IEC 60122-1

Edition 3.0 2017-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

AMENDMENT 1
AMENDEMENT 1

Quartz crystal units of assessed quality –
Part 1: Generic specification

Résonateurs à quartz sous assurance de la qualité –
Partie 1: Spécification générique

IEC 60122-1:2002-08/AMD1:2017-12 (en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 31.140 ISBN 978-2-8322-7377-7

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FOREWORD

This amendment 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 (2019-11) corresponds to the monolingual English version, published in 2017-12.

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

FDIS	Report on voting
49/1254/FDIS	49/1259/RVD

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

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

The committee has decided that the contents of this amendment and the base 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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

1.2 Normative references

Add the following reference to the existing list of normative references:

IEC 61760-1:2006, *Surface mounting technology – Part 1: Standard method for the specification of surface mounting components (SMDs)*

4.9 Endurance test procedure

Replace Subclause 4.9 with the following new content:

4.9 Endurance test procedure

4.9.1 Standard aging test for production verification

4.9.1.1 Purpose

This test is usable for the statistical verification of aging performance in the production process.

4.9.1.2 Procedure

– Take sample from the production lot.

– Initial measurement of f_s and R_1 at (25 ± 2) °C.

– Store in oven at T_{oven} = (+85 ± 3) °C.

– Take and record additional measurements after 1 day and at least three more times at time intervals recommended in Annex A.

– For the measurement, remove the crystals from oven, and store at room temperature for 1 h, avoiding temperature shocks. Measurement of f_s and R_1 at (25 ± 2) °C in accordance with IEC 60444-5 or equivalent.

– Final measurement of f_s and R_1 at (25 ± 2) °C after 30 days.

4.9.1.3 Evaluation

The difference between the highest and lowest frequency measurement shall not exceed the specified value. The resistance R_1 shall never exceed the specified maximum values.

4.9.2 Accelerated aging

4.9.2.1 Purpose

For special applications, an accelerated aging procedure at higher temperatures is applied to shorten the verification time and/or to gain performance data at higher operating temperatures.

4.9.2.2 Procedure

The procedure is as in 4.9.1, except that the preferred oven temperature is T_{oven} = +105 °C, +125 °C or +150 °C. This temperature has to be lower or equal to the specified maximum storage temperature.

The ratio between the storage time at 25 °C and the storage time at an elevated temperature T_{oven} to achieve the same amount of frequency aging is called "time acceleration factor" (TAF). This factor depends on the design of the crystal unit and on the production process. It can be determined experimentally as described in Annex A, or taken from experience with structurally similar crystals, or can be mutually agreed between the manufacturer and the user.

If the time acceleration factor TAF is not otherwise specified, the following approach is recommended.

Applying Arrhenius's law, the time acceleration factor TAF is related to the activation energy E_a (in eV) by the following equation:

$$\text{TAF} = e^{\frac{E_a \cdot \left(\frac{1}{T_{ref}} - \frac{1}{T_{oven}} \right)}{k}}$$

where

k is Boltzmann's constant ($k \approx 8{,}617 \times 10^{-5}$ eV/K), and the temperatures are given in K.

Published experimental results (see [6] and [7]) show that the activation energy E_a is decreasing over time, i.e. the acceleration factor becomes lower with the aging time. Furthermore, E_a varies between the different crystals and oscillators, depending on frequency, package size, resonator design and production processes. The observed values of E_a were between > 0,1 eV and < 1 eV.

A common assumption is TAF = 12 for T_{oven} = +85 °C, i.e. 30 days (1 month) aging at 85 °C are considered to be equivalent to 365 days (12 months) aging at 25 °C, which corresponds to an activation energy E_a of 0,38 eV.

With this value of E_a, the time acceleration factor for other aging temperatures can be calculated. Table 5 below shows the time acceleration factor TAF and the number of days N_d equivalent to 365 days at 25 °C.

Table 5 – Time acceleration factors for E_a = 0,38 eV

T_{oven} °C	TAF	N_d days
+25	1	365
+85	12	30
+105	23	16
+125	41	9
+150	79	5

Other time acceleration factors may be agreed between the manufacturer and the user based on their own reliability calculations.

4.9.2.3 Evaluation

The evaluation is as in 4.9.1.

4.9.3 Reference aging test

4.9.3.1 Purpose

This procedure is used for higher confidence level. This method should be used for high-precision crystals and as reference method in case of dispute.

4.9.3.2 Procedure

See Annex A.

4.9.3.3 Evaluation

The test data of the series resonance frequency f_s is subjected to the data fitting procedure.

The frequency measurement data $f_i(t)$ shall be fitted using the method of least squares of the following function (logarithmic fit):

$$\left[\frac{\Delta f(t)}{f_{init}}\right] = a_0 + a_1 \times \ln(a_2 \times t + 1)$$

where

$\Delta f(t)$ is the frequency difference of the crystal t days after the start of the aging cycle and the initial frequency f_{init} measured after the stabilization time t_{stab} (the time origin for measurements analysis shall be the beginning of the stabilization period).

The coefficients a_0, a_1 and a_2 are constants to be determined from the least squares fit.

The default fitting algorithm is the logarithmic fit. In some cases, namely when the aging response has a very small curvature, the logarithmic fit may not yield reasonable results. In this case, the following polynomial fit is recommended to be calculated additionally:

$$\left[\frac{\Delta f(t)}{f_{\text{init}}}\right] = a_0 + a_1 \times t + a_2 \times t^{\frac{1}{2}} + a_3 \times t^{\frac{1}{3}}$$

This approach should only be used if the square root of the least square fit variance (SLQ) of the measurements from the polynomial fit is at least five times smaller than that of the logarithmic fit.

The total frequency change and the aging rate at the end of the specified aging period ($t = T_a$) shall be determined from the fitting equation using the constants determined from the least squares fit. The square root of the least squares fit variance of the measurements from the curve-fit function shall not exceed 5 % of the total aging change allowed during the test period.

For the logarithmic fitting (default), the aging rate (in ppm or ppb[1] per day) at $t = T_a$ is:

$$\left[\frac{d\left(\frac{\Delta f(t)}{f_{\text{init}}}\right)}{dt}\right]_{t=T_a} = \frac{a_1 \times a_2}{a_2 \times T_a + 1} \approx \frac{f(T_a + 1) - f(T_a)}{f_{\text{init}}}$$

If the polynomial fitting was used, the aging rate at $t = T_a$ ($T_a > 0$) is:

$$\left[\frac{d\left(\frac{\Delta f(t)}{f_{\text{init}}}\right)}{dt}\right]_{t=T_a} = a_1 + \frac{a_2}{2} \times T_a^{-\frac{1}{2}} + \frac{a_3}{3} \times T_a^{-\frac{2}{3}}$$

The projected total frequency change for a time period shall be calculated with the following formulas:

Aging per month $\approx \dfrac{f(T_a + 30) - f(T_a)}{f_{\text{init}}}$

Aging per (1st) year $\approx \dfrac{f(T_a + 365) - f(T_a)}{f_{\text{init}}}$

Aging over N years $\approx \dfrac{f(T_a + N \times 365) - f(T_a)}{f_{\text{init}}}$

The resistance R_1 shall never exceed the specified maximum values.

1 ppm = parts per million; ppb = parts per billion.

4.9.4 Extended aging

4.9.4.1 Purpose

The purpose is to evaluate the reliability and long-term performance.

4.9.4.2 Procedure

This test shall be carried out in accordance with 4.9.1, except that the continuous periods shall be 1 000 h, 2 000 h or 8 000 h, as prescribed in the detail specification and shall be used for information purposes only.

The measurements shall be carried out at (25 ± 2) °C or any other specified reference temperature in accordance with IEC 60444-5 or equivalent.

The measurement intervals can be extended to two weeks or longer. For the intermediate and the final measurement, the crystals can be removed from the oven, and stored at room temperature for 1 h. Thermal shocks should be avoided.

4.9.4.3 Evaluation

The difference between the highest and lowest frequency measurement shall not exceed the specified value (if applicable). The resistance R_1 shall never exceed the specified maximum values.

This test shall be used for information only. The crystal units used for these tests should not be supplied to any customer.

Add the following new Annex A:

Annex A
(normative)

Procedure for the determination of the fitting parameters for the frequency aging

A.1 Assumption

A general description of frequency aging is possible in the form of:

$$\Delta f/f\,(t,T) = g(t) \times h(T)$$

where

$$g(t) = b_0 + b_1 \times \log(b_2 \times t + 1) \text{ (logarithmic fit);}$$

or

$$g(t) = c_0 + c_1 \times (t - {}_{t0}) + c_2 \times (t - t_0)\text{^}(1/2) + c_3 \times (t - t_0)\text{^}(1/3) \text{ (polynomial fit);}$$

and

$$h(T) = a_1 \times \exp(E_a \times (1/T_{ref} - 1/T)/k)$$

where

k is Boltzmann's constant ($k \approx 8{,}617 \times 10^{-5}$ eV/K), and the temperatures are given in K;

T_{ref} is 298 K.

A.2 Determination of the fitting parameters b_0, b_1, b_2 (and/or c_0, c_1, c_2, c_3) and a_1, and E_a

The procedure of Table A.1 shall be applied.

Table A.1 – Procedure for the determination of the frequency aging parameters

Procedure	Conditions
Aging test procedure	Passive
Reflow solder test	2x ROHS-profile (IEC 61760-1:2006) [a]
Initial pre-aging (time and temperature)	48 h at >20 K above upper operating temperature, but T < upper storage temperature
Sample size per lot (from one production lot)	≥ 30[*] depending on needed confidence level
Number of aging temperatures	3
Recommended aging temperatures	85 °C, 105 °C, 125 °C, 150 °C[a] depending on application, T < specified upper storage temperature
Recommend temperature for measurement	(25 ± 2) °C, measurement > 1 h after removal from the temperature chamber. Avoid thermal shocks.
Recommended aging time	500 h, 1 000 h, 2 000 h [a] depending on needed confidence level
Test intervals (in "logarithmic" steps)	After 48 h stabilization: 24 h, 72 h, 250 h, 500 h, 750 h, 1 000 h (1 500 h, 2 000 h)
Algorithms to determine g(t) and h(T)	Least square fitting[b] $g(t)$: log fit and polynomial fit Polynomial fit – only if sum of least squares SLQ < 5 times SLQ of logarithmic fit $h(T)$: least square fitting Result: E_a E_a may vary with time. Use E_a for t ≥ 500 h

[a] If not otherwise specified.

[b] For monotonic aging, all measurements shall be used for the curve fitting. If the aging trend is not monotonic, the measurement period shall be extended up to 40 days or longer after the extremum in the aging trend, and the measurements form 12 days after the extremum is reached at the end of the aging measurement period shall be fit to the above functions for $g(t)$.

Bibliography

Replace the Bibliography with the following new Bibliography:

[1] IEC 60068-2-58:1999, *Environmental testing – Part 2: Tests – Test Td: Solderability, resistance to dissolution of metallization and soldering heat of Surface Mounting Devices (SMD)*

[2] IEC 60068-2-64:1993, *Environmental testing – Part 2: Tests methods – Test Fh: Vibration, broad-band random (digital control) and guidance*

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

[4] IEC QC 001002-1:1998, *IEC Quality Assessment System for Electronic Components (IECQ) – Rules of procedure – Part 1: Administration*

[5] IEC Guide 102:1996, *Electronic components. Specification structures for quality assessment (Qualification approval and capability approval)*

[6] Wang S-Y, Neubig B., Sato K., Hosoda T., Seydel E, Wu J-H, Ma T-F, Wang Ji, *Aging Models and Parameters of Quartz Crystal Resonators and Oscillators*; Proc. 2015 Symp on Piezoelectricity, Acoustic Waves and Device Applications, p. 382-385

[7] Shen, C-N, Yang X-W, Chang C, Chao M-C, *The Study of Activation Energy (Ea) by Aging and High Temperature Storage for Quartz Resonator's Life Evaluation*; Proc. 2010 Symp on Piezoelectricity, Acoustic Waves and Device Applications, p. 118-122