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Measurement of quartz crystal unit parameters -
Part 11: Standard method for the determination of the load resonance frequency f_L and the effective load capacitance C_{Leff} using automatic network analyzer techniques and error correction

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IEC 60444-11 has been prepared by IEC technical committee 49: Piezoelectric, dielectric and electrostatic devices and associated materials for frequency control, selection and detection. It is an International Standard.

This second edition cancels and replaces the first edition published in 2010. This edition constitutes a technical revision.

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

a) key content of withdrawn IEC TR 60444-4 is reproduced as Annex A;
b) some formulae in the first edition have been corrected.

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

Draft	Report on voting
49/1489/CDV	49/1515/RVC

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60444 series, published under the general title *Measurement of quartz crystal unit parameters*, 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 webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,
– withdrawn, or
– revised.

INTRODUCTION

This part of IEC 60444 defines the measuring method of load resonance frequency f_L using automatic network analyzer techniques.

At the same time, even though IEC TR 60444-4 [8][1] specifying the manual measuring method has been withdrawn, the main contents of the manual measuring method remain as Annex A for the user's convenience. However, in case of dispute, the standard method as described below should be used as reference.

The figure of merit M, according to IEC 60122-1:2002, Table 1, is expressed in the following formula:

$$M = \frac{Q}{r} = \frac{1}{\omega C_0 R_1} \tag{1}$$

This gives good results in a frequency range up to 200 MHz. This method allows the calculation of load resonance frequency offset Δf_L, frequency pulling range Δf_{L1}, Δf_{L2} and pulling sensitivity S as described in IEC 60122-1:2002, 2.2.31. This measurement technique avoids the use of physical load capacitors, and allows higher accuracy, better reproducibility and correlation to the application. It extends the upper frequency limit from 30 MHz by the manual method to 200 MHz approximately. This method is based on the error-corrected measurement technique of IEC 60444-5 [9] and therefore allows the measurement of f_L and C_{Leff} together with the determination of the equivalent crystal parameters in one sequence without changing the test fixture.

With this method the frequency f_L is searched where the reactance X_C of the crystal has the opposite value of the reactance of the load capacitance.

$$X_C = -X_{CL} = \frac{1}{\omega_L C_L} \tag{2}$$

Furthermore, this method allows to determine the effective load capacitance C_{Leff} at the nominal frequency f_{nom}.

[1] Numbers in square brackets refer to the Bibliography.

1 Scope

This part of IEC 60444 defines the standard method of measuring load resonance frequency f_L at the nominal value of C_L, and the determination of the effective load capacitance C_{Leff} at the nominal frequency for crystals with the figure of merit $M > 4$.

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 60122-1:2002, *Quartz crystal units of assessed quality - Part 1: Generic specification*
IEC 60122-1:2002/AMD1:2017

IEC 60444-1:1986, *Measurement of quartz crystal unit parameters by zero phase technique in a pi-network - 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
IEC 60444-1:1986/AMD1:*1999*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60122-1 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

– IEC Electropedia: available at https://www.electropedia.org/
– ISO Online browsing platform: available at https://www.iso.org/obp

4 General concepts

4.1 Load resonance frequencies f_{Lr} and f_{La}

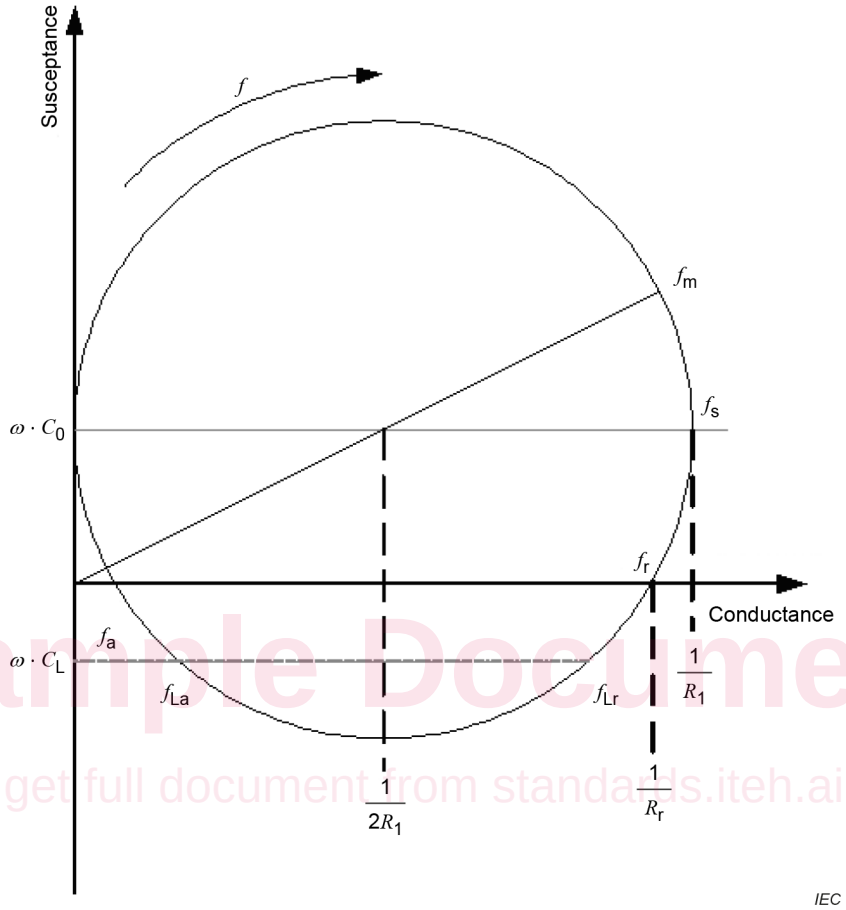
As can be seen in Figure 1, there are two intersection frequencies where $X_C = -X_{CL}$, f_{Lr} with high admittance (low impedance) and f_{La} with low admittance (high impedance).

The load resonant frequency f_L is one of the two frequencies of a crystal unit in association with a series or with a parallel load capacitance, at which the electrical admittance (respectively impedance) of the combination is resistive. The load resonance frequency f_L is the lower of the two frequencies.

In a first approximation f_L can be calculated by:

$$f_S = \frac{1}{2\pi\sqrt{L_1 C_1}} \tag{3}$$

$$f_L \approx f_S \cdot \left(1 + \frac{C_1}{2 \cdot (C_0 + C_L)}\right) \tag{4}$$



NOTE f_{Lr} is the load resonance frequency that is commonly expressed as f_L.

Figure 1 – Admittance of a quartz crystal unit

4.2 Effective load capacitance C_{Leff}

C_{Leff} is defined by the reactance of the crystal at the nominal frequency:

$$C_{Leff} = \frac{1}{\omega_{nom} X_C(\omega_{nom})} \tag{5}$$