

# 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

STANDARD PREVIEW  
(standards.iteh.ai)

IEC 62127-2:2007  
<http://standards.iteh.ai/catalog/standards/siv/ec62/16-8310-4800-a25-18069dd7887f/iec-62127-2-2007>





## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2007 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
Fax: +41 22 919 03 00  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

#### Useful links:

IEC publications search - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

The advanced search enables you to find IEC publications by a variety of criteria (reference number, text, technical committee,...).

It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available on-line and also once a month by email.

Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary (IEV) on-line.

Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [csc@iec.ch](mailto:csc@iec.ch).

### A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

### A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

#### Liens utiles:

Recherche de publications CEI - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

La recherche avancée vous permet de trouver des publications CEI en utilisant différents critères (numéro de référence, texte, comité d'études,...).

Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

Just Published CEI - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Restez informé sur les nouvelles publications de la CEI. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (VEI) en ligne.

Service Clients - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: [csc@iec.ch](mailto:csc@iec.ch).



IEC 62127-2

Edition 1.0 2007-08

# 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**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

PRICE CODE **XC**  
CODE PRIX

ICS 17.140.50

ISBN 978-2-83220-136-7

**Warning! Make sure that you obtained this publication from an authorized distributor.**  
**Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

## CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references.....	8
3 Terms, definitions and symbols.....	9
4 List of symbols.....	13
5 Overview of calibration procedures.....	15
5.1 Principles.....	15
5.2 Summary of calibration procedures.....	16
5.3 Reporting of results.....	17
5.4 Recommended calibration periods.....	18
6 Generic requirements of a hydrophone calibration system.....	19
6.1 Mechanical positioning.....	19
6.1.1 General.....	19
6.1.2 Accuracy of the axial hydrophone position.....	19
6.1.3 Accuracy of the lateral hydrophone position.....	19
6.2 Temperature measurements and temperature stability.....	19
6.3 Hydrophone size.....	20
6.4 Measurement vessel and water properties.....	20
6.5 Measurement of output voltage.....	20
7 Electrical considerations.....	21
7.1 Signal type.....	21
7.2 Earthing.....	21
7.3 Measurement of hydrophone output voltage.....	21
7.3.1 General.....	21
7.3.2 Electrical loading by measuring instrument.....	21
7.3.3 Electrical loading by extension cables.....	22
7.3.4 Noise.....	22
7.3.5 Cross-talk (radio-frequency <i>rf</i> pick-up) and acoustic interference.....	22
7.3.6 Integral hydrophone pre-amplifiers.....	23
8 Preparation of hydrophones.....	23
8.1 General.....	23
8.2 Wetting.....	23
8.3 Hydrophone support.....	23
8.4 Influence of cable.....	23
9 Free field reciprocity calibration.....	23
9.1 General.....	23
9.2 Object.....	23
9.3 General principles.....	24
9.3.1 General.....	24
9.3.2 Three-transducer reciprocity calibration method.....	24
9.3.3 Self-reciprocity calibration method.....	24
9.3.4 Two-transducer reciprocity calibration method.....	24
9.4 Two-transducer reciprocity calibration method.....	24
9.4.1 Apparatus.....	24

ITC STANDARD PREVIEW  
(standards.iteh.ai)

IEC 62127-2:2007

[https://standards.iteh.ai/catalog/standards/sist/ee6f911b-8810-48d0-af25-](https://standards.iteh.ai/catalog/standards/sist/ee6f911b-8810-48d0-af25-18069dd7887f/iec-62127-2-2007)

[18069dd7887f/iec-62127-2-2007](https://standards.iteh.ai/catalog/standards/sist/ee6f911b-8810-48d0-af25-18069dd7887f/iec-62127-2-2007)

9.4.2	Procedure .....	25
10	Free field calibration by planar scanning .....	25
10.1	General .....	25
10.2	Object .....	25
10.3	General principle .....	25
10.4	Procedural requirements .....	27
10.4.1	Hydrophone scanning .....	27
10.5	Procedure .....	27
10.5.1	Power measurement .....	27
10.5.2	Transducer mounting .....	27
10.5.3	Measurement conditions .....	27
10.5.4	Measurements .....	28
10.6	Corrections and sources of uncertainty .....	28
11	Free field calibration by optical interferometry .....	28
11.1	General .....	28
11.2	Principle .....	28
12	Calibration by comparison using a standard hydrophone .....	28
12.1	General .....	28
12.2	Object .....	28
12.3	Principle .....	29
12.4	Procedural requirements .....	29
12.4.1	Source transducer .....	29
12.4.2	Source transducer drive signal .....	29
12.4.3	Measurement system .....	29
12.5	Procedure .....	30
12.5.1	Measurements (Type I): determination of the directional response of a hydrophone .....	30
12.5.2	Measurements (Type II): calibration by comparison using a standard hydrophone .....	30
12.6	Maximum hydrophone size .....	31
Annex A (informative)	Assessment of uncertainty in free field calibration of hydrophones .....	32
Annex B (informative)	Behaviour of PVDF polymer sensors in high intensity ultrasonic fields .....	34
Annex C (informative)	Electrical loading corrections .....	37
Annex D (informative)	Absolute calibration of hydrophones using the planar scanning technique .....	38
Annex E (informative)	Properties of water .....	46
Annex F (informative)	The absolute calibration of hydrophones by optical interferometry up to 40 MHz .....	48
Annex G (informative)	Waveform concepts .....	58
Annex H (informative)	Time delay spectrometry – requirements and a brief review of the technique .....	68
Annex I (informative)	Determination of the phase response of hydrophones .....	71
Annex J (informative)	Maximum size considerations for the active element of a hydrophone .....	77

Bibliography .....	79
Figure F.1 – Experimental set-up of the interferometric foil technique .....	51
Figure F.2 – End-of-cable open-circuit sensitivity, $M_C$ , of a coplanar membrane hydrophone .....	53
Figure F.3 – Hydrophone waveform generated by a 9 $\mu\text{m}$ coplanar membrane hydrophone positioned at the focus of a 5 MHz transducer (focal length 51 mm) .....	54
Figure F.4 – Interferometer (displacement) waveform generated with the pellicle positioned at the focus of the 5 MHz transducer (focal position 51 mm) .....	55
Figure F.5 – Frequency spectrum of the displacement waveform (lower curve) and the differentiated displacement waveform (upper curve) .....	55
Figure F.6 – Sensitivity of a 0,2 mm active element diameter of a 9 $\mu\text{m}$ bilaminar membrane hydrophone determined at 5 MHz intervals over the frequency range 5 MHz to 60 MHz .....	56
Figure G.1 – Coordinates of a field point, P, in the near field of a plane- circular source transducer of radius, $a_t$ .....	65
Figure I.1 – Phase of end-of-cable open-circuit sensitivity for two membrane hydrophones .....	73
Figure I.2 – Phase of end-of-cable open-circuit sensitivity for a $\varnothing 0,2$ mm needle hydrophone .....	75
<b>iTeh STANDARD PREVIEW</b> (Standards.Teh.ai)	
Table 1 – List of typical uncertainty values obtained by the calibration methods specified in this standard and for the frequency range listed here .....	17
Table E.1 – Speed of sound $c$ [ , ] and specific acoustic impedance, $\rho c$ , as a function of temperature, for propagation in water .....	46
Table G.1 – Temporal waveform and hydrophone position concepts described in this Annex .....	58
Table I.1 – Example of uncertainties (where a coverage factor, $k = 2$ , is used) for a HTDS phase calibration of a needle hydrophone with a diameter of 0,2 mm, expressed at a confidence level of 95 % .....	73

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

---

**ULTRASONICS – HYDROPHONES –****Part 2: Calibration for ultrasonic fields up to 40 MHz**

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of 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, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). 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. 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 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 IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for any way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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 text of this standard is based on the following documents:

Enquiry draft	Report on voting
87/353/CDV	87/372/RVC

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

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.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC website 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
- amended.

**iTeh STANDARD PREVIEW**  
**(standards.iteh.ai)**

The contents of the corrigendum of August 2008 have been included in this copy.

[IEC 62127-2:2007](http://standards.iteh.ai/catalog/standards/sist/ee6f911b-8810-48d0-af25-18069dd7887f/iec-62127-2-2007)

<https://standards.iteh.ai/catalog/standards/sist/ee6f911b-8810-48d0-af25-18069dd7887f/iec-62127-2-2007>



## 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 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.

IFU STANDARD PREVIEW

(standards.iteh.ai)

<https://standards.iteh.ai/catalog/standards/sist/ee6f911b-8810-48d0-af25-18069dd7887f/iec-62127-2-2007>

## 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 electro-acoustics*

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, *Ultrasonics – Hydrophones – Part 1: Measurement and characterization of medical ultrasonic fields up to 40 MHz*

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 catalog/standards/sist/ec6f911b-8810-48d0-af25-18069dd7887f/iec-62127-2-2007

#### 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.

[IEC 62127-2:2007](https://standards.iteh.ai/catalog/standards/sist/ee6f911b-8810-48d0-af25-18069dd7887f/iec-62127-2-2007)

### 3.9 effective radius of a non-focused 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 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

$Z_L$

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 ( $\Omega$ ).

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 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)

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).

### 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.

### 3.23 instantaneous intensity $I(t)$

acoustic energy transmitted per unit time in the direction of acoustic wave propagation per unit area normal to this direction at a particular instant in time and at a particular point in an acoustic field

NOTE 1 Instantaneous intensity is the product of instantaneous acoustic pressure and particle velocity. It is difficult to measure intensity in the ultrasound frequency range. For the measurement purposes referred to in this standard, and if it is reasonable to assume **far field** conditions, the **instantaneous intensity**,  $I$  is approximated as

$$I(t) = \frac{p(t)^2}{\rho c} \quad (1)$$

where

$p(t)$  is the **instantaneous acoustic pressure**;

$\rho$  is the density of the medium;

$c$  is the velocity of sound in the medium.

NOTE 2 Instantaneous intensity is expressed in watts per metre squared ( $\text{W/m}^2$ ).

### 3.24 reference centre

point on or near a **hydrophone** about which its acoustic receiving sensitivity is defined

NOTE Unless stated otherwise (explicitly and quantitatively) by the manufacturer, it is understood for the purposes of this standard that this is given by the geometrical centre of the front surface of the **hydrophone** active element.

(See IEC 60565: 2006, 3.25)

[IEC 62127-2:2007](https://standards.iteh.ai/catalog/standards/sist/ec6f911b-8810-48d0-af25-18069dd7887f/iec-62127-2-2007)

<https://standards.iteh.ai/catalog/standards/sist/ec6f911b-8810-48d0-af25-18069dd7887f/iec-62127-2-2007>

### 3.25 uncertainty

parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

NOTE See the ISO Guide to the Expression of Uncertainty in Measurement [3], 2.2.3.

## 4 List of symbols

$a_h$	effective hydrophone radius ( $a_{h3}$ , $a_{h6}$ : with special reference to a 3 dB or 6 dB definition, respectively)
$a_g$	hydrophone geometrical radius
$a_{max}$	maximum effective radius for a specific hydrophone application
$a_P$	lateral distance from the beam axis ( $a_{PmaxE}$ , $a_{PmaxH}$ : maximum values with respect to avoiding edge wave and head wave interference, respectively)
$a_t$	effective radius of a non-focused ultrasonic transducer
$A_g$	geometrical area of an ultrasonic transducer
$B/A$	Fox-Wallace non-linearity parameter
$c$	speed of sound in a medium (usually water)
$C_H$	end-of-cable capacitance of the hydrophone including any integral cable and connector
$D(\theta)$	normalized directional response function
$e$	base of natural logarithms
$f$	frequency
$f_f$	fundamental drive frequency of a signal used to generate non-linear distortion