IEC 62458

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Sound system equipment – Electroacoustical transducers – Measurement of large signal parameters

Équipements pour systèmes électroacoustiques – Transducteurs électroacoustiques – Mesurage des paramètres de signaux forts

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IEC 62458

Edition 1.0   2010-01

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 33.160.50

ISBN 978-2-8322-1080-3

CONTENTS

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SOUND SYSTEM EQUIPMENT –
ELECTROACOUSTICAL TRANSDUCERS –
MEASUREMENT OF LARGE SIGNAL PARAMETERS

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International Standard IEC 62458 has been prepared by IEC technical committee 100: Audio, video and multimedia systems and equipment.

This first edition cancels and replaces IEC/PAS 62458 published in 2006. It constitutes a technical revision. The main changes are listed below:

– descriptions of the methods of measurement are adjusted to the state of the technology;

– addition of Clauses 4 to 15;

– integration of Annex A in the main body of the standard;

– overall textual review.

The text of this standard is based on the following documents:

FDIS	Report on voting
100/1624/FDIS	100/1647/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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532c-4b3c-ae95-c528b0dc1617/iec-62458-2010

INTRODUCTION

Electro-mechanical-acoustical transducers such as loudspeaker drive units, loudspeaker systems, headphones, micro-speakers, shakers, and other actuators behave in a nonlinear manner at higher amplitudes. This limits the acoustical output and generates nonlinear signal distortion. Linear models fail in describing the large signal behaviour of such transducers and extended models have been developed which consider dominant nonlinearities in the motor and suspension. The free parameters of the large signal model have to be measured on the particular transducer by using static or dynamic methods. The large signal parameters show the physical cause of the signal distortion directly and are very important for the objective assessment of sound quality and failure diagnostics in development and manufacturing. Furthermore, the model and parameters identified for a particular transducer are the basis for predicting the maximum output and signal distortion for any input signal. The close relationship between causes and symptoms simplifies the interpretation of the harmonic and intermodulation distortion measured according to IEC 60268-5. Large signal parameters are valuable input data for the synthesis of loudspeaker systems and the development of electrical control systems dedicated to loudspeakers.

SOUND SYSTEM EQUIPMENT –
ELECTROACOUSTICAL TRANSDUCERS –
MEASUREMENT OF LARGE SIGNAL PARAMETERS

1 Scope

This International Standard applies to transducers such as loudspeaker drive units, loudspeaker systems, headphones, micro-speakers, shakers and other actuators using either an electro-dynamical or electro-magnetic motor coupled with a mechanical suspension. The large signal behaviour of the transducer is modelled by a lumped parameter model considering dominant nonlinearities such as force factor, stiffness and inductance as shown in Figure 1. The standard defines the basic terms and parameters of the model, the methods of measurements and the way the results should be reported.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60268-1, *Sound system equipment – Part 1: General*

IEC 60268-5:2003, *Sound system equipment – Part 5: Loudspeakers*
Amendment 1 (2007)

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
electro-mechanical equivalent circuit
electrical circuit of an electro-dynamical transducer, as shown in Figure 1
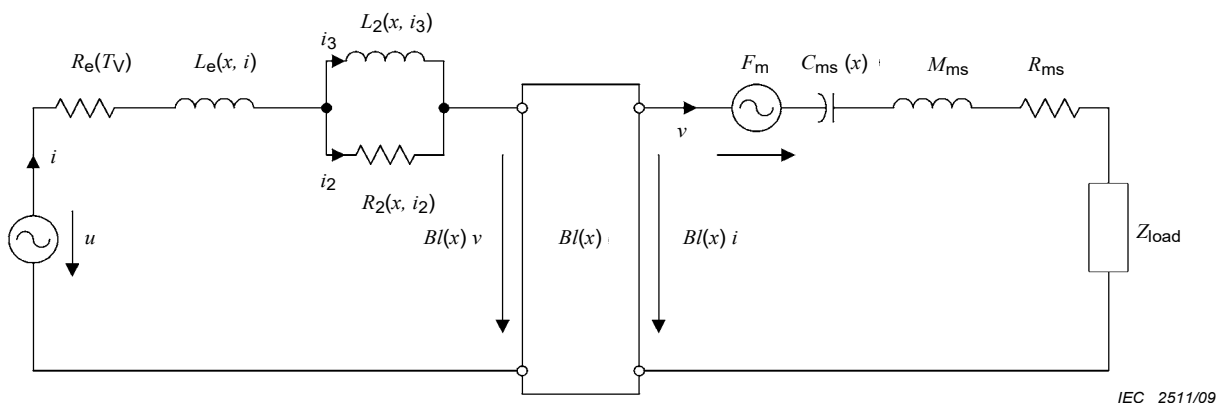
NOTE 1 This Figure shows an example of a lumped parameter model of an electro-dynamical transducer considering the dominant nonlinearities.

NOTE 2 Other equivalent circuits can be applied. Contrary to the results of linear modelling some parameters of the lumped elements are not constant but depend on instantaneous state variables (such as displacement x, velocity v, current i).

Figure 1 – Electro-dynamical transducer

3.2
input current and voltage
i, u
electrical state variables at the terminals of the transducer

3.3   displacement
x
deflection of the voice coil from the rest position

3.4
velocity
v
time derivative of displacement x

3.5
d.c. resistance
R_e
electrical impedance $Z_e(s)$ at very low frequencies where the effect of the back EMF can be neglected

NOTE 1   Electrical impedance can be used for measuring the d.c. resistance R_e of the voice coil. The d.c. resistance R_e depends on the mean voice coil temperature T_V.

3.6
nonlinear inductance and losses
nonlinear elements to model the effect of the magnetic a.c. field, the losses in the magnetic material, and the losses caused by eddy currents where the equivalent circuit in Figure 1 uses the LR-2 model comprising the inductance $L_e(x, i)$, the inductance $L_2(x, i_2)$ and additional resistance $R_2(x, i_3)$

3.7
nonlinear force factor
Bl(x)
dependency of instantaneous force factor $Bl(x)$ on voice coil displacement x defined by the integral of magnetic flux density B versus the voice-coil conductor of length l

NOTE 1   The product of force factor $Bl(x)$ and velocity v is the back EMF generated on the electrical side in an equivalent circuit as shown in Figure 1. The product of force factor $Bl(x)$ and input current i gives the electro-dynamical driving force of the mechanical system.

3.8
reluctance force
F_m
additional electro-magnetic driving force caused by the displacement varying inductances $L_e(x, i)$ and $L_2(x, i_2)$

3.9
stiffness, $K_{ms}(x)$, of the suspension
ratio between the instantaneous restoring force $F(x)$ and the displacement x as given by

$$K_{ms}(x) = \frac{F(x)}{x}$$ (1)

NOTE 1   The nonlinear compliance $C_{ms}(x) = 1/K_{ms}(x)$ is the reciprocal quantity of the mechanical stiffness.

3.10
mechanical mass
M_{ms}
total moving mass including the mass of the moving assembly and the reactive part of the air load on both sides of the diaphragm

3.11
mechanical resistance
R_{ms}
non-electrical losses of the driver, due to suspension, turbulences and radiation

3.12
mechanical impedance
Z_{load}
mechanical impedance which may represent any additional load caused by mechanical elements (cone, panel) or acoustical elements (such as a vented enclosure or horn)

4 Test signals

4.1 General

The measurement of the large signal parameters requires an electrical, mechanical or acoustical stimulus. Depending on the method used for the measurement of the large signal parameters different kind of test signals are used as stimulus for the excitation of the transducer. Since the loudspeaker behaves as a time-varying system the stimulus may cause a permanent or temporary change of the loudspeaker properties. Thus, the properties of the stimulus (spectral bandwidth, crest factor, proability density function) shall be statet. The same stimulus should be used if the numerical values of the results should be compared from two measurements.

4.2 Large d.c. signal

A constant d.c. voltage or d.c current of defined magnitude and sufficient duration is supplied to the electrical terminals to measure the steady-state response of the transducer. If the transducer is mounted in a sealed enclosure a difference between the static air pressures inside and outside the enclosure may be used as d.c. stimulus.

4.3 Large d.c. signal and small a.c. signal

A constant d.c. signal of defined magnitude and sufficient duration (see 4.2) superimposed with a small a.c. signal is used as stimulus. The a.c. signal (such as noise, sinusoidal sweep, impulsive test signals) should have sufficient bandwidth to identify all parameters of the loudspeaker model.

4.4 Broadband noise signal

One of the noise signals defined in IEC 60268-1 or any other noise having sufficient bandwidth and amplitude may be used as stimulus. The crest factor of the noise should be less than 4 to reduce clipping in the amplifier.

4.5 Music

Ordinary music, speech of sufficient bandwidth and amplitude may be used as a stimulus.

NOTE   The dynamic methods need a stimulus which provides persistent excitation of the loudspeaker to identify the parameters correctly. The stimulus should have enough spectral components at least one octave below resonance frequency f_s and one decade above f_s.

5   Mounting condition

5.1   Drive units

The driver unit may be mounted

  a) in free air without a baffle or enclosure,

  b) in a standard baffle according to 11.1 of IEC 60268-5,

  c) in half-space free field according to 5.2 of IEC 60268-5,

  d) in the standard measuring enclosure (type A or type B) according to 11.2 of IEC 60268-5, or another, specified enclosure,

  e) in vacuum,

  f) other configuration defined in the presentation of the results.

The acoustic loading depends upon the mounting arrangement, which shall be clearly described in the presentation of the results.

During the measurement the transducer should be firmly clamped to suppress additional mechanical resonances close to the resonance frequency f_s. A vertical position of the transducer (cone displacement in horizontal direction) is recommended to avoid any bias due the weight of the moving assembly.

Drive units for horn loaded loudspeakers, headphones, micro-speakers and microphones should preferably be measured in a vacuum to reduce the acoustic load, suppress additional acoustic resonances, and to avoid nonlinear damping due to turbulent air flow.

5.2   Loudspeaker systems

Loudspeaker systems are measured under conditions which correspond with the intended use.

6   Climatic conditions

The measurements should be made at an ambient temperature 15°C to 35°C, preferably at 20°C, relative humidity 25 % to 75 %, air pressure 86 kPa to 106 kPa as specified in IEC 60268-1 to avoid any influence of temperature and humidity that may affect the properties of the drive unit suspensions.

7   Acoustical environment

The measurement room shall be large enough that the influence of the acoustical environment on the mechanical vibration of the transducer is negligible.

If the measurement of the large signal parameters is based on sound pressure output it is recommended to place the measuring microphone in the near field of the transducer. It is recommended to use a method that measures electrical or mechanical signals only, which is thus immune to unwanted acoustic noise.

8   Preconditioning

The loudspeaker should be preconditioned according to Clause 12 of IEC 60268-5. A temporary voice coil offset caused by storing the transducer for some time in the horizontal position can be removed by operating the transducer for at least 5 min in the vertical position before performing the regular measurement.

9 Time-varying properties of the loudspeaker

The stimulus provided to the electrical input of the loudspeaker may cause a heating of the voice coil and may also change the properties of the suspension during measurement. Thus, the electrical resistance of the coil should be measured during measurement and considered in the calculation of the loudspeaker parameters (e.g. electrical loss factor Q_{es}).

10 Methods of measurement

10.1 General

The following methods may be used for the measurement of the large signal parameters. The method used should be stated together with the results.

### 10.2 Static or quasi-static method

10.2.1 General

This technique determines the non-linear parameters of the transducer by using a d.c. signal with magnitude u_i (usually voltage) as stimulus. After reaching steady state relevant state variables (d.c. displacement x_i, d.c. force F_i) are measured and the parameter value (such as $K(x_i) = F_i/x_i$) is calculated. After changing the magnitude of the d.c. signal the measurement is repeated at further working points x_i with $i = 1, ..., N$ to measure the non-linear parameters within the working range $-x_{peak} < x_i < x_{peak}$ with sufficient resolution.

Due to the visco-elastic behaviour of the suspension material, the settling time required to reach steady state may exceed several seconds and a static method is very time consuming. In a quasi-static method the state variables are measured before steady state is reached and the settling time used should be stated.

Creep and other visco-elastic properties of the suspension cause significant discrepancies between the stiffness $K(x)$ measured statically by using a d.c. signal and the stiffness $K_{ms}(x)$ measured dynamically by using an broadband noise signal.

The d.c. signal of the static and quasi-static methods cannot be used for the measurement of the nonlinear voice coil inductance $L_e(x, i)$. Figure 2 shows a setup for static and quasi-static measurement of large signal parameters.
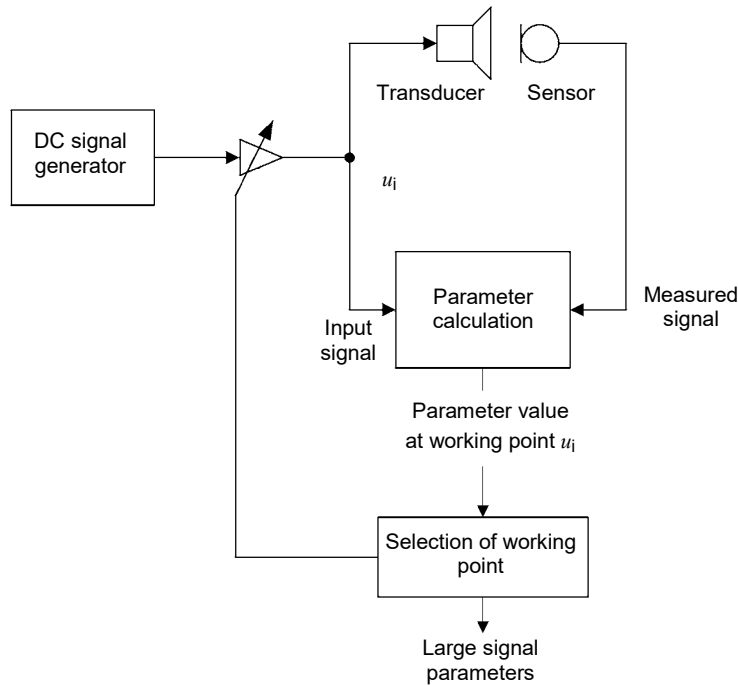
IEC 2512/09

Figure 2 –Static and quasi-static measurement setup

10.2.2 Procedure

Proceed as follows.

a) According to the limits of working range $-x_{peak} < x_i < x_{peak}$ investigated and the resolution required, the number of measurements N is determined, a starting voltage u_{start} is selected and the incremental voltage u_{step} is defined.

b) The first working point $i = 1$ is initialized.

c) The transducer is excited by a d.c. signal voltage $u_i = u_{start} + i \times u_{step}$.

d) At the working point, i, the displacement, x_i, and other relevant state variables (such as force F_i) are measured after the transducer has reached steady state or a defined settling time T has passed.

e) The nonlinear parameter (for example, $K(x_i) = F_i/x_i$) is calculated.

f) The next working point $i = i + 1$ is selected and previous steps 1 to 5 are repeated until $i > N$.

g) The parameter values are interpolated between the working points x_i with $i = 1, ..., N$ or the coefficients of the power series expansion (such as Equation (3)) are calculated.

10.3 Point-by-point dynamic method

10.3.1 General

This technique determines the non-linear parameters of the transducer with a d.c. signal, u_i (such as d.c. voltage or a constant air pressure), superimposed with a small a.c. signal, u_{ac}, as stimulus. After reaching the steady state, the relevant state variables (d.c. displacement x_i and the amplitudes of the a.c. force F_{ac} and a.c. displacement x_{ac}) are measured and the parameter value (such as the incremental stiffness $K_{inc}(x_i) = F_{ac}/x_{ac}$) is calculated. After changing the magnitude of the d.c. part of the stimulus the measurement is repeated at further working points x_i with $i = 1, ..., N,$ to measure the non-linear parameters within the working range $-x_{peak} < x_i < x_{peak}$ with sufficient resolution.

The amplitude u_{ac} of the a.c. stimulus is sufficiently small to ensure that the transducer behaves linearly ($K(x_i + x_{ac}) \approx$ constant, $Bl(x_i + x_{ac}) \approx$ constant and $L_e(x_i + x_{ac}) \approx$ constant) and a linear loudspeaker model can be applied.

Whereas some small signal parameters (force factor $Bl(x_i)$ and inductance $L_e(x_i)$) are identical to the large signal parameters measured by other methods, this technique provides the incremental stiffness, $K_{inc}(x_i)$, which can only be transformed into the regular stiffness by integration

$$K(x) = \frac{1}{x} \int_0^x K_{inc}(x)\mathrm{d}x \tag{2}$$

Due to the visco-elastic behaviour of the suspension material, there are significant differences between the stiffness $K(x)$ measured by the point-by-point method using a d.c. signal and the stiffness Kms(x) measured dynamically with a program like an a.c. signal. Figure 3 shows a setup for point-by-point dynamic measurement of large signal parameters.

10.3.2   Test equipment

The stimulus comprising a d.c part and an a.c. part can be produced by using a generator with a d.c. offset and a d.c.-coupled power amplifier. However, providing the d.c. part via the electrical input produces significant heating of the voice coil at high amplitudes. Alternatively, the transducer may be mounted in a sealed box, and the voice coil position may be varied by changing the d.c. air pressure inside the box.
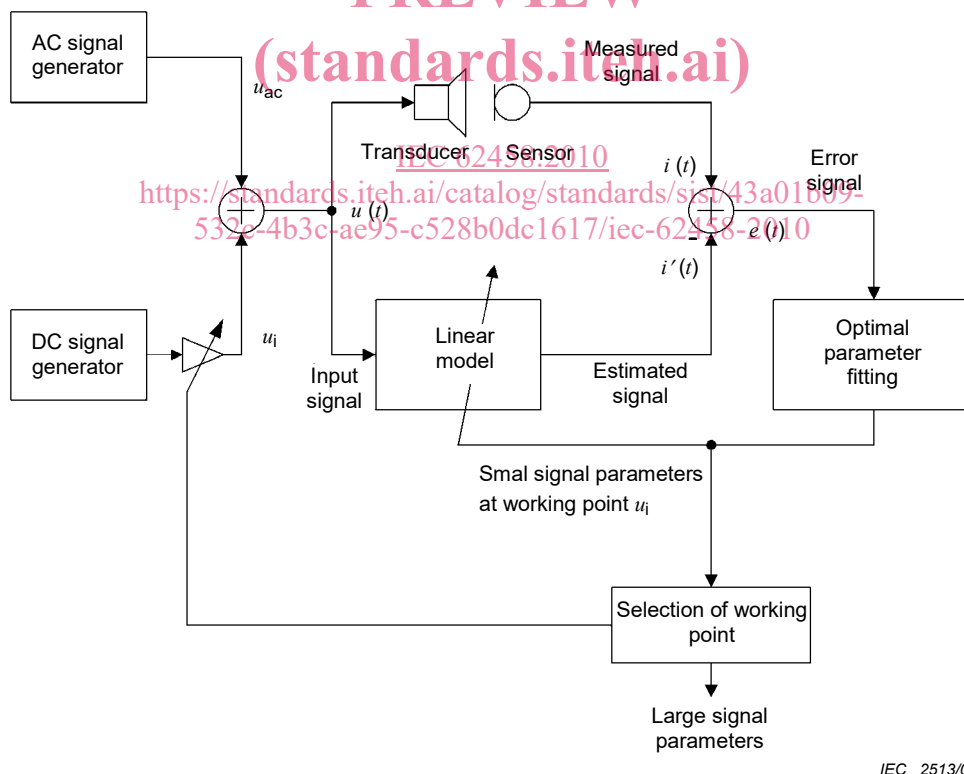
**Figure 3 – Setup for measurement of large signal parameters
by using the point-by-point dynamic method**