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Specifications and guide to the use

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SYNTHETIC QUARTZ CRYSTAL – SPECIFICATIONS AND GUIDE TO THE USE

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

This third edition cancels and replaces the second edition, published in 1993, and its amendments 1 (1997) and 2 (2001).

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

a) it combines the information given in the second edition and in the amendments into one single document;
b) it adds the infrared absorbance alpha value compensation method as Annex E.

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

FDIS	RVD
49/696/FDIS	49/701/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 committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site 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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

SYNTHETIC QUARTZ CRYSTAL – SPECIFICATIONS AND GUIDE TO THE USE

1 Scope

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

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 60068-1:1988, *Environmental testing – Part 1: General and guidance*

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

IEC 60410:1973, *Sampling plans and procedures for inspection by attributes*

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

3 Terms and definitions

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

3.1
hydrothermal crystal growth
literally, 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. 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). 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 (also known as cultured quartz crystal**)**
single crystal of α quartz grown by the hydrothermal method. The crystal is of either handedness and in the as-grown condition

3.2.1
as-grown synthetic quartz crystal
single crystal quartz grown hydrothermally. As-grown refers to the state of processing and indicates a state prior to whatever treatment might occur after growth, excluding quality control operations

3.2.2
as-grown Y-bar
crystals which are produced using seed with the largest dimension in the Y-direction

3.2.3
as-grown Z-bar
crystals in which the Z-grown sector is much larger that the X-grown sector. The relative size of the growth sector is controlled by the X-dimension of the seed

3.3
synthetic quartz crystal batch
synthetic quartz crystals grown at the same time in one autoclave

3.4
seed
rectangular parallelepiped quartz plate or bar to be used as a nucleus for crystal growth

3.5
growth zones
regions of a synthetic quartz crystal resulting from growth along different crystallographic directions (see Figure 1)

3.6
orientation of a synthetic quartz crystal
orientation of its seed with respect to the orthogonal axes specified in 3.7

3.7
orthogonal axial system of a quartz crystal

3.7.1
axial system for quartz illustrated in Figure 2

NOTE The Z-cut seed may be oriented at an angle of less than 20° to the Y-axis, in this case the axial system becomes X, Y′, Z′.

3.7.2
AT-cut plate
rotated Y-cut crystal plate oriented at an angle of about +35° around the X-axis or about -3° from the z (minor rhombohedral)-face as shown in Figure 3

3.7.3
z (minor rhombohedral)-cut plate
crystal plate parallel to the z (minor rhombohedral)-face as shown in Figure 3a

3.7.4
X-cut plate
crystal plate perpendicular to the X-axis as shown in Figure 3b

3.7.5
Y-cut plate
crystal plate perpendicular to the Y-axis as shown in Figure 3b

3.7.6
Z-cut plate
crystal plate perpendicular to the Z-axis as shown in Figure 3b

3.8
dimensions
dimensions pertaining to growth on Z-cut seed rotated less than 20° from the Y-axis

3.8.1
gross dimensions
maximum dimensions along the X-, Y-, or Y′-, and Z- or Z′-axes measured along the X-, Y′- and Z′-axes

3.8.1.1
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_{eff} ,as shown in Figure 1

3.8.1.2
minimum Z-dimension
minimum distance from seed surface to Z-surface described by Z_{min} as shown in Figure 1d

3.8.2
dimensions pertaining to growth on a Z-cut seed rotated more than 20° from the X-axis
(under consideration)

3.9
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. A particularly common inclusion is the mineral acmite (sodium iron silicate)

3.9.1
seed veil
array of inclusions or voids at the surface of the seed upon which a crystal has been grown

3.9.2
etch channel
roughly cylindrical void that is present along dislocation line after etching a quartz crystal

3.10
dopant
any additive used in the growth process which may change the crystal habit, chemical composition, physical or electrical properties of the synthetic quartz batch

3.11
pre-dimensioned bar
any bar whose as-grown dimensions have been altered by sawing, grinding, lapping, etc., to meet a particular dimensional requirement

3.12
impurity concentration
concentration of impurities relative to silicon atoms

3.13
dislocations
linear defects in the crystal due to misplaced planes of atoms

3.14
etch channel
roughly cylindrical void present along a dislocation line after etching a test wafer prepared from a quartz crystal

3.15
autoclave
vessel for the high-pressure high-temperature condition required for growth of synthetic quartz crystal

3.16
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. Right-handed quartz is the crystal of dextrorotatory and left-handed quartz is the crystal of levorotary

3.17
twins
twins follow laws of crystallography relating symmetrically to specific faces or axes.

The following 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

3.18
infrared absorption coefficient α-value
coefficient (referred to as the α-value) established by determining the relationship between absorption of two wavelengths: one with minimal absorption due to OH impurity, the other with 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-inducting impurities. The α-value is a measure of OH concentration and is correlated with expected mechanical losses due to material impurities. The infrared absorption coefficient α-value is determined using the following equation:

$$\alpha = \frac{1}{t}\log\frac{T_1}{T_2}$$

where

α is the infrared absorption coefficient;

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

T_1 is the per cent transmission at a wave number of 3 800 cm^{-1} or 3 979 cm^{-1};

T_2 is the per cent transmission at a wave number of 3 410 cm^{-1}, 3 500 cm^{-1} or 3 585 cm^{-1} .

3.19
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

3.19.1
lumbered Y-bar
quartz bars which are lumbered from an as-grown Y-bar

3.19.2
lumbered Z-bar
quartz bars which are lumbered from an as-grown Z-bar

3.20
reference surface
surface of the lumbered bar prepared to specific flatness and orientation with respect to a crystallographic direction (typically the X-direction)

4 Specification for as-grown synthetic quartz crystal

4.1 Standard values

4.1.1 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 2.

4.1.2 Inclusion density

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.

Table 1 – Inclusion densities for the grades

Grade/size range µm	Densities per cm^3			
	10-30	**30-70**	**70-100**	**>100**
Ia	2	1	0	0
Ib	3	2	1	1
I	6	4	2	2
II	9	5	4	3
III	12	8	6	4

Users requiring a grade in only one or more of the size ranges may designate their requirement as the grade followed by the appropriate size range.

4.1.3 Infra-red quality indications, α_{3500}, α_{3585}, α_{3410}

An infra-red extinction coefficient value (α-value) of synthetic quartz (measured as in 4.2.6) shall be as listed under the appropriate heading for α_{3500}, α_{3585}, or α_{3410} in Table 2 for the various grades.

Table 2 – Infra-red quality indications for the grades

Grades	Maxima			Pre-1987[a]
	α_{3500}	α_{3585}	α_{3410}	Q · 10^6 units
Aa	0,026	0,015	0,075	3,8
A	0,033	0,024	0,082	3,0
B	0,045	0,050	0,100	2,4
C	0,060	0,069	0,114	1,8
D	0,080	0,100	0,145	1,4
E	0,120	0,160	0,190	1,0

[a] These Q-values were obtained from α-measurements and empirical correlation, and were in common usage prior to 1987. These are included here as the previous labels to maintain continuity through the change in emphasizing α-labels. α is the physical meaurement now used to control and specify quality in sythetic quartz.

The test limits above either correspond to or are unchanged (except in the cases of grades B and D) from the α_{3500} limits that correspond to the *Q*-value grades listed in the first edition of IEC 60758. This earlier publication designated some of the same grades in terms of minimum indicated *Q*'s in 10^6 units, as follows:

A = 3,0;

B = 2,2 (basis used herein), changed from 2,4 in the earlier edition;

C = 1,8;

D = 1,4 (revised);

E = 1,0 (the same as the earlier D-grade).

4.1.4 Frequency-versus-temperature characteristics (Figure 4 and 4.2.7)

The frequency-versus-temperature characteristics of synthetic quartz crystal units shall be assessed by determination of the fractional frequency deviation measured at 15 °C and 35 °C with respect to the series resonance frequency at 25 °C. The fractional deviation shall satisfy the following:

– fractional frequency deviation at 15 °C: +0,5 to +1,5 $\times 10^{-6}$;

– fractional frequency deviation at 35 °C: –0,5 to –1,5 $\times 10^{-6}$.

Measurement shall be made in accordance with 4.7.3 of IEC 60122-1.

4.1.5 Etch channel density ρ

When required, the etch channel density, ρ, per cm^2 (measured as in 4.2.8) for each grade, shall comply with the listings in Table 3.

Table 3 – Etch channel densities for the grades

Grade	Maximum number ρ per cm^2
1	10
2	30
3	100
4	300
5	600

4.2 Requirements and measuring methods

4.2.1 Orientation

The orientation of the seed shall be along specified directions, with a deviation of less than 30 min from nominal.

4.2.2 Handedness

The handedness of the seed shall be specified, either right-hand or left-hand (see Figure 2).

4.2.3 Synthetic quartz crystal dimensions

The dimension shall be measured by calipers or point calipers which enable the hollow point of a synthetic quartz crystal to be measured (see Annex D).

4.2.3.1 Dimension along Y or Y′-axis

The dimension shall be as specified (see Figure 1d).

4.2.3.2 Dimension along Z or Z′-axis dimension shall be measured by a neck ipers

The dimension along the Z or Z′-axis shall be specified as the maximum dimension along the Z or Z′-axis in the greater X zone (see Figure 1c).

4.2.3.3 Dimension Z_{eff} or Z'_{eff}

The Z_{eff} or Z'_{eff} dimension shall be specified as the minimum dimension along the Z or Z′-axis (see Figure 1c).

4.2.3.4 Dimension Z_{min} or Z'_{min}

The dimension shall be as specified (see Figures 1c and 1d).

4.2.3.5 Dimension along X-axis

The gross dimension along the X-axis shall be as specified (see Figure 1c).

4.2.4 Seed dimensions

4.2.4.1 Z or Z′-dimension

The Z or Z′-dimension (i.e. thickness) of the Z-cut or rotated Z-cut seed shall be less than 3 mm, unless otherwise specified.

4.2.4.2 X-dimension

The dimension X of the seed shall be as specified.

4.2.5 Imperfections

4.2.5.1 Twinning

There shall be no electrical or optical twinning in the usable region. The existence of twinning shall be checked by visual inspection.

4.2.5.2 Cracks and fractures

There shall be no cracks or fractures in the usable region. The existence of cracks and fractures shall be checked by visual inspection.

4.2.5.3 Inclusion density

The following two measuring methods are used and either one may be chosen.

Method 1

Inclusions within stated ranges are counted visually per cm^3 in sample volumes within a crystal using a stereo binocular microscope operating at 30× to 40× magnification equipped for counting within either a circular or a square field and with a calibrated reticule scale for determining particle sizes, intense side illumination (such as halogen lamps) over a recessed black matt background, an index matching liquid (n = 1,55, approximately) for transparency, and means of measuring the dimensions of the sample volumes counted.