IEC 62884-3

Edition 1.0 2018-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Measurement techniques of piezoelectric, dielectric and electrostatic oscillators –
Part 3: Frequency aging test methods

Techniques de mesure des oscillateurs piézoélectriques, diélectriques et électrostatiques –
Partie 3: Méthodes d'essai du vieillissement en fréquence

IEC 62884-3:2018-03(en-fr)

IEC 62884-3

Edition 1.0 2018-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Measurement techniques of piezoelectric, dielectric and electrostatic oscillators –
Part 3: Frequency aging test methods

Techniques de mesure des oscillateurs piézoélectriques, diélectriques et électrostatiques –
Partie 3: Méthodes d'essai du vieillissement en fréquence

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 31.140

ISBN 978-2-8322-6207-8

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

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

MEASUREMENT TECHNIQUES OF PIEZOELECTRIC, DIELECTRIC AND ELECTROSTATIC OSCILLATORS –

Part 3: Frequency aging test methods

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 the 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 itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
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 62884-3 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 (2018-11) corresponds to the monolingual English version, published in 2018-03.

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

CDV	Report on voting
49/1248/CDV	49/1272/RVC

Full information on the voting for the approval of this International 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 document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62884 series, published under the general title *Measurement techniques of piezoelectric, dielectric and electrostatic oscillators*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

INTRODUCTION

This document was developed from the works related to IEC 60679-1:2007 (third edition), the measurement techniques of which were restructured into different parts under a new project reference. This document describes the measurement method for frequency aging only.

MEASUREMENT TECHNIQUES OF PIEZOELECTRIC, DIELECTRIC AND ELECTROSTATIC OSCILLATORS –

Part 3: Frequency aging test methods

1 Scope

This part of IEC 62884 describes the methods for the measurement and evaluation of frequency aging tests of piezoelectric, dielectric and electrostatic oscillators, including Dielectric Resonator Oscillators (DRO) and oscillators using FBAR (hereinafter referred to as "Oscillator"). The purpose of those tests is to provide statistical data supporting aging predictions.

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 60027 (all parts), *Letter symbols to be used in electrical technology*

IEC 60050-561, *International electrotechnical vocabulary – Part 561: Piezoelectric, dielectric and electrostatic devices and associated materials for frequency control, selection and detection*

IEC 60469, *Transitions, pulses and related waveforms – Terms, definitions and algorithms*

IEC 60617, *Graphical symbols for diagrams*, available at http://std.iec.ch/iec60617

IEC 60679-1, *Piezoelectric, dielectric and electrostatic oscillators of assessed qualify – Part 1: Generic specification*

IEC 62884-1:2017, *Measurement techniques of piezoelectric, dielectric and electrostatic oscillators – Part 1: Basic methods for the measurement*

ISO 80000-1, *Quantities and units – Part 1: General*

3 Terms and definitions, units and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60679-1 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

3.2 Units and symbols

Units, graphical symbols, letter symbols and terminology shall, wherever possible, be taken from the following standards:

- IEC 60027;
- IEC 60050-561;
- IEC 60469;
- IEC 60617;
- ISO 80000-1.

4 Frequency aging test

4.1 General

The test and measurement procedures shall be carried out in accordance with the relevant detail specification.

Where any discrepancies occur for any reason, documents shall rank in the following order of precedence:

– detail specification;
– sectional specification;
– generic specification;
– any other international documents (for example of the IEC) to which reference is made.

The same order of precedence shall apply to equivalent national documents.

4.2 Test and measurement conditions

4.2.1 General

General test and measurement conditions refer to IEC 62884-1, and especially the output frequency measurement to 4.5.4 of IEC 62884-1:2017.

4.2.2 Active aging test (non-destructive)

Purpose: Statistical verification of aging performance.

Unless otherwise specified, the operating oscillator unit shall be maintained at the specified temperature for a continuous period as given in Annex A.

During the period of test, the control of temperature and the accuracy of frequency measurement shall be consistent with the accuracy of the maximum frequency variations specified. The oscillator unit shall remain in the chamber throughout the duration of the test and shall be continually supplied with input power, unless otherwise specified.

After insertion into the oven, the oscillator shall be allowed to equilibrate with chamber air temperature. Then the oscillator shall be energized and stabilized prior to beginning of and during the measurement acquisition cycle.

The stabilization time t_{stab} depends on the type of oscillator as shown in Table 1.

The initial frequency f_{init} of the oscillator shall be measured immediately after the stabilization period t_{stab} and thereafter at intervals as shown in Table 1.

Table 1 – Measurement parameters depending on the oscillator type

Oscillator type	Stabilization time t_{stab}*	Test intervals*	Aging temperature T_{oven} (°C)*	Aging temperature tolerance**
SPXO, VCXO	1 h	See Annex A	See Annex A	± 3 K
TCXO	48 h	See Annex A	See Annex A	± 3 K
OCXO	48 h	See Annex A	+25 °C	± 3 K
* unless otherwise specified				
** measurement tolerance < ± 0,5 K				

The measurement interval should be divided logarithmically.

If the aging test is used for qualification, at least 5 oscillators of identical or structurally similar type shall be tested.

The frequency change between the initial frequency f_{init} and all subsequent frequencies measured within the specified period shall not exceed the maximum frequency change specified. Measurements shall be carried out according to 4.5.4 of IEC 62884-1:2017.

4.2.3 Data fitting

If a projected total frequency change for a period (such as 365 days (1 year)) is specified, an extrapolation shall be used from the end of the aging measurement period using the coefficients determined from a curve fitting to the measurements.

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

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

where $\Delta f(t)$ is the frequency difference of the oscillator at 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.

For monotonic aging, all the measurements shall be used for the curve fitting. If the aging trend is not monotonic, the measurement period shall be extended to 40 days or longer after the extremum in the aging trend, and the measurements from 12 days after the extremum is reached to the end of the aging measurement period shall be fit to the above function (unless otherwise specified).

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:

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

This approach should only be used if the square root of the least square fit variance 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 percent of the total aging change allowed during the test period.

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

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

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

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

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

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

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

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

If polynomial fitting was used inflection of the aging response may occur over time.

If aging after N_{op} days operation is specified (for OCXO usually T_{op} = 30 days), in the above formulae T_a should be replaced by (T_a + N_{op}).

4.2.4 Accelerated aging (non-active)

For special applications, it is possible to accelerate the aging of SPXO, VCXO and TCXO at higher temperatures, e.g. at +85 °C, +105 °C or +125 °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 used crystal unit and on the production process. It can be determined experimentally as described in Annex A, or taken from experience with structurally similar oscillators, or can be mutually agreed between manufacturer and user.

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

Applying Arrhenius' law, the acceleration factor TAF is related to the activation energy E_a by the following equation:

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

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

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.

For example, 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 2 below shows the time acceleration factor TAF and the number of days N_d for to equivalent of 365 days at +25 °C.

Table 2 – 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

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

4.2.5 Extended aging

Purpose: Evaluation of reliability and long-term performance.

This test shall be carried out in accordance with 4.2.1, except that the continuous periods shall be 1 000 h, 2 000 h or 8 000 h, as prescribed in the detail specification. Measurements shall be carried out according to 4.5.4 of IEC 62884-1:2017, except that they should be made at (25 ± 2) °C or any other specified temperature. The measurement intervals can be extended to 2 weeks or longer. For the intermediate and the final measurements, the oscillator can be removed from the oven, and stored at room temperature for 1 hour. Thermal shocks should be avoided. The frequency measurement shall be performed at a reference temperature of (25 ± 2) °C.

This test shall be used for information purposes only.