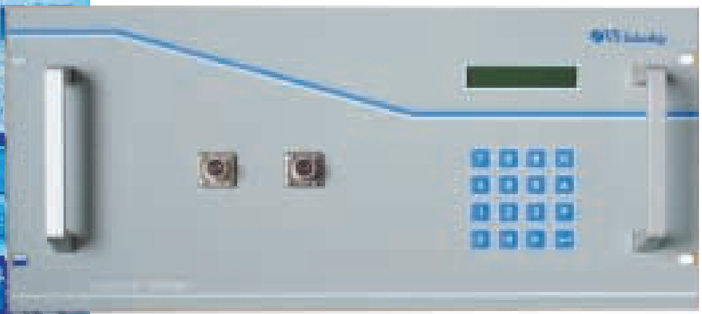
Device Linearity Tester



- 10 kHz driving signal, amplitude: self-adjusting, from 0.01 to 10 V
- DC bias from 0.1 to 10 V
- Component impedance range: from 10 m up to 100
- Maximum measurement rate: 30 times per second
- IEEE 488 Interface
- I/O Handler
- High-speed auto-ranging feature
- Third harmonic threshold level < -140 dB
- Advanced screening technique
- Evaluation of non-linearity variations in time domain

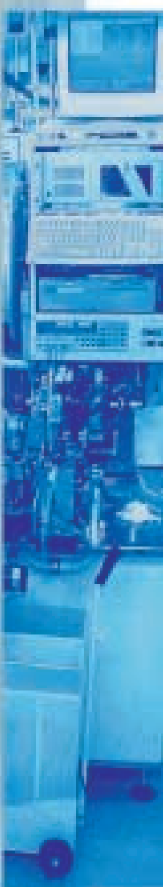
Non-linearities and LTC 1010 in practice

The range of practical applications of LTC 1010 is very wide, being preferably focused on:

- 100% production testing of electronic components
- Development of new components
- Quality and reliability testing of contacts
- Non-linearity research
- Selection of components for audio applications
- Material and chemical analysis

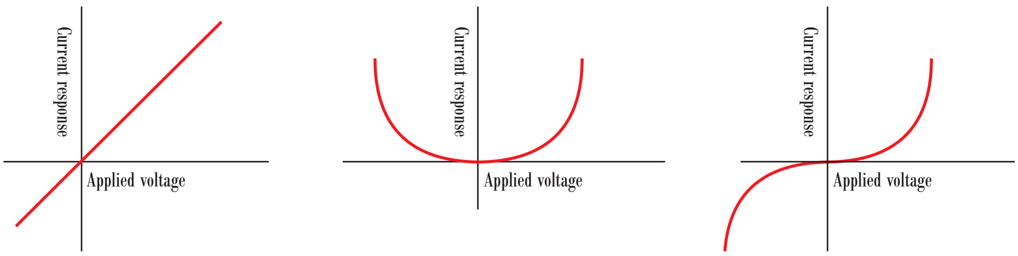
The most common application area of LTC 1010 is that of reliability assessment of passive components. Defective or degraded components are not only less reliable, but they also show non-linearities caused by the inhomogeneous and time-fluctuating current density, which in turn is due to defects. Measurements of non-linearities have been successfully used to assess the quality and reliability of the components, listed below.

- Thin and thick-film resistors
- Ceramic capacitors
- Tantalum and Niobium capacitors
- Aluminium capacitors
- Testing of interconnection in general of any mechanical/electromechanical switching system
- Adjustable potentiometers and trimmers
- Printed Circuit Board testing
- Unipolar, under DC bias operated semiconductor devices



What is non-linearity?

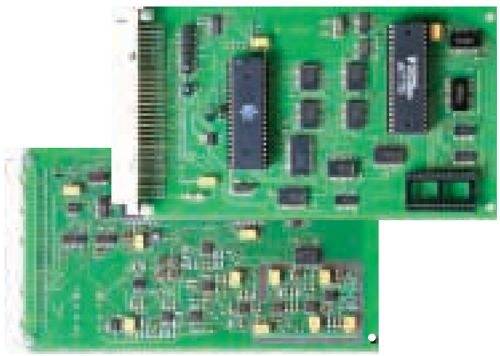
Non-linearity as such is either an unwanted feature of linear passive components caused by non-linear elements within the bulk of these components, or, a desired and useful feature of some semiconductor devices. What is actually the ever-present non-linearity? Generally speaking, is it a change in the component impedance which depends on the level or polarity of biasing, or, its change in the time, expressed in the general form of the Ohm's law as a voltage versus current relationship in the time domain. A linear response plot and two non-linear response plots are shown in Fig. 1, which illustrates an absolutely linear element and elements showing second-order and third-order non-linearities, respectively.



Linear component.   Non-linearity of the second order.   Non-linearity of the third order.

Fig.1. Linear and non-linear regions of V-I characteristics

Let us remark, by way of introduction, that an absolutely linear component will be very difficult to find in the present world. Fortunately, specially designed electrical circuits of LTC 1010 allows one to measure and compare the levels of non-linearity with specified assessment criteria obtained from V-I curve scanning. It is to be said, however that a real component shows a lot of elementary non-linearities and they may also be frequency dependent.



In principle, any non-linearity consists of four basic components:

Non linearity component
a) None or minimal
b) Built-in
c) Unwanted - excessive or additive
d) Unstable values in the time domain

a) None or minimal. This is the case where the resistance increases considerably or the contacts are disconnected = hence the connection is lost and the current flow equals zero, whereas the non-linearity will be the same as that in no-load status, like in an open circuit. The non-linearity will in principle drop to the background level.

b) The built-in component is an additive quantity, which is present, to a certain extent within any device (e.g. semiconductor diodes, unipolar dielectric capacitors, etc.) and its level is always to be considered as a non-linearity mean value. Unfortunately, the higher the built-in component, the higher the measurement threshold and, consequently, the more difficult the detection of the unwanted excessive non-linearity. It is to be noted that, ideally, the unwanted component should be the most significant one to determine the device (non-) linearity and reliability and, therefore, should not be buried in the built-in component.

c) The unwanted, excessive or additive component may be of the same origin as the built-in one as far as the physical origin is concerned, however, there is one significant difference there, namely, that it equals zero under normal circumstances (no defect present) or, at least, tends to zero. The unwanted non-linearity, or, in the real life, their sum, makes the V-I curve deviate from its ideally linear shape.

What may this phenomenon be due to?

i) too high contact resistance of any junction within the circuitry, which gives rise to quite a complicated network of passive components, affecting the shape of the V-I characteristics
ii) physical properties of the base material (e.g., ferromagnetics)
iii) defect states or inhomogeneities within the material structure
iv) interference or interaction with the environment (temperature, humidity, vibrations etc.)

d) Unstable in the time domain. The present method of analysis extends significantly the suspect device recognition capability within the whole spectrum of non-linearity values. The level of stability is determined by means of a continuous measurement carried out during a specified time interval, while the current flow from the generator is fed into the device under test. The AC current flowing through the device starts to heat up all lowest local conductivity spots. Linear response spots change only their local resistivity with the temperature, the resistivity itself exhibiting no non-linearity features and showing only marginal contribution to the time domain instability, if any. However, the non-linearity is temperature dependent, therefore, due to the heating up of these spots the non-linearity will change significantly within the time domain. This method allows to overload components being tested for a short period. This is useful for stressing the device, thus ensuring an extended dynamic range of reliability measurements.

Principle of non-linearity measurements of LTC 1010

The principle of the non-linearity measurement method consist in determining the deviations from linear V-I characteristics, which are real-time analyzed subsequently. To determine the non-linearity, it is essential to use a power supply generating a highly pure sine-wave first harmonic signal, which is applied across the device under test (DUT) (See Fig. 2.). We assume that linear devices do not convert the input signal into any other frequency components, except heat, which is in fact a kind of signal as well, whose frequency is however occupying a far higher frequency interval.

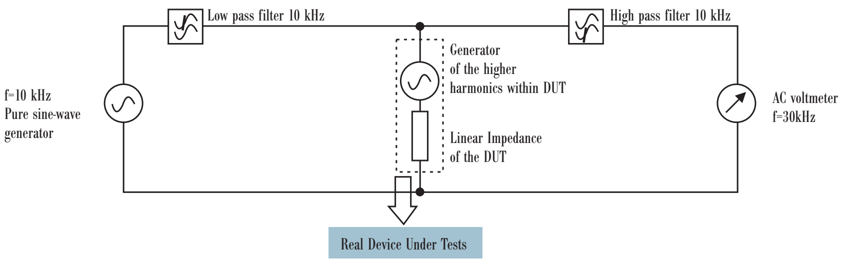
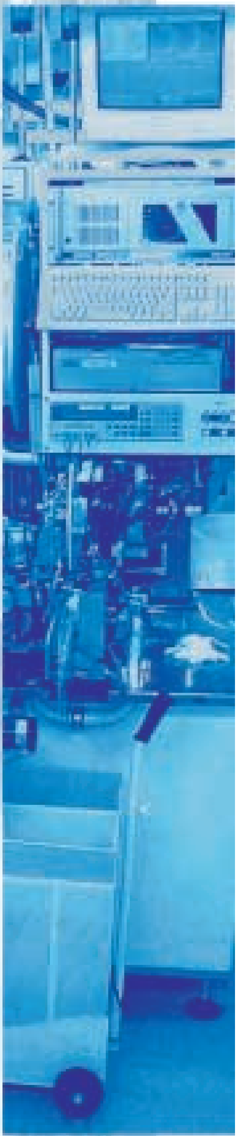


Fig. 2. Block diagram of the non-linearity measurement setup.



If the device impedance depends on the amplitude of the first harmonic, thus being non-linear for whatever reason, "noise" of higher harmonics will be superimposed to the first harmonic sine-wave and the response signal will consist of the pure first harmonic signal (coming from the generator) plus some higher harmonic components. Therefore, the first harmonic will be removed from the spectrum by means of a high pass filter tuned to the third harmonic frequency so that only the "modulating" higher harmonic signal will be left. The third harmonic voltage (the response) will be proportional to the number or extent of elementary non-linearities (non-linearity performance) as well as to the amplitude of the first harmonic. It follows from experiments that

$$U3 = U1^{2 \approx 3} \text{ x Component non-linearity performance}$$

U1 = first harmonic signal level in volts
U3 = third harmonic response level in volts

If the first harmonic amplitude increases, the response of the modulated signal will grow, following the above power function. Sometimes, this allows us to distinguish the built-in and the unwanted non-linearity components from each other. However, this will only work if the built-in non-linearity exponent is lower than that of the unwanted component.

The third harmonic signal has been chosen intentionally, because it makes a predominant component of the noise spectra, thus indicating the device non-linearity degree most suitably.

Statistical evaluation of measurement results

The actual statistical distribution of the third harmonic levels within the population of identical-impedance samples (stemming from the same batch) fits the Poissonian distribution function provided that the parameter to evaluate is a voltage (the response in volts), or the Gaussian distribution function provided that we are processing the signal transfer function NLI.

$$NLI = -20 \text{ x } \log \frac{U3}{U1} \quad [dB]$$

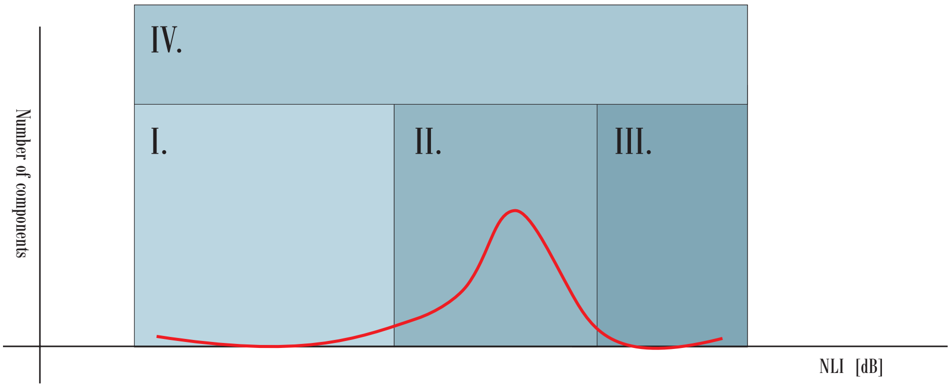
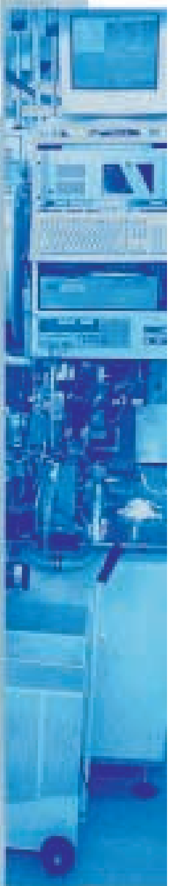


Fig. 3, shows a statistical distribution of the third harmonic for a single batch. The transfer function NLI has been chosen because of a wide span of the measured parameter values extending over several orders of magnitude. In this way, we are taking advantage of the semilog representation which highlights small-value relative deviations.

Note: Because of the minus sign on the righ-hand-side of the above formula, the scale of NLI is value-reversed, which means that higher non-linearities are plotted at the left-hand-end of the horizontal axis

I. Region of Unwanted, excessive non-linearity
II. Region of Built-in non linearity = "ALL GOOD DEVICES"
III. Region of None or Minimal non-linearity
IV. Unstable values in the time domain



LTC 1010: Technical specifications

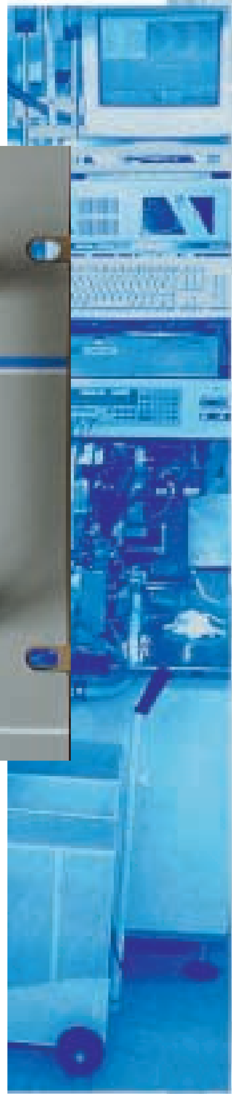
Basic frequency	10 kHz	
Output power	max. 12 W	
Third harmonic background threshold	max -140 dB	
Analog to digital conversion	12 bit	
Impedance ranges	2 ranges	A: 0.1W ± 50 %
		B: 10W ± 20 %
Internal DC Bias	0 ... 10 V (8 bits resolution)	
Accuracy	± 5 %	
Measurement rate	max. 30 / sec	

Front panel I/O features

Display	2 rows
Input connector	2 x PL
Control keyboard	16 keys

Rear panel I/O features

IEEE 488 bus	24-pole, Champ
External handler bus	Cannon 9 pins
Power on/off switch	
Mains fuse	1 A, slow blow
Mains socket	



Power supply

Voltage	90 - 130 V AC (optional)
	200 - 260 V AC
Frequency	45 - 65 Hz
Power consumption	< 100 VA

Dimensions and weight

Height	220 mm (8.7")
Width	480 mm (19")
Depth	470 mm (18.5")
Weight	18 kg (40 lb)

LTC 1010: Functions and settings

Impedance range specific

A: 0.1W	**10 kHz voltage**	**max 1 Vrms in 0.01 V steps**	
	Measurement ranges of the third harmonics (with 30 dB dynamic auto-scale-up)	Range:	Auto-scale-up:
		0 ... 10 µV	(max. 328 µV)
		0 ... 100 µV	(max. 3.28 mV)
		0 ... 1mV	(max. 32.8 mV)
	Internal DC bias	N/A	
	Type of connection	PL type connector, 4 wire	
B: 10W	**10 kHz voltage**	**max 10 Vrms in 0.1 V steps**	
	Measurement ranges of the third harmonics (with 30 dB dynamic auto-scale-up)	Range:	Auto-scale-up:
		0 ... 100 µV	(max. 3.28 mV)
		0 ... 1mV	(max. 32.8 mV)
		0 ... 10mV	(max. 328 mV)
	Internal DC bias	0 ... 10 V in 0.1V steps	
	Type of connection	PL type connector	
		2/4 wire (optional)	

Measurement methods

Continuous measurement

External-triggered non-recurrent measurement

Time domain measurement up to 255 successive measurements in a row

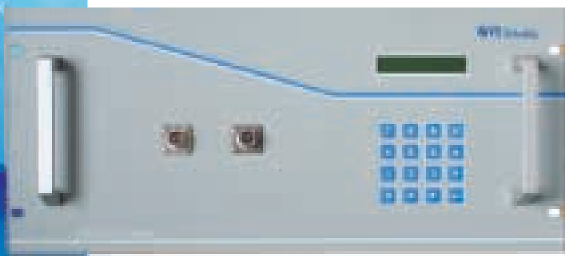
Automatic screening:

Programmable lower and upper limits

Recurrent measurements in the time domain: reject limits allowed-change-in-time up and down, with respect to the measured value different values can have different reject levels (according to the linear fit scheme employed)

Timing

Measurement cycle time	min. 10 msec.
Trigger delay	0 ... 999 msec. (time step 1 msec.)
Input impedance switchover delay	max. 1.5 sec.

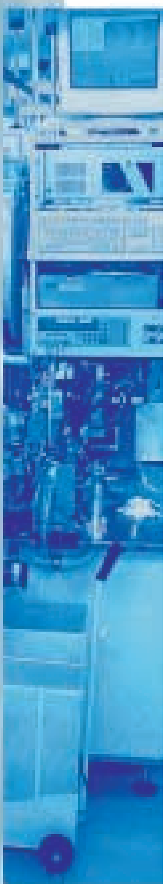


Triggering

Internal

External via IEEE 488 Bus

External via handler



Remote control and setting

IEEE 488

IEEE parameter setting options:	- 10 kHz voltage - Internal DC Bias - Input impedance range - Third harmonic measurement range - Triggering: INT, EXT - Trigger delay - 2/4 wire connection (10W range only) - All screening criteria - Measurement in the time domain
IEEE parameter reading options:	- Measured values (two if the time domain measurement is enabled) - Instrument set up parameters - Error status messages (flags)

External handler

I/0 optocoupler insulation

Inputs	- Triggering (optionally with positive or negative triggering edge)
Outputs (I max = 2 mA)	- Lower limit status (pass/fail) - Upper limit status (pass/fail) - Both lower and upper limit at a time: it means that 10 kHz voltage level has not been reached - Limit overrun in the time domain evaluation mode (pass/fail) - EOM (end of measurement) status