

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Ultrasonics – Hydrophones –
Part 2: Calibration for ultrasonic fields up to 40 MHz

Ultrasons – Hydrophones –
Partie 2: Etalonnage des champs ultrasoniques jusqu'à 40 MHz

IEC 62127-2:2007

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INTERNATIONAL
ELECTROTECHNICAL
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ELECTROTECHNIQUE
INTERNATIONALE

ICS 11.040.50

ISBN 978-2-8322-0649-2

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ULTRASONICS – HYDROPHONES –

Part 2: Calibration for ultrasonic fields up to 40 MHz

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The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience. A vertical line in the margin shows where the base publication has been modified by amendment 1. Additions and deletions are displayed in red, with deletions being struck through.

International Standard IEC 62127-2 has been prepared by IEC technical committee 87: Ultrasonics.

IEC 62127-1, IEC 62127-2 and IEC 62127-3 are being published simultaneously. Together these cancel and replace IEC 60866:1987, IEC 61101:1991, IEC 61102:1991, IEC 61220:1993 and IEC 62092:2001.

This bilingual version (2012-06) corresponds to the monolingual English version, published in 2007-08.

The French version of this standard has not been voted upon.

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

A list of all parts of IEC 62127 series, published under the general title *Ultrasonics – Hydrophones*, can be found on the IEC website.

NOTE Words in **bold** in the text are defined in Clause 3.

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IEC 62127-2:2007

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INTRODUCTION

The spatial and temporal distribution of acoustic pressure in an ultrasonic field in a liquid medium is commonly determined using miniature ultrasonic **hydrophones**. These devices are not absolute measurement instruments and require calibration. The purpose of this part of IEC 62127 is to specify those calibration methods to be used in determining the response of a **hydrophone** in the ultrasonic range, i.e. above 20 kHz up to a frequency of 40 MHz. The main **hydrophone** application in this context lies in the measurement of ultrasonic fields emitted by medical diagnostic equipment in water. **Hydrophone** behaviour over this wide frequency band is required in order to reliably characterize the acoustic parameters of the applied acoustic field. In particular, the frequency range above 15 MHz is important to fully characterize this equipment, primarily due to the increased appearance of high-frequency components in the ultrasonic signals, caused by ~~non-linear~~ **nonlinear** propagation. In addition, the number of medical ultrasonic systems that use frequencies above 15 MHz, particularly intra-operative probes, is growing. It has turned out in recent years that the **hydrophone** response below 0,5 MHz is also required to reliably determine the peak-negative (rarefactional) acoustic pressure.

While the term "**hydrophone**" can be used in a wider sense, it is understood here as referring to miniature piezoelectric **hydrophones**. It is this instrument type that is used today in various areas of medical ultrasonics and, in particular, to characterize quantitatively the field structure of medical diagnostic instruments. With regard to other pressure sensor types, such as those based on fibre optics, some of the requirements of this standard are applicable to these as well but others are not. If in the future these other "**hydrophone**" types gain more importance in field measurement practice, their characteristics and calibration will have to be dealt with in a revised version of this standard or in a separate one.

NOTE This standard covers the ultrasonic frequency range, from 20 kHz to an upper frequency of 40 MHz. Standards dealing with **hydrophone** properties (IEC 62127-3) and **hydrophone** use (IEC 62127-1) are being developed in parallel as part of a programme of maintenance activities aimed at restructuring and merging, where possible, all existing ultrasonic **hydrophone** standards. This will eventually lead to unified standards covering the whole field of practical **hydrophone** application.

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ULTRASONICS – HYDROPHONES –

Part 2: Calibration for ultrasonic fields up to 40 MHz

1 Scope

This part of IEC 62127 specifies:

- absolute **hydrophone** calibration methods;
- relative (comparative) **hydrophone** calibration methods.

Recommendations and references to accepted literature are made for the various relative and absolute calibration methods in the frequency range covered by this standard.

This standard is applicable to

- **hydrophones** used for measurements made in water and in the ultrasonic frequency range up to 40 MHz;

NOTE 1 Although some physiotherapy medical applications of medical ultrasound are developing which operate in the frequency range 40 kHz to 100 kHz, the primary frequency range of diagnostic imaging remains above 2 MHz. It has recently been established that, even in the latter case, the **hydrophone** response at substantially lower frequencies can influence measurements made of key acoustic parameters [1].

- **hydrophones** employing circular piezoelectric sensor elements, designed to measure the pulsed wave and continuous wave ultrasonic fields generated by ultrasonic equipment;

NOTE 2 Some hydrophones can have non-circular active elements, arising from slight deviations from a circular structure caused, for example by electrode structure, or conversely, the active elements can actually be squares. The clauses within this standard remain valid, although, in these cases, special attention should be paid to the directional response and to the effective radii of the active element through various axes of rotation.

- **hydrophones** with or without a hydrophone pre-amplifier.

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 60050-801:~~1994~~, *International Electrotechnical Vocabulary – Chapter 801: Acoustics and electroacoustics*

IEC 60565, *Underwater acoustics – Hydrophones – Calibration in the frequency range 0,01 Hz to 1 MHz*

IEC 61161:~~2006~~, *Ultrasonics – Power measurement – Radiation force balances and performance requirements*

IEC 61828:~~2006~~, *Ultrasonics – Focusing transducers – Definitions and measurement methods for the transmitted fields*

IEC 62127-1:~~2007~~, *Ultrasonics – Hydrophones – Part 1: Measurement and characterization of medical ultrasonic fields up to 40 MHz*
Amendment 1:2013

IEC 62127-3, *Ultrasonics – Hydrophones – Part 3: Properties of hydrophones for ultrasonic fields up to 40 MHz*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in IEC 62127-1 and the following apply.

3.1

acoustic centre

point on or near a transducer from which the spherically divergent sound waves emitted by the transducer, and observable at remote points, appear to diverge

3.2

beam axis

straight line that passes through the **beam centrepoints** of two planes perpendicular to the line which connects the point of maximal **pulse-pressure-squared integral** with the centre of the **external transducer aperture**

NOTE 1 The location of the first plane is the location of the plane containing the maximum **pulse-pressure-squared integral** or, alternatively, is one containing a single main lobe which is in the focal Fraunhofer zone. The location of the second plane is as far as is practicable from the first plane and parallel to the first with the same two orthogonal scan lines (*x* and *y* axes) used for the first plane.

NOTE 2 In a number of cases, the term **pulse-pressure-squared integral** is replaced in the above definition by any linearly related quantity, for example

- a) in the case of a continuous wave signal the term **pulse-pressure-squared integral** is replaced by mean square acoustic pressure as defined in IEC 61689,
- b) in cases where signal synchronisation with the scanframe is not available the term **pulse-pressure-squared integral** may be replaced by **temporal average intensity**.

NOTE 3 See Figure 1 of IEC 62127-1.

NOTE 4 Definition adopted from IEC 62127-1.

3.3

beam centrepoint

position determined by the intersection of two lines passing through the **beamwidth midpoints** of two orthogonal planes, *xz* and *yz*

NOTE Definition adopted from IEC 61828:2001.

3.4

beamwidth

W_6 , W_{12} , W_{20}

greatest distance between two points on a specified axis perpendicular to the **beam axis** where the **pulse-pressure-squared integral** falls below its maximum on the specified axis by a specified amount

NOTE 1 In a number of cases, the term **pulse-pressure-squared integral** is replaced in the above definition by any linearly related quantity, for example

- a) in the case of a continuous wave signal the term **pulse-pressure-squared integral** is replaced by mean square acoustic pressure as defined in IEC 61689,
- b) in cases where signal synchronisation with the scanframe is not available the term **pulse-pressure-squared integral** may be replaced by **temporal average intensity**.

NOTE 2 Commonly used **beamwidths** are specified at – 6 dB, –12 dB and –20 dB levels below the maximum. The decibel calculation implies taking 10 times the logarithm of the ratios of the integrals.

NOTE 3 **Beamwidth** is expressed in metres (m).

NOTE 4 Definition adopted from IEC 62127-1.

3.5 beamwidth midpoint

linear average of the location of the centres of **beamwidths** in a plane

NOTE 1 The average is taken over 20 beamwidth levels corresponding to intervals in the –0,1 dB to –26 dB range (see IEC 61828, Clause B.2).

NOTE 2 Definition adopted from IEC 61828:2001.

3.6 beam centre

point in a plane in the **far field**, usually perpendicular to the **beam axis**, at which the **spatial-peak temporal-peak acoustic pressure** occurs

3.7 diametrical beam scan

set of measurements of the hydrophone output voltage made while moving the hydrophone in a straight line passing through a point on the beam axis and in a direction normal to the beam axis

NOTE 1 The **diametrical beam scan** may extend to different distances on either side of the **beam axis**.

NOTE 2 Definition adopted from IEC 62127-1.

3.8 directional response

description, generally presented graphically, of the response of a **hydrophone**, as a function of direction of propagation of the incident plane sound wave, in a specified plane through the **reference centre** and at a specified frequency

NOTE Definition adopted from IEC 60565.

3.9 effective radius of a **non-focused non-focusing** ultrasonic transducer

a_t

radius of a perfect disc piston-like ultrasonic source transducer that has a predicted axial acoustic pressure distribution approximately equivalent to the observed axial acoustic pressure distribution over an axial distance until at least the last axial maximum has passed

NOTE 1 The **effective radius of a non-focused non-focusing ultrasonic transducer** is expressed in metres (m).

NOTE 2 Definition adopted from IEC 62127-1.

3.10 effective hydrophone radius

a_h, a_{h3}, a_{h6}

radius of a stiff disc receiver **hydrophone** that has a predicted **directional response** function with an angular width equal to the observed angular width

NOTE 1 The angular width is determined at a specified level below the peak of the **directional response** function. For the specified levels of 3 dB and 6 dB, the radii are denoted by a_{h3} and a_{h6} respectively.

NOTE 2 The **effective hydrophone radius** is expressed in metres (m).

NOTE 3 The radius is usually a function of frequency. For representative experimental data, see [2].

NOTE 4 Definition adopted from IEC 62127-3.

3.11**electric load impedance** \underline{Z}_L

complex electric input impedance (consisting of a real and an imaginary part) to which the **hydrophone assembly** output cable is connected or is to be connected

NOTE 1 The **electric load impedance** is expressed in ohms (Ω).

NOTE 2 Definition adopted from IEC 62127-3.

3.12**end-of-cable loaded sensitivity****end-of-cable loaded sensitivity of a hydrophone (or hydrophone-assembly)** $M_L(f)$

ratio of the instantaneous voltage at the end of any integral cable or output connector of a **hydrophone** or **hydrophone-assembly**, when connected to a specified **electric load impedance**, to the **instantaneous acoustic pressure** in the undisturbed free field of a plane wave in the position of the reference centre of the **hydrophone** if the **hydrophone** were removed

NOTE 1 **End-of-cable loaded sensitivity** is expressed in volts per pascal (V/Pa).

NOTE 2 Definition adopted from IEC 62127-3.

3.13**end-of-cable open-circuit sensitivity****end-of-cable open-circuit sensitivity of a hydrophone** $M_c(f)$

ratio of the instantaneous open-circuit voltage at the end of any integral cable or output connector of a **hydrophone** to the **instantaneous acoustic pressure** in the undisturbed free field of a plane wave in the position of the **reference centre** of the **hydrophone** if the **hydrophone** were removed

NOTE 1 **End-of-cable open-circuit sensitivity** is expressed in volts per pascal (V/Pa).

NOTE 2 Definition adopted from IEC 62127-3.

3.14**external transducer aperture**

part of the surface of the **ultrasonic transducer** or **ultrasonic transducer element group assembly** that emits ultrasonic radiation into the propagation medium.

NOTE 1 This surface is either directly in contact with the patient or is in contact with a water or liquid path to the patient (see Figure-2 1 of IEC 62127-1).

NOTE 2 Definition adopted from IEC 61828:2001.

3.15**far field**

~~acoustic (sound) field at distances from an ultrasonic transducer where the values of the instantaneous acoustic pressure and particle velocity are substantially in phase (see also IEC 60050-801, 801-23-30) region of the field where $z > z_T$ aligned along the beam axis for planar non-focusing transducers~~

NOTE 1 In the **far field**, the sound pressure appears to be spherically divergent from a point on or near the radiating surface. Hence, the pressure produced by the sound source is approximately inversely proportional to the distance from the source.

NOTE 2 The term "**far field**" is used in this standard only in connection with non-focusing source transducers. For focusing transducers a different terminology for the various parts of the transmitted field applies (see IEC 61828).

NOTE 3 If the shape of the transducer aperture produces several **transition distances**, the one furthest from the transducer shall be used.

[SOURCE: IEC 62127-1:2007/Amendment 1:2013, definition 3.28]

3.16

free field

sound field in a homogeneous and isotropic medium in which the effects of boundaries are negligible

NOTE Definition adopted from IEC 60565: 2006, 3.13.

3.17

hydrophone

transducer that produces electric signals in response to waterborne acoustic signals.

NOTE Definition adopted from IEC 60050-801, 801-32-26.

3.18

hydrophone assembly

combination of **hydrophone** and **hydrophone pre-amplifier**

NOTE 2 Definition adopted from IEC 62127-3.

3.19

hydrophone axis

nominal symmetry axis of the **hydrophone** active element

NOTE 1 Unless stated otherwise (explicitly and quantitatively) by the manufacturer, it is understood for the purposes of this standard that this is given by the apparent geometrical symmetry axis of the **hydrophone**.

NOTE 2 Definition adopted from IEC 62127-3.

3.20

hydrophone geometrical radius

geometrical radius of a hydrophone active element

a_g

radius defined by the dimensions of the active element of a **hydrophone**

NOTE 1 The **hydrophone geometrical radius** is expressed in metres (m)

NOTE 2 Definition adopted from IEC 62127-3.

3.21

hydrophone pre-amplifier

active electronic device connected to, or to be connected to, a particular hydrophone and reducing its output impedance

NOTE 1 A **hydrophone pre-amplifier** requires a supply voltage (or supply voltages).

NOTE 2 The **hydrophone pre-amplifier** may have a forward voltage transmission factor of less than one, i.e. it need not necessarily be a voltage amplifier in the strict sense.

NOTE 3 Definition adopted from IEC 62127-3.

3.22

instantaneous acoustic pressure

$p(t)$

pressure minus the ambient pressure at a particular instant in time and at a particular point in an acoustic field (see also IEC 60050-801, 801-21-19)

NOTE 1 **Instantaneous acoustic pressure** is expressed in pascal (Pa).

NOTE 2 Definition adopted from IEC 62127-1.