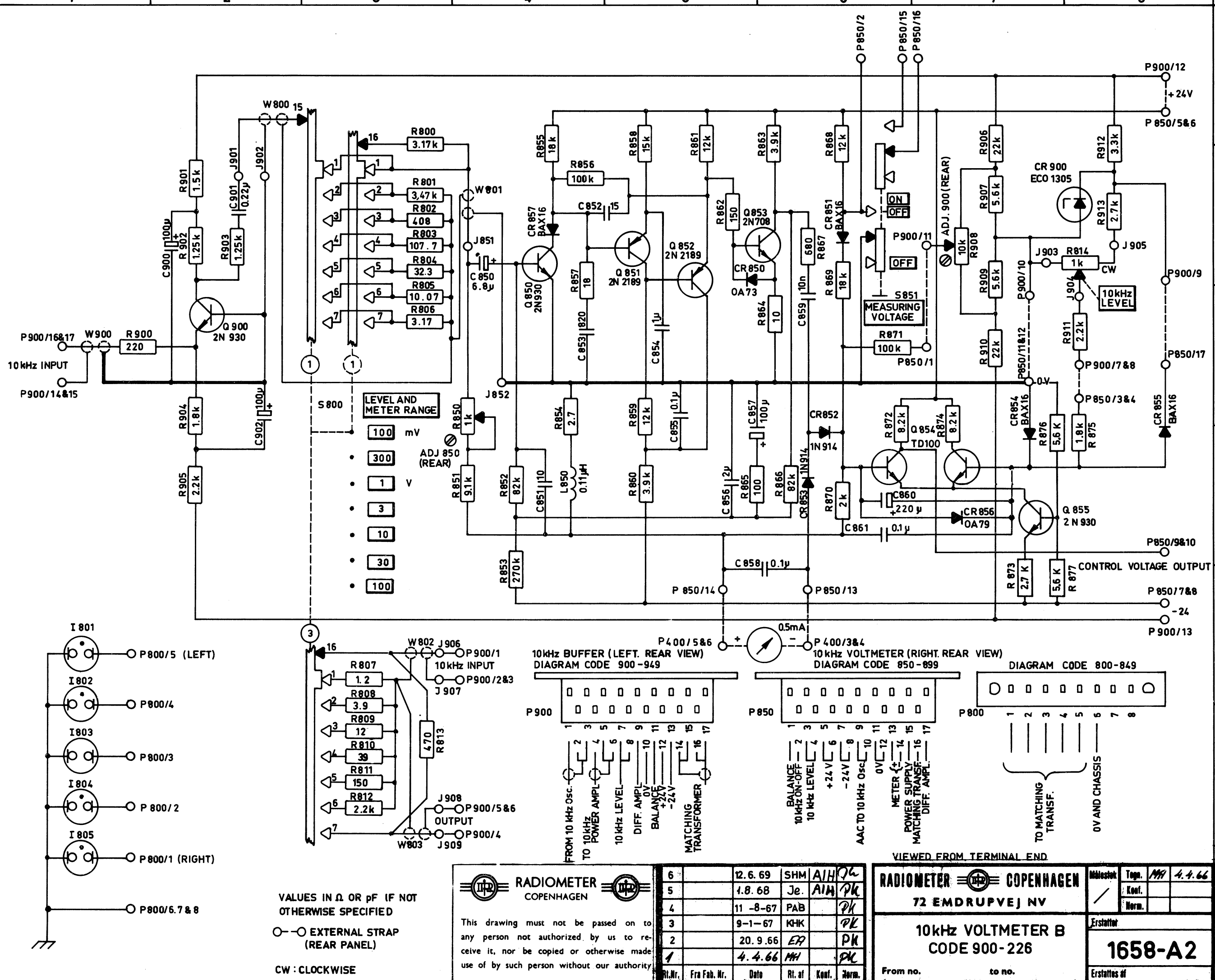
to no.

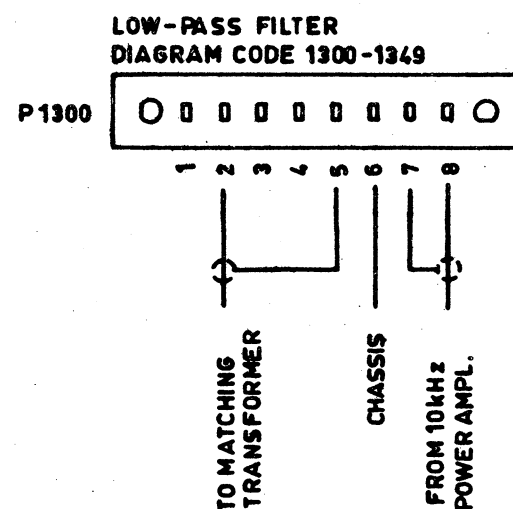
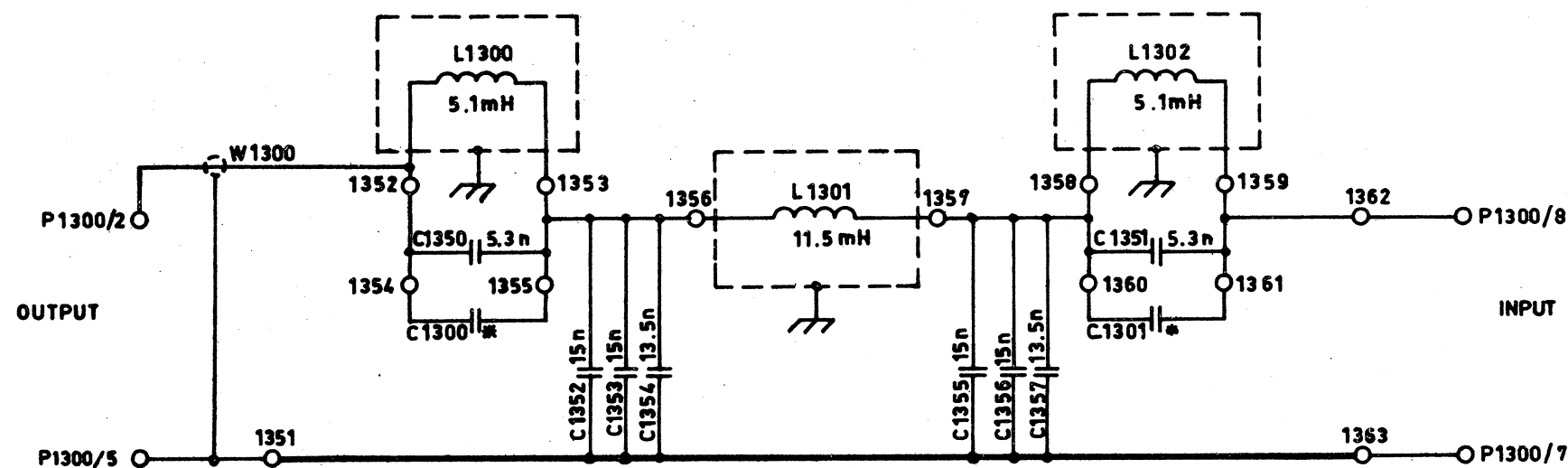
Målestok
Tegn. MH 28.3.66
Kont. PK 5/6 CC
Norm. PK 5/6 CC

Erstatte

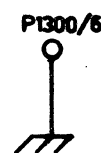
1670-A2

Erstatte af





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* FINAL VALUE FACTORY ADJUSTED

PRINT TERMINAL
1350

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Rt. Nr.	Fra Fab. Nr.	Dato	Rt. a:	Kont.	Norm.
4	5-1-67	KHK			PK
3	21.9.66	EA			PK
2	31.3.66	EA			PK
1	30.11.65	EA			PK

RADIOMETER COPENHAGEN
72 EMDRUPVEJ NV

LOW-PASS FILTER
TYPE CODE 900-229

From no. to no.

Målestok Tegn. EA 31.3.66
Konf. Norm.

Erstatler

1646-A2

Erstattes af

A

B

C

D

E

F

G

A

B

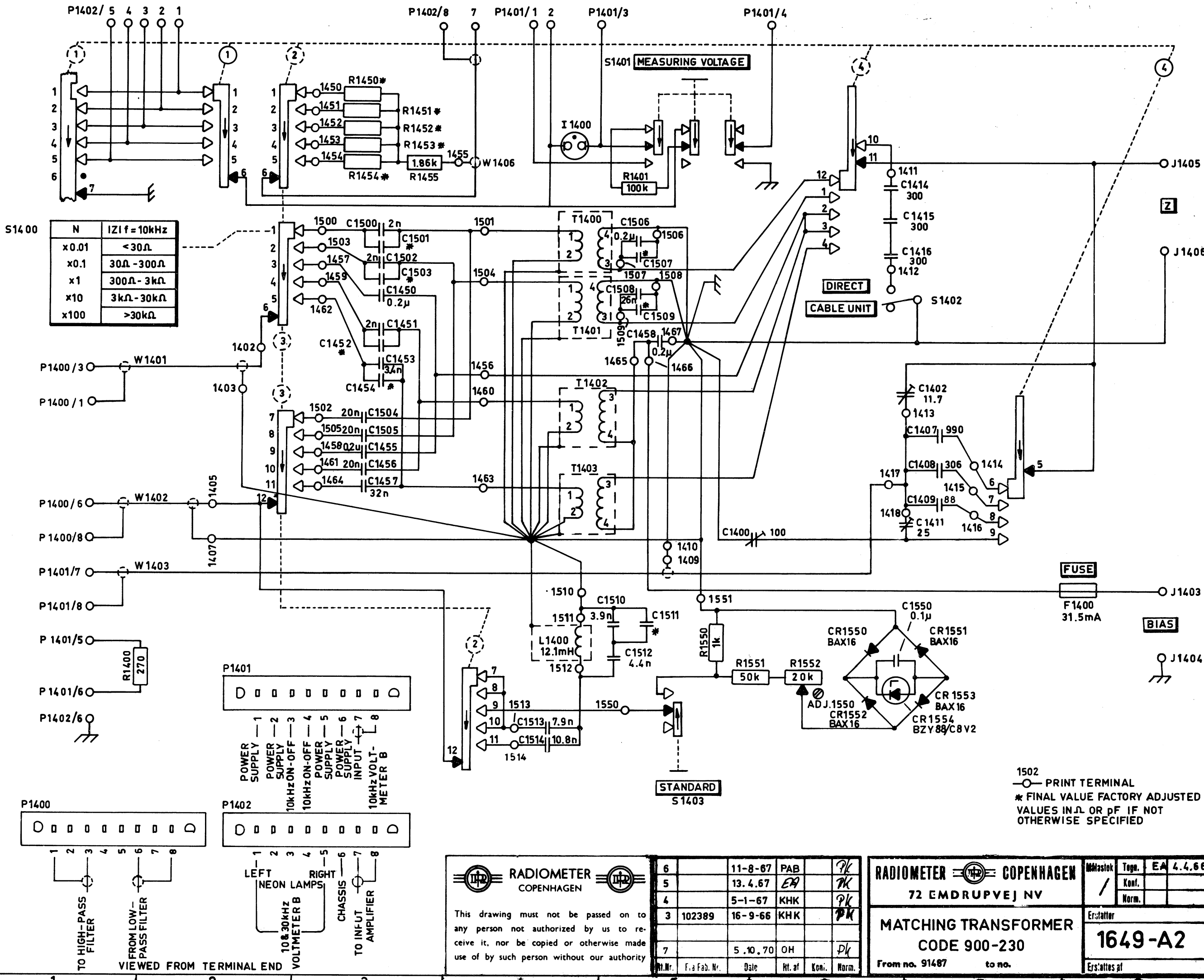
C

D

E

F

G

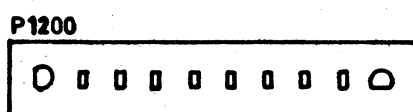
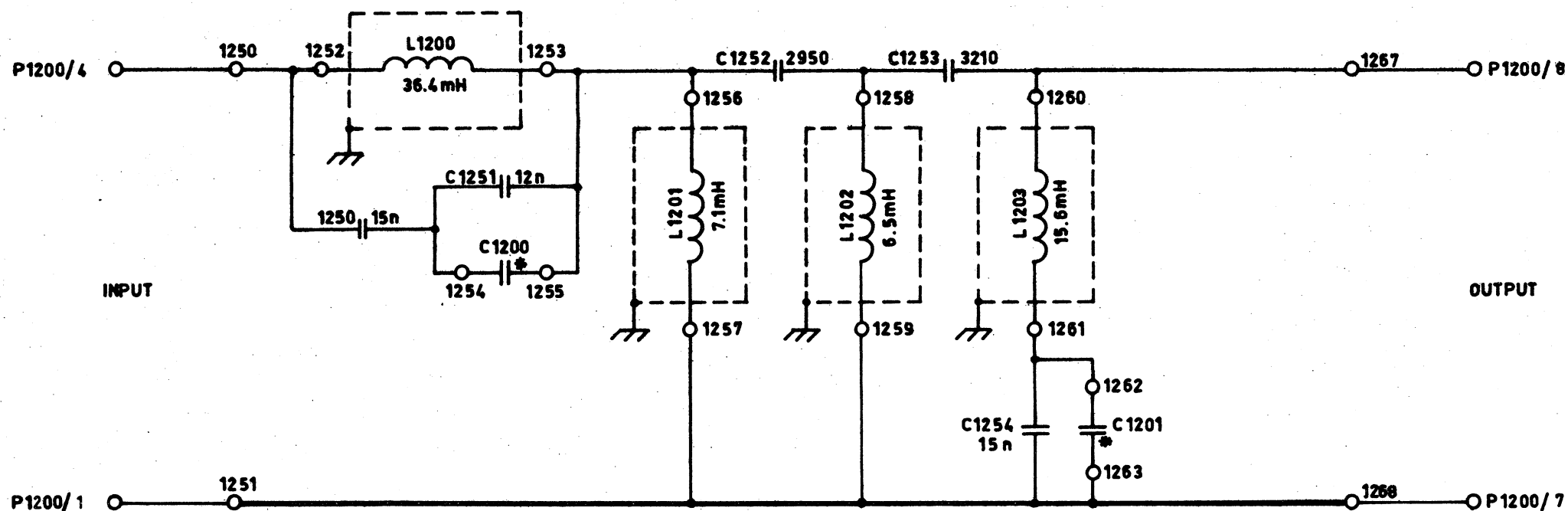


RADIOMETER COPENHAGEN

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6	11-8-67	PAB	PK
5	13.4.67	EA	PK
4	5-1-67	KHK	PK
3	102389	16-9-66	KHK
7	5.10.70	OH	PK
Mt. Nr.	F.a Fab. Nr.	Date	Mt. af Konf. Norm.

RADIOMETER COPENHAGEN		MMastok	Tegn.	EA 4.4.66
72 EMDRUPVEJ NV		Konf.		
MATCHING TRANSFORMER		Norm.		
CODE 900-230		Erstat		
From no. 91487 to no.		1649-A2		
		Erstat af		



FROM MATCHING
TRANSFORMER

CHASSIS

TO INPUT
AMPLIFIER

VIEWED FROM TERMINAL END



VALUES IN Ω OR μF IF NOT
OTHERWISE SPECIFIED
*FINAL VALUE FACTORY ADJUSTED
○ PRINT TERMINAL
1250

RADIOMETER
COPENHAGEN

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Rev.	Rev. No.	Date	Rev. at	Rev. of	Rev. of
3	5-1-67	KHK			pk
2	23.9.66	MH			pk
1	31.3.66	EA			pk

RADIOMETER
72 EMDRUPVEJ NV

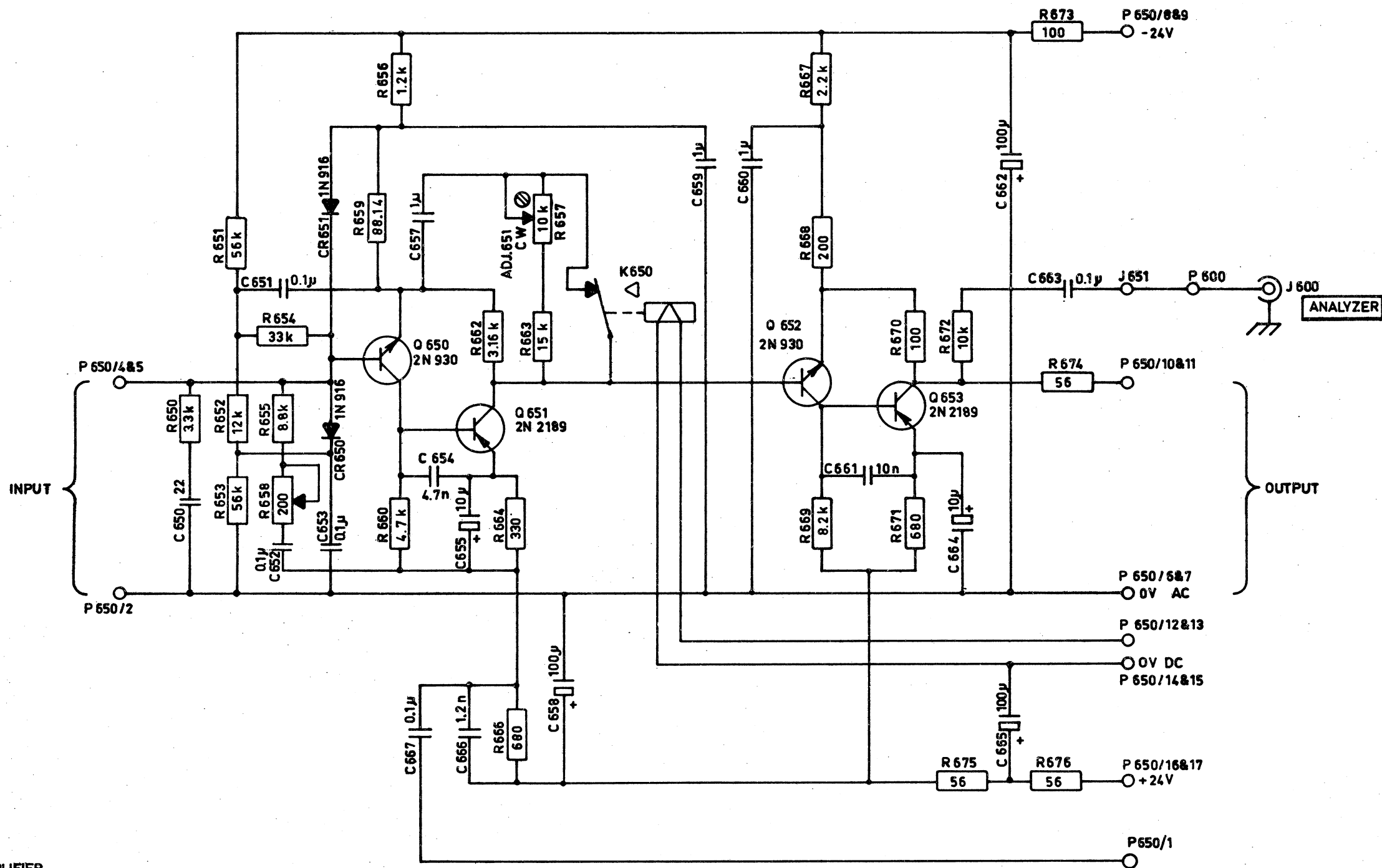
HIGH-PASS FILTER
CODE 900-228

From no. to no.

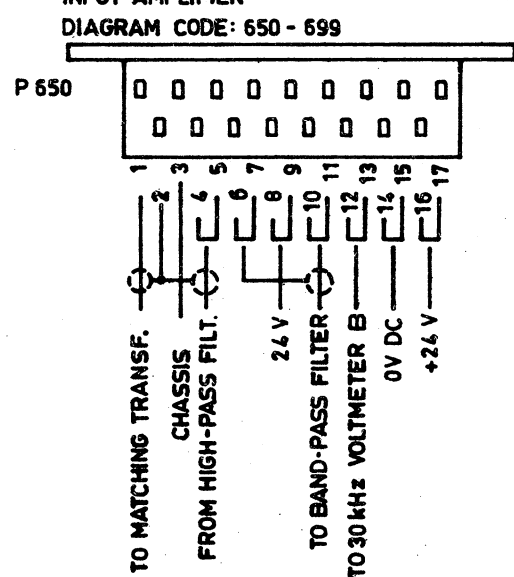
Material
Tegn. EA 31.3.66
Konf.
Norm.

Erstatning
1648-A2

Erstatning af



INPUT AMPLIFIER
DIAGRAM CODE: 650 - 699



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VALUES IN Ω OR pF IF NOT
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CW: CLOCKWISE

RADIOMETER COPENHAGEN

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Rt. Nr.	Fra Fab. Nr.	Date	Rt. af	Kont.	Norm.
4		17-4-67	KHK	PK	
3		5-1-67	KHK	PK	
2	91487	16-9-66	KHK		
1		30.3.66	MH	PK	

RADIOMETER COPENHAGEN
72 EMDRUPVEJ NV

INPUT AMPLIFIER
CODE 900-224

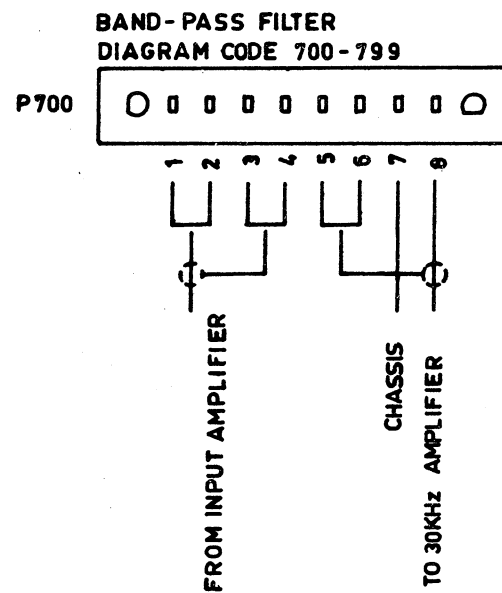
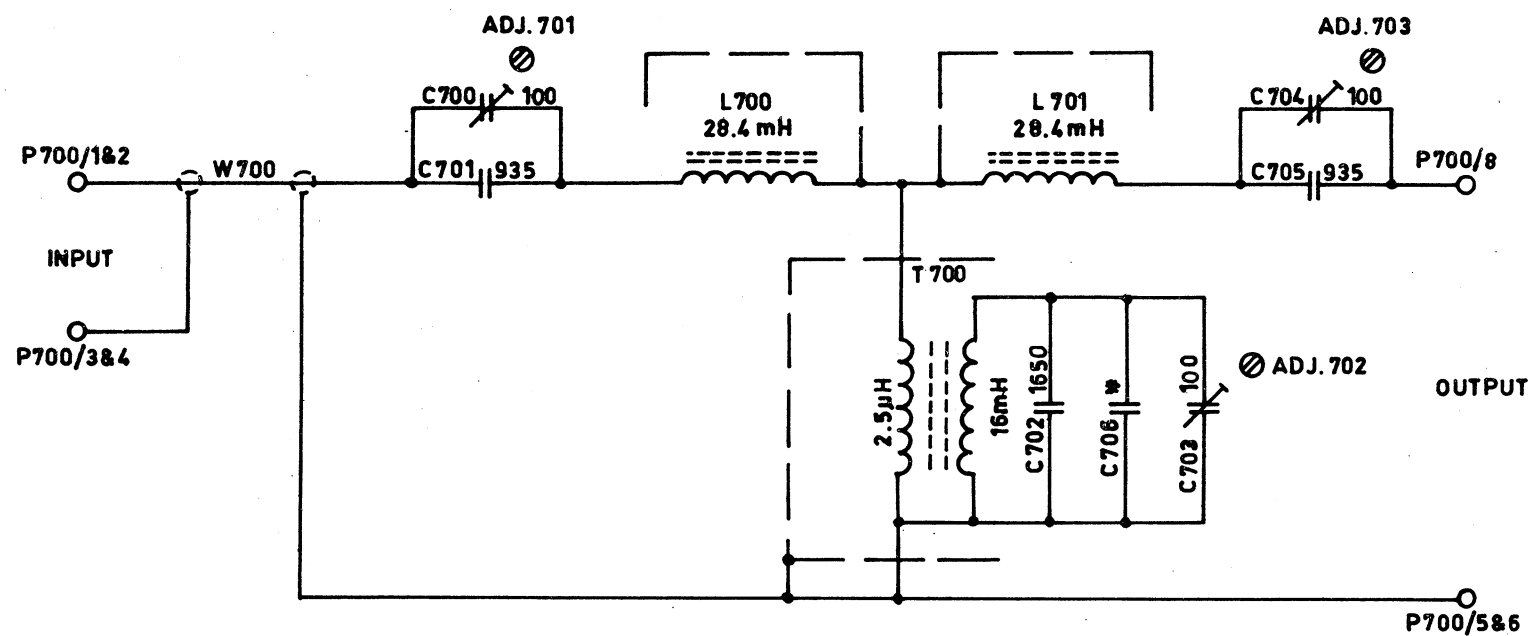
From no. 91487 to no.

Målestok
Tegn. *MH* 30.3.66
Kont.
Norm.

Erstatte

1657-A2

Erstatte af



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VALUES IN Ω OR pF IF NOT OTHERWISE SPECIFIED
*FINAL VALUE FACTORY ADJUSTED

RADIOMETER
COPENHAGEN

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Rt. Nr.	Fr. Feb. Nr.	Dato	Rt. af	Kont.	Norm.
3	10-8-67	PAB.		PK	
2	9-1-67	KHK		PK	
1	31.3.66	EA		PK	

RADIOMETER **COPENHAGEN**
72 EMDRUPVEJ NV

BAND-PASS FILTER
CODE 900-225

From no. to no.

Målestok Tegn. EA 31.3.66
Konf. Norm.

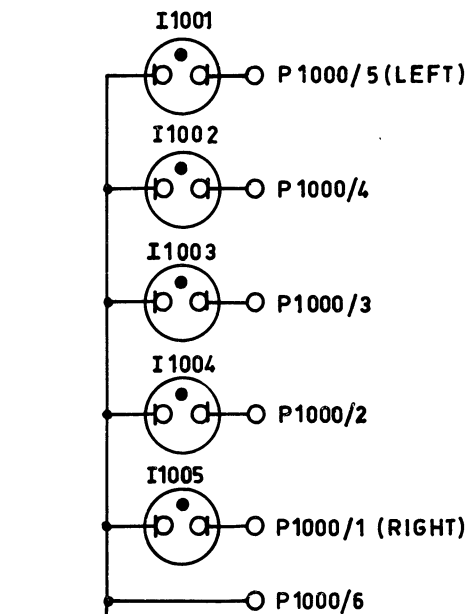
Erstatter
1674-A2
Erstattes af

METER RANGE S1000

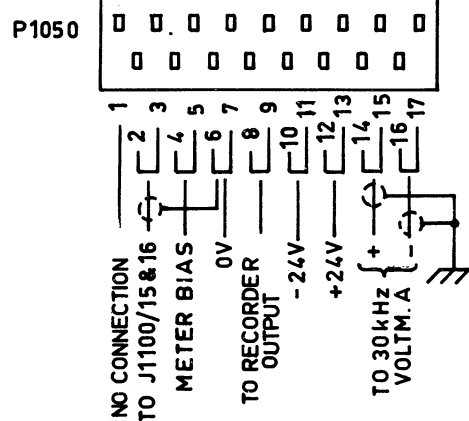
METER INDICATION S1100

100mV
30mV
10mV
3mV
1mV
300µV
100µV
30µV
10µV
3µV
1µV

INPUT
P1100/3&4
P1100/1&2



30kHz VOLTMETER (LEFT-REAR VIEW)
DIAGRAM CODE 1050 - 1099



VIEWED FROM TERMINAL END

LOG. AMPLIFIER (RIGHT-REAR VIEW)
DIAGRAM CODE 1100 - 1149

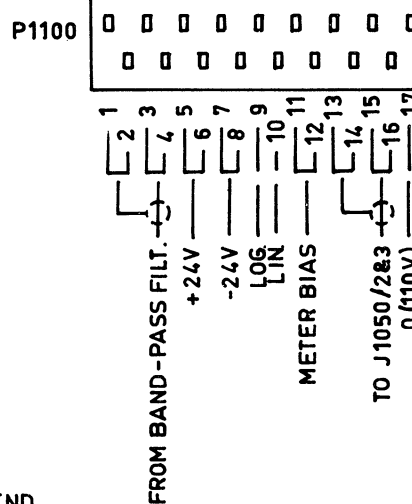
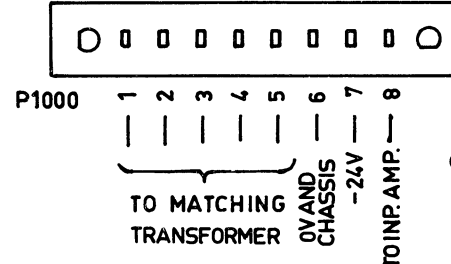


DIAGRAM CODE 1000-1049



VALUES IN Ω OR pF IF NOT OTHERWISE SPECIFIED
○-○ EXTERNAL STRAP (REAR PANEL).

6		14/2-69	Je.	AIH	PK
5		4-1-68	PAB	PK	
4		11-8-67	PAB	PK	
3	114091	16-12-66	KHK	PK	
7		5.5.70	SHM	PK	
Rt.Nr.	Fra.ah	Data	Ref	Kont.	Norm.

RADIOMETER COPENHAGEN
72 EMDRUPVEJ NV

30 kHz VOLTMETER B
CODE 900-227

From no. 91487 to no.

RADIOMETER COPENHAGEN

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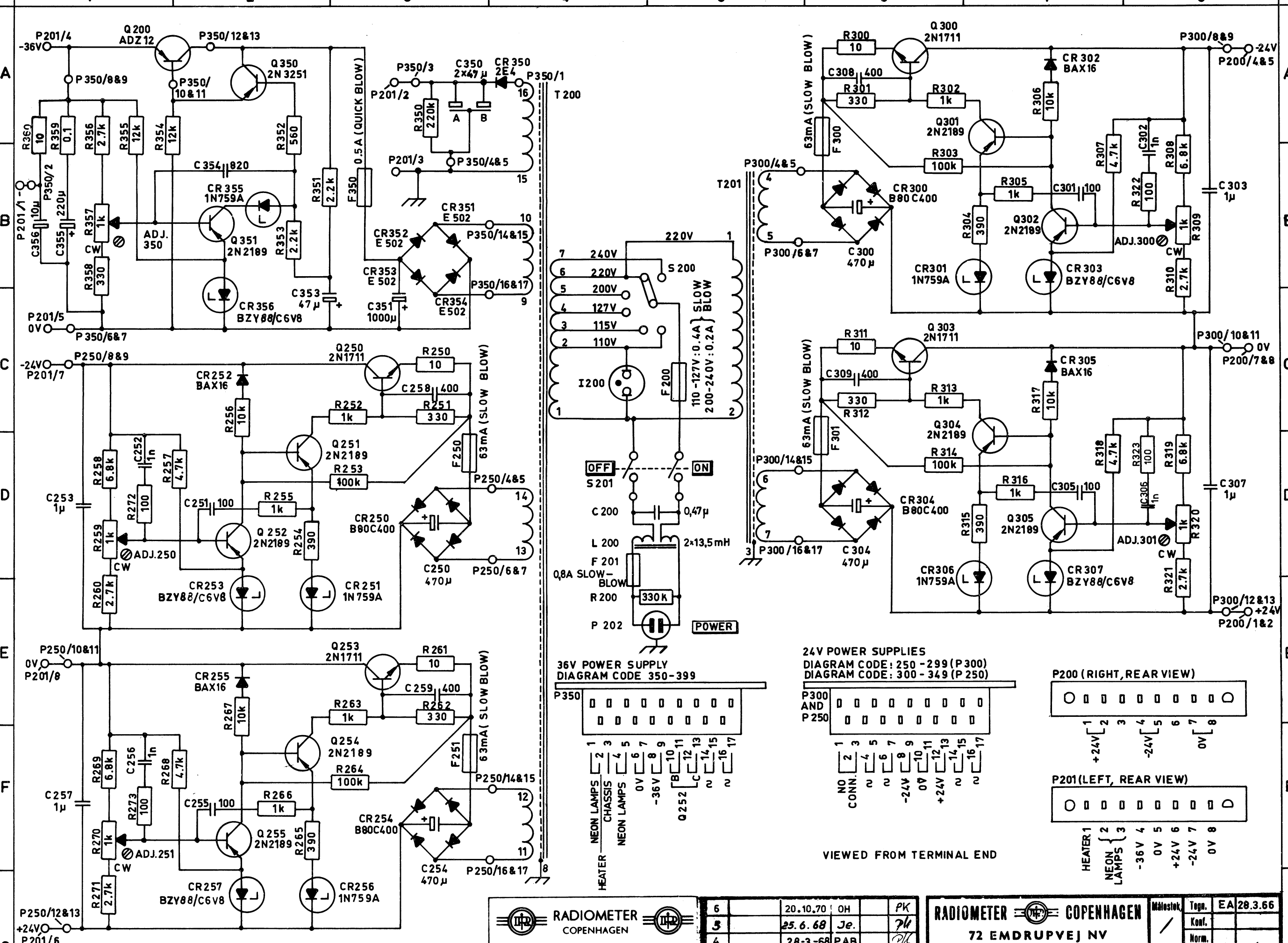
Målestok Yogh. EA 24.3.66

Kont. Norm.

Erstatter

1644-A2

Erstatter af



VALUES IN Ω OR pF IF NOT OTHERWISE SPECIFIED
CW: CLOCKWISE POSITION

RADIOMETER
COPENHAGEN

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6	20.10.70	OH	PK
5	25.6.68	Je	PK
4	28-3-68	PAB	PK
3	10-8-67	PAB	PK
2	9-1-67	KHK	PK
1	28.3.66	EA	PK
Pr. Nr.	Fra Fcb. Nr.	Gato	Rt. af
		Kont.	Kont.

RADIOMETER COPENHAGEN
72 EMDRUPVEJ NV

POWER SUPPLY
CODE 900-221

From no. to no.

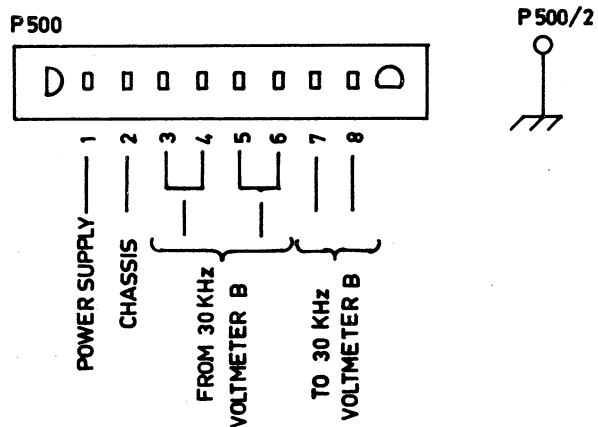
Målestok: Tegn. EA 28.3.66

Kont. Norm.

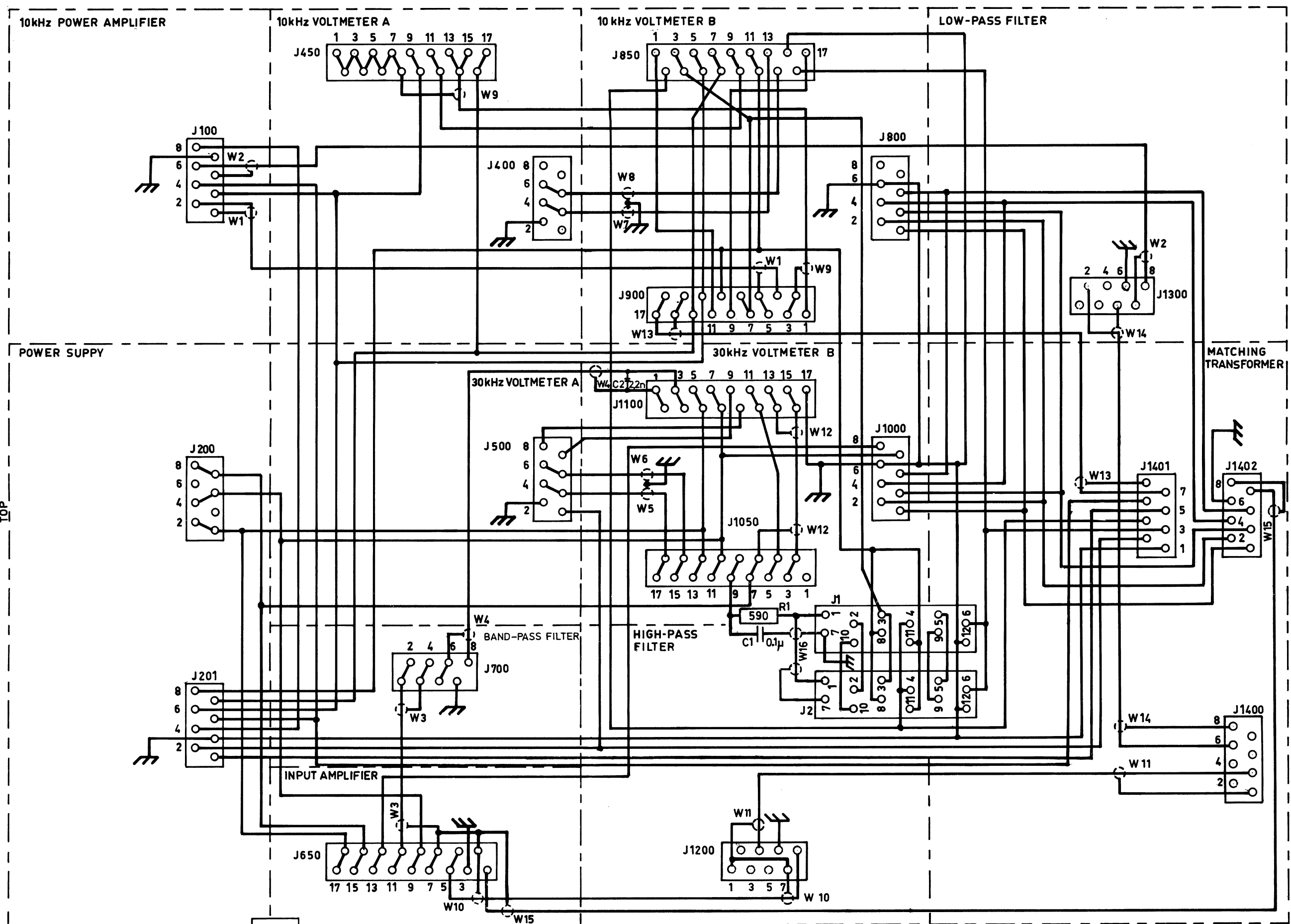
Erstatfor

1660-A2

Erstatfor af





1		6-1-67	KHK	<i>PH</i>	
Rt. Nr.	Fra Fab. Nr.	Dato	Rt. af	Kont.	Norm.



7	○ ○	1 RECORDER OUTPUT
10	○ ○	2
8	○ ○	3 10kHz LEVEL
11	○ ○	4 10kHz ON-OFF
9	○ ○	5
12	○ ○	6 CONTROL LAMP


J1 AND J2

**RADIOMETER**
COPENHAGEN

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6		27.1.70	OH	EJP	PK
5		3-2-69	Je	AIH	PK
4		1-8-67	PAB		PK
3		5-1-67	KHK		PK
2	102389	9-9-66	KHK		PK
1		5.4.66	EA		PK

Rt. Nr. Fab. Nr. Dato. Rt. af Konf. Norm.

RADIOMETER  **COPENHAGEN**
72 EMDRUPVEJ NV

CLT1: REAR PANEL WIRING
CODE 884-508

From no. 91487 to no. .

Målestok Tegn. EA 5.4.66
Konf. Norm.

Erstatfor
1654-A2
Erstatfor af