

Specification for

Quartz crystal units of assessed quality: generic data and methods of test

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Foreword

This British Standard, prepared under the direction of the Electronic Components Standards Committee, is the generic specification for quartz crystal units within the BS 9000 series of standards for electronic components of assessed quality, and is a revision of BS 9610:1977, which is withdrawn.

Account has been taken of experience gained in the use of the previous edition and this revision incorporates the following major changes:

- a) improvements to the procedures for the inspection of structurally similar components and a revision of the structural similarity clause;
- b) inclusion of supplementary procedures for qualification approval;
- c) a new marking and identification code of crystal units;
- d) new definitions published by the International Electrotechnical Commission (IEC) and the revision of some definitions to achieve harmonization.

This standard calls for the use of substances and/or test procedures that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and in no way absolves either the supplier or the user from legal obligations relating to health, safety and fire hazard at any stage of manufacture or use.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 31 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. Principles and mandatory procedures

1.1 General matters

1.1.1 Scope

This British Standard specifies requirements and methods of test and other general requirements and information for quartz crystal units of assessed quality. Requirements for individual types of quartz crystal unit are specified in the relevant detail specification. Procedures necessary for preparing these detail specifications are given in section 2 of this standard.

1.1.2 Related documents

BS 1991	<i>Letter symbols, signs and abbreviations</i>
BS 2011	<i>Basic environmental testing procedures</i>
(IEC 68-1)	Part 1.1 <i>General</i>
(IEC 68-2-3)	Part 2.1Ca <i>Test Ca. Damp heat, steady state</i>
(IEC 68-2-27)	Part 2.1Ea <i>Test Ea. Shock</i>
(IEC 68-2-29)	Part 2.1Eb <i>Test Eb. Bump</i>
(IEC 68-2-6)	Part 2.1Fc <i>Test Fc. Vibration (sinusoidal)</i>
(IEC 68-2-7)	Part 2.1Ga <i>Test Ga. Acceleration, steady state</i>
(IEC 68-2-14)	Part 2.1N <i>Test N. Change of temperature</i>
(IEC 68-2-17)	Part 2.1Q <i>Test Q. Sealing</i>
(IEC 68-2-21)	Part 2.1U <i>Test U. Robustness of termination and integral mounting devices</i>
	Part 2.1Z/ABDM <i>Climatic sequence, primarily intended for components</i>
BS 3939	<i>Graphical symbols for electrical power, telecommunications and electronics diagrams</i>
BS 4727	<i>Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms</i>
BS 5069	<i>Dimensions of piezoelectric devices</i>
(IEC 122-3 and IEC 122-3A)	Part 1 <i>Specification for standard outlines and pin connections for quartz crystal units</i>
BS 6001	<i>Sampling procedures and tables for inspection by attributes</i>

BS 9000	<i>General requirements for a system for electronic components of assessed quality</i> Part 1 <i>Specification of basic rules and rules of procedures</i> Part 2 <i>Data on generic and detail specifications</i>
IEC 302	<i>Standard definitions and methods of measurement for piezoelectric vibrators operating over the frequency range up to 30 MHz</i>
IEC 444	<i>Basic method for the measurement of resonance frequency and equivalent series resistance of quartz crystal units by zero phase technique in a π-network</i>

NOTE 1 Where reference to an IEC Publication is given in parentheses, the British Standard is identical with the IEC Publication.

NOTE 2 Where reference is made in this standard to BS 9000-2:1972, it should be noted that this Part will eventually be replaced by Appendix B of BS 9000-1:1981.

1.1.3 Terminology

For the purposes of this British Standard the following terms and their definitions apply, together with those given in BS 4727.

1.1.3.1 crystal element

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

1.1.3.2 electrode

an electrically conductive plate or film in contact with, or in proximity to, a face of a crystal element, by means of which an electric field is applied to the element

1.1.3.3 crystal vibrator

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

1.1.3.4 mounting

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

1.1.3.5 enclosure

the enclosure protecting the crystal vibrator(s) and mounting

1.1.3.6 enclosure type

a crystal enclosure of specific outline dimensions and material with a defined method of sealing

1.1.3.7**crystal unit**

a crystal vibrator mounted in an enclosure

1.1.3.8**socket**

a component into which the crystal unit is inserted to hold the crystal unit and to provide electrical connection

1.1.3.9**mode of vibration**

the 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. The common modes of vibration are:

- a) flexural;
- b) extensional;
- c) face shear;
- d) thickness shear.

1.1.3.10**fundamental crystal unit**

a crystal vibrator designed to operate at the lowest order of a given mode

1.1.3.11**overtone crystal unit**

a crystal vibrator designed to operate at a higher order than the lowest of the given mode

1.1.3.12**overtone order**

the numbers allotted to the successive overtones of a given mode of vibration from the ascending series of integral numbers commencing with the fundamental as unity. For shear and extensional modes, this overtone is the integral multiple of the fundamental frequency to which the overtone frequency approximates

1.1.3.13**crystal unit equivalent circuit**

the electric circuit that has the same impedance as the unit in the region of the desired resonance and anti-resonance frequencies. 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 usually 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 1 The equivalent circuit does not represent all the characteristics of a crystal unit.

NOTE 2 The values of R_e , X_e , G_p and B_p vary rapidly around the resonance frequency, where

R_e is the equivalent circuit series resistance of the vibrator;

X_e is the equivalent circuit series reactance of the vibrator;

G_p is the equivalent circuit parallel conductance of the vibrator;

B_p is the equivalent circuit parallel susceptance of the vibrator.

1.1.3.14**motional resistance (R_1)**

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

1.1.3.15**motional inductance (L_1)**

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

1.1.3.16**motional capacitance (C_1)**

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

1.1.3.17**shunt capacitance (C_0)**

the shunt capacitance in parallel with the motional arm of the equivalent circuit

1.1.3.18**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 is resistive

1.1.3.19**resonance resistance (R_r)**

the resistance of the crystal unit alone at the resonance frequency f_r

1.1.3.20**anti-resonance frequency (f_a)**

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

1.1.3.21**load capacitance (C_L)**

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

1.1.3.22**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

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 2) for a given value of load capacitance (C_L), these frequencies are identical for all practical purposes and are given by the expression

$$\frac{1}{f} = 2\pi \sqrt{\left\{ \frac{L_1 C_1 (C_0 + C_L)}{C_1 + C_0 + C_L} \right\}} \quad (1)$$

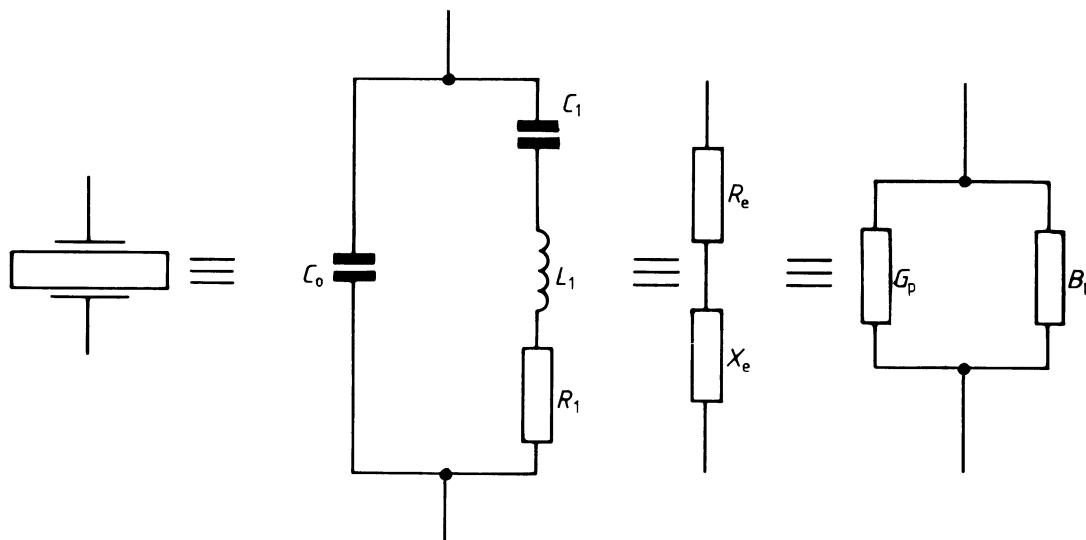


Figure 1 — Equivalent electric circuit of a piezoelectric vibrator near a resonance

NOTE 1 The frequencies defined in 1.1.3.18, 1.1.3.20 and 1.1.3.22 are listed as being the terms more commonly used. The frequencies associated with a quartz crystal are numerous and for a full explanation IEC Publication 302 should be consulted.

NOTE 2 When higher accuracies are required or secondary data (e.g. values of crystal unit motional parameters) are to be derived from the frequency measurements, IEC Publications 302 and 444 should be consulted.

1.1.3.23 load resonance resistance (R_L)

the resistance of the crystal unit in series with a stated external capacitance at the load resonance frequency f_L

NOTE To a close approximation the value of R_L is related to the value of R_r by the expression:

$$R_L \approx R_r \left(1 + \frac{C_0}{C_L}\right)^2 \quad (2)$$

1.1.3.24 nominal frequency

the frequency assigned to the crystal unit by the manufacturer

1.1.3.25 working frequency (f_w)

the operational frequency of the crystal unit together with its associated circuits

1.1.3.26 load resonance frequency offset (Δf_L)

$$\Delta f_L = f_L - f_r \quad (3)$$

it can be calculated approximately from the expression

$$\Delta f_L \approx \frac{f_r C_1}{2(C_0 + C_L)} \quad (4)$$

in usage the load resonance frequency offset for a given value of load capacitance can be written as for instance Δf_{30} or Δf_{20} to indicate the actual value of load capacitance (in pF) involved

1.1.3.27 fractional load resonance frequency offset (D_L)

$$D_L = \frac{f_L - f_r}{f_r} \quad (5)$$

it can be approximately calculated from the expression

$$D_L \approx \frac{C_1}{2(C_0 + C_L)} \quad (6)$$

this can be written as for instance D_{30} to indicate the fractional load resonance offset with a load capacitance of 30 pF

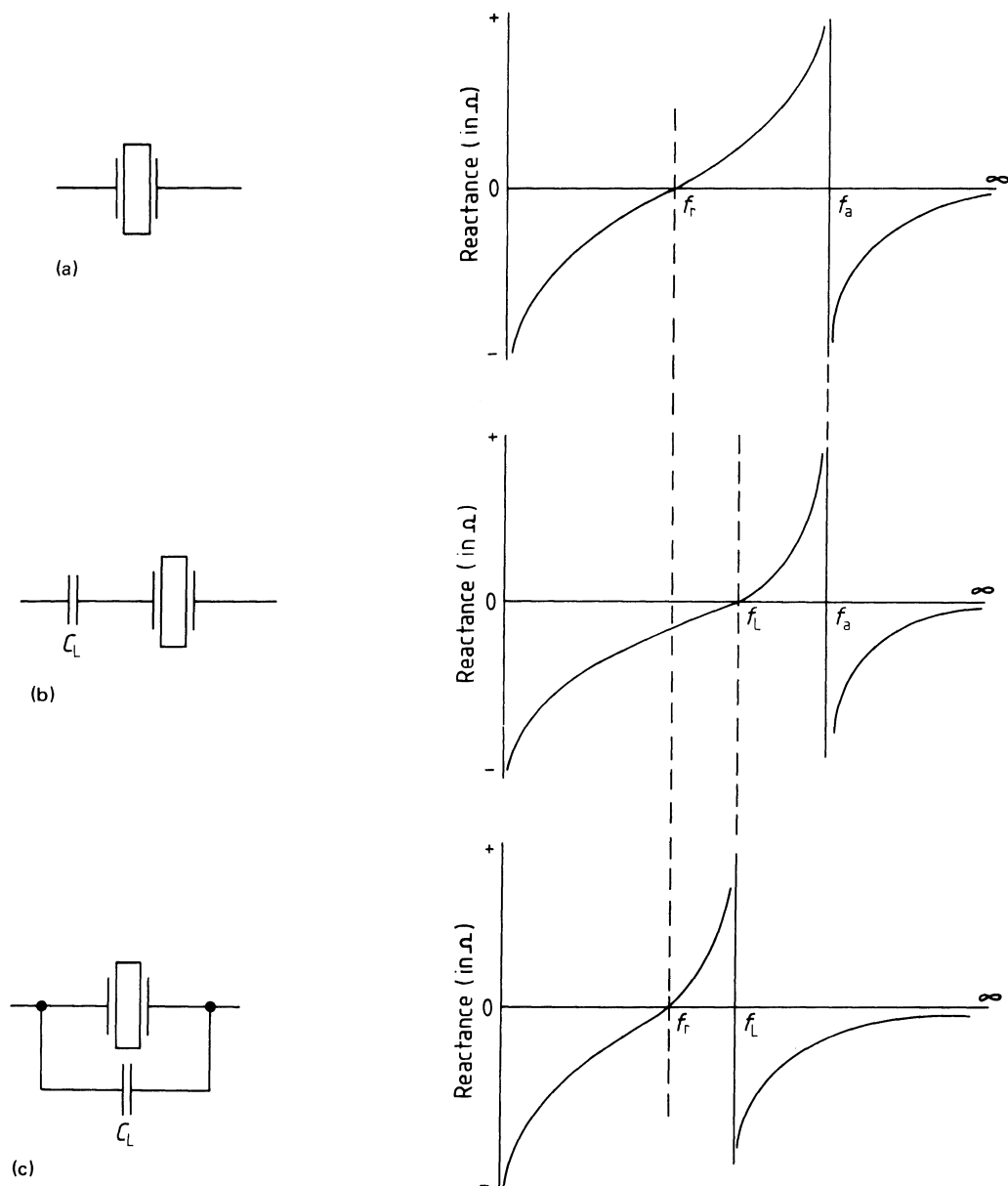
1.1.3.28 frequency pulling range ($\Delta f_{L1, L2}$)

$$\Delta f_{L1, L2} = |f_{L1} - f_{L2}| \quad (7)$$

it can be approximately calculated from the expression

$$\Delta f_{L1, L2} \approx \left| \frac{f_r C_1 (C_{L2} - C_{L1})}{2(C_0 + C_{L1})(C_0 + C_{L2})} \right| \quad (8)$$

this can be written as for instance $f_{20, 30}$ to indicate the frequency pulling range between load capacitances of 20 pF and 30 pF



NOTE 1 The values of load capacitances shown in (b) and (c) are equal.
NOTE 2 See 1.1.3.18, 1.1.3.20 and 1.1.3.22.

Figure 2 — Resonance, anti-resonance and load resonance frequencies

1.1.3.29
fractional pulling range ($D_{L1, L2}$)

$$D_{L1, L2} = \left| \frac{f_{L1} - f_{L2}}{f_r} \right| = \left| D_{L1} - D_{L2} \right| \tag{9}$$

it can be approximately calculated from the expression

$$D_{L1, L2} \approx \left| \frac{C_1 (C_{L2} - C_{L1})}{2(C_o + C_{L1})(C_o + C_{L2})} \right| \tag{10}$$

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

1.1.3.30
pulling sensitivity (S)

$$S = \frac{dD_L}{dC_L} \approx \frac{-C_1}{2(C_o + C_L)^2} \tag{11}$$

this can be written as for example S_{30} to indicate the pulling sensitivity at a load capacitance of 30 pF

1.1.3.31**operating temperature range**

the range of temperature over which the crystal unit will function within the specified frequency tolerances

1.1.3.32**reference temperature**

the temperature at which certain crystal measurements are made. For controlled temperature units the reference temperature is the midpoint of the controlled temperature range. For non-controlled temperature units the reference is normally $25 \pm 2^\circ\text{C}$

1.1.3.33**level of drive**

a measure of the conditions imposed upon the crystal unit expressed in terms of the power dissipated

NOTE In special cases the level of drive may be specified in terms of crystal current or voltage.

1.1.3.34**unwanted response**

a resonant state of a crystal vibrator other than that associated with the nominal frequency

1.1.3.35**frequency tolerance**

the maximum permissible deviation of the working frequency due to a specific cause or to a combination of causes. The frequency tolerance is usually stated in parts per million (p.p.m.) of the nominal frequency

NOTE The tolerances normally used are as follows:

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

1.1.4 Letter symbols, signs and abbreviations

The letter symbols, signs and abbreviations that are employed in all documents applicable to electronic components covered by this standard shall be in accordance with BS 1991 or shall be derived in accordance with the principles of that standard.

1.1.5 Graphical symbols

The graphical symbols that are employed in all documents applicable to electronic components covered by this standard shall be in accordance with BS 3939 or shall be derived in accordance with the principles of that standard.

1.1.6 Marking of the component and package

1.1.6.1 General. The marking of the crystal unit and package shall consist of:

- a) the number of the detail specification;

b) the appropriate marking and identification code (see **1.1.6.1.1**);

c) the enclosure type, e.g. "Type CX";

d) the nominal frequency of the crystal unit expressed in kHz or MHz as appropriate (the characters kHz or MHz shall form part of the marking, e.g. 2345.678 kHz or 67.890 MHz);

e) the date code (see clause **22** of BS 9000-1:1981);

f) the manufacturer's code.

Where the available surface area of miniature crystal enclosures imposes practical limits on the amount of marking, instruction on the marking to be applied shall be given in the detail specification.

1.1.6.1.1 Marking and identification code for quartz crystal units. Crystals shall be marked and identified by a five character code that shall identify the major parameters.

1st character One numerical character identifying the order of operation, e.g.:

- 1 = fundamental
- 3 = third overtone
- 5 = fifth overtone

2nd and 3rd characters Two alphabetical characters identifying the frequency tolerances and temperature range as selected from Appendix E (see note).

4th and 5th characters Two numerical characters identifying the circuit conditions in terms of picofarads.
Series resonance operation shall be identified by the numerals 00.

NOTE With regard to the 2nd and 3rd characters, additional specification code letters may be added subject to the approval of the Technical Committee, to whom application should be made via The Secretary, Technical Committee ECL/11, British Standards Institution, 2 Park Street, London W1A 2BS.

1.1.6.2 Crystal units selected for tests:

numbering. Crystal units selected for tests in groups C and D (see clause **20** of BS 9000-1:1981) shall be marked with a serial number that need not be durable beyond the test period.

1.1.7 Eligibility for qualification approval

Quartz crystal units shall be eligible for submission for qualification approval and release to BS 9000 if the primary stage of manufacture and subsequent processing is carried out at an approved manufacturing facility.

The primary stage of manufacture in accordance with 14.2 of BS 9000-1:1981 is the final surface finishing of the crystal element. The use of 14.3.2 of BS 9000-1:1981 is not permitted.

NOTE The final surface finishing of the crystal element could be any of the following operations; lapping; polishing; etching; cleaning, in the case of polished plates.

1.1.8 Structurally similar components

Structurally similar components are a range of crystal units usually covered by a single detail specification, incorporating the same:

- a) materials and method of sealing for the enclosure;
- b) mode of vibration.

1.1.8.1 Inspection of structurally similar components. If a manufacturer aggregates the current production of crystal units, the following safeguards shall apply.

- a) A lot shall consist of crystal units from the same detail specification.
- b) The sample tested shall contain a due proportion of crystal units of various sizes, ratings and characteristics comprising the lot, with particular emphasis on different temperature ranges and frequency tolerances.
- c) The sample shall comprise a selection of crystal units of which approximately one-third are near the highest frequency, one-third are near mid frequency and one-third are near the lowest frequency of the range to be covered.

1.1.9 Delayed delivery

Crystal units held for a period exceeding two years following acceptance inspection shall be reinspected for the electrical tests detailed in 1.2.4.1 and 1.2.4.3, prior to release.

1.1.10 Supplementary procedures for qualification approval (of thickness shear mode crystal units only)

1.1.10.1 For shelf life, paragraph 3 of 14.1 of BS 9000-1:1981 can be implemented after 1 000 h.

1.1.10.2 Having obtained approval on a specific specification code, it is permissible to claim approval on additional specification codes within the following framework:

- a) the same frequency tolerance over narrower operating temperature ranges;
- b) wider frequency tolerances over the same operating temperature range;
- c) the same adjustment tolerance at an elevated temperature (temperature controlled types only);
- d) operation at other circuit conditions than the one for which approval has been given;

e) all drive levels below that for which approval has been given;

f) smaller frequency tolerances over shorter temperature ranges provided they are within the control capability for the angle of cut established on approved units (see note);

g) wider frequency tolerances over wider temperature ranges provided they are within the control capability for the angle of cut established on approved units (see note);

h) equivalent frequency/temperature coefficients (on temperature controlled types only) based on the same control capability for the angle of cut established on approved units (see note);

i) inclusive tolerances, where the overall tolerance is not smaller than the sum of the adjustment tolerance and the frequency/temperature variation for the operating temperature ranges covered by a) to h).

NOTE From typical AT cut frequency/temperature curves it can be seen that the frequency variation with temperature is dependent upon the angle of cut. Control of the angle of cut therefore gives a control of the frequency temperature performance of the crystal unit.

Items f), g) and h) are based on the fact that if a certain control capability for angle measurement can be demonstrated on the approved units, that same degree of control can be applied equally at any angle of cut to give known frequency/temperature performances over different operating temperature ranges.

In any event, production quantities are adequately safeguarded because the frequency variation with temperature is included as a group A test.

1.1.11 Certified test records

The results of specified tests from groups C and D shall be summarized and presented in the form of a certified test record (CTR). Details of the information required and the method of presentation are given in 2.3.

Certified test records shall be supplied for crystal units at the full assessment level, but are not mandatory for units at the basic assessment level.

1.1.12 Standard ratings and characteristics

Preferred operating ranges and values are given in 1.1.12.1 to 1.1.12.9.

1.1.12.1 Operating temperature ranges

a) *Temperature ranges in °C suitable for ambient operation*

– 55 to + 125	– 10 to + 50	– 40 to + 80
– 55 to + 105	– 10 to + 60	– 40 to + 90
– 55 to + 90	– 10 to + 70	0 to + 60
– 40 to + 70	– 20 to + 60	0 to + 50
– 30 to + 80	– 20 to + 70	+ 10 to + 40
– 25 to + 80	– 20 to + 80	+ 15 to + 50
– 20 to + 85	– 30 to + 70	