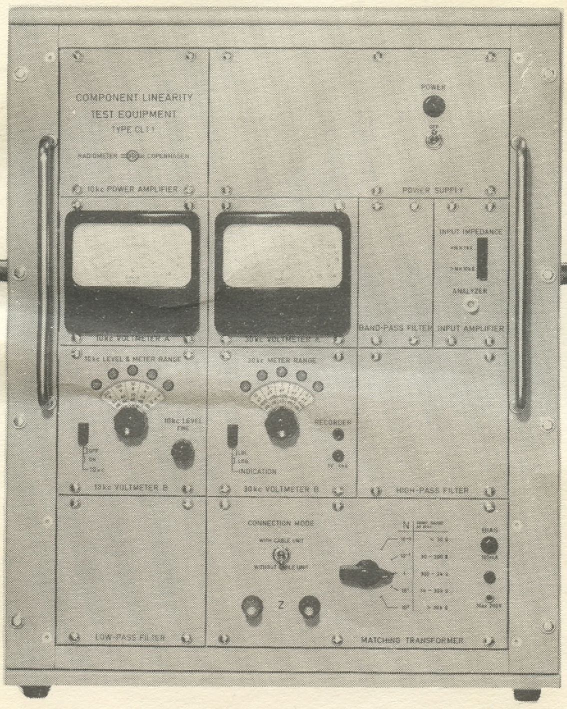
May 65

PROVISIONAL

type CLT 1

COMPONENT LINEARITY TEST EQUIPMENT



RADIOMETER

RADIOMETER A/s 72 EMDRUPVEJ COPENHAGEN NV, DENMARK

COMPONENT LINEARITY TEST EQUIPMENT
TYPE CLT1

GENERAL

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

As its predecessor, the Component Linearity Test Equipment, type CLT1, is intended for investigation of the non-linearity of nominally linear components, such as resistors and capacitors, as well as of non-linear devices and materials. Due to some very important improvements it is especially suited for:

Quality control of component manufacture,

Acceptance testing of components,

Reliability investigations.

The working principle of the equipment is a determination of the non-linearity of a component by a selective measurement of the 3rd harmonic signal, generated in the component, when a pure sinusoidal 10 kc voltage is applied to it.

By measuring the non-linearity of the components of a batch, the bad specimens can be found, since these are characterized by a non-linearity considerably greater than the average non-linearity of the batch. Rejection of the bad specimens greatly improves the reliability of the batch.

Typical effects which cause non-linearity are as follows:

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.

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.

SPECIAL FEATURES

- Wide impedance range of components: from less than 1Ω to above 100 MΩ.
- 1 VAdelivered to component under test within impedance range 3Ω to 300 kΩ.
- Max. 10 kc test voltage: 560 V.
- 3rd harmonic as much as 150-160 dB below the fundamental can be measured.
- Common control knob for both generator voltage range and sensitivity range of voltmeter for fundamental.
- 3rd harmonic indication either linear or logarithmic. 60 dB range of latter ensures convenient production testing.
- Recorder output for 3rd harmonic registration (linear and logarithmic).
- Low response time makes possible measurements of 10 to 20 components per second.
- External control of test voltage amplitude for recording the 3rd harmonic as a function of test voltage applied.
- No sensitivity to hum.
- Fully transistorized.

DESCRIPTION

The operating principle of the type CLT1 Component Linearity Test Equipment is indicated in the simplified block diagram of Fig. 1 and can be described as follows:

The output from the 10 kc oscillator is fed via an automatic gain control stage, AGC, and an attenuator, AT1, to a special low-distortion power amplifier, A1. The output voltage of the latter is fed to a low-pass filter, LP, in order to obtain a very pure sinusoidal electromotive force which is applied to the component under test via the matching transformer, MT. As the operating principle is based on the measurement of the 3rd harmonic voltage generated in the component, it is obvious that the 10 kc test voltage must be very pure, i.e. the 3rd harmonic must be suppressed by at least 170 - 180 dB. To achieve this high suppression, great care has been taken in designing and manufacturing the low-pass filter and the matching transformer.

The inductors of the low-pass filter and the transformer are air-cored because magnetic materials would introduce non-linearity. However, as the leakage inductance of an air-cored transformer at the frequencies in question is quite large, and the main inductance is fairly small, a special network is introduced in order to make the matching transformer ideal at 10 kc and 30 kc.

The 10 kc voltage which is applied to the component is measured by means of the voltmeter, VM. An automatic amplitude control stage, AAC, is connected to the voltmeter and controls the AGC stage in order to keep the 10 kc voltage constant and independent of variations in the impedance of the components under test. As the attenuator AT2 of the voltmeter and the range switch AT1 of the 10 kc generator are mechanically connected, the sensitivity of the voltmeter is automatically set in accordance with the selected voltage range of the generator - an operational convenience. Adjustment of the 10 kc voltage to a value within the range selected is accomplished by means of a control knob. Further, external control of the 10 kc voltage can be introduced by applying a dc voltage to the AAC stage. Therefore, by applying a sliding dc voltage, the 3rd harmonic can be recorded as a function of the 10 kc voltage.

Due to the non-linearity of the component, harmonics are generated inside it. However, as the 3rd harmonic voltage usually is highly prevailing, harmonic voltages of a higher order than the 3rd order are disregarded in the description which follows.

The 3rd harmonic voltage that has a frequency of 30 kc is passed via the matching transformer to the high-pass filter, HP, of the 30 kc level meter. The high-pass filter, which serves to suppress the 10 kc 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 30 kc voltage is then fed via a preamplifier, A3, to a band-pass filter, BP, which provides for a high selectivity of the 30 kc level meter in order to keep the noise voltage sufficiently low. An attenuator, AT3, which follows the band-pass filter serves to attenuate the 30 kc voltage to a level that matches the meter amplifier A4. The level of the 3rd harmonic is indicated on the meter M. Linear meter indication is normal, but as the non-linearity of the individual components of a batch may vary considerably, logarithmic meter indication over a 60 dB range is also possible.

When the test equipment is used for manual production testing, the logarithmic meter indication will ensure maximum operating speed as sensitivity adjustments very seldom are necessary. In the case of high-speed automatic production testing the logarithmic meter indication is indispensable as sensitivity adjustments cannot be made. The low response time of the test equipment makes it possible to test more than 10 components per second. A recorder output, which also can be switched from linear to logarithmic indication, provides for registration of the 3rd harmonic.

As previously mentioned, the component under test is connected to the generator and the 30 kc level meter by means of a matching transformer. Actually the main component range 3 Ω to 300 kΩ is divided into 5 ranges as follows: A basic range 300 Ω to 3 kΩ where no matching transformer is employed, and 4 transformation ranges, each having a separate matching transformer and covering a decade. As the input impedance of the equipment at 30 kc, $Z_{i,30}$, is not infinite, the 30 kc voltage measured is not the open-circuit value of the 3rd harmonic voltage which it is usually desired to determine. However, the open-circuit value can be calculated by multiplying the measured 30 kc voltage by a correction factor equal to

$$\left| 1 + \frac{Z_{x,30}}{Z_{i,30}} \right| ,$$

where $Z_{x,30}$ is the impedance of the component at 30 kc. This is illustrated in Fig. 2 where the voltage e represents the open-circuit value of the 3rd harmonic voltage.

The input impedance $Z_{i,30}$ is usually N · 1 kΩ, where N is the impedance transformation ratio of the matching transformer. However, by pressing a push-button the input impedance is increased approx. 10 times, whereby the correction factor is reduced. For many applications the correction factor can then be neglected - an operational convenience.

Another important mission of the matching transformer is to match the component to the generator in order to obtain maximum power delivered. In the main range 3Ω to 300 kΩ 1 VA can be delivered, but above and below the main range the power drops off because of the unavoidable mismatch.

Above the upper limit of the main range the above mentioned loading of the component's "harmonic generator" reduces the sensitivity of the equipment. This is reflected in an increasing correction factor which, for example, is 1000 at a resistance of 100 MΩ. However, as the generated 3rd harmonic voltage in most cases increases with increasing resistance, it is usually possible to carry out the measurements. Below the lower limit of the main range the most serious restriction is the power available, as the correction factor approaches 1 for decreasing impedance values.

In some cases it is of interest to investigate the non-linearity on the basis of harmonics of a higher order than the third order. The high-pass filter allows the higher harmonics to pass (up to the 9th harmonic), so that these can be measured with a wave analyzer connected to the output of amplifier A3. However, since the matching transformers are ideal at 10 kc and 30 kc only, the measurement of the higher harmonics can only be carried out with the equipment set for the basic impedance range where no matching transformer is utilized.

Note: Basic measuring principle patented.

Patents pending on circuitry.

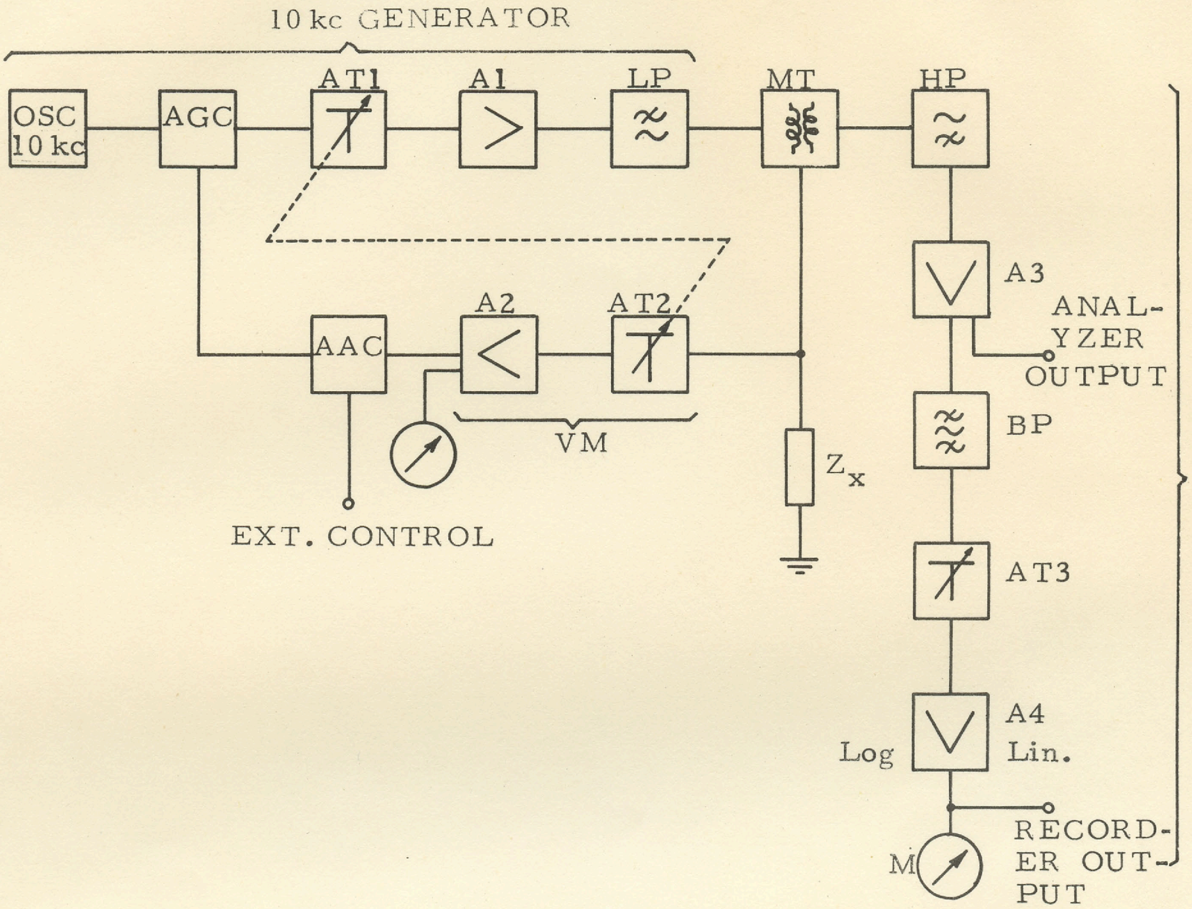


Fig. 1: Simplified block diagram

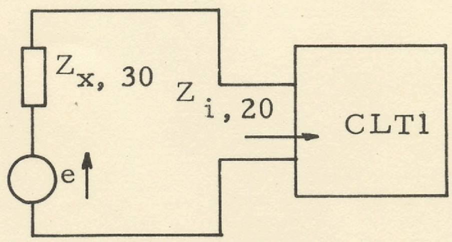


Fig. 2: Loading of component under test

TENTATIVE SPECIFICATIONS

COMPONENT RANGE

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

The individual ranges are indicated in ohms corresponding to the magnitude $|Z_{x,10}|$ of the component's impedance at 10 kc.

Main Range

3 Ω to 300 kΩ in the following sub-ranges:

Basic Range:	300 Ω	to	3 kΩ	N+)	≈	1
Transformation Ranges:	3 Ω	to	30 Ω	N	≈	0.01
	30 Ω	to	300 Ω	N	≈	0.1
	3 kΩ	to	30 kΩ	N	≈	10
	30 kΩ	to	300 kΩ	N	≈	100

+) N indicates the impedance transformation ratio of the built-in matching transformer.

The main range is characterized by:

1. The maximum power delivered to the component under test is 1 VA.
2. The residual non-linearity corresponding to 0.25 VA delivered to the component under test is less than -150 dB. See the item Residual Non-Linearity.

Supplementary Ranges

Above 300 kΩ and below 3 Ω in the following ranges:

Upper Supplementary Range: Above 300 kΩ N ≈ 100

The upper range is characterized by:

1. The maximum power delivered to the component under test is $\frac{0.3}{|Z_{x,10}|}$ VA, where $Z_{x,10}$ is inserted in MΩ.

2. The residual non-linearity with a 10 kc voltage of 280 V+) applied to the component under test is less than $-\left[162-20\log\left|1+\frac{Z_{x,10}}{0.1}\right|\right]$ dB, where $Z_{x,10}$ is inserted in MΩ.

   Examples: $|Z_{x,10}| =$ 10 MΩ: -122 dB

   $|Z_{x,10}| =$ 100 MΩ: -102 dB

   +) 280 V correspond to 0.25 VA dissipated in 300 kΩ.

Lower Supplementary Range: Below 3 Ω N = 0.01

The lower range is characterized by:

1. The maximum power delivered to the component under test is $0.3 \cdot |Z_{x,10}|$ VA, where $Z_{x,10}$ is inserted in Ω.

2. The residual non-linearity with a 10 kc current of 280 mA+) applied to the component under test is less than $-\left[162-20\log\left|1+\frac{10}{Z_{x,10}}\right|\right]$ dB.

   Example: $|Z_{x,10}| =$ 1 Ω: -141 dB

   +) 280 mA correspond to 0.25 VA dissipated in 3 Ω.

GENERATOR FREQUENCY

10 kc

MEASURING FREQUENCY

30 kc (3rd harmonic of generator voltage).

POWER RANGE

Up to 1 VA delivered from generator to components with impedances within the main range 3 Ω to 300 kΩ.

Available output voltages as specified under item 10 kc Voltmeter.

OUTPUT IMPEDANCE OF GENERATOR

Less than N • 3 Ω, where N indicates the impedance transformation ratio of the built-in matching transformer.

INPUT IMPEDANCE OF 30 kc LEVEL METER

By means of a push-button switch two input impedances can be selected:

$N \cdot 1\ k\Omega$ +)

Magnitude: $N \cdot 1\ k\Omega \pm 2\%$.

Phase Angle: Less than 5^o.

$> N \cdot 10\ k\Omega$ +)

Magnitude: Greater than $N \cdot 10\ k\Omega$.

+) N indicates the impedance transformation ratio of the built-in matching transformer.

CORRECTION FACTOR

Provided that the input impedance of the 30 kc level meter is $N \cdot 1\ k\Omega$, the correction factor is defined as $\left|\frac{Z_{x,30}}{N} + 1\right|$, where $Z_{x,30}$ indicates the component's impedance at 30 kc in kΩ, and N indicates the impedance transformation ratio of the built-in matching transformer.

By multiplying the 3rd harmonic reading by the correction factor the open-circuit value of the 3rd harmonic voltage produced by the component is obtained.

Typical values of the correction factor are:

For Measurements on Resistors

Main Range:	Max. 4 (12 dB).
Lower Supplementary Range:	Max. 1.3 (2.3 dB).
Upper Supplementary Range:	R = 10 MΩ: Approx. 100 (40 dB).
	R = 100 MΩ: Approx. 1000 (60 dB).

For Measurements on Inductors

Main Range:	Max. 9 (19 dB).
Lower Supplementary Range:	Max. 1.4 (3 dB).

For Measurements on Capacitors

Main Range:	Max. 1,4 (3 dB).
Lower Supplementary Range:	Max. 1.04(0.4 dB).

RESIDUAL NON-LINEARITY

The residual non-linearity is defined as:

$$20 \log \frac{\text{residual 3rd harmonic + noise}}{\text{fundamental}}$$

and is specified under the item Component Range.

Note: 1. Noise comprises the thermal noise of the component under test and the noise of the instrument proper.

2. Measuring error originating from the residual non-linearity is max. 10% for a non-linearity of the component under test being 20 dB above the residual non-linearity.

10 kc VOLTMETER

The equipment has a common range switch for the generator amplitude and the voltmeter sensitivity. Therefore, the voltage range indicated is valid for both the generator and the voltmeter. A fine control sets the 10 kc voltage within the range selected. The range index is automatically switched in accordance with the selected transformation ratio N of the built-in matching transformer.

Basic Range

N = 1	(300 Ω to 3 kΩ):	0.1 V to 100 V f.s. in 7 ranges.

Transformation Ranges

N = 0.01	(3 Ω to 30 Ω):	0.01 V to 10 V f.s. in 7 ranges.
N = 0.1	(30 Ω to 300 Ω):	0.03 V to 30 V f.s. in 7 ranges.
N = 10	(3 kΩ to 30 kΩ):	0.3 V to 300 V f.s. in 7 ranges.
N = 100	(30 kΩ to 300 kΩ):	1 V to 1000 V f.s. in 7 ranges.

Upper Supplementary Range

N = 100	(above 300 kΩ):	1 V to 1000 V f.s. in 7 ranges.

Lower Supplementary Range

N = 0.01	(below 3 Ω):	0.01 V to 10 V f.s. in 7 ranges.

Note: All ranges in a 1-3-10 sequence.
Max. output voltage is 560 V.

Accuracy

1% of reading + 1% of full scale.

Meter Scales

Two linear voltage scales 0 to 1 and 0 to 3.

One dB scale 0 to 22 dB. Total dB range by utilizing the range switch: 82 dB. dB calibration referred to 1 V.

10 kc Voltage On-Off Switch

A push-button ON-OFF switch, which can be locked in either position, switches the 10 kc voltage on and off.

30 kc LEVEL METER

The range index of the sensitivity switch is switched automatically in accordance with the selected impedance transformation ratio N of the built-in matching transformer. The sensitivities are indicated without regard to the correction factor.

Linear Indication

Basic Range

N = 1	(300 Ω to 3 kΩ):	1 μV to 300 mV f. s. in 12 ranges.

Transformation Ranges

N = 0.01	(3 Ω to 30 Ω):	0.1 μV to 30 mV f. s. in 12 ranges.
N = 0.1	(30 Ω to 300 Ω):	0.3 μV to 100 mV f. s. in 12 ranges.
N = 10	(3 kΩ to 30 kΩ):	3 μV to 1 V f. s. in 12 ranges.
N = 100	(30 kΩ to 300 kΩ):	10 μV to 3 V f. s. in 12 ranges.

Upper Supplementary Range

N = 100	(above 300 kΩ):	10 μV to 3 V f. s. in 12 ranges.

Lower Supplementary Range

N = 0.01	(below 3 Ω):	0.1 μV to 30 mV f. s. in 12 ranges.

Note: All ranges in a 1-3-10 sequence.

Measurement of a 3rd harmonic-to-fundamental ratio as large as -39 dB is possible for 0.25 VA dissipated in the component under test.

Accuracy

Provided that the input impedance of the 30 kc level meter is set to N · 1 kΩ, the accuracy is as follows:

Basic Range (300 Ω to 3 kΩ)

3% of reading + 1% of full scale.

Transformation Ranges and Supplementary Ranges

5% of reading + 1% of full scale.

Meter Scales

Two linear voltage scales 0 to 1 and 0 to 3.

One dB scale 0 to 22 dB. Total dB range by utilizing the range switch: 132 dB. dB calibration referred to 1 V.

Logarithmic Indication (total range)

Basic Range

N = 1	(300 Ω to 3 kΩ):	From 10 dB to 120 dB below 1 V.

Transformation Ranges

N = 0.01	(3 Ω to 30 Ω):	From 30 dB to 140 dB below 1 V.
N = 0.1	(30 Ω to 300 Ω):	From 20 dB to 130 dB below 1 V.
N = 10	(3 kΩ to 30 kΩ):	From 0 dB to 110 dB below 1 V.
N = 100	(30 kΩ to300 kΩ):	From-10 dB to 100 dB below 1 V.

Upper Supplementary Range

N = 100	(above 300 kΩ):	From -10 dB to 100 dB below 1 V.

Lower Supplementary Range

N = 0.01	(below 3 Ω):	From 30 dB to 140 dB below 1 V.

Accuracy

Provided that the input impedance of the 30 kc level meter is set to N · 1 kΩ, the accuracy is as follows:

Basic Range (300 Ω to 3 kΩ)

1 dB.

Transformation Ranges and Supplementary Ranges

1.3 dB

Meter Scale

A linear dB scale 0 to 60 dB.

EXTERNAL VOLTAGE CONTROL

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

dc Control Voltage

1 V ±1% for a 10 kc voltage amplitude equal to range indication. The 10 kc voltage is proportional to the control voltage.

Input Resistance

Greater than 2 kΩ.

EXTERNAL ON-OFF CONTROL

A control input makes possible remote switching of the 10 kc voltage. Switching is performed by an external switch. The 10 kc voltage is present when the switch is closed.

External switching can be performed only when the 10 kc Voltage On-Off Switch is set to OFF.

DC BIAS

A dc bias input provides for dc bias of the component under test.

Max. dc Voltage

200 V.

Max. dc Current

100 mA.

ANALYZER OUTPUT

For investigations of harmonics of a higher order than the 3rd. Requires that the instrument is set for the basic range (300 Ω to 3 kΩ), where no matching transformer is employed.

RECORDER OUTPUT

For registration of the 3rd harmonic at both linear and logarithmic indication.

Output Voltage

1 V dc ±1% for full scale deflection on meter.

Output Resistance

4 kΩ.

Note: Loading of the recorder output does not affect the meter reading.