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First edition
2004-04

Measurement of quartz crystal unit parameters –

Part 7: Measurement of activity and frequency dips of quartz crystal units

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MEASUREMENT OF QUARTZ CRYSTAL UNIT PARAMETERS –

Part 7: Measurement of activity and frequency dips of quartz crystal units

FOREWORD

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International Standard IEC 60444-7 has been prepared by IEC technical committee 49: Piezoelectric and dielectric devices for frequency control and selection.

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

FDIS	Report on voting
49/637/FDIS	49/664/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.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

This standard forms Part 7 of a series of publications dealing with measurements of quartz crystal unit parameters

IEC 60444 consists of the following parts, under the general title *Measurement of quartz crystal unit parameters:*

Part 1: Basic method for the measurement of resonance frequency and resonance resistance of quartz crystal units by zero phase technique in a pi-network

Part 2: Phase offset method for measurement of motional capacitance of quartz crystal units

Part 4: Method for the measurement of the load resonance frequency f_L, load resonance resistance R_L and the calculation of other derived values of quartz crystal units, up to 30 MHz

Part 5: Methods for the determination of equivalent electrical parameters using automatic network analyzer techniques and error correction

Part 6: Measurement of drive level dependence (DLD)

Part 7: Measurement of activity and frequency dips of quartz crystal units

Part 8: Test fixture for surface mounted quartz crystal units

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

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- withdrawn;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

INTRODUCTION

The tolerable activity dips of resonant resistance and frequency (Bandbreak) will be specified in the detail specification. The measurement and evaluation of the activity/frequency dip for the quartz crystal unit requires special consideration as it uses the linear least squares method.

MEASUREMENT OF QUARTZ CRYSTAL UNIT PARAMETERS –

Part 7: Measurement of activity and frequency dips of quartz crystal units

1 Scope

This standard applies to activity and frequency dips for quartz crystal units over a temperature range.

2 Definitions

2.1
activity dip
undesirable change in the crystal unit's load resonance frequency and/or resonance resistance caused by the coupling of different modes in a narrow temperature range and at a specified load capacitance and level of drive (see Figures 1 and 2)

2.2
frequency dip (bandbreak)
undesirable perturbation or fluctuation in the crystal frequency occurring in a narrow temperature range as a deviation of the load resonance frequency from the smooth regular frequency temperature characteristic described by a polynomial of up to the 5^{th} order. It usually shows an associated resistance change (see Figure 2) and the effect is usually drive level dependent

3 Measurements

The following measurement parameters are necessary and should be given in the detail specification:

– operating temperature range;
– load capacitance;
– level of drive.

The evaluation of the data is made using a computer and is described in 3.3.

Care shall be taken in selecting a suitable measurement time; this will depend on the type of crystal unit being measured. The drive current (in microamperes) shall also be correct and controlled.

The inspection method is selected from the following and specified in the individual specification:

a) lot inspection and guaranteed by process control;
b) sample inspection.

3.1 Reference method

The measurement system consists of a π-network in accordance with IEC 60444 and a high precision temperature chamber, which allows to ramp-up the temperature at a constant small rate.

Each crystal is measured individually within the specified temperature range beginning at the lowest temperature as defined below. The temperature is then increased with a constant rate up to the maximum temperature as defined below.

NOTE The temperature performance of the chamber should allow for the appropriate resolution and a monotonic small temperature ramp.

The minimum/maximum measurement temperature shall be 5 K lower/10 K higher than the specified minimum/maximum operating temperature.

The number of data points should be such, that the temperature intervals between the measurement points are less or equal to 0,2 K.

The rate of temperature change shall be 2 K/min ± 10 % within the whole temperature range.

The actual temperature at a location in the vicinity of the crystal under test must be recorded at each measurement point together with the actual (load) resonance frequency and resistance.

The frequency and resistance are measured at the specified drive level and at the specified resonance condition, i.e. load resonance, resonance (zero phase), or series resonance.

The measurement points shall lie within one tenth of the resonance bandwidth.

NOTE Because of the irregular and discontinuous behaviour of the crystal impedance at the occurrence of an activity dip, more distant measurement points can lead to erroneous results.

Only the data within the operating temperature range are used for the evaluation. The method is given in 3.3 and is the same as described for the batch method.

3.2 Batch method

The measurement system consists of a π-network in accordance with IEC 60444 and a variable temperature chamber.

In the batch method, a number of crystals are measured in sequence in the temperature chamber. Each crystal is measured in turn at each temperature beginning at the lowest specified temperature. The temperature is then increased in steps up to the maximum specified temperature.

The recommended temperature step is 2 K.

NOTE 1 Narrow dips may require a high precision temperature chamber and smaller temperature steps.

NOTE 2 The temperature performance of the chamber should allow for the appropriate resolution and stability. Absolute temperature accuracy is less important.

It is recommended that the maximum and minimum measurement temperatures exceed the specified temperature range by 5 K.

3.3 Evaluation

When performing an evaluation of the measurement data the order/degree of the polynomial used for curve fitting is chosen from the table below.

Table 1 – Order/degree of the polynomial used for curve fitting

ΔT_{OTR}	Order No.	
	$F(T)$*	$R(T)$
≤40 K	3	2
40 K < ΔT < 120 K	4	2
≥120 K	5	3
* for crystals with a basic 2nd order $F(T)$ characteristic, for example BT-cuts and low-frequency crystals, one order less is sufficient.		

Using the linear least squares method, fit the measured frequency data to a polynomial function of temperature. The order of the polynomial and the number of data points should be defined in the agreed specification. Calculate the difference between the measured frequency data (F_m) and the computed frequency data (F_c) for each of the data points according to

$$\Delta F(T) = F_m(T) - F_c(T)$$

Using the linear least squares method, fit the measured resistance data to a polynomial function of temperature. Calculate the difference in the measured resistance (R_m) and the computed resistance (R_c) for each data point according to

$$\Delta R(T) = R_m(T) - R_c(T)$$

The evaluation conditions for individual specifications of resonance frequency and series resistance can be as follows:

– for frequency dips (bandbreaks)

(A) $\max\left|\Delta F(T_i)\right| < \Delta F_{dip}$ in 1×10^{-6} (given in the detail specification)

(B) $\max\left|\dfrac{\Delta F_{i+1} - \Delta F_i}{T_{i+1} - T_i}\right| \leq \Delta F_{slope}$ in 1×10^{-6}/K (given in the detail specification)

– for activity dips

(C) $\max(R_m(T_i)) \leq R_{max}$ (given in the detail specification)

(D) $\max\left|\dfrac{\Delta R_{i+1} - \Delta R_i}{T_{i+1} - T_i}\right| \leq \Delta R_{slope}$ (given in the detail specification)

Warning

The differentiation of measured data may cause misleading results due to stochastic and systematic noise in the measurement data in particular the temperature. This shall be avoided by selection of suitable smoothing algorithms for the test data.

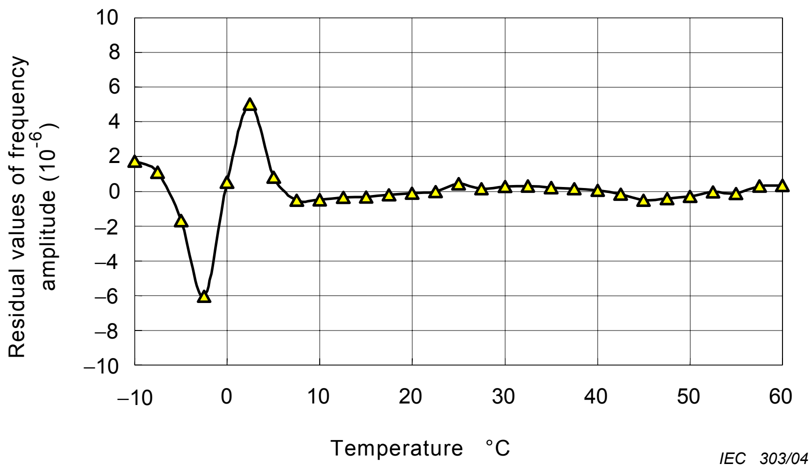

Figure 1 – Residual values of frequency amplitude

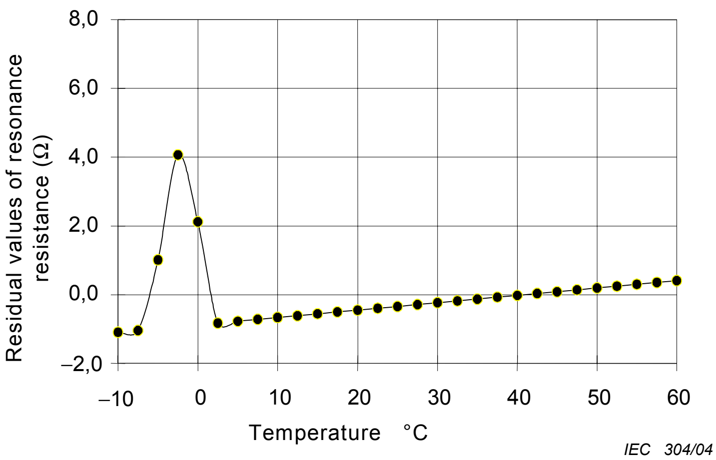

Figure 2 – Residual values of resonance resistance

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