

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE

**Synthetic quartz crystal – Specifications and guidelines for use**

**Cristal de quartz synthétique – Spécifications et lignes directrices d'utilisation**

IEC 60758:2016

<https://standards.iteh.ai/catalog/standards/sist/d4da6bf5-83b6-49bf-9f46-42999e371bf5/iec-60758-2016>



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## SYNTHETIC QUARTZ CRYSTAL – SPECIFICATIONS AND GUIDELINES FOR USE

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International Standard IEC 60758 has been prepared by IEC technical committee 49: Piezoelectric, dielectric and electrostatic devices and associated materials for frequency control, selection and detection.

This bilingual version (2017-11) corresponds to the monolingual English version, published in 2016-05.

This fifth edition cancels and replaces the fourth edition, published in 2008. This edition constitutes a technical revision.

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

- order rearrangement and review of terms and definitions;
- abolition as a standard of the infrared absorbance coefficient  $\alpha_{3\ 410}$ ;
- addition of the  $\alpha$  value measurement explanation by FT-IR equipment in annex;
- addition of the synthetic quartz crystal standards for optical applications.



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

FDIS	Report on voting
49/1185/FDIS	49/1190/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.

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.

The committee has decided that the contents of this publication will remain unchanged until the stability 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

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## INTRODUCTION

The reason for adding synthetic quartz crystal for optical application to this International Standard is as follows.

Quartz crystal produced for optical applications is produced by many of the same suppliers manufacturing quartz for electronic applications. The equipment and methods to produce optical quartz are similar to those used in the production of electronic quartz. Also, with a few exceptions the characterization methods of electronic and optical material are similar. Therefore, IEC 60758 serves as the proper basis for including addenda related to quartz crystal for optical applications.

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# SYNTHETIC QUARTZ CRYSTAL – SPECIFICATIONS AND GUIDELINES FOR USE

## 1 Scope

This International Standard applies to synthetic quartz single crystals intended for manufacturing piezoelectric elements for frequency control, selection and optical applications.

## 2 Normative references

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

IEC 60068-1:2013, *Environmental testing – Part 1: General and guidance*

IEC 60122-1:2002, *Quartz crystal units of assessed quality – Part 1: Generic specification*

IEC 60410, *Sampling plans and procedures for inspection by attributes*

IEC 61994 (all parts), *Piezoelectric and dielectric devices for frequency control and selection – Glossary*

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## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61994 and the following apply.

### 3.1

#### **hydrothermal crystal growth**

crystal growth in the presence of water, elevated temperatures and pressures by a crystal growth process believed to proceed geologically within the earth's crust

Note 1 to entry: The industrial synthetic quartz growth processes utilize alkaline water solutions confined within autoclaves at supercritical temperatures (330 °C to 400 °C) and pressures (700 to 2 000 atmospheres).

Note 2 to entry: The autoclave is divided into two chambers: the dissolving chamber, containing raw quartz chips at the higher temperature; the growing chamber, containing cut seeds at the lower temperature (see 7.1.2).

### 3.2

#### **synthetic quartz crystal**

single crystal of  $\alpha$  quartz grown by the hydrothermal method

Note 1 to entry: Cultured quartz has the same meaning as synthetic quartz crystal.

### 3.3

#### **as-grown synthetic quartz crystal**

state of synthetic quartz crystal prior to grinding or cutting

### 3.4

#### **as-grown Y-bar**

crystals which are grown by using long stick seed in the Y-direction

### 3.5

#### **as-grown Z-bar**

crystals which are grown by using Z-cut seed

### 3.6

#### **synthetic quartz crystal batch**

synthetic quartz crystals grown at the same time in one autoclave

### 3.7

#### **seed**

rectangular parallelepiped quartz plate or bar to be used as a nucleus for crystal growth

### 3.8

#### **growth zones**

regions of a synthetic quartz crystal resulting from growth along different crystallographic directions

SEE: Figure 2.

### 3.9

#### **orientation of a synthetic quartz crystal**

orientation of the seed of a synthetic quartz crystal with respect to the orthogonal axes specified in 3.7

### 3.10

#### **orthogonal axial system of $\alpha$ quartz crystal**

orthogonal axis system consisting of three axes with a mutually vertical X axis, Y axis and Z axis as illustrated in Figure 1

Note 1 to entry: The z-cut seed may be oriented at an angle of less than  $20^\circ$  to the Y-axis, in this case the axial system becomes X, Y', Z'.

### 3.11

#### **AT-cut plate**

rotated Y-cut crystal plate oriented at an angle of about  $+35^\circ$  around the X-axis or about  $-3^\circ$  from the z (minor rhombohedral)-face

SEE: Figure 3.

### 3.12

#### **X-cut plate**

crystal plate perpendicular to the X-axis

SEE: Figure 3b.

### 3.13

#### **Y-cut plate**

crystal plate perpendicular to the Y-axis

SEE: Figure 3b.

### 3.14

#### **Z-cut plate**

crystal plate perpendicular to the Z-axis

SEE: Figure 3b.

### 3.15

#### **z (minor rhombohedral)-cut plate**

crystal plate parallel to the z (minor rhombohedral)-face

SEE: Figure 3a.

### **3.16 dimensions**

dimensions pertaining to growth on Z-cut seed rotated less than 20° from the Y-axis

### **3.17 effective Z-dimension**

as-grown effective Z dimension defined as the minimum measure in the Z ( $\theta = 0^\circ$ ) or Z' direction in usable Y or Y' area of an as-grown crystal and described by  $Z_{\text{eff}}$

SEE: Figure 2.

### **3.18 minimum Z-dimension**

minimum distance from seed surface to Z-surface described by  $Z_{\text{min}}$

SEE: Figure 2d.

### **3.19 inclusions**

any foreign material within a synthetic quartz crystal, visible by examination of scattered light from a bright source with the crystal immersed in a refractive index-matching liquid

Note 1 to entry: A particularly common inclusion is mainly the minerals called acmite and emeleusite.

### **3.20 seed veil**

array of inclusions or voids at the surface of the seed upon which a crystal has been grown

### **3.21 etch channel**

roughly cylindrical void that is present along the dislocation line after etching a quartz crystal

### **3.22 dopant**

additive used in the growth process which may change the crystal habit, chemical composition, physical or electrical properties of the synthetic quartz batch

### **3.23 pre-dimensioned bar**

bar whose as-grown dimensions have been altered by sawing, grinding, lapping, etc., to meet a particular dimensional requirement

### **3.24 impurity concentration**

concentration of impurities relative to silicon atoms

### **3.25 dislocations**

linear defects in the crystal due to misplaced planes of atoms

### **3.26 autoclave**

vessel for the high-pressure and high-temperature condition required for growth of a synthetic quartz crystal

### 3.27

#### **right-handed quartz or left-handed quartz**

handedness of quartz crystal as determined by observing the sense of handedness of the optical rotation in the polarized light

Note 1 to entry: Right-handed quartz is the crystal of dextrorotatory and left-handed quartz is the crystal of levorotatory

### 3.28

#### **twins**

two or more same single crystals which are combined together by the low of symmetrical plane or axis

Note 1 to entry: The following twin types have been identified in synthetic quartz crystals:

a) Electrical twins

Quartz crystal in which regions with the common Z-axis exist showing a polarity reversal of the electrical X-axis.

b) Optical twins

Quartz crystal in which regions with the common Z-axis exhibit handedness reversal of the optical Z-axis.

### 3.29

#### **infrared absorption coefficient $\alpha$ value**

coefficient (referred to as the  $\alpha$  value) established by determining the relationship between absorption of two wave numbers

Note 1 to entry: One wave number is minimal absorption due to OH impurity, the other is high absorption due to presence of OH impurities in the crystal lattice. The OH impurity creates mechanical loss in resonators and its presence is correlated to the presence of other loss-inducing impurities. The  $\alpha$  value is a measure of OH concentration and is correlated with expected mechanical losses due to material impurities.

Note 2 to entry: For the coefficient defined here, the logarithm base 10 is used. The infrared absorption coefficient value  $\alpha$  is determined using the following equation:

$$\alpha = \frac{1}{t} \log_{10} \left( \frac{T_1}{T_2} \right)$$

where

$\alpha$  is the infrared absorption coefficient;

$t$  is the thickness of Y-cut sample, in cm;

$T_1$  is the per cent transmission at a wave number of 3 800 cm<sup>-1</sup> or 3 979 cm<sup>-1</sup>;

$T_2$  is the per cent transmission at a wave number of 3 500 cm<sup>-1</sup>, or 3 585 cm<sup>-1</sup>.

### 3.30

#### **lumbered synthetic quartz crystal**

synthetic quartz crystal whose X- and Z- or Z'- surfaces in the as-grown condition have been processed flat and parallel by sawing, grinding, lapping, etc., to meet specified dimensions and orientation

### 3.31

#### **reference surface**

surface of the lumbered bar prepared to specific flatness and orientation with respect to a crystallographic direction (typically the X-direction)

### 3.32

#### **synthetic quartz for optical applications**

synthetic quartz which satisfies the requirements for the use of optical pickups, optical lowpass filters (OLPF) and wave plates for digital single-lens reflex camera, monitoring camera, digital video camera and optical communication module operating in the 300 nm to 1 700 nm wave length (5 882 cm<sup>-1</sup> to 33 333 cm<sup>-1</sup>)

**3.33****internal transmittance**

internal transmittance which does not include loss of surface refraction

Note 1 to entry: This definition applies to synthetic quartz for optical applications only. Internal transmission values require statement of sample thickness for which the value is calculated, e.g. 2 mm.

**3.34****striae**

short range deviations of refractive index in quartz, growing defects in which the refractive index fluctuates with a typical period of fractions of one millimetre to several millimetres

Note 1 to entry: This definition applies to synthetic quartz for optical applications only.

**3.35****growth band**

contrasting density band that can be observed in the Y-cut crystal by Schlieren and similar optical method

Note 1 to entry: The cause of this contrast is that elements such as aluminium, sodium, lithium and iron are trapped in the crystal when a crystal is growing.

Note 2 to entry: Larger amounts of trapped impurities typically cause an increase in  $\alpha$ .

Note 3 to entry: Growth bands cannot be observed when  $\alpha_{3585}$  is less than 0,160 or  $\alpha_{3500}$  is less than 0,120.

Note 4 to entry: This definition applies to synthetic quartz for optical applications only.

**4 Specification for synthetic quartz crystal****4.1 Standard values**

IEC 60758:2016

**4.1.1 Shape of synthetic quartz for optical applications**

<https://standards.iteh.ai/catalog/standards/sist/d4da6bf5-83b6-49bf-9f46-42999e316b5/iec-60758-2016>

A seed crystal is removed and the growth faces are machined to a specified uniform surface roughness and to a specified flatness with the specified crystallographic orientation.

**4.1.2 Orientation of the seed**

Standard orientation for the seeds are Z-cuts and rotated X-cuts, minor rhombohedral (z-minor) cut, 1°30' rotated Z-cut, 2° rotated Z-cut, 5° rotated Z-cut, and 8°30' rotated Z-cut, the Z'-axis of the latter three seeds being rotated as shown in Figure 1.

**4.1.3 Inclusion density****4.1.3.1 Inclusion density of synthetic quartz for piezoelectric applications**

The inclusion density (measured as in 4.2.5.3) for each grade shall not exceed the figures in any required size range for that grade listed in Table 1.