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Ultrasonics - Hydrophones -
Part 3: Properties of hydrophones for ultrasonic fields

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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Ultrasonics - Hydrophones - Part 3: Properties of hydrophones for ultrasonic fields

FOREWORD

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This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 62127-3 edition 2.1 contains the second edition (2022-12) [documents 87/818/FDIS and 87/824/RVD] and its amendment 1 (2026-02) [documents 87/897/CDV and 87/914/RVC].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

IEC 62127-3 has been prepared by IEC technical committee 87: Ultrasonics. It is an International Standard.

This second edition cancels and replaces the first edition published in 2007 and Amendment 1:2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition.

a) The upper frequency limit of 40 MHz has been removed.
b) Hydrophone sensitivity definitions have been changed to recognize sensitivities as complex-valued quantities.
c) Procedures to determine the effective hydrophone size have been changed according to the rationale outlined in Annex B.
d) Requirements on the frequencies for which the effective hydrophone size shall be provided have been changed to achieve practicality for increased frequency bands.
e) The new Annex B and Annex C have been added.
f) Annex A has been updated to reflect the changes of the normative parts.

The text of this International Standard is based on the following documents:

Draft	Report on voting
87/818/FDIS	87/824/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 document and its amendment will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,
– withdrawn, or
– revised.

This corrected version of IEC 62127-3:2026 incorporates the following corrections:

- In Terms 3.7 and 3.8, alignement of the Fourier transform symbol $\mathcal{F}$ in both definitions and equations.

INTRODUCTION

The spatial and temporal distribution of acoustic pressure in an ultrasonic field in a liquid medium is commonly determined using miniature ultrasonic **hydrophones**. The properties of these **hydrophones** have been dealt with in a number of IEC standards in various aspects. The purpose of this document is to bring together all these specifications and to establish a common standard on the properties of ultrasonic **hydrophones**. The main **hydrophone** application in this context is the measurement of ultrasonic fields emitted by medical diagnostic equipment in water. Other medical applications are field measurements for therapy equipment such as that used in lithotripsy, high-intensity focused ultrasound (HIFU) and physiotherapy. **Hydrophones** are also used extensively in non-medical applications for both product development and quality control including:

– mapping of the ultrasound field within ultrasonic cleaning baths;
– characterization of acoustic fields used in transmission measurement systems (e.g. ultrasonic spectrometers, ultrasonic attenuation meters and velocimeters);
– characterization of acoustic fields used in reflection measurement systems (e.g. Doppler flowmeters).

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 ultrasonics and, in particular, to quantitatively characterize 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 document 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 properties will have to be dealt with in a revised version of this document or in a separate one.

Underwater **hydrophones** as covered by IEC 60500, IEC 60565-1, and IEC 60565-2 are not included in this document, although there is an overlap in the frequency ranges. Underwater **hydrophones** are used in natural waters, even in the ocean, and this leads to different technical concepts and requirements. In addition, the main direction of acoustic incidence in underwater applications is at various angles and often at right angles to the **hydrophone axis**, whereas in this document it is assumed that the main direction of acoustic incidence is in the direction of the **hydrophone axis**.

Historically, ultrasonic **hydrophones** were used almost exclusively as amplitude sensors. However, the complex-valued nature of a **hydrophone's** system response function is well understood and IEC 62127-1:2022 makes use of this within the deconvolution procedures it contains. In this document, requirements are specified for the amplitude aspect of the **hydrophone** sensitivity and recommendations are provided for the phase aspect which can be derived either via calibration, or via calculation methods that are discussed in IEC 62127-1:2022.

INTRODUCTION to Amendment 1

The second edition of IEC 62127-3 was published in 2022. The application of the document has revealed improvement potential with respect to the measurement requirements for **directional responses** and regarding data evaluation requirements for **effective hydrophone size** determination. This amendment addresses these items to ensure the practicality of the required measurements as well as the generation of a common data base to support **hydrophone** spatial averaging correction methods and the simplifying assumptions therein.

1 Scope

This part of IEC 62127 specifies relevant **hydrophone** characteristics.

This document is applicable to:

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

– **hydrophones** used for measurements made in water;

– **hydrophones** with or without an associated pre-amplifier.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 62127-1, *Ultrasonics – Hydrophones – Part 1: Measurement and characterization of medical ultrasonic fields*

IEC 62127-2, *Ultrasonics – Hydrophones – Part 2: Calibration 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, IEC 62127-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
acoustic pulse waveform
temporal waveform of the **instantaneous acoustic pressure** at a specified position in an acoustic field and displayed over a period sufficiently long to include all significant acoustic information in a single pulse or tone-burst, or one or more cycles in a continuous wave

Note 1 to entry: Temporal waveform is a representation (e.g. oscilloscope presentation or formula) of the **instantaneous acoustic pressure**.

[SOURCE: IEC 62127-1:2022, 3.1]

3.2
directional response
description 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 1 to entry: Although **directional response** is a complex-valued function, it is generally the modulus of **directional response** that is of most interest and this is commonly presented graphically.

[SOURCE: IEC 60565:2006, 3.5, modified – In the definition, ", generally presented graphically," has been deleted; "electro-acoustic transducer" has been replaced by

"hydrophone"; and "radiated or incident sound" has been replaced by "incident plane sound wave,".]

3.3
effective hydrophone size
a_h
size of a theoretical receiver **hydrophone** that has a predicted **directional response** function with an angular width equal to the observed angular width

Note 1 to entry: The size is usually a function of frequency. For representative experimental data, see [1].

Note 2 to entry: The **effective hydrophone size** is expressed in metres (m).

Note 3 to entry: For hydrophones with a circular geometry, the **effective hydrophone size** is a radius.

Note 4 to entry: For hydrophones with a rectangular geometry, the **effective hydrophone size** is the half of the largest value of the length or width.

[SOURCE: IEC 62127-1:2022, 3.20]

3.4
electric load impedance
$\underline{Z}_L$
complex electric input impedance (consisting of a real and an imaginary part) to which the **hydrophone** unit output cable is connected or is intended to be connected

Note 1 to entry: The **electric load impedance** is expressed in ohms (Ω).

[SOURCE: IEC 62127-1:2022, 3.22]

3.5
end-of-cable
<**hydrophone** or **hydrophone assembly** with integral output cable> relating to the end of the integral output cable

3.6
end-of-cable
<**hydrophone** or **hydrophone assembly** without integral output cable> relating to the output connector firmly connected with the **hydrophone** or **hydrophone assembly** and not to an extra cable

3.7
end-of-cable loaded sensitivity
$\underline{M}_L(f)$
<of a **hydrophone** or **hydrophone assembly**> quotient of the Fourier transformed **hydrophone** voltage-time signal $\mathcal{F}(u_L(t))$ 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 Fourier transformed **acoustic pulse waveform** $\mathcal{F}(p(t))$ in the undisturbed free field of a plane wave in the position of the **reference centre** of the **hydrophone** if the **hydrophone** were removed

$$\underline{M}_L(f) = \frac{\mathcal{F}\left(u_L(t)\right)}{\mathcal{F}\left(p(t)\right)} \tag{1}$$

Note 1 to entry: The **end-of-cable loaded sensitivity** is a complex-valued parameter. Its modulus is expressed in units of volt per pascal (V/Pa), its phase angle is expressed in degrees, and represents the phase difference between the electrical voltage and the sound pressure.

3.8
end-of-cable open-circuit sensitivity
$\underline{M}_{\mathrm{c}}(f)$
<of a **hydrophone**> quotient of the Fourier transformed **hydrophone** open-circuit voltage-time signal $\mathcal{F}(u_{\mathrm{c}}(t))$ at the end of any integral cable or output connector of a **hydrophone** to the Fourier transformed **acoustic pulse waveform** $\mathcal{F}(p(t))$ in the undisturbed free field of a plane wave in the position of the **reference centre** of the **hydrophone** if the **hydrophone** were removed

$$\underline{M}_{\mathrm{c}}(f) = \frac{\mathcal{F}\left(u_{\mathrm{c}}(t)\right)}{\mathcal{F}\left(p(t)\right)} \tag{2}$$

Note 1 to entry: The **end-of-cable open-circuit sensitivity** is a complex-valued parameter. Its modulus is expressed in units of volt per pascal (V/Pa), its phase angle is expressed in degrees, and represents the phase difference between the electrical voltage and the sound pressure.

3.9
end-of-cable loaded sensitivity level
$L_{M_{\mathrm{L}}}(f)$
<of a **hydrophone** or **hydrophone assembly**> twenty times the logarithm to the base 10 of the quotient of the modulus of the **end-of-cable loaded sensitivity** $|\underline{M}_{\mathrm{L}}(f)|$ to a reference sensitivity M_{ref}

$$L_{M_{\mathrm{L}}}(f) = 20\log_{10}\frac{\left|\underline{M}_{\mathrm{L}}(f)\right|}{M_{\mathrm{ref}}}\ \mathrm{dB} \tag{3}$$

Note 1 to entry: Commonly used values of the reference sensitivity M_{ref} are 1 V/μPa or 1 V/Pa.

Note 2 to entry: The **end-of-cable loaded sensitivity level** is expressed in decibels (dB).

3.10
free field
sound field in a homogeneous and isotropic medium in which the effects of boundaries are negligible

[SOURCE: IEC 60565:2006, 3.13]

3.11
hydrophone geometrical size
geometrical size of a hydrophone active element
a_{g}
size defined by the lateral extents of the active element of a **hydrophone**

Note 1 to entry: The **hydrophone geometrical size** is expressed in metres (m).

Note 2 to entry: For **hydrophones** with a circular geometry, the **hydrophone geometrical size** is a radius.

Note 3 to entry: For **hydrophones** with a rectangular geometry, the **hydrophone geometrical size** is a half of the largest value of the length or width.

3.12
hydrophone
transducer that produces electric signals in response to pressure fluctuations in water

[SOURCE: IEC 60050-801:2021, 801-32-26]

3.13
hydrophone assembly
combination of **hydrophone** and **hydrophone pre-amplifier**

3.14
hydrophone axis
nominal symmetry axis of the **hydrophone** active element

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

3.15
hydrophone pre-amplifier
active electronic device connected to, or to be connected to, a particular **hydrophone** and reducing its output impedance

Note 1 to entry: A **hydrophone pre-amplifier** requires a supply voltage (or supply voltages).

Note 2 to entry: 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.

3.16
reference centre
point on or near a **hydrophone** about which its acoustic receiving sensitivity is defined

Note 1 to entry: Unless stated otherwise (explicitly and quantitatively) by the manufacturer, it is understood for the purposes of this document that this is given by the geometrical centre of the front surface of the **hydrophone** active element.

[SOURCE: IEC 60565:2006, 3.25, modified – In the definition, "transducer" has been replaced by "hydrophone" and "transmitting responses" has been omitted. The note has been replaced.]

3.17
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 1 to entry: See ISO/IEC Guide 98-3:2008 [2], 2.2.3.

[SOURCE: IEC 62127-1:2022, 3.92]

4 List of symbols

a_g	**hydrophone geometrical size**
a_h	**effective hydrophone size**
c	speed of sound in a medium
D_H	model function used during the determination of **effective hydrophone size** from a measured **directional response** of a **hydrophone**
f	frequency
k	wavenumber, equal to $2\pi/\lambda$