# INTERNATIONAL STANDARD

# IEC 61000-4-7

Second edition
2002-08

BASIC EMC PUBLICATION

**Electromagnetic compatibility (EMC) –**

**Part 4-7:**
**Testing and measurement techniques –**
**General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

# ELECTROMAGNETIC COMPATIBILITY (EMC) –

## Part 4-7: Testing and measurement techniques – General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto

## FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
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International Standard IEC 61000-4-7 has been prepared by subcommittee 77A: Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

This standard forms part 4-7 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This second edition cancels and replaces the first edition published in 1991, and constitutes a technical revision.

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

| FDIS | Report on voting |
|---|---|
| 77A/382/FDIS | 77A/387/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 3.

Annexes A, B and C are for information only.

The committee has decided that the contents of this publication will remain unchanged until 2005. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

The contents of the corrigendum of July 2004 have been included in this copy.

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# INTRODUCTION

IEC 61000 is published in separate parts, according to the following structure:

**Part 1: General**

General considerations (introduction, fundamental principles)

Definitions, terminology

**Part 2: Environment**

Description of the environment

Classification of the environment

Compatibility levels

**Part 3: Limits**

Emission limits

Immunity limits (in so far as they do not fall under the responsibility of the product committees)

**Part 4: Testing and measurement techniques**

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Measurement techniques

Testing techniques

**Part 5: Installation and mitigation guidelines**

Installation guidelines

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**Part 6: Generic standards**

**Part 9: Miscellaneous**

Each part is further subdivided into several parts, published either as International Standards or as technical specifications or technical reports, some of which have already been published as sections. Other will be published with the part number followed by a dash and a second number identifying the subdivision (example: 61000-6-1).

These publications will be published in chronological order and numbered accordingly.

This part is an International Standard for the measurement of harmonic currents and voltages in power supply systems and harmonic currents emitted by equipment. It also specifies the performance of a standard measuring instrument.

# ELECTROMAGNETIC COMPATIBILITY (EMC) –

# Part 4-7: Testing and measurement techniques – General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto

## 1 Scope

This part of IEC 61000 is applicable to instrumentation intended for measuring spectral components in the frequency range up to 9 kHz which are superimposed on the fundamental of the power supply systems at 50 Hz and 60 Hz. For practical considerations, this standard distinguishes between harmonics, interharmonics and other components above the harmonic frequency range, up to 9 kHz.

This standard defines the measurement instrumentation intended for testing individual items of equipment in accordance with emission limits given in certain standards (for example, harmonic current limits as given in IEC 61000-3-2) as well as for the measurement of harmonic currents and voltages in actual supply systems. Instrumentation for measurements above the harmonic frequency range, up to 9 kHz is tentatively defined (see Annex B).

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NOTE 1 This document deals in detail with instruments based on the discrete Fourier transform.

NOTE 2 The description of the functions and structure of the measuring instruments in this standard is very explicit and meant to be taken literally. This is due to the necessity of having reference instruments with reproducible results irrespective of the characteristics of the input signals.

NOTE 3 The instrument is defined to accommodate measurements of harmonics up to the 50th order.

## 2 Normative references

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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 60050-161, *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility*

IEC 61000-3-2, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤16 A per phase)*

IEC 61967-1, *Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz – Part 1: Measurement conditions and definitions*[1]

[1] To be published

## 3 Definitions, symbols and indices

For the purposes of this part of IEC 61000, the definitions given in IEC 60050-161 (IEV) and the following, apply.

### 3.1 Definitions related to frequency analysis

Notations: The following notations are used in the present guide for the Fourier series development because it is easier to measure phase angles by observations of the zero crossings:

$$f(t) = c_0 + \sum_{m=1}^{\infty} c_m \sin\left(\frac{m}{N}\omega_1 t + \varphi_m\right) \quad (1)$$

with:

$$\begin{cases} c_m = \left|b_m + ja_m\right| = \sqrt{a_m^2 + b_m^2} \\ C_m = \dfrac{c_m}{\sqrt{2}} \\ \varphi_m = \arctan\left(\dfrac{a_m}{b_m}\right) \text{ if } b_m \geq 0 \\ \varphi_m = \pi + \arctan\left(\dfrac{a_m}{b_m}\right) \text{ if } b_m < 0 \end{cases} \quad (2)$$

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and:

$$\begin{cases} b_m = \dfrac{2}{T_w}\displaystyle\int_0^{T_w} f(t) \times \sin\left(\frac{m}{N}\omega_1 t\right) dt \\ a_m = \dfrac{2}{T_w}\displaystyle\int_0^{T_w} f(t) \times \cos\left(\frac{m}{N}\omega_1 t\right) dt \\ c_0 = \dfrac{1}{T_w}\displaystyle\int_0^{T_w} f(t)\, dt \end{cases} \quad (3)$$

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where

$\omega_1$ is the angular frequency of the fundamental ($\omega_1 = 2\pi f_1$);

$T_w$ is the width (or duration) of the time window ($T_w = NT_1$; $T_1 = 1/f_1$); the time window is that time span of a time function over which the Fourier transform is performed;

$c_m$ is the amplitude of the component with frequency $f_m = \frac{m}{N} f_1$;

$N$ is the number of fundamental periods within the window width;

$c_0$ is the d.c. component;

$m$ is the ordinal number (order of the spectral line) related to the frequency basis ($f = 1/Tw$).

NOTE 1 Strictly speaking these definitions apply to steady-state signals only.

The Fourier series is actually in most cases performed digitally, i.e. as a discrete Fourier transform (DFT).

The analogue signal $f(t)$ to be analysed is sampled, A/D-converted and stored. Each group of $M$ samples forms a time window on which DFT is performed. According to the principles of Fourier series expansion, the window width $T_w$ determines the frequency resolution $f_w = 1/T_w$ (i.e. the frequency separation of the spectral lines) for the analysis and thus the frequency basis for the result of the transform. Therefore, the window width $T_w$ must be an integer multiple $N$ of the fundamental period $T_1$ of the system voltage: $T_w = N \times T_1$. The sampling rate is in this case $f_s = M/(NT_1)$ (where $M$ = number of samples within $T_w$).

Before DFT-processing, the samples in the time window $T_w$ are often weighted by multiplying them with a special symmetrical function "windowing function"). However, for periodic signals and synchronous sampling, it is preferable to use a rectangular weighting window which multiplies each sample by unity.

The DFT-processor yields the orthogonal Fourier-coefficients $a_m$ and $b_m$ of the corresponding harmonic frequencies $f_m = m/T_w$, $m$= 0, 1, 2….$2^i$-1. However, only $m$ values up to half of the maximum value are useful, the other half just duplicates them.

When there is sufficient synchronisation, the harmonic order $n$ related to the fundamental frequency $f_1$ is given by $n = m/N$ ($N$ = number of periods in $T_w$.).

NOTE 2 The fast Fourier transform (FFT) is a special algorithm allowing short computation times. It requires that the number of samples $M$ be an integer power of 2, $M = 2^i$, with $i \geq 10$ for example.

## 3.2 Definitions related to harmonics

### 3.2.1
**harmonic frequency**

$f_n$

frequency which is an integer multiple of the power supply (fundamental) frequency ($f_n = n \times f_1$)

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### 3.2.2
**harmonic order**

$n$

(integer) ratio of a harmonic frequency to the power-supply frequency. In connection with the analysis using DFT and synchronisation between $f_1$ and $f_s$ (sampling rate), the harmonic order $n$ is given by $n = k/N$ ($k$ = number of the Fourier component, $N$ = number of periods $T_1$ in $T_w$)

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### 3.2.3
**r.m.s. value of a harmonic component**

$G_n$

r.m.s. value of one of the components having a harmonic frequency in the analysis of a non-sinusoidal waveform

For brevity, such a component may be referred to simply as a 'harmonic'

NOTE 1 The harmonic component $G_n$ is identical with the spectral component $C_k$ with $k = N \times n$; ($G_n = C_{Nn}$). It is replaced, as required, by the symbol $I_n$ for currents or by the symbol $U_n$ for voltages.

NOTE 2 The symbol $C_k$ represents the r.m.s. value of the spectral component $C_m$ for $m = k$ in equation 2.

NOTE 3 For the purposes of this standard, the time window has a width of $N$ = 10 (50 Hz systems) or $N$ = 12 (60 Hz systems) fundamental periods, i.e. approximately 200 ms (see 4.4.1). This yields $G_n = C_{10n}$ (50 Hz systems) and $G_n = C_{12n}$ (60 Hz systems).

**3.2.4**
**r.m.s. value of a harmonic group**
$G_{g,n}$
square root of the sum of the squares of the r.m.s. value of a harmonic and the spectral components adjacent to it within the time window, thus summing the energy contents of the neighbouring lines with that of the harmonic proper. See also equation 8 and figure 4. The harmonic order is given by the harmonic considered

**3.2.5**
**r.m.s. value of a harmonic subgroup**
$G_{sg,n}$
square root of the sum of the squares of the r.m.s. value of a harmonic and the two spectral components immediately adjacent to it. For the purpose of including the effect of voltage fluctuation during voltage surveys, a subgroup of output components of the DFT is obtained by summing the energy contents of the frequency components directly adjacent to a harmonic with that of the harmonic proper. (See also equation 9 and figure 6.) The harmonic order is given by the harmonic considered

### 3.3 Definitions related to distortion factors

**3.3.1**
**total harmonic distortion**
**THD**

*THD* (symb.)
ratio of the r.m.s. value of the sum of all the harmonic components ($G_n$) up to a specified order ($H$) to the r.m.s. value of the fundamental component ($G_1$):

$$THD = \sqrt{\sum_{n=2}^{H} \left( \frac{G_n}{G_1} \right)^2} \qquad (4)$$

NOTE 1 The symbol $G$ represents the r.m.s. value of the harmonic component (see 3.2.3). It is replaced, as required, by the symbol $I$ for currents or by the symbol $U$ for voltages.

NOTE 2 The value of $H$ is defined in each standard concerned with limits (IEC 61000-3 series).

**3.3.2**
**group total harmonic distortion**
**THD**
*THDG* (symb.)
ratio of the r.m.s. value of the harmonic groups ($g$) to the r.m.s. value of the group associated with the fundamental:

$$THDG = \sqrt{\sum_{n=2}^{H} \left( \frac{G_{gn}}{G_{g1}} \right)^2} \qquad (5)$$

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