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**Generic specification and test methods of
quartz crystal units**

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry based on the provision of Article 14, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act in response to a proposal for revision of Japanese Industrial Standard with a draft being attached, submitted by Japanese Standards Association (JSA), an accredited standards development organization. This edition replaces the previous edition (**JIS C 6701** : 2007), which has been technically revised.

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Generic specification and test methods of quartz crystal units

Introduction

This Japanese Industrial Standard has been prepared based on **IEC 60122-1** : 2002, Edition 3, and Amendment 1 : 2017 with some modifications of the technical contents to correspond to the actual situations in Japan. The amendment to the said International Standard has been incorporated into this Standard.

Annex JA to Annex JE are unique to **JIS** and not given in the corresponding International Standard. The dotted underlines indicate changes from the corresponding International Standard. A list of modifications with the explanations is given in Annex JF.

1 Scope

This Standard specifies the methods of test and general requirements for quartz crystal units of assessed quality using either capability approval and/or qualification approval procedures.

NOTE 1 Where any discrepancies occur for any reason, documents may rank in the following order of precedence:

- the detail specifications;
- the sectional specification;
- the generic specification;
- any other international documents (e.g. **IEC**) to which reference is made.

NOTE 2 The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

IEC 60122-1 : 2002 *Quartz crystal units of assessed quality — Part 1 : Generic specification* + Amendment 1 : 2017 (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

Part or all of the provisions of the following standards, through reference in this text, constitute provisions of this Standard. For standards indicated below, only the editions of the indicated year shall be applied and any revisions (including amendments) made thereafter shall not be applied.

JIS C 60068-1 : 2016 *Environmental testing — Part 1 : General and guidance*

NOTE Normative reference in the corresponding International Standard : IEC 60068-1 : 2013 *Environmental testing — Part 1 : General and guidance*

JIS C 60068-2-1 : 2010 *Environmental testing — Part 2-1 : Tests — Test A : Cold*

NOTE Normative reference in the corresponding International Standard : IEC 60068-2-1 : 2007 *Environmental testing — Part 2-1 : Tests — Test A : Cold*

JIS C 60068-2-2 : 2010 *Environmental testing — Part 2-2 : Tests — Test B : Dry heat*

NOTE Normative reference in the corresponding International Standard : IEC 60068-2-2 : 2007 *Environmental testing — Part 2-2 : Tests — Test B : Dry heat*

JIS C 60068-2-6 : 2010 *Environmental testing — Part 2-6 : Tests — Test Fc : Vibration (sinusoidal)*

NOTE Normative reference in the corresponding International Standard : IEC 60068-2-6 : 2007 *Environmental testing — Part 2-6 : Tests — Test Fc : Vibration (sinusoidal)*

JIS C 60068-2-7 : 1993 *Basic environmental testing procedures Part 2 : Tests — Test Ga and guidance : Acceleration, steady state*

NOTE Normative reference in the corresponding International Standard : IEC 60068-2-7 : 1983 + AMD1 : 1986 *Basic environmental testing procedures — Part 2-7 : Tests — Test Ga and guidance : Acceleration, steady state*

JIS C 60068-2-14 : 2011 *Environmental testing — Part 2-14 : Tests — Test N : Change of temperature*

NOTE Normative reference in the corresponding International Standard : IEC 60068-2-14 : 2009 *Environmental testing — Part 2-14 : Tests — Test N : Change of temperature*

JIS C 60068-2-17 : 2001 *Basic environmental testing procedures — Part 2 : Tests — Test Q : Sealing*

NOTE Normative reference in the corresponding International Standard : IEC 60068-2-17 : 1994 *Basic environmental testing procedures — Part 2-17 : Tests — Test Q : Sealing*

JIS C 60068-2-20 : 2010 *Environmental testing — Part 2-20 : Tests — Test T : Test methods for solderability and resistance to soldering heat of devices with leads*

NOTE Normative reference in the corresponding International Standard : IEC 60068-2-20 : 2008 *Environmental testing — Part 2-20 : Tests — Test T : Test methods for solderability and resistance to soldering heat of devices with leads*

JIS C 60068-2-21 : 2009 *Environmental testing — Part 2-21 : Tests — Test U : Robustness of terminations and integral mounting devices*

- NOTE Normative reference in the corresponding International Standard : IEC 60068-2-21 : 2006 *Environmental testing — Part 2-21 : Tests — Test U : Robustness of terminations and integral mounting devices*
- JIS C 60068-2-27 : 2011 *Environmental testing — Part 2-27 : Tests — Test Ea : Shock*
- NOTE Normative reference in the corresponding International Standard : IEC 60068-2-27 : 2008 *Environmental testing — Part 2-27 : Tests — Test Ea and guidance: Shock*
- JIS C 60068-2-30 : 2011 *Environmental testing — Part 2-30 : Tests — Test Db : Damp heat, cyclic (12 h + 12 h cycle)*
- NOTE Normative reference in the corresponding International Standard : IEC 60068-2-30 : 2005 *Environmental testing — Part 2-30 : Tests — Test Db : Damp heat, cyclic (12 h + 12 h cycle)*
- JIS C 60068-2-31 : 2013 *Environmental testing — Part 2-31 : Tests — Test Ec : Rough handling shocks, primarily for equipment-type specimens*
- JIS C 60068-2-45 : 1995 *Environmental testing procedures of electronic and electrical resistance to solvents (immersion in cleaning solvents)*
- NOTE Normative reference in the corresponding International Standard : IEC 60068-2-45 : 1980 + AMD1 : 1993 *Basic environmental testing procedures — Part 2-45 : Tests — Test XA and guidance : Immersion in cleaning solvents*
- JIS C 60068-2-64 : 2011 *Environmental testing — Part 2-64 : Tests — Test Fh : Vibration, broadband random and guidance*
- JIS C 60068-2-78 : 2015 *Environmental testing — Part 2-78 : Tests — Test Cab : Damp heat, steady state*
- JIS Z 8000-1 : 2014 *Quantities and units — Part 1 : General*
- IEC 60027-1 : 1992 *Letter symbols to be used in electrical technology — Part 1 : General*
- IEC 60050-561 : 2014 *International electrotechnical vocabulary — Part 561 : Piezoelectric, dielectric and electrostatic devices and associated materials for frequency control, selection and detection*
- IEC 60122-3 : 2010 *Quartz crystal units of assessed quality — Part 3 : Standard outlines and lead connections*
- IEC 60444-1 : 1986 *Measurement of quartz crystal unit parameters by zero phase technique in a π -network. Part 1 : Basic method for the measurement of resonance frequency and resonance resistance of quartz crystal units by zero phase technique in a π -network*

- IEC 60444-2 : 1980 *Measurement of quartz crystal unit parameters by zero phase technique in a π -network. Part 2 : Phase offset method for measurement of motional capacitance of quartz crystal units*
- IEC TR 60444-4 : 1988 *Measurement of quartz crystal unit parameters by zero phase technique in a π -network. 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*
- IEC 60444-5 : 1995 *Measurement of quartz crystal units parameters — Part 5 : Methods for the determination of equivalent electrical parameters using automatic network analyzer techniques and error correction*
- IEC 60444-8 : 2016 *Measurement of quartz crystal unit parameters — Part 8 : Test fixture for surface mounted quartz crystal units*
- IEC 60617 : 2012 *Graphical symbols for diagrams*
- IEC 61178-2 : 1993 *Quartz crystal units — A specification in the IEC Quality Assessment System for Electronic Components (IECQ) — Part 2 : Sectional specification. Capability approval*
- IEC 61178-3 : 1993 *Quartz crystal units — A specification in the IEC Quality Assessment System for Electronic Components (IECQ) — Part 3 : Sectional specification — Qualification approval*
- IEC 61760-1 : 2006 *Surface mounting technology — Part 1 : Standard method for the specification of surface mounting components (SMDs)*

3 Terms and definitions

3.1 General

Units, graphic symbols, letter symbols and terminology shall, wherever possible, be taken from the following standards.

- IEC 60027-1
- IEC 60050-561
- IEC 60617
- JIS Z 8000-1

3.2 Terms and definitions

For the purpose of this Standard, the following terms and definitions apply.

3.2.1

crystal element (crystal blank)

piezoelectric material cut to a given geometrical shape, size and orientation with respect to the crystallographic axes of the crystal

3.2.2

electrode

electrically conductive plate or film in contact with, or in proximity to, a face of a crystal element

Note 1 to entry By means of this, an electric field is applied to the element.

3.2.3

crystal resonator

mounted crystal element that vibrates when an alternating electric field exists between the electrodes

3.2.4

mounting

means by which the crystal resonator is supported (within its enclosure)

3.2.5

enclosure

container protecting the crystal resonator(s) and mounting

3.2.6

crystal unit

crystal resonator mounted in an enclosure

3.2.7

mode of vibration

pattern of motion in a vibrating body of the individual particles resulting from stresses applied to the body, the frequency of oscillation and the boundary conditions existing

Note 1 to entry The common modes of vibration are :

- flexural;
- extensional;
- face shear;
- thickness shear.

3.2.8

crystal unit equivalent circuit

electric circuit which has the same impedance as the crystal unit in the region of the desired resonance and anti-resonance frequencies

Note 1 to entry It is represented by an inductance, capacitance and resistance in series, this series arm being shunted by the capacitance between the terminals of the unit. The parameters of the series branch of inductance, capacitance and resistance are given by L_1 , C_1 and R_1

respectively : these are termed “motional parameters” of the crystal unit. The shunt (parallel) capacitance is denoted by C_0 (see Figure 1).

Note 2 to entry Generally, the parameters are independent of frequency for isolated modes of vibration. The mode of vibration in question is sufficiently isolated from other modes to permit this assumption. When this is not true, the equations and measuring methods outlined herein do not apply. For identification of symbols used in this Standard, see Table 1.

Note 3 to entry The equivalent circuit does not represent all the characteristics of a crystal unit.

Note 4 to entry The values of R_e , X_e , G_p and B_p vary rapidly around the resonance frequency.

R_e is the equivalent circuit motional resistance of the resonator.

X_e is the equivalent circuit series reactance of the resonator.

G_p is the equivalent circuit parallel conductance of the resonator.

B_p is the equivalent circuit parallel susceptance of the resonator.

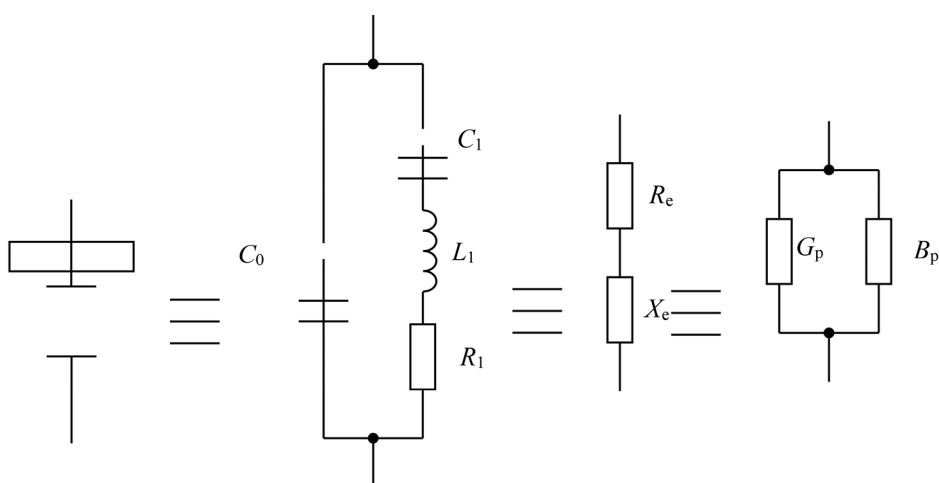


Figure 1 Symbols and equivalent electrical circuit of crystal unit in the vicinity of resonance point

3.2.9

motional resistance (R_1)

resistance in the motional (series) arm of the equivalent circuit

3.2.10

motional inductance (L_1)

inductance in the motional (series) arm of the equivalent circuit

3.2.11

motional capacitance (C_1)

capacitance in the motional (series) arm of the equivalent circuit

3.2.12

shunt capacitance (C_0)

capacitance in parallel with the motional arm of the equivalent circuit

3.2.13

parameters of piezoelectric resonators

fundamental parameters C_1 , L_1 , R_1 and C_0 that define the equivalent electric circuit (see Figure 1)

Note 1 to entry All other parameters may be derived from them. At a given frequency, the parameters of the equivalent electric circuit can only be determined by experiment.

The equation for the impedance Z or admittance Y :

$$Z = \frac{1}{Y} = \frac{j}{\omega C_0} \times \frac{\Omega - j\delta}{1 - \Omega + j\delta} \dots\dots\dots (1)$$

of the equivalent electric circuit of the piezoelectric resonator is the basic equation describing the relationships between the various parameters.

$$\Omega = \frac{f^2 - f_s^2}{f_p^2 - f_s^2} \quad \text{and} \quad \delta = 2\pi f C_0 R_1$$

are the normalized frequency factor and the normalized damping factor, respectively. See Table 1, for definitions of f_p , f_s , and the other symbols used Equation (1) and for other essential parameters. The characteristic frequencies of Equation (1) are defined in Table 2.

The magnitude of the impedance of the equivalent electric network ($|Z|$), its motional resistance component (R_e), its reactive component (X_e), and the reactance X_1 of the L_1 and C_1 branch are plotted as functions of frequency in Figure 2, for the purpose of defining the different characteristic frequencies. $|Z_m|$ and $|Z_n|$ denote minimum and maximum impedance respectively, and R_r , R_a the impedances at zero phase angle. These curves, however, have only qualitative character and do not represent a particular piezoelectric resonator.

The impedance and admittance circles of a piezoelectric resonator are shown in Figure 3. However, the circle representation of the impedance or admittance of a piezoelectric resonator is valid only if the circle diameter of the admittance diagram is large compared with the change of $2\pi f C_0$ in the resonance range

or if $r \ll Q^2$, which is fulfilled in most resonators. If the latter conditions are not fulfilled, the admittance curve shows a cissoidal character. Throughout the remainder of this Standard, it is assumed that the impedance (or admittance) of the resonator can be represented by a circle diagram. Table 3 gives data for Q , r , and Q^2/r for various types of resonators, indicating that this assumption is valid for all practical cases.

It is necessary to make approximations in deriving practical equations for general use. As a first approximation sufficient for many practical purposes, the following assumptions can be made:

$$f_m = f_r = f_s \quad \text{and} \quad f_a = f_n = f_p$$

M means the figure of merit, $M = Q/r$. More exact relations between the characteristic frequencies f_m , f_r , f_a , f_p , f_n , and the series resonance frequency f_s of a resonator, valid for the figure of merit $M > 10$ and the capacitance ratio $r > 10$, are shown in Table 4. These relationships have been derived by various authors under the assumption that $M \gg 1$.

The separation between parallel and series resonance frequencies is given by :

$$\frac{f_p^2 - f_s^2}{f_s^2} = \frac{C_1}{C_0} = \frac{1}{r} \dots\dots\dots (2)$$

The approximation :

$$\begin{aligned} \frac{f_p - f_s}{f_s} &= \sqrt{1 + r^{-1}} - 1 \\ &= \frac{1}{2r} \left(1 - \frac{1}{4r} + \dots \right) \approx \frac{1}{2r} \dots\dots\dots (3) \\ &= \frac{1}{2} \frac{C_1}{C_0} \end{aligned}$$

can be used for larger values of r (for example, when r is equal to or greater than 25, the error is equal to or less than 1 %).

3.2.14

resonance frequency (f_r)

the lower of the two frequencies of the crystal unit alone, under specified conditions, at which the electrical impedance of the crystal unit is resistive

3.2.15

resonance resistance (R_r)

resistance of the crystal unit alone at the resonance frequency f_r

3.2.16

anti-resonance frequency (f_a)

the higher of the two frequencies of the crystal unit alone, under specified conditions, at which the electrical impedance of the crystal unit is resistive

3.2.17**load capacitance (C_L)**

effective external capacitance associated with the crystal unit which determines the load resonance frequency f_L

3.2.18**load resonance frequency (f_L)**

one of the two frequencies of a crystal unit in association with a series or with a parallel load capacitance, under specified conditions at which the electrical impedance of the combination is resistive

Note 1 to entry The load resonance frequency is the lower of the two frequencies when the load capacitance is in series and the higher when it is in parallel (see Figure 4).

For a given value of load capacitance C_L , these frequencies are identical for all practical purposes and are given by the following equation (see Figure 5).

$$\frac{1}{f_L} = 2\pi \sqrt{\frac{L_1 C_1 (C_0 + C_L)}{C_1 + C_0 + C_L}} \dots\dots\dots (4)$$

Note 2 to entry The frequencies defined in **3.2.14**, **3.2.16** and **3.2.18** are listed as being the terms more commonly used. The frequencies associated with crystal units are numerous, and for a full explanation, Table 2 and Table 4 should be consulted. When higher accuracies are required or secondary data (for example, values of crystal unit motional parameters) are to be derived from the frequency measurements, Table 1, **IEC 60444-1**, **IEC 60444-5** and **IEC 60444-8** should be consulted.

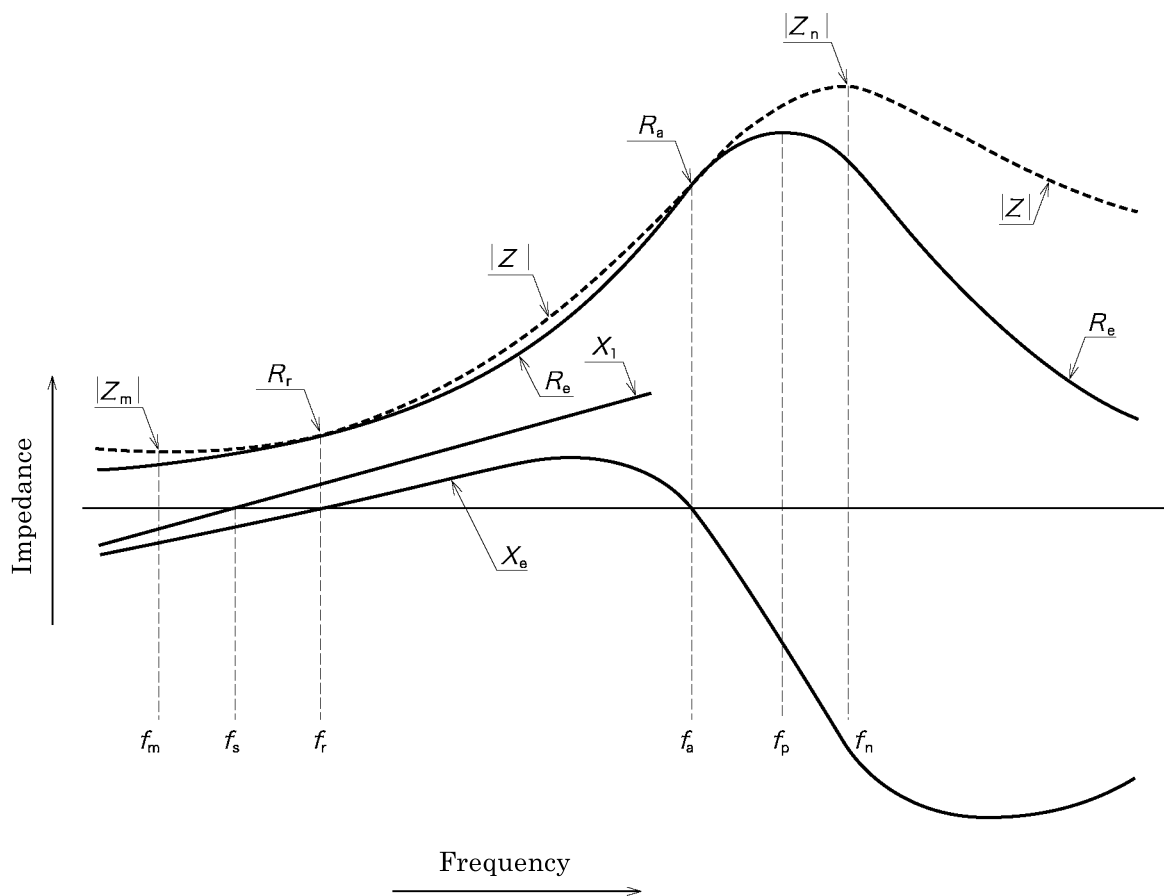


Figure 2 Impedance $|Z|$, resistance R_e , reactance X_e , and series arm reactance X_1 of a piezoelectric resonator as a function of frequency

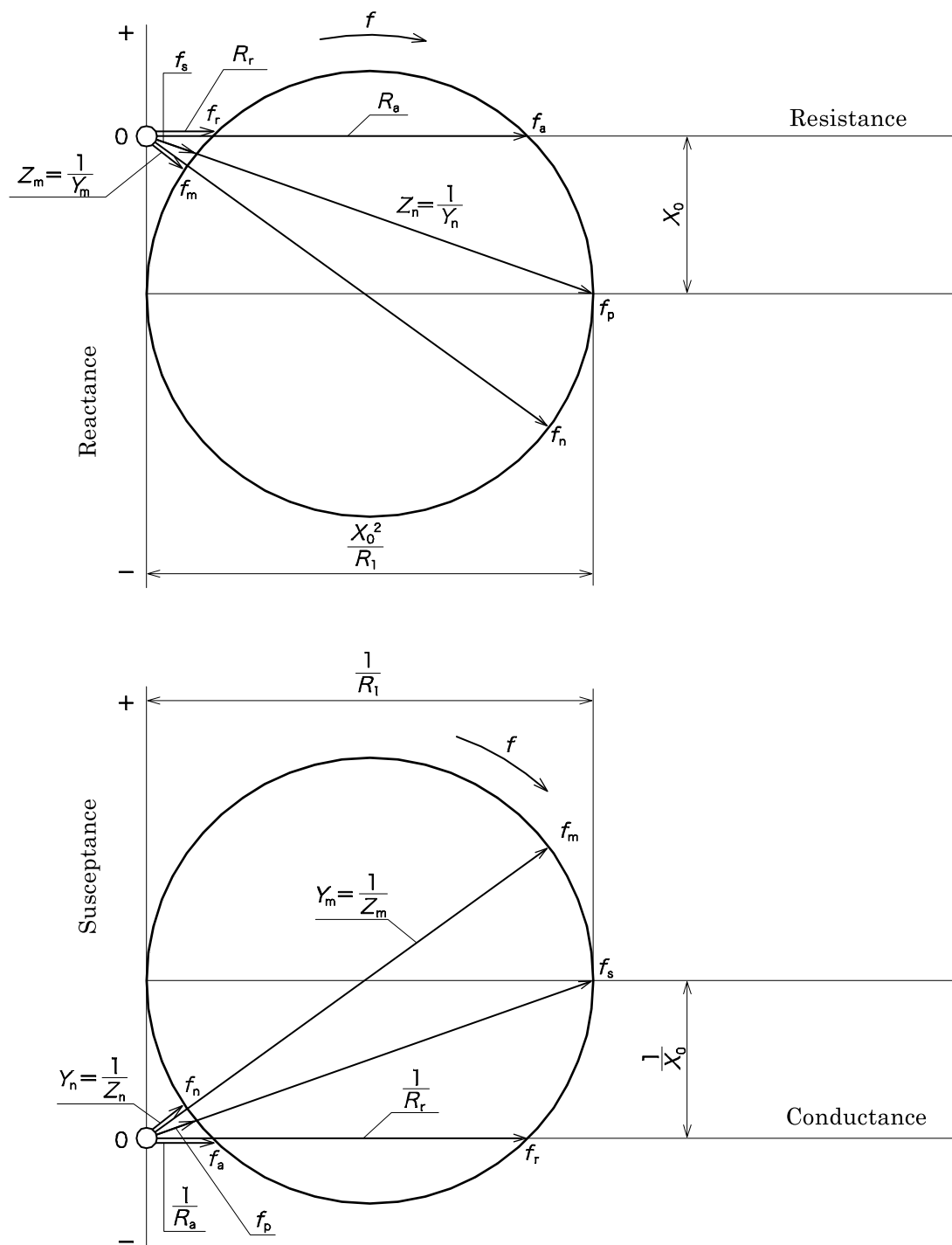
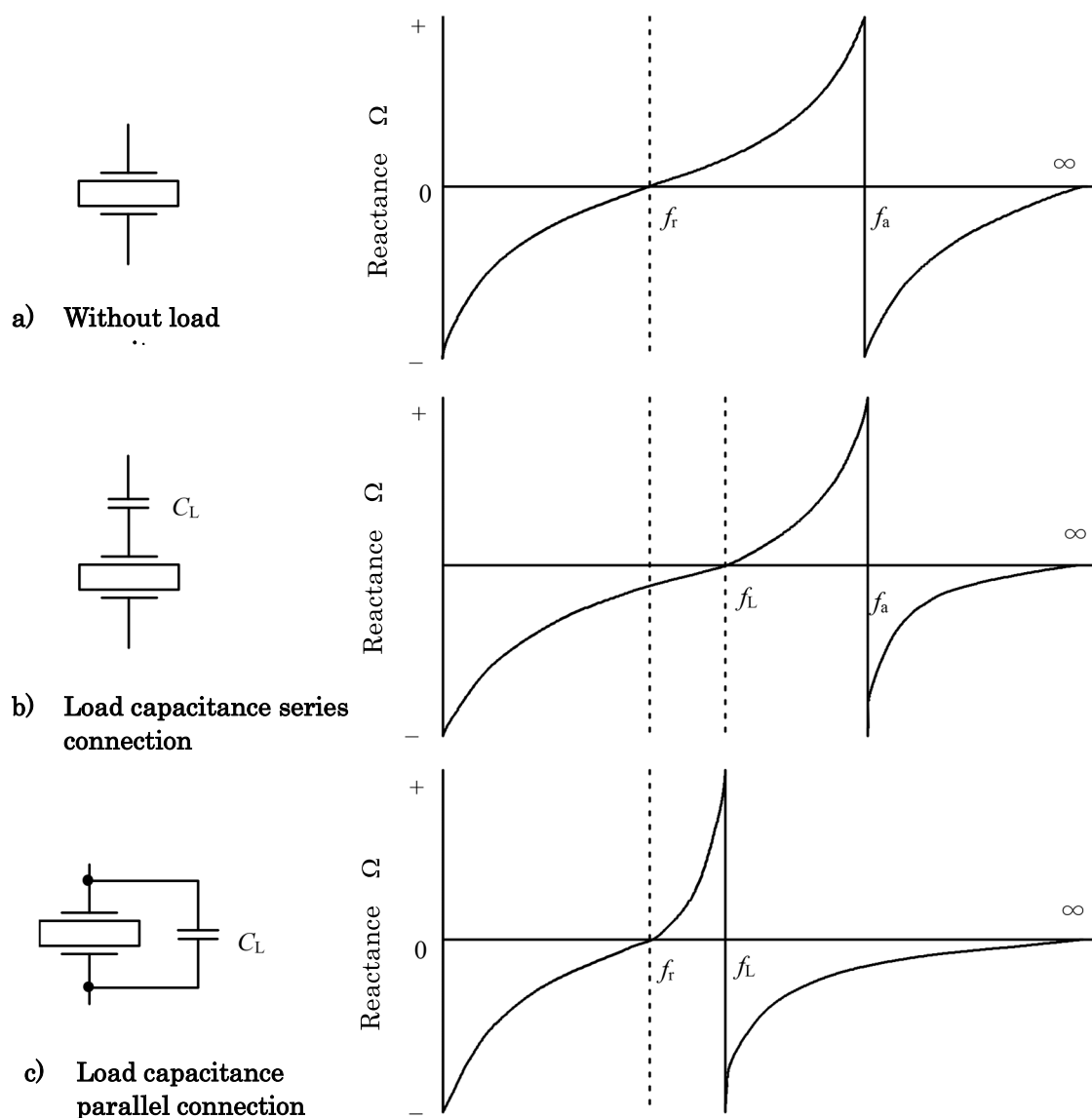


Figure 3 Impedance and admittance diagram of a piezoelectric resonator



NOTE 1 The values of load capacitances shown in **b)** and **c)** are equal.

NOTE 2 See 3.2.14, 3.2.16 and 3.2.18.

Figure 4 Resonance, anti-resonance and load resonance frequencies

3.2.19

load resonance resistance (R_L)

the resonance resistance of the crystal unit in series with a stated external capacitance at the load resonance frequency f_L (see Figure 5)

Note 1 to entry To a close approximation the value of R_L is related to the value of R_r by the expression :

$$R_L \cong R_r \left(1 + \frac{C_0}{C_L} \right)^2 \dots\dots\dots (5)$$

3.2.20

nominal frequency (f_{nom})

frequency assigned to the crystal unit by the manufacturer

3.2.21

working frequency (f_w)

operational frequency of the crystal unit together with associated circuits

3.2.22

frequency pulling range ($\Delta f_{L1, L2}$)

the difference of resonance frequencies between two optional load capacitances

Note 1 to entry It can be calculated from the following equation. This can also be written as, for instance $\Delta f_{20, 30}$ to indicate the frequency pulling range between load capacitances of 20 pF and 30 pF.

$$\Delta f_{L1, L2} = |f_{L1} - f_{L2}| \dots\dots\dots (6)$$

Approximately,

$$\Delta f_{L1, L2} = \left| \frac{f_r C_1 (C_{L2} - C_{L1})}{2(C_0 + C_{L1})(C_0 + C_{L2})} \right| \dots\dots\dots (7)$$

3.2.23

fractional pulling range ($D_{L1, L2}$)

the ratio of the frequency pulling range $\Delta f_{L1, L2}$ to the resonance frequency f_r

Note 1 to entry It can be calculated from the following equation. This can be written as, for instance, $D_{20, 30}$, to indicate the fractional pulling range between load capacitances of 20 pF and 30 pF.

$$D_{L1, L2} = \left| \frac{f_{L1} - f_{L2}}{f_r} \right| = |D_{L1} - D_{L2}| \dots\dots\dots (8)$$

Approximately,

$$D_{L1, L2} = \left| \frac{C_1 (C_{L2} - C_{L1})}{2(C_0 + C_{L1})(C_0 + C_{L2})} \right| \dots\dots\dots (9)$$

3.2.24

operating temperature range

the range of temperatures as measured on the enclosure

Note 1 to entry “Operable temperature range” refers to the range of temperatures as measured on the enclosure over which the crystal unit will not sustain permanent damage, though not necessarily func-

tioning within the specified tolerances. “Storage temperature range” refers to the minimum and maximum temperatures, as measured on the enclosure, at which the crystal unit may be stored without deterioration or damage to its performance.

3.2.25

reference temperature

the temperature at which certain crystal measurements are made

Note 1 to entry For crystal units of non-controlled temperature type, the reference temperature is normally $25\text{ °C} \pm 2\text{ °C}$.

3.2.26

level of drive

a measure of the conditions imposed upon the crystal unit

Note 1 to entry This may be expressed in terms of current through or power dissipated in the crystal element.

3.2.27

drive level dependency (DLD)

effect of changes in drive level conditions upon the resonance resistance of the crystal unit

Note 1 to entry This parameter can be specified by defining the ratio of resistance between two specified drive levels. This ratio is represented by the expression :

$$\frac{R_{r1}}{R_{r2}}$$

where, R_{r1} : the resistance at the lower level of drive
 R_{r2} : the resistance at the higher level of drive

3.2.28

unwanted response

state of resonance of a crystal unit other than that associated with the working frequency

3.2.29

frequency tolerance

the maximum permissible deviation of the working frequency due to a specified cause or a combination of causes

Note 1 to entry The frequency tolerance is usually stated in parts per million (1×10^{-6}) of the nominal frequency. The tolerances normally used are as follows :

- deviation from nominal frequency at the reference temperature under specified conditions;

- deviation over the temperature range from the frequency at the specified reference temperature;
- deviation as a result of aging under specified conditions;
- deviation from nominal frequency due to all causes (overall tolerance).