PHILIPS

Data handbook

PHILIPS Electronic components and materials

Components and materials

Part 9 August 1979

Piezoelectric quartz devices

COMPONENTS AND MATERIALS

PART 9 - AUGUST 1979

PIEZOELECTRIC QUARTZ DEVICES

QUARTZ CRYSTAL UNITS GENERAL — A

QUARTZ CRYSTAL UNITS FOR SPECIAL APPLICATIONS — B

QUARTZ CRYSTAL UNITS FOR GENERAL FREQUENCY STABILIZATION — C

TEMPERATURE COMPENSATED CRYSTAL OSCILLATORS — D

DATA HANDBOOK SYSTEM

Our Data Handbook System is a comprehensive source of information on electronic components, sub-assemblies and materials; it is made up of three series of handbooks each comprising several parts.

ELECTRON TUBES	BLUE
SEMICONDUCTORS AND INTEGRATED CIRCUITS	RED
COMPONENTS AND MATERIALS	GREEN

The several parts contain all pertinent data available at the time of publication, and each is revised and reissued periodically.

Where ratings or specifications differ from those published in the preceding edition they are pointed out by arrows. Where application information is given it is advisory and does not form part of the product specification.

If you need confirmation that the published data about any of our products are the latest available, please contact our representative. He is at your service and will be glad to answer your inquiries.

ELECTRON TUBES (BLUE SERIES)

Part 1a	December 1975	ET1a 12-75	**Transmitting tubes for communication, tubes for r.f. heating** Types PE05/25 to TBW15/25
Part 1b	August 1977	ET1b 08-77	**Transmitting tubes for communication, tubes for r.f. heating, amplifier circuit assemblies**
Part 2a	November 1977	ET2a 11-77	**Microwave tubes** Communication magnetrons, magnetrons for microwave heating, klystrons, travelling-wave tubes, diodes, triodes T-R switches
Part 2b	May 1978	ET2b 05-78	**Microwave semiconductors and components** Gunn, Impatt and noise diodes, mixer and detector diodes, backward diodes, varactor diodes, Gunn oscillators, sub-assemblies, circulators and isolators
Part 3	January 1975	ET3 01-75	**Special Quality tubes, miscellaneous devices**
Part 4	March 1975	ET4 03-75	**Receiving tubes**
Part 5a	March 1978	ET5a 03-78	**Cathode-ray tubes** Instrument tubes, monitor and display tubes, C.R. tubes for special applications
Part 5b	December 1978	ET5b 12-78	**Camera tubes and accessories, image intensifiers**
Part 6	January 1977	ET6 01-77	**Products for nuclear technology** Channel electron multipliers, neutron tubes, Geiger-Müller tubes
Part 7a	March 1977	ET7a 03-77	**Gas-filled tubes** Thyratrons, industrial rectifying tubes, ignitrons, high-voltage rectifying tubes
Part 7b	May 1979	ET7b 05-79	**Gas-filled tubes** Segment indicator tubes, indicator tubes, switching diodes, dry reed contact units
Part 8	July 1979	ET8 07-79	**Picture tubes and components** Colour TV picture tubes, black and white TV picture tubes, monitor tubes, components for colour television, components for black and white television.
Part 9	March 1978	ET9 03-78	**Photomultiplier tubes; phototubes**

SEMICONDUCTORS AND INTEGRATED CIRCUITS (RED SERIES)

Part 1a	**August 1978**	**SC1a 08-78**	**Rectifier diodes, thyristors, triacs** Rectifier diodes, voltage regulator diodes (> 1,5 W), transient suppressor diodes, rectifier stacks, thyristors, triacs
Part 1b	**May 1977**	**SC1b 05-77**	**Diodes** Small signal germanium diodes, small signal silicon diodes, special diodes, voltage regulator diodes (< 1,5 W), voltage reference diodes, tuner diodes
Part 2	**November 1977**	**SC2 11-77**	**Low-frequency and dual transistors***
Part 2	**June 1979**	**SC2 06-79**	**Low-frequency power transistors**
Part 3	**January 1978**	**SC3 01-78**	**High-frequency, switching and field-effect transistors**
Part 4a	**December 1978**	**SC4a 12-78**	**Transmitting transistors and modules**
Part 4b	**September 1978**	**SC4b 09-78**	**Devices for optoelectronics** Photosensitive diodes and transistors, light emitting diodes, photocouplers, infrared sensitive devices, photoconductive devices
Part 4c	**July 1978**	**SC4c 07-78**	**Discrete semiconductors for hybrid thick and thin-film circuits**
Part 5a	**November 1978**	**SC5a 11-76**	**Professional analogue integrated circuits**
Part 5b	**March 1977**	**SC5b 03-77**	**Consumer integrated circuits** Radio-audio, television
Part 6	**October 1977**	**SC6 10-77**	**Digital integrated circuits** LOCMOS HE4000B family
Signetics integrated circuits 1978			Bipolar and MOS memories Bipolar and MOS microprocessors Analogue circuits Logic - TTL

* Low-frequency general purpose transistors will be transferred to SC3 later in 1979. The old book SC2 11-77 should be kept until then.

COMPONENTS AND MATERIALS (GREEN SERIES)

Part 1	July 1979	CM1 07-79	**Assemblies for industrial use** PLC modules, high noise immunity logic FZ/30-series, NORbits 60-series, 61-series, 90-series, input devices, hybrid integrated circuits, peripheral devices
Part 2a	October 1977	CM2a 10-77	**Resistors** Fixed resistors, variable resistors, voltage dependent resistors (VDR), light dependent resistors (LDR), negative temperature coefficient thermistors (NTC), positive temperature coefficient thermistors (PTC), test switches
Part 2b	February 1978	CM2b 02-78	**Capacitors** Electrolytic and solid capacitors, film capacitors, ceramic capacitors, variable capacitors
Part 3a	September 1978	CM3a 09-78	**FM tuners, television tuners, surface acoustic wave filters**
Part 3b	October 1978	CM3b 10-78	**Loudspeakers**
Part 4a	November 1978	CM4a 11-78	**Soft ferrites** Ferrites for radio, audio and television, beads and chokes, Ferroxcube potcores and square cores, Ferroxcube transformer cores
Part 4b	February 1979	CM4b 02-79	**Piezoelectric ceramics, permanent magnet materials**
Part 6	April 1977	CM6 04-77	**Electric motors and accessories** Small synchronous motors, stepper motors, miniature direct current motors
Part 7	September 1971	CM7 09-71	**Circuit blocks** Circuit blocks 100 kHz-series, circuit blocks 1-series, circuit blocks 10-series, circuit blocks for ferrite core memory drive
Part 7a	January 1979	CM7a 01-79	**Assemblies** Circuit blocks 40-series and CSA70 (L), counter modules 50-series, input/output devices
Part 8	June 1979	CM8 06-79	**Variable mains transformers**
Part 9	August 1979	CM9 08-79	**Piezoelectric quartz devices** Quartz crystal units, temperature compensated crystal oscillators
Part 10	April 1978	CM10 04-78	**Connectors**

QUARTZ CRYSTAL UNITS GENERAL

A

Survey of types	A2
Introduction	A4
Terms and definitions	A5
Electrical properties and behaviour	A7
Measuring procedures	A18
Holders	A21
How to specify a quartz crystal unit	A25

SURVEY OF TYPES

AT-cut quartz crystals for general frequency stabilization.

mode of vibration	frequency range MHz	holder			basic catalogue number
		type	housing	connections	
fundamental	4 to 10	RW-36	resistance welded	pins	4322 148 5
		RW-10	resistance welded	flying leads	4322 148 6
	1,6 to 25	RW-36	resistance welded	pins	4322 149 5
		HC-6/U	solder sealed	pins	4322 152 5
		HC-27/U	all-glass	pins	4322 154 5
	4 to 25	HC-26/U	all-glass	flying leads	4322 155 5
		HC-29/U	all-glass	pins	4322 155 6
		RW-43	resistance welded	flying leads	4322 156 5
		RW-42	resistance welded	pins	4322 156 6
third overtone	10 to 61	HC-6/U	solder sealed	pins	4322 157 5
		HC-27/U	all-glass	pins	4322 159 5
		RW-36	resistance welded	pins	4322 162 5
	17 to 61	RW-43	resistance welded	flying leads	4322 161 5
		RW-42	resistance welded	pins	4322 161 6
	20 to 61	HC-26/U	all-glass	flying leads	4322 160 5
		HC-29/U	all-glass	pins	4322 160 6
fifth overtone	50 to 125	HC-6/U	solder sealed	pins	4322 163 5
		HC-27/U	all-glass	pins	4322 165 5
		HC-26/U	all-glass	flying leads	4322 166 5
		HC-29/U	all-glass	pins	4322 166 6
		RW-43	resistance welded	flying leads	4322 167 5
		RW-42	resistance welded	pins	4322 167 6
		RW-36	resistance welded	pins	4322 168 5

AT-cut quartz crystals for special applications.

frequency MHz	holder *	application	catalogue number
4,000 000	RW-43	tuning	4322 143 04090
4,194 304	RW-43	clocks	4322 143 04070
4,194 812	RW-43	car clocks	4322 143 04060
4,433 619	RW-10	colour television	4322 152 01100
4,433 619	RW-43	colour television	4322 143 04040
4,780 000	RW-43	two-tone dialling	4322 143 04030
5,000 000	RW-43	colour television cameras	8222 298 40760 **
5,120 000	RW-43	car radios	8222 298 40921 **
6,000 000	RW-43	teletext, etc.	4322 143 04100
8,867 238	RW-43	colour television	4322 143 04050
8,867 238	RW-10	colour television	4322 143 03120
10,000 000	HC-27/U	high precision	4322 159 00001

* All these holders are resistance welded and provided with flying leads, except type HC-27/U which is an all-glass type provided with pins.

** Development types.

INTRODUCTION

A quartz crystal unit consists of a quartz crystal element with electrodes, mounted in an enclosure with connecting pins or leads.

The quartz crystal element is a vibrating resonant plate which relies upon the piezoelectric effect to couple it to electrical circuits. The intrinsic properties of quartz make it a unique device for accurate and stable frequency control and selection. Although the properties of quartz (T.C., ageing, high Q-factor) are very stable, the ultimate performance of the element is largely dependent on the environment and the associated electrical circuits. We strongly advise that a particular application be discussed with the crystal manufacturer at the earliest stage in any design.

Crystal elements are normally cut in the form of plates or bars. The dimensions of these elements and their orientation with respect to the axes of the crystal give the characteristic of the element. The dimensions are such that the mechanical resonance frequency equals the desired electrical frequency. There are a large number of crystal cuts but the most advantageous orientation is the so-called AT-cut. The frequency range that can be covered herewith is from 1 to 250 MHz. A practical range is from 1,8 to 125 MHz. The crystal element may vibrate in the frequency of a fundamental mode of vibration or in the third, fifth or higher overtone.

TERMS AND DEFINITIONS

in accordance with IEC 122-1

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.
Anti-resonance frequency f_a	The higher of the two frequencies of a crystal unit alone, under specified conditions, at which the electrical impedance of the crystal unit is resistive.
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. This frequency is the lower of the two frequencies when the load capacitance is in series and the higher when it is in parallel (see Fig. 2). For a given value of load capacitance (C_L), these frequencies are identical for all practical purposes and given by: $\frac{1}{f} = 2\pi\sqrt{\frac{L_1C_1(C_0 + C_L)}{C_1 + C_0 + C_L}}$
Nominal frequency f_n	The frequency assigned by the specification of the crystal unit.
Working frequency f_w	The operational frequency of the crystal unit together with its associated circuits.
Overall tolerance	The maximum permissible deviation of the working frequency from nominal frequency due to a specific cause or a combination of causes.
Adjustment tolerance	The permissible deviation from the nominal frequency at the reference temperature under specified conditions.
Ageing tolerance	The permissible deviation due to time under specified conditions.
Tolerance over the temperature range	The permissible deviation over the temperature range with respect to the frequency at the specified refe-rance temperature.
Tolerance due to level of drive variation	The permissible deviation due to the variation of level of drive.

Operating temperature range

The range of temperatures as measured on the enclosure over which the crystal unit must function within the specified tolerances.

Operable temperature range

The range of temperatures as measured on the enclosure over which the crystal unit must function though not necessarily within the specified tolerances.

Reference temperature

The temperature at which certain crystal measurements are made. For controlled temperature units, the reference temperature is the mid-point of the controlled temperature range. For non-controlled temperature units, the reference temperature is normally 25 ± 2 °C.

Resonance resistance R

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

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: The value of R_L is related to the value of R by the following expression:

$$R_L = R\left(1 + \frac{C_0}{C_L}\right)^2$$

Level of drive

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

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

Unwanted response

A state of resonance of a crystal vibrator other than that associated with the working frequency.

Load capacitance C_L

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

Ageing (long-term parameter variation)

The relation which exists between any parameter (e.g. resonance frequency) and time.

Note: Such parameter variation is due to long-term changes in the crystal unit and is usually expressed in fractional parts per period of time.

Motional capacitance C_1

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

Motional inductance L_1

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

ELECTRICAL PROPERTIES AND BEHAVIOUR

CRYSTAL UNIT EQUIVALENT CIRCUIT

The equivalent circuit, which has the same impedance as the unit in the immediate neighbourhood of resonance, is usually represented by an inductance, capacitance and resistance in series, this series branch being shunted by the capacitance between the terminals of the unit. The parameters of the series branch are usually given by L_1, C_1 and R_1. The parallel capacitance is given by C_0 (see Fig. 1).

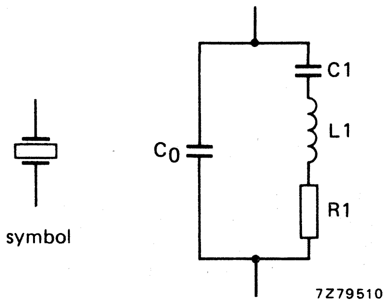


Fig. 1 Crystal unit equivalent circuit.

The parameters of the series branch are termed the "motional parameters" of the crystal unit. The parameter C_0 is termed the "parallel capacitance".

The equivalent circuit has two resonance frequencies at which the electrical impedance is resistive: the "resonance frequency f_r" and the "anti-resonance frequency f_a". The resistance of the equivalent circuit at the resonance frequency f_r is termed the "resonance resistance R".

For $R_1 \ll \frac{1}{\omega C_0}$ the following relations hold:

$$f_r = \frac{1}{2\pi\sqrt{L_1 C_1}} \qquad (1)$$

$$f_a = \frac{1}{2\pi\sqrt{L_1 \frac{C_1 C_0}{C_1 + C_0}}} \qquad (2)$$

$$R = R_1 \qquad (3)$$

LOAD CAPACITANCE AND FREQUENCY PULLING

During manufacture definable limits are set to the accuracy of frequency. In an oscillator, a load capacitance C_L is required to trim the working frequency f_W to the nominal frequency f_n. Figure 2 shows the crystal unit equivalent circuit with a load capacitance in series and in parallel. Each combination has two resonance frequencies at which the electrical impedance of the circuit is resistive. The lower of the two frequencies, when the load capacitance is connected in series and the higher, when it is connected in parallel are termed "load resonance frequencies f_L". At the frequency f_L the resistance of the combination with the load capacitance in series is termed "load resonance resistance R_L".
For $R_1 \ll 1/\omega C_0$:

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

$$\boxed{R_L = R\left(1 + \frac{C_0}{C_L}\right)^2} \; * \qquad (5)$$

For a given value of C_L the load resonance frequencies of the series and the parallel combinations are identical.
In practice, however, the parallel combination shown in Fig. 2c rarely occurs in an oscillator.
From equation (4) two conspicuous second parameters of vital concern can be derived: the difference between load resonance frequency f_L and resonance frequency f_r, "Δf", and the relative change in frequency as a function of the change in load capacitance, termed "pulling sensitivity S".

"Δf"

$$\Delta f = f_L - f_r \qquad (6)$$

with f_L from equation (4)

$$\Delta f = \tfrac{1}{2} f_r \frac{C_1}{C_0 + C_L} - \frac{\Delta f^2}{2 f_s} \qquad (7)$$

and to a close approximation

$$\boxed{\Delta f = \tfrac{1}{2} f_r \frac{C_1}{C_0 + C_L}} \qquad (8)$$

Equation (8) greatly simplifies calculations and methods of measurement, whilst the error is negligible in nearly all cases.

* The resistance of the combination with the load capacitance in parallel is given by

$$R_{L\,par} = \frac{1}{R_1 . \omega_r^2 (C_0 + C_L)^2}$$

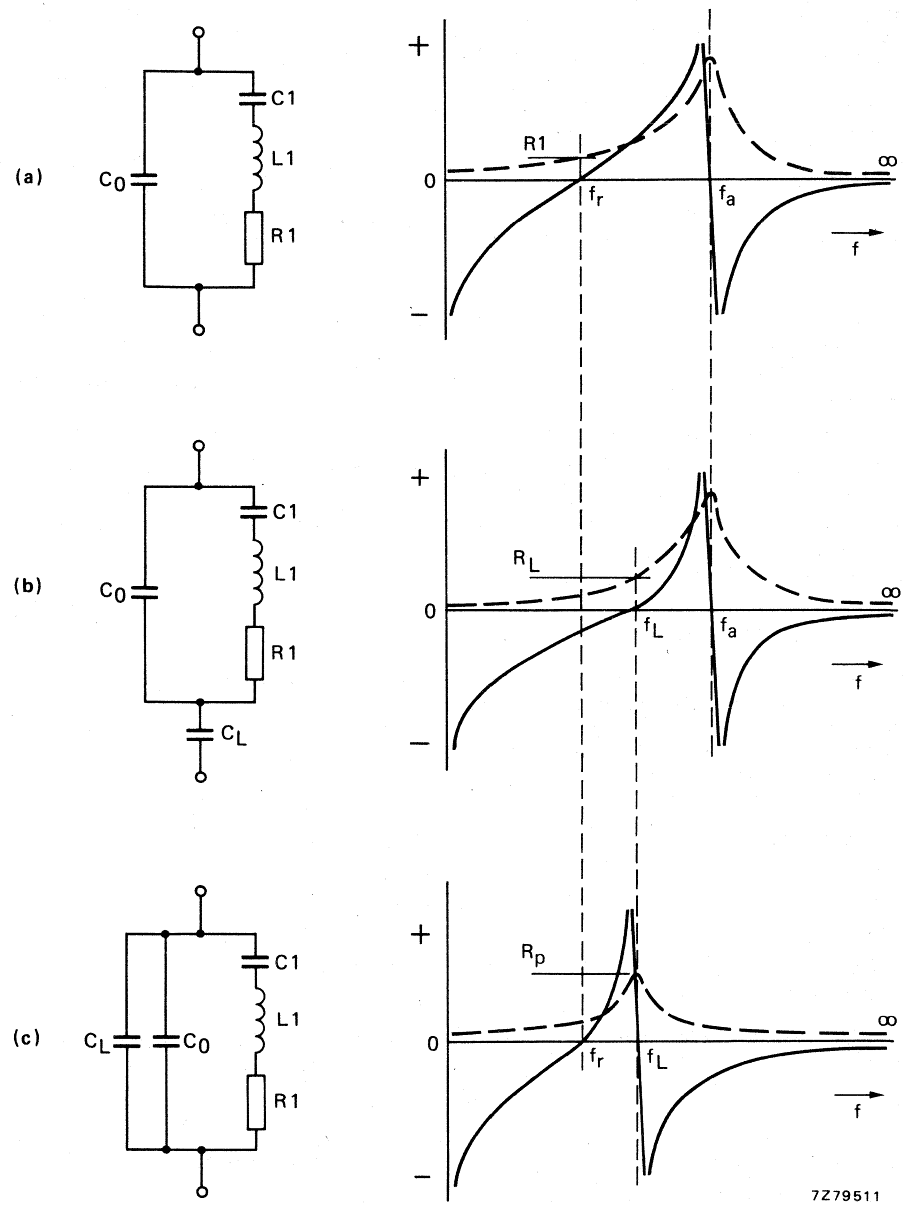


Fig. 2 Resonance, anti-resonance and load resonance frequency.
——— reactance
– – – resistance

Pulling sensitivity S

$$S = \frac{1}{f_L} \left(\frac{\delta f}{\delta C_L}\right)_{f = f_L} = + \frac{1}{f_L} \cdot \frac{\delta \Delta f}{\delta C_L}$$

with Δf from equation (8)

$$S = -\frac{1}{2} f_r \frac{C1}{(C_0 + C_L)^2} \cdot \frac{1}{f_L} \qquad (9)$$

and to a close approximation

$$\boxed{S = -\frac{C1}{2(C_0 + C_L)^2}} \qquad (10)$$

Standard values of load capacitance

The standard values of load capacitance for crystal units operating at the fundamental frequency of the mode are:

20 pF, 30 pF, 50 pF, 100 pF.

Note that in some countries 32 pF is still in use, but this value should not be considered as a standard value and its use is deprecated.

In special cases load capacitances of the values 8, 12 and 15 pF may be used for fundamental mode crystal units.

Overtone crystals are often operated at series resonance. Where a load capacitance is used, it should be chosen from the following standard values:

8 pF, 12 pF, 15 pF, 20 pF, 30 pF.

The pulling sensitivity expressed in 10^{-6}/pF is a good measure for the frequency sensitivity as a function of load capacitance variations at the working frequency.
Figure 3 illustrates Δf and the pulling sensitivity S as a function of the load capacitance, for two quartz crystals having different C_1 values. It should be noted that a tolerance of ½ pF on a 20 pF load capacitance may lead to an error of ± 11.10^{-6}.

Crystal (a)

f_r = 10 000,000 kHz
C_0 = 5 pF
C_1 = 28 fF
C_L = 20 pF
f_L = 10 005,600 kHz
S = $-22,4.10^{-6}$/pF

Crystal (b)

f_r = 10 000,000 kHz
C_0 = 2 pF
C_1 = 5,6 fF
C_L = 20 pF
f_L = 10 001,273 kHz
S = $-5,79.10^{-6}$/pF

Specified, or in special cases, measured Δf and S, as given for crystal (a) in Table 1, offer a simple direct guidance.

Table 1

nominal frequency $f_n = f_L$	10 000,000 kHz	
nominal load capacitance C_L	20 pF	
	specified	measured
Δf	5,600 kHz	5,700 kHz
pulling sensitivity S	$-22 \pm 2 \times 10^{-6}$/pF	$-22,4 \times 10^{-6}$/pF

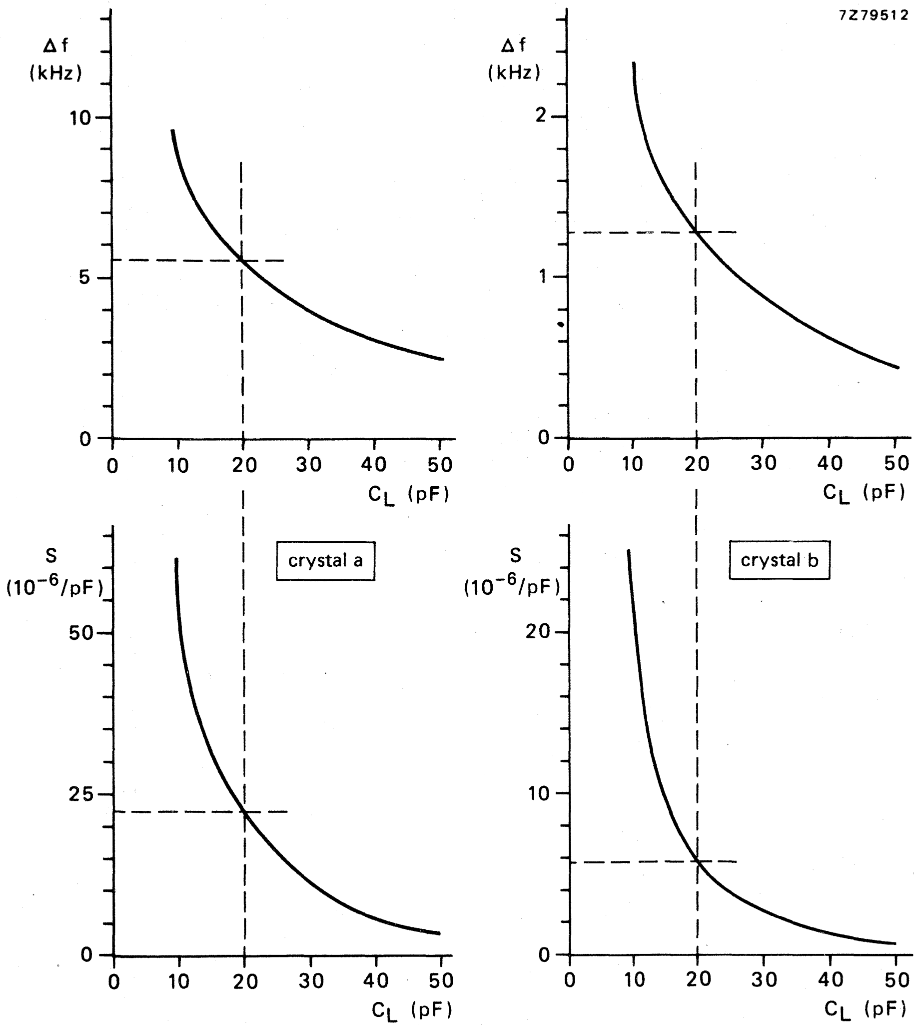


Fig. 3 Δf and pulling sensitivity as a function of the load capacitance. Tolerances on the parameters f_r, C_0 and C_1 are required for calculating the "Δf" and the "pullability at f_n".

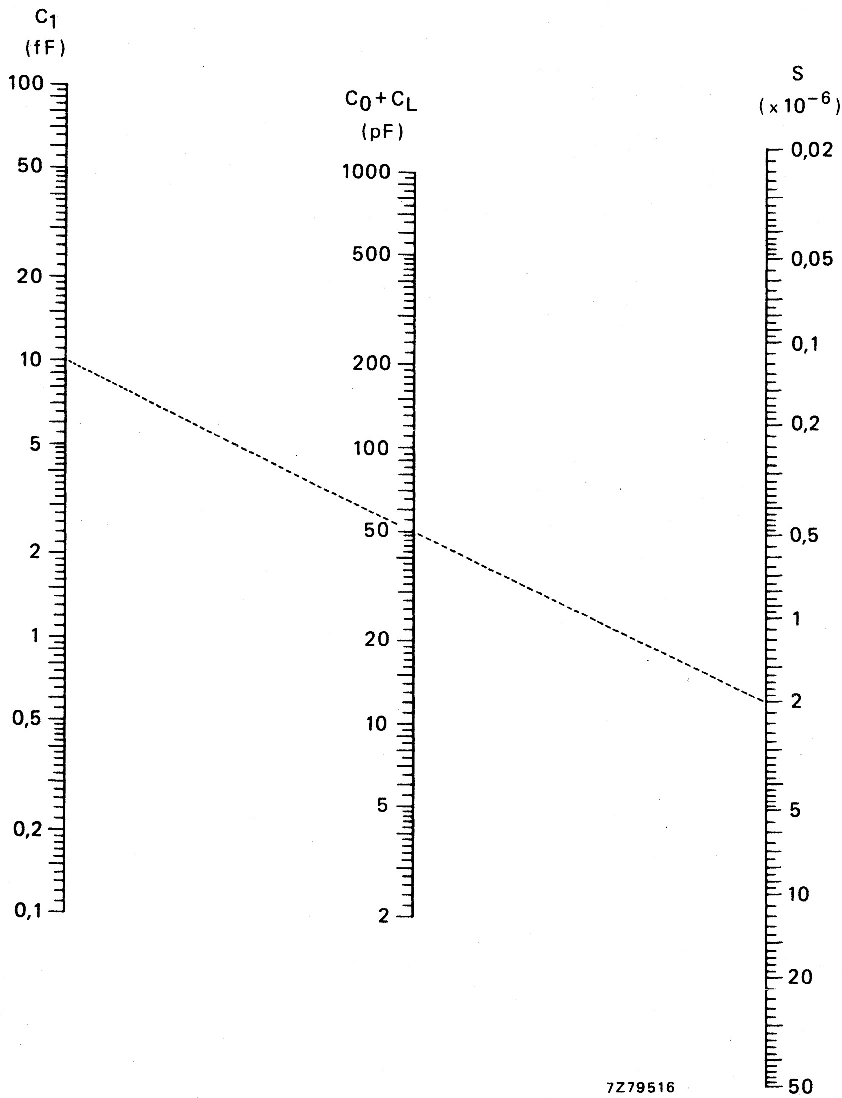


Fig. 4 Nomogram enabling the determination of the pulling sensitivity S.

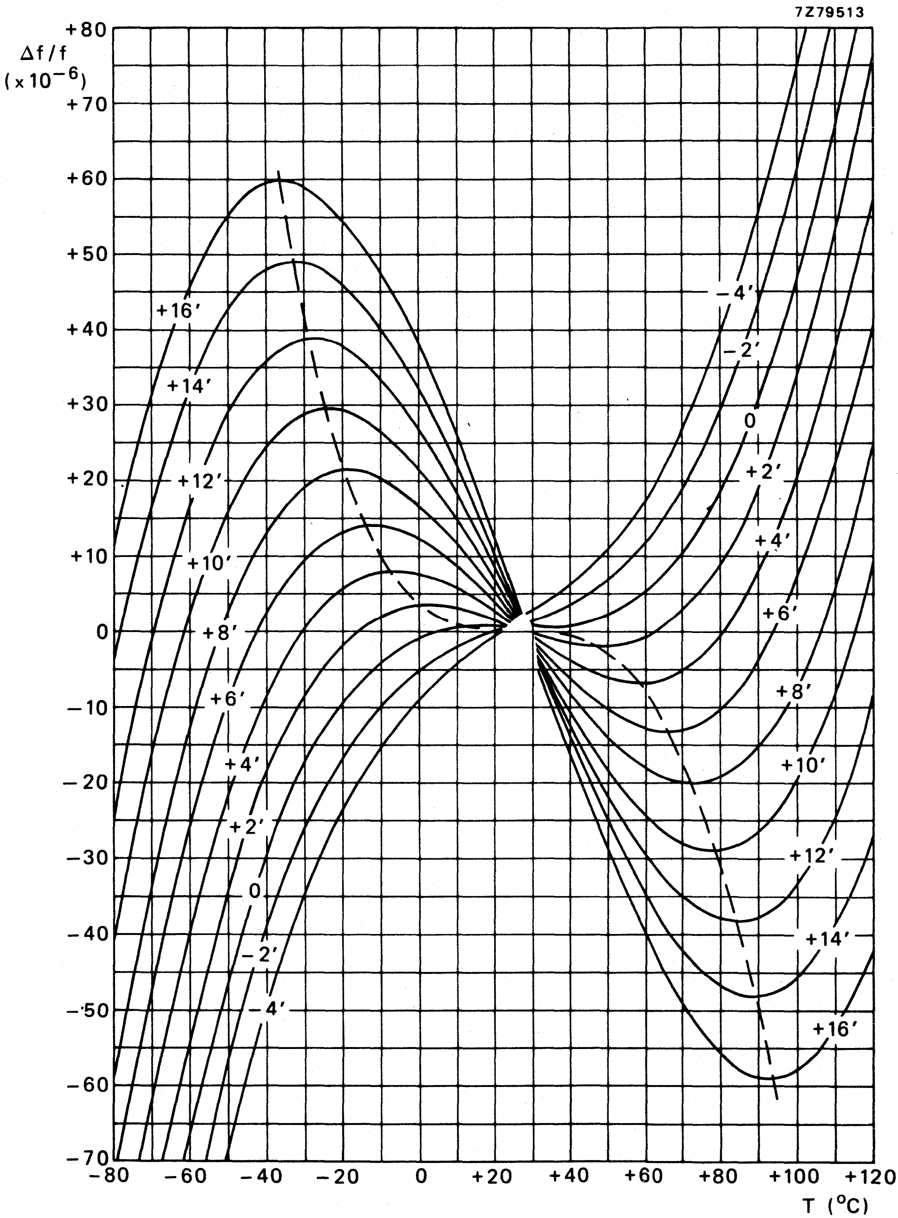


Fig. 5 Frequency/temperature characteristics of a special crystal design.

LEVEL OF DRIVE

The power dissipated in a crystal unit is termed "level of drive" and is usually expressed in mW. In the level of drive range 10^{-12} to 10^{-3} W the drive level dependency of the crystal unit characteristics is almost negligible. For drive levels greater than approximately 1 mW, the crystal unit characteristics tend to change. For this reason the crystal unit characteristics are specified at a level of drive of 0,5 mW.

Low drive levels

If a crystal unit in an oscillator starts to build up electrical power, low drive levels $< 10^{-12}$ W may occur depending on the circuit applied. The load resonance resistance R_L and resonance resistance R may increase slightly at these low levels.

High drive levels

For high stable applications drive levels greater than 0,5 mW should be avoided. Excessively high drive levels ($>$ 10 mW) may lead to serious deviations.

FREQUENCY/TEMPERATURE CHARACTERISTICS

The frequency drift as a function of temperature can be represented by a graph, the T.C. curve or drift characteristic. In the case of AT cuts, the relation of drift and temperature is approximated by a cubic curve; the drift characteristic of the other cuts is parabolic in shape.

Figure 5 shows a number of frequency-temperature curves obtained from AT-cut crystals with various angles of cut α (from −4′ to + 16′ increasing angle of cut). The curves are symmetrical with respect to 27 °C, and it is not possible to shift this point. A temperature range which is fairly symmetrical with respect to 27 °C (e.g. 0 - 60 °C) will, therefore, result in the smallest frequency drift in that range. A small frequency drift over a wide temperature range, e.g. −40 to + 80 °C, will result in a quite steep temperature coefficient at room temperature.

It will be evident that, for AT-cut crystals, the angle of cut and its accuracy are decisive for the frequency drift over a given temperature range.

ADVANTAGES OF ALL-GLASS HOLDERS

Crystal units with all-glass holders show the following advantages over those with metal holders:

(a) a lower series resistance, which also means a higher Q-factor, thanks to the fact that glass holders are evacuated giving less mechanical damping;

(b) better performance under adverse climatic conditions;

(c) a higher frequency stability.

AGEING

A non-reversible, mostly gradual change with time in resonance frequency is called (an effect of) ageing. Only where a very good long-term stability is required should ageing be of consequence. It should be borne in mind that (with a view to ageing only):

(a) crystal units having an all-glass holder are favourable compared with those having a metal holder;

(b) low frequency crystals are favourable compared with high frequency crystals having the same crystal cut;

(c) overtone crystals are favourable compared with fundamental crystals for the same frequency (or fifth overtone compared with third overtone crystals).

CRYSTAL BEHAVIOUR IN AN OSCILLATOR

In the vicinity of resonance the impedance of a quartz crystal unit can be represented by a circle (see Fig. 6). The circle is shifted downwards with respect to the resistance axis over

$$X_0 = \frac{1}{2\pi f_r C_0}.$$

When a load capacitance is connected in series with the unit the shift is $X_0 + X_L$, where

$$X_L = \frac{1}{2\pi f_L C_L}.$$

The frequency difference between anti-resonance frequency and resonance frequency

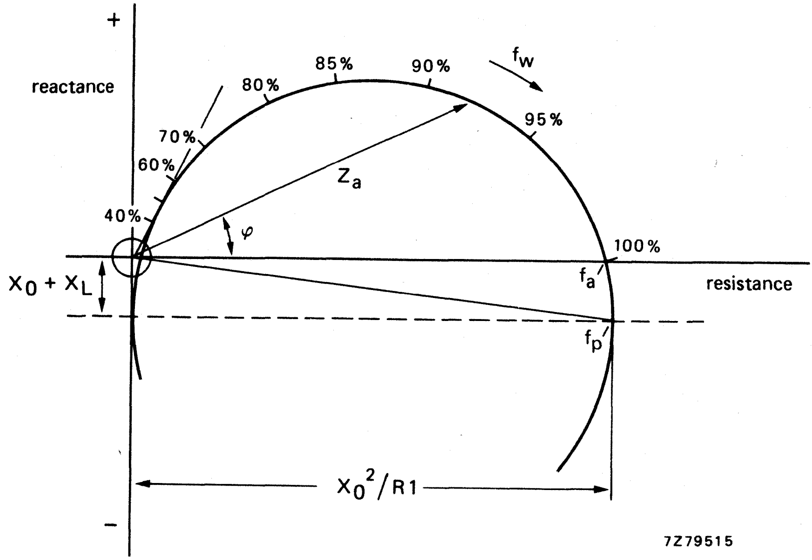
$$f_a - f_r \approx \frac{C_1}{2C_0} \cdot f_r \cdot \frac{C_L}{C_0 + C_L}$$

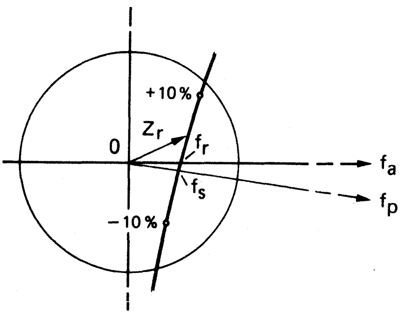
is assumed to be 100%.
It can be seen that the frequency difference between the two frequencies, determined by the phase angle φ, disappears at $f_W = 50\%$. The phase angle in the oscillator should be kept sufficiently small to avoid crystal unit operation in the uncertain 50% area (frequency switching).

Quartz crystal units for frequencies higher than 100 to 125 MHz (depending on type) have an impedance circle with a greater downwards shift, even to below the real axis. When the figure of merit given by

$$M = \frac{X_0}{R_1} = \frac{1}{(2\pi f_r) R_1 C_0}$$

is less than approximately 5, the resonance frequency f_r is arbitrary.





Enlarged area around the zero point.

f_a = anti-resonance frequency
f_r = resonance frequency
f_s = series resonance frequency
f_w = working frequency
Z_r = impedance at working frequency

Fig. 6 Working frequency and impedance of a quartz crystal unit in the impedance diagram.

Indications for use

Keep phase deviations in the circuit sufficiently low to avoid crystal unit operation in the 50% working frequency area, in particular when phase variation is used for frequency pulling (P.L.L. system).

Ensure that amplification is sufficiently high, in particular when applying phase variation.

Keep crystal unit drive level low (generally $\leqslant$ 0,5 mW), see Fig. 7.

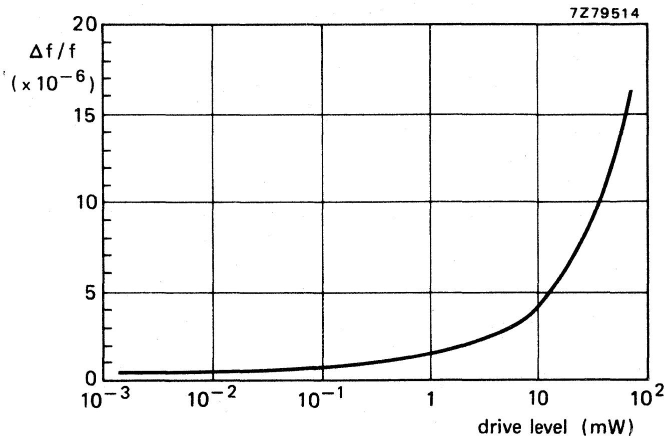


Fig. 7.

MEASURING PROCEDURES

Several methods of measuring quartz crystal units are in use.* Because different methods may give different results, our measuring procedure is given below. This is the *passive method with π-network* according to IEC publication 444. Further, the method is mentioned with *crystal test oscillator type 150A,* make Saunders, which is recommended if a frequency correlation of 2 to 5 ppm is tolerable. The accuracy of reproduction of the π-network method ranges between 10^{-6} and 10^{-8} depending on the type of crystal unit to be measured. The π-network method can be extended for measuring crystal unit parameters very accurately. This is achieved by a slight modification of the π-network, the use of precision reference resistors and two precision high-frequency load capacitors.

PASSIVE METHOD WITH π-NETWORK (IEC)

The principle of this method is very simple. With the equipment shown in the block diagram of Fig. 1, a stable signal source (frequency synthesizer) is adjusted to the frequency at which the signal has zero phase change when passing through the crystal as measured by the phase meter; this frequency (measured with the frequency counter) is then the resonance frequency of the crystal.

For ease of operation, it is possible to phase-lock the system by feeding back the analogue output of the phase error (from zero) to control the precise frequency of the signal source (A.F.C. loop shown by dashed line).

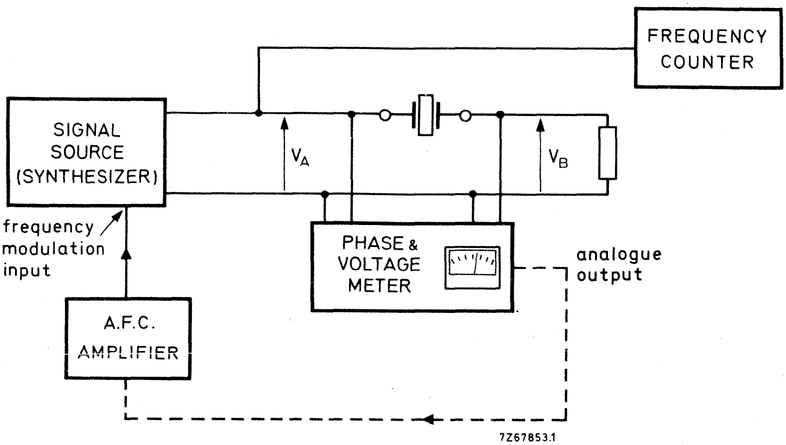


Fig. 1.

* The following measuring methods can be applied on request for the time the obsolete equipment is available:
Method using *Crystal Test Set, type TS193A* (British Military Standard).
Method using *Crystal Impedance Meter TS330/TSM* (U.S. Army Standard).
Method using *Crystal Impedance Meter TS683/TSM* (U.S. Army Standard).

π-network

The first departure which must be made from the simple system of Fig. 1 is the test jig for holding the crystal. The test jig consists of two π-connected resistive pads, carefully manufactured to represent a pure, constant resistance, which is frequency insensitive at the terminals of the quartz crystal (see Fig. 2).

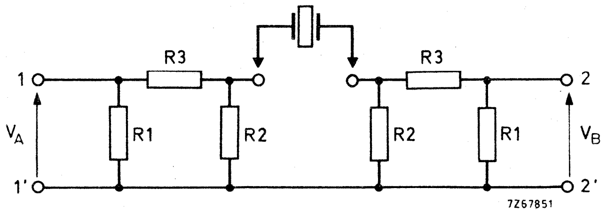


Fig. 2.

The function of the input and output'pads' is twofold:
(a) to match the crystal impedance to the associated equipment,
(b) to attenuate reflections from the associated equipment.

For further particulars consult IEC recommendations, Publication 444.

Quartz crystal parameter measurements

A 5 pF trimming capacitor should be connected in parallel with each of the resistors R2 for accurate compensation of the transmission circuit. A shield is mounted between the contacting plates to reduce the capacitance between them. Two measuring procedures for crystal parameter measurement with the modified π-network are in use:

The C_L method

In general, this method is used for fundamental mode crystal units with frequencies up to 25 MHz.

Precision load capacitors are inserted in the π-network. Load resonance frequency and load resonance resistance can then be measured directly. C1 can be calculated.

The impedance method

Generally this method is used for higher frequencies up to approximately 125 MHz.

Phase and impedance are measured, all other parameters can be calculated by means of a computer.

Crystal shielding

Depending on the application, crystal shielding may give rise to frequency deviations, in particular for fundamental mode crystal units with a considerable pulling sensitivity.
In our procedure the metal enclosure of the crystal unit normally is not earthed. If, in special cases, earthing is required this should be mentioned in the specification for ordering.

METHOD WITH CRYSTAL TEST OSCILLATOR 150A AND PRINTER PROCESSOR 2000A

Initial calibration

The accuracy of the crystal test oscillator is for a considerable part determined by the alignment of the capacitance meter. Alignment and check of the capacitance meter by means of a stable precision 75 pF capacitor is recommended. For further particulars see 150 A manual.

HOLDERS

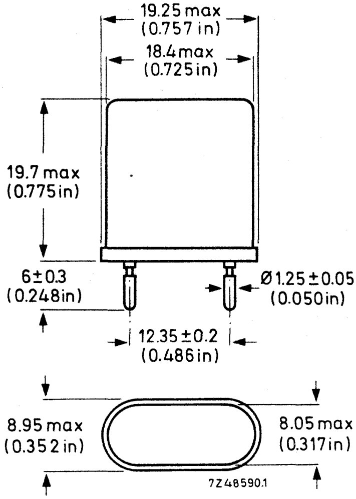
The following holders state the nominal frequency by means of 7 (or 8) figures, in kHz in the case of fundamental crystals and in MHz in the case of overtone crystals. Other figures on the faces constitute registration numbers that relate to the date and series of manufacture.

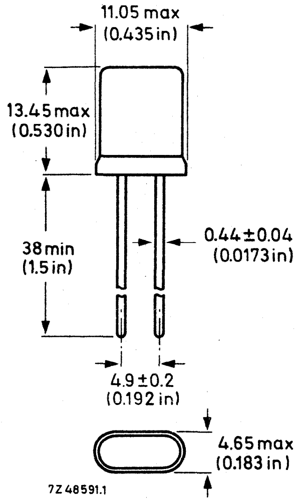
ALL-GLASS HOLDERS

Dimensions in mm
(in inches between brackets)

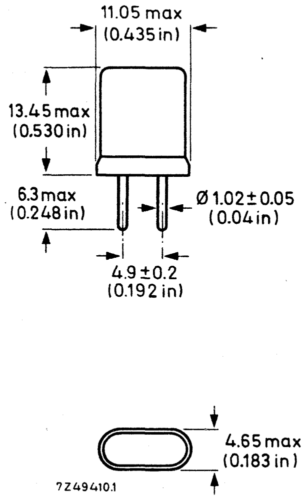
HC-27/U

(IEC type DB is identical except for the height which is 26 mm max. instead of 19,7 max.).





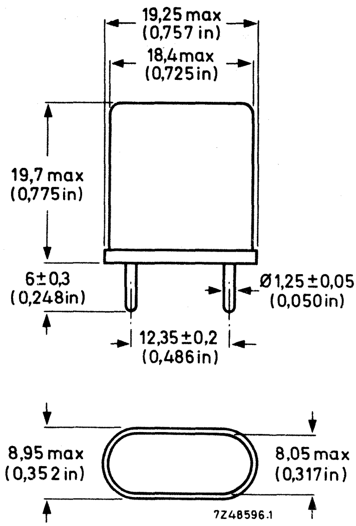
HC-26/U



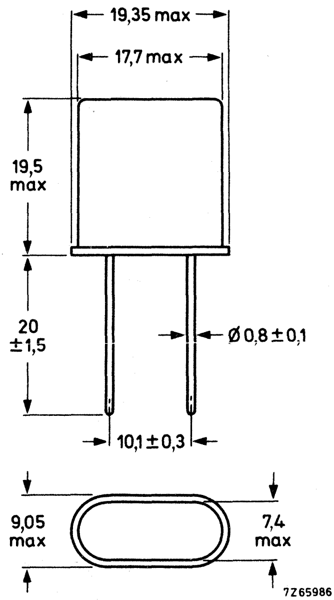
HC-29/U

METAL HOLDERS

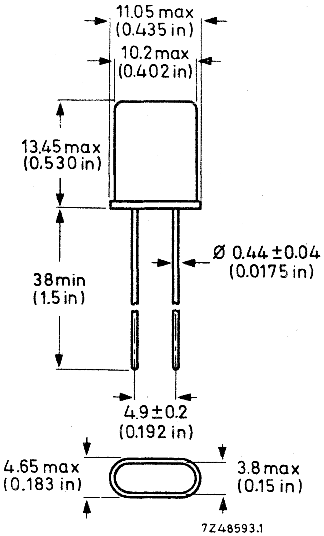
Dimensions in mm
(in inches between brackets)



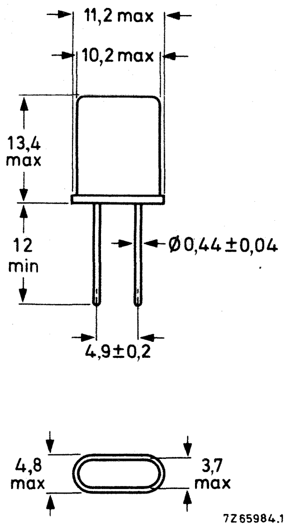
HC-6/U, solder sealed
RW-36, resistance welded



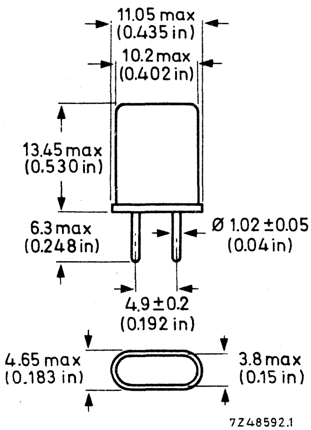
RW-10
resistance welded



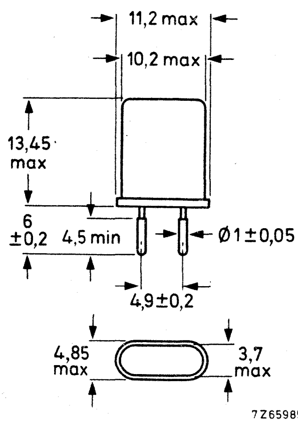
HC-18/U
solder sealed



RW-43
resistance welded



HC-25/U
solder sealed



RW-42
resistance welded

CORRESPONDING IEC AND DIN TYPE NUMBERS

	IEC 122-3	DIN 45110
HC-6/U	AA	K1A
HC-18/U	BC	M2A
HC-25/U	CX	M1A
HC-26/U	CY	R2A
HC-27/U	DA	Q1A
HC-29/U	CZ	R1A
(height 26 mm max.)	DB	Q1B
RW-10	DS	K4A
RW-36	—	K3A
RW-42	DQ	M3A
RW-43	DP	M4A

HOW TO SPECIFY A QUARTZ CRYSTAL UNIT

For quotation or ordering a quartz crystal unit which still has no complete catalogue number (12 digits), the supplier needs to know certain basic information. Please use the following check list.

Type of crystal unit	
Type of holder	
Nominal frequency	kHz
Mode of vibration	fundamental or third/fifth overtone
Allowable deviation from nominal frequency (adjustment tolerance) at + 25 °C	$\times 10^{-6}$
Temperature range	from to °C
Frequency drift over specified temperature range	$\times 10^{-6}$
Circuit conditions:	
resonance frequency f_r or	kHz
load resonance frequency f_L and	kHz
load capacitance C_L	pF
maximum resonance resistance R or	Ω
maximum load resonance resistance R_L	Ω
Crystal unit equivalent parameters	
C_1	fF
C_0	pF
R_1	Ω
L_1	mH
Level of drive	mW
Ageing Δf/f per month or year	$\times 10^{-6}$
Mechanical requirements/tests	

QUARTZ CRYSTAL UNITS FOR SPECIAL APPLICATIONS B

Tests and requirements B2
Data sheets B3

TESTS AND REQUIREMENTS

Applicable to all units in RW-43 holder, with catalogue number 4322 143 0 . . . .

IEC 122	IEC 68-2	test	procedures	requirements
2.5.17	Ba	aging	1000 h +100 °C	$\Delta f_r \leqslant 5 \times 10^{-6}$. $\Delta R \leqslant 20\%$.
2.5.12 2.5.13 2.5.14	Db	accelerated damp heat	+ 25 to + 55 °C, 6 cycles 95 to 100% R.H.	$\Delta f_r \leqslant 5 \times 10^{-6}$. $\Delta R \leqslant 20\%$.
	Na	temperature cycling test	−40/+ 125 °C, 10 cycles, 1 h/cycle.	$\Delta f_r \leqslant 5 \times 10^{-6}$. $\Delta R \leqslant 20\%$.
2.5.2	Ea	shock	100g sawtooth 6 shocks, 3 directions	$\Delta f_r \leqslant 5 \times 10^{-6}$. $\Delta R \leqslant 20\%$.
2.5.3	Fc	vibration	10-500-10 Hz, 10g, 3 h, 3 directions.	$\Delta f_r \leqslant 5 \times 10^{-6}$. $\Delta R \leqslant 20\%$.
	Tb	resistance to soldering heat	3 s, 350 °C.	$\leqslant 5 \times 10^{-6}$. $\leqslant 20\%$.
2.5.6	Ub	bending of terminations	1 x 90°, 5 N.	no visible damage.
	Eb	bump	3000 bumps, 30g	$\Delta f_r \leqslant 5 \times 10^{-6}$. $\Delta R \leqslant 20\%$.
	Ed	free fall	3 x 0,75 m on steel	$\Delta f_r \leqslant 5 \times 10^{-6}$. $\Delta R \leqslant 20\%$.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	8 867,238 kHz
Mode of vibration	fundamental
Type of holder	RW-10

APPLICATION

Intended to be used in the sub-carrier oscillator of colour television sets according to the PAL system.

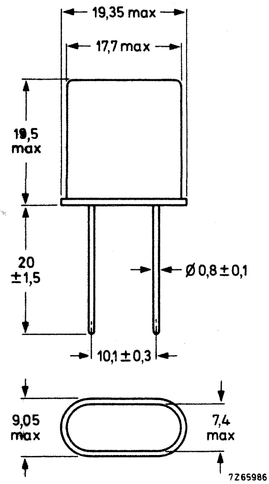
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in a resistance welded metal holder, provided with two connecting leads.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 2 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number and a code for the date of manufacture are stamped on the holder.

Mounting

The unit can be soldered directly into a printed-wiring board.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of 25 ± 2 °C and a level of drive of 0,5 mW related to 25 Ω.

Load resonance frequency f_L, load capacitance 20 pF	8 867, 238 kHz
Adjustment tolerance	± max. 40 x 10^{-6}
Tolerance over the temperature range of + 10 to + 60 °C, with respect to + 25 °C	± max. 30 x 10^{-6}
Trimability at a load cap. of 20 pF with a load cap. variation of 10 pF	min. 950 Hz
Motional capacitance (C_1)	typ. 21 fF
Parallel capacitance (C_0)	max. 6 pF, typ. 5 pF
Resonance resistance	typ. 15 Ω
in temperature range of + 10 to + 60 °C	max. 60 Ω
Maximum permissible d.c. voltage between terminations	100 V
Operating temperature range	+ 10 to + 60 °C

TESTS AND REQUIREMENTS

Essentially the following tests mentioned in the schedule of IEC publication 122 are carried out along the lines of IEC publication 68.

IEC 122 clause	IEC 68-2 test method	test	procedure	requirements
2.5.17	—	aging	30 days, + 85 °C	Δf/f ± max. 15 x 10^{-6}
2.5.12	Db	damp heat accelerated	1 day, + 55 °C 100% R.H.	Δf/f ± max. 10 x 10^{-6} R_{ins} at 50 V d.c. min. 20 MΩ
	Na	rapid change of temperature	–20/+ 50 °C 15 cycles 1 h per cycle	Δf/f ± max. 5 x 10^{-6}
2.5.2	Ea	shock	40g, sawtooth 6 directions, 1 blow per direction	Δf/f ± max. 5 x 10^{-6} ΔR/R ± max. 15%
2.5.3	Fc	vibration	10-55-10 Hz, 0,75 mm displacement 2 h, 3 directions*	Δf/f ± max. 5 x 10^{-6} ΔR/R ± max. 15%
2.5.6	Ub	flexibility of terminations	1 x 90°, 5 N	no visible damage
2.5.10	T	soldering	300 °C, 2 s	Δf/f ± max. 2 x 10^{-6} good tinning no visible damage

* The batch is divided into three equal parts, each part is tested in one of the three perpendicular directions.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	4 782,720 kHz
Mode of vibration	fundamental
Type of holder	RW-43

APPLICATION

Two-tone telephone dialling system.

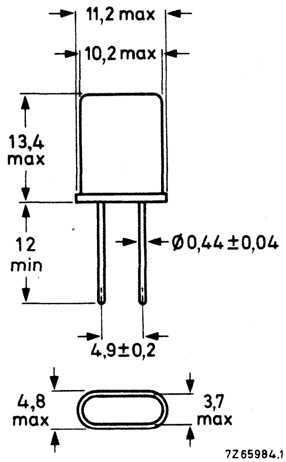
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in a hermetically sealed resistance welded metal holder, provided with two connecting leads.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 1 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number, and a code for the date of manufacture are stamped on the holder.

Mounting

The unit can be soldered directly onto a printed-wiring board.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of 25 ± 2 °C and a level of drive of 0,5 mW related to 25 Ω.

Resonance frequency f_L	4 782,720 kHz
Adjustment tolerance	± max. 50 x 10^{-6}
Tolerance over the temperature range of −20 to + 70 °C, with respect to + 25 °C	± max. 50 x 10^{-6}
Motional capacitance (C_1)	typ. 21,4 fF
Parallel capacitance (C_0)	typ. 5,8 pF
→ Resonance resistance	max. 60 Ω
Maximum permissible d.c. voltage between terminations	100 V
Operating temperature range	−20 to + 70 °C

TESTS AND REQUIREMENTS

See page B2.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	4 433,619 kHz
Mode of vibration	fundamental
Type of holder	RW-43

APPLICATION

Intended to be used in the sub-carrier oscillator of colour television sets according to the PAL system.

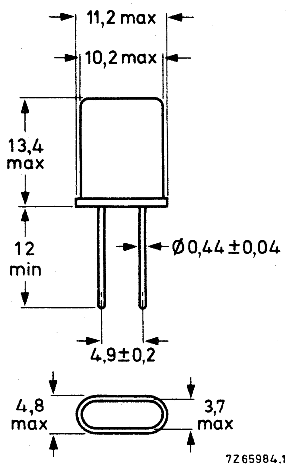
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in a hermetically sealed resistance welded metal holder, provided with two connecting leads.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 1 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number, and a code for the date of manufacture are stamped on the holder.

Mounting

The unit can be soldered directly onto a printed-wiring board.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of 25 ± 2 °C and a level of drive of 0,5 mW related to 25 Ω.

Load resonance frequency f_L, load capacitance 20 pF	4 433,619 kHz
Adjustment tolerance	± max. 40 x 10^{-6}
Tolerance over the temperature range of −10 to + 60 °C, with respect to + 25 °C	± max. 30 x 10^{-6}
Motional capacitance (C_1)	typ. 20,4 fF
Parallel capacitance (C_0)	typ. 5,4 pF
Resonance resistance	max. 60 Ω
Pullability $\left(-\frac{df}{dC}\right)$ at f_L with load capacitance variation	min. + 12 x 10^{-6} x f_L/pF
Maximum permissible d.c. voltage between terminations	100 V
Operating temperature range	−10 to + 60 °C

TESTS AND REQUIREMENTS

See page B2.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	8 867,238 kHz
Mode of vibration	fundamental
Type of holder	RW-43

APPLICATION

Intended to be used in the sub-carrier oscillator of colour television sets according to the PAL system.

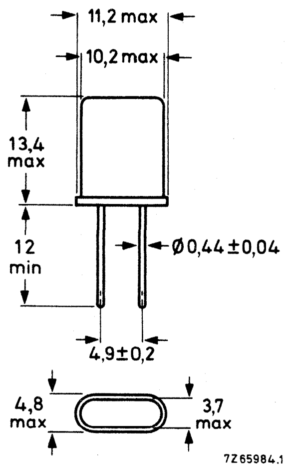
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in a hermetically sealed resistance welded metal holder, provided with two connecting leads.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 1 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number, and a code for the date of manufacture are stamped on the holder.

Mounting

The unit can be soldered directly onto a printed-wiring board.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of 25 ± 2 °C and a level of drive of 0,5 mW related to 25 Ω.

Load resonance frequency f_L, load capacitance 20 pF	8 867,238 kHz
Adjustment tolerance	± max. 40 x 10^{-6}
Tolerance over the temperature range of −10 to + 60 °C, with respect to + 25 °C	± max. 25 x 10^{-6}
→ Motional capacitance (C_1)	typ. 24 fF
Parallel capacitance (C_0)	typ. 5,5 pF
Resonance resistance	max. 60 Ω
Pullability $\left(-\frac{df}{dC}\right)$ at f_L with load capacitance variation	min. + 16 x 10^{-6} x f_L/pF
Maximum permissible d.c. voltage between terminations	100 V
Operating temperature range	−10 to + 60 °C

TESTS AND REQUIREMENTS

See page B2.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	4 194,812 kHz
Mode of vibration	fundamental
Type of holder	RW-43

APPLICATION

Quartz clocks, dividing ratio 2^{22}: 1 + offset.

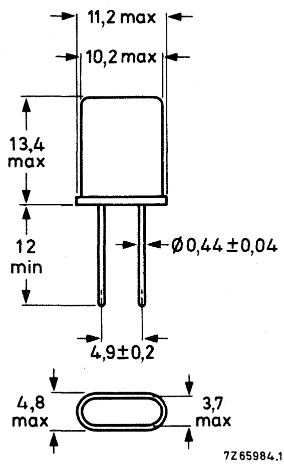
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in a hermetically sealed resistance welded metal holder, provided with two connecting leads.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 1 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number, and a code for the date of manufacture are stamped on the holder.

Mounting

The unit can be soldered directly onto a printed-wiring board.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of 25 ± 2 °C and a level of drive of 1 mW related to 25 Ω.

Load resonance frequency f_L, load capacitance 17 pF	4 194,812 kHz
Adjustment tolerance	± max. 40 x 10^{-6}
Tolerance over the temperature range of −40 to + 80 °C, with respect to + 25 °C	± max. 50 x 10^{-6}
Motional capacitance (C_1)	typ. 13 fF
Parallel capacitance (C_0)	typ. 3,3 pF
Resonance resistance	max. 100 Ω
Pullability ($-\frac{df}{dC}$) at f_L with load capacitance variation	min. + 11 x 10^{-6} x f_L/pF
Maximum permissible d.c. voltage between terminations	100 V
Operating temperature range	−40 to + 80 °C

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	4 194,304 kHz
Mode of vibration	fundamental
Type of holder	RW-43

APPLICATION

Quartz clocks, dividing ratio $2^{22}:1$.

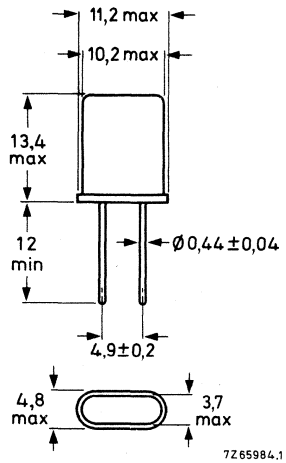
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in a hermetically sealed resistance welded metal holder, provided with two connecting leads.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 1 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number, and a code for the date of manufacture are stamped on the holder.

Mounting

The unit can be soldered directly onto a printed-wiring board.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of 25 ± 2 °C and a level of drive of 0,5 mW related to 25 Ω.

Load resonance frequency f_L, load capacitance 12 pF	4 194,304 kHz
Adjustment tolerance	± max. 40 x 10^{-6}
Tolerance over the temperature range of −10 to + 60 °C, with respect to + 25 °C	± max. 25 x 10^{-6}
Motional capacitance (C_1)	typ. 11,6 fF
Parallel capacitance (C_0)	typ. 2,9 pF
Resonance resistance	max. 35 Ω, typ. 20 Ω
Pullability $\left(-\frac{df}{dC}\right)$ at f_L with load capacitance variation	min. + 22 x 10^{-6} x f_L/pF
Maximum permissible d.c. voltage between terminations	100 V
Operating temperature range	−10 to + 60 °C

TESTS AND REQUIREMENTS

See page B2

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	4 000,000 kHz
Mode of vibration	fundamental
Type of holder	RW-43

APPLICATION

General purpose, e.g. digital tuning.

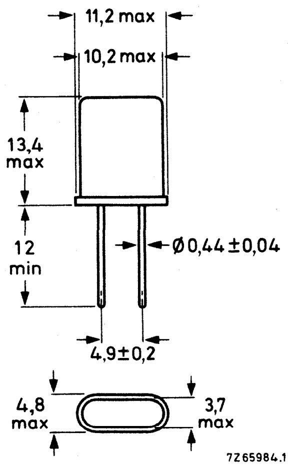
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in a hermetically sealed resistance welded metal holder, provided with two connecting leads.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 1 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number, and a code for the date of manufacture are stamped on the holder.

Mounting

The unit can be soldered directly onto a printed-wiring board.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of 25 ± 2 °C and a level of drive of 0,5 mW related to 25 Ω.

Load resonance frequency f_L, load capacitance 30 pF	4 000,000 kHz
Adjustment tolerance	± max. 40 x 10^{-6}
Tolerance over the temperature range of −10 to + 60 °C, with respect to + 25 °C	± max. 25 x 10^{-6}
Motional capacitance (C_1)	typ. 11 fF
Parallel capacitance (C_0)	typ. 2,8 pF
Resonance resistance	max. 60 Ω
Pullability $\left(-\frac{df}{dC}\right)$ at f_L with load capacitance variation	min. + 5 x 10^{-6} x f_L/pF
Maximum permissible d.c. voltage between terminations	100 V
Operating temperature range	−10 to + 60 °C

TESTS AND REQUIREMENTS

See page B2.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	6 000,000 kHz
Mode of vibration	fundamental
Type of holder	RW-43

APPLICATION

Teletext and Viewdata.

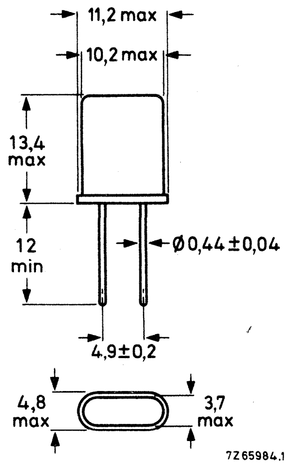
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in a hermetically sealed resistance welded metal holder, provided with two connecting leads.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 1 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number, and a code for the date of manufacture are stamped on the holder.

Mounting

The unit can be soldered directly onto a printed-wiring board.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of 25 ± 2 °C and a level of drive of 0,5 mW related to 25 Ω.

Load resonance frequency f_L, load capacitance 20 pF	6 000,000 kHz
Adjustment tolerance	± max. 40 x 10^{-6}
Tolerance over the temperature range of −20 to +70 °C, with respect to + 25 °C	± max. 30 x 10^{-6}
Motional capacitance (C_1)	typ. 28 fF
Parallel capacitance (C_0)	typ. 7,1 pF
Resonance resistance	max. 60 Ω
Pullability $\left(-\frac{df}{dC}\right)$ at f_L with load capacitance variation	min. + 16 x 10^{-6} x f_L/pF
Maximum permissible d.c. voltage between terminations	100 V
Operating temperature range	−20 to +70 °C

TESTS AND REQUIREMENTS

See page B2.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	4 433,619 kHz
Mode of vibration	fundamental
Type of holder	RW-10

APPLICATION

Intended to be used in the sub-carrier oscillator of colour television sets according to the PAL system.

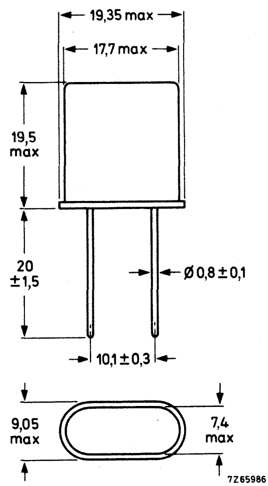
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in a resistance welded metal holder, provided with two connecting leads.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 2 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number and a code for the date of manufacture are stamped on the holder.

Mounting

The unit can be soldered directly into a printed-wiring board.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of 25 ± 2 °C and a level of drive of 0,5 mW related to 25 Ω.

Load resonance frequency f_L, load capacitance 20 pF	4 433,619 kHz
Adjustment tolerance	± max. 40 x 10^{-6}
Tolerance over the temperature range of + 10 to + 60 °C, with respect to + 25 °C	± max. 30 x 10^{-6}
Trimability at a load cap. of 20 pF with a load cap. variation of 10 pF	min. 600 Hz
Motional capacitance (C_1)	typ. 29 fF
Parallel capacitance (C_0)	max. 7 pF, typ. 6,5 pF
Resonance resistance in temperature range of + 10 to + 60 °C	typ. 15 Ω max. 50 Ω
Maximum permissible d.c. voltage between terminations	100 V
Operating temperature range	+ 10 to + 60 °C

TESTS AND REQUIREMENTS

Essentially the following tests mentioned in the schedule of IEC publication 122 are carried out along the lines of IEC publication 68.

IEC 122 clause	IEC 68-2 test method	test	procedure	requirements
2.5.17	–	aging	30 days, + 85 °C	Δf/f max. 15 x 10^{-6}
2.5.12	Db	damp heat accelerated	1 day, + 55 °C 100% R.H.	Δf/f max. 10 x 10^{-6} R_{ins} at 50 V d.c. min. 20 MΩ
	Na	rapid change of temperature	–20/+ 50 °C 15 cycles 1 h per cycle	Δf/f ± max. 5 x 10^{-6}
2.5.2	Ea	shock	40g, sawtooth 6 directions, 1 blow per direction	Δf/f ± max. 5 x 10^{-6} ΔR/R ± max. 15%
2.5.3	Fc	vibration	10-55-10 Hz, 0,75 mm displacement 2 h, 3 directions*	Δf/f ± max. 5 x 10^{-6} ΔR/R ± max. 15%
2.5.6	Ub	flexibility of terminations	1 x 90°, 5 N	no visible damage
2.5.10	T	soldering	300 °C, 2 s	Δf/f ± max. 2 x 10^{-6} good tinning no visible damage

* The batch is divided into three equal parts, each part is tested in one of the three perpendicular directions.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	10 MHz
Mode of vibration	third overtone
Type of holder	all-glass, HC-27/U

APPLICATION

For frequency stabilization in circuits in which a high stability and a low series resistance are required.

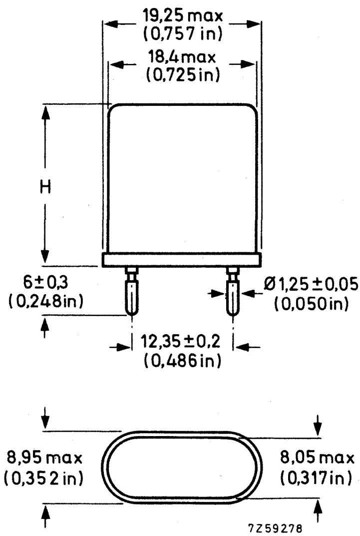
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in a hermetically sealed, evacuated glass holder, provided with two connecting pins.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 2,5 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number, and a code for the date of manufacture are stamped on the holder.

Mounting

The unit is provided with pins for socket mounting.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of +25 ± 2 °C and a level of drive of 1 mA.*

Load resonance frequency f_L, load capacitance 75 pF**	10 000 kHz
Adjustment tolerance	± max. 5 x 10^{-6}
Tolerance over the temperature range of +69 to +71 °C, with respect to +25 °C	± max. 3 x 10^{-7}
Motional capacitance (C_1)	typ. 2,1 fF
Parallel capacitance (C_0)	typ. 5 pF
Motional inductance (L_1)	typ. 120 mH
Resonance resistance over the temperature range of −40 to +75 °C	max. 40 Ω
Maximum permissible d.c. voltage between terminations	100 V
Aging	±5 x 10^{-8}/month
Operating temperature range	−40 to +75 °C

Stability of oscillator frequency. This depends on the crystal oven used. Stability figures of 1 x 10^{-6} to 1 x 10^{-7} can be achieved.

TESTS AND REQUIREMENTS

According to MIL-C-3098C.	$\Delta f/f$	± max. 3 x 10^{-6}
	$\Delta R/R$	± max. 15%

* Influence of drive level on frequency is max. 2 x 10^{-8}/dB.

** Data at other C_L and for series resonance available on request.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	5000 kHz
Mode of vibration	fundamental
Type of holder	RW-43

APPLICATION

Television cameras.

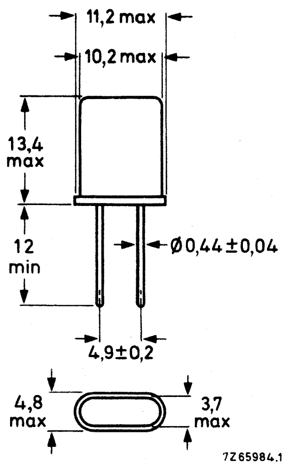
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in a hermetically sealed resistance welded metal holder, provided with two connecting leads.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 1 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number, and a code for the date of manufacture are stamped on the holder.

Mounting

The unit can be soldered directly onto a printed-wiring board.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of 25 ± 2 °C and a level of drive of 0,5 mW related to 25 Ω.

Load resonance frequency f_L, load capacitance 20 pF	5000 kHz
Adjustment tolerance	± max. 40×10^{-6}
Tolerance over the temperature range of −20 to + 70 °C, with respect to + 25 °C	± max. 30×10^{-6}
Motional capacitance (C_1)	typ. 14,4 fF
Parallel capacitance (C_0)	typ. 3,3 pF
Resonance resistance	max. 60 Ω
Pullability ($-\frac{df}{dC}$) at f_L with load capacitance variation	min. + $12 \times 10^{-6} \times f_L$/pF
Maximum permissible d.c. voltage between terminations	100 V
Operating temperature range	−20 to + 70 °C

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Nominal frequency	5120 kHz
Mode of vibration	fundamental
Type of holder	RW-43

APPLICATION

Car radios.

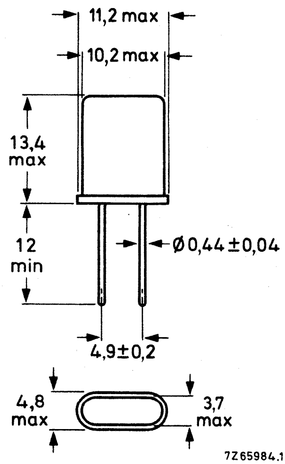
DESCRIPTION

The unit consists of a metal-plated AT-cut quartz plate, mounted in hermetically sealed resistance welded metal holder, provided with two connecting leads.

MECHANICAL DATA

Dimensions in mm

Outlines



Mass 1 g approximately

Marking

The frequency in kHz, the last 5 digits of the catalogue number, and a code for the date of manufacture are stamped on the holder.

Mounting

The unit can be soldered directly onto a printed-wiring board.

ELECTRICAL DATA

Unless otherwise specified the values apply at a temperature of 25 ± 2 ^oC and a level of drive of 0,5 mW related to 25 Ω.

Load resonance frequency f_L, load capacitance 20 pF	5120 kHz
Adjustment tolerance	± max. 40×10^{-6}
Tolerance over the temperature range of −20 to + 70 ^oC, with respect to + 25 ^oC	± max. 30×10^{-6}
Motional capacitance (C_1)	typ. 14,6 fF
Parallel capacitance (C_0)	typ. 3,2 pF
Resonance resistance	max. 60 Ω
Pullability ($-\frac{df}{dC}$) at f_L with load capacitance variation	min. + $15 \times 10^{-6} \times f_L$/pF
Maximum permissible d.c. voltage between terminations	100 V
Operating temperature range	−20 to + 70 ^oC

QUARTZ CRYSTAL UNITS FOR GENERAL FREQUENCY STABILIZATION

C

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	4 to 10 MHz
Mode of vibration	fundamental
Type of holder	RW-10 or RW-36

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 4 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 20 \times 10^{-6}$
Load capacitance C_L*	30 pF
Level of drive	0,5 mW
Motional capacitance C_1	see Fig. 1
Parallel capacitance C_0	see Fig. 1
Motional inductance L_1	see Fig. 1
Resonance resistance R_1	typ. 25 Ω
Frequency tolerance with respect to + 25 °C in temperature range:	
0 to + 60 °C	$\pm$ max. 30×10^{-6}
–30 to + 80 °C	$\pm$ max. 35×10^{-6}
+ 15 to + 45 °C	$\pm$ max. 10×10^{-6}
Maximum permissible d.c. voltage between terminations	100 V
Aging	within adjustment tolerance

* Data at other C_L values and for series resonance available on request.

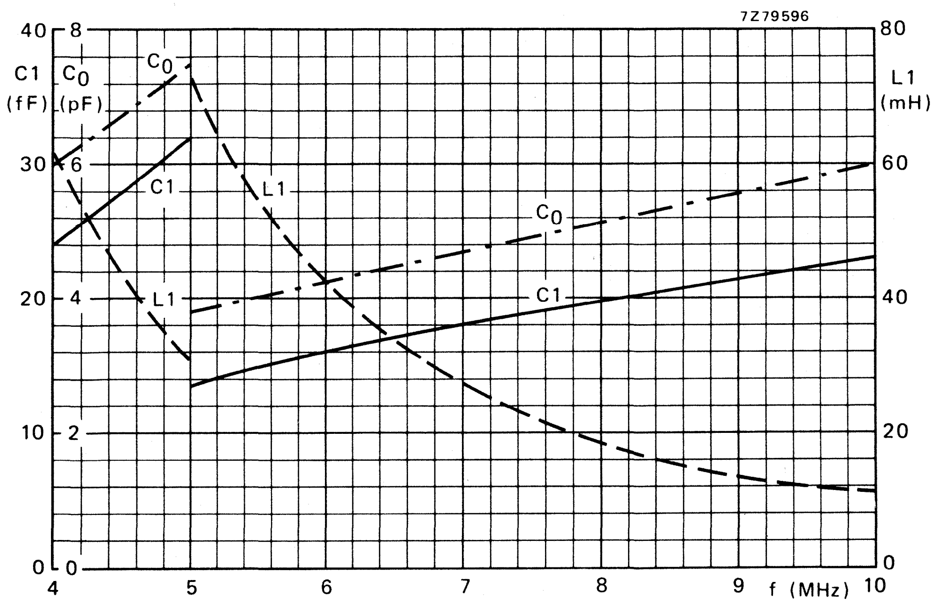


Fig. 1 Typical values for C_0, C_1 and L_1 as a function of frequency.

TESTS AND REQUIREMENTS

test	IEC-122 clause	IEC-68-2 test method	procedure	requirements
aging	2.5.17	–	30 days + 85 °C	$\Delta f/f \leqslant 10 \times 10^{-6}$
acceleration	2.5.12 2.5.13 2.5.14	Db		$\Delta f/f \leqslant 10 \times 10^{-6}$ $R_{ins} > 20$ MΩ at 50 V (d.c.)
temperature cycling	–	Na	–20/+ 50 °C, 15 cycles, 1 h/cycle	$\Delta f/f \leqslant 5 \times 10^{-6}$
shock	2.5.2	Ea	100g sawtooth 6 directions, 1 blow/direction	$\Delta f/f \leqslant 5 \times 10^{-6}$ $\Delta R/R < 15\%$
vibration	2.5.3	Fc	10-55-10 Hz 2 hours*	$\Delta f/f \leqslant 5 \times 10^{-6}$ $\Delta R/R < 15\%$
soldering**	2.5.10	T		no visible damage, terminals well-tinned $\Delta f/f \leqslant 2 \times 10^{-6}$
bending of terminations**	2.5.6	Ub	1 x 90°, 5 N	no visible damage

* The batch is divided into 3 equal parts, each part is tested in 1 of the 3 perpendicular directions.
** Holder RW-10 only.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	1,6 to 25 MHz
Mode of vibration	fundamental
Type of holder	RW-36

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 4 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 20 \times 10^{-6}$
Load capacitance C_L*	30 pF
Level of drive	0,5 mW
Motional capacitance C_1	5 to 30 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	see Table 1
Frequency tolerance in different temp. ranges with respect to + 25 °C	see Table 2
Maximum permissible d.c. voltage between terminations	100 V
Aging	within adjustment tolerance

TESTS

Mechanical and climatic tests	according to MIL and IEC procedures

* Data at other C_L values and for series resonance available on request.

Table 1 Resonance resistance R_1

frequency MHz	max. R_1 Ω
1,600000 – 1,999999	300
2,000000 – 2,249999	250
2,250000 – 3,749999	150
3,750000 – 4,999999	100
5,000000 – 6,999999	50
7,000000 – 9,999999	30
10,000000 – 25,000000	25

Table 2 Frequency tolerance in different temperature ranges with respect to + 25 °C

frequency range MHz	temperature range °C	frequency tolerance		
		class 0	class I	class II
1,6 - 25	−5/+ 45	± 5 x 10^{-6}	± 7,5 x 10^{-6}	± 10 x 10^{-6}
	−10/+ 50	± 7,5 x 10^{-6}	± 10 x 10^{-6}	± 15 x 10^{-6}
	−15/+ 70	± 10 x 10^{-6}	± 15 x 10^{-6}	± 20 x 10^{-6}
1,6 - 2,3	−55/+ 105	± 30 x 10^{-6}	± 35 x 10^{-6}	± 40 x 10^{-6}
2,3 - 4	−55/+ 105	± 32,5 x 10^{-6}	± 35 x 10^{-6}	± 40 x 10^{-6}
4 - 25	−55/+ 105	± 25 x 10^{-6}	± 30 x 10^{-6}	± 40 x 10^{-6}
1,6 - 25	T_{nom} ± 5	± 5 x 10^{-6}		

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	1,6 to 25 MHz
Mode of vibration	fundamental
Type of holder	HC-6/U

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 4 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 20 \times 10^{-6}$
Load capacitance C_L*	30 pF
Level of drive	0,5 mW
Motional capacitance C_1	5 to 30 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	see Table 1
Frequency tolerance in different temp. ranges with respect to + 25 °C	see Table 2
Maximum permissible d.c. voltage between terminations	100 V
Aging	within adjustment tolerance

TESTS

Mechanical and climatic tests	according to MIL and IEC procedures

* Data at other C_L values and for series resonance available on request.

Table 1 Resonance resistance R_1

frequency MHz	max. R_1 Ω
1,600000 – 1,999999	300
2,000000 – 2,249999	250
2,250000 – 3,749999	150
3,750000 – 4,999999	100
5,000000 – 6,999999	50
7,000000 – 9,999999	30
10,000000 – 25,000000	25

Table 2 Frequency tolerance in different temperature ranges with respect to + 25 °C

frequency range MHz	temperature range °C	frequency tolerance		
		class 0	class I	class II
1,6 - 25	–5/+ 45	± 5 x 10^{-6}	± 7,5 x 10^{-6}	± 10 x 10^{-6}
	–10/+ 50	± 7,5 x 10^{-6}	± 10 x 10^{-6}	± 15 x 10^{-6}
	–15/+ 70	± 10 x 10^{-6}	± 15 x 10^{-6}	± 20 x 10^{-6}
1,6 - 2,3	–55/+ 105	± 30 x 10^{-6}	± 35 x 10^{-6}	± 40 x 10^{-6}
2,3 - 4	–55/+ 105	± 32,5 x 10^{-6}	± 35 x 10^{-6}	± 40 x 10^{-6}
4 - 25	–55/+ 105	± 25 x 10^{-6}	± 30 x 10^{-6}	± 40 x 10^{-6}
1,6 - 25	T_{nom} ±5	± 5 x 10^{-6}		

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	1,6 to 25 MHz
Mode of vibration	fundamental
Type of holder	
1,6 to 2,3 MHz	DB (26 mm)
2,4 to 25 MHz	HC-27/U

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 2,5 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	± 10 x 10^{-6}
Load capacitance C_L*	30 pF
Level of drive	0,5 mW
Motional capacitance C_1	see Figs 1 to 4
Parallel capacitance C_0	max. 7 pF, see also Fig. 1
Motional inductance L_1	see Figs 1 to 4
Resonance resistance R_1	see Table 1
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table 2
Maximum permissible d.c. voltage between terminations	100 V
Aging after 90 days non-operative at + 85 ± 2 °C	(–0,5 to + 1) x 10^{-6}

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

* Data at other C_L values and for series resonance available on request.

Table 1 Resonance resistance R_1

frequency MHz	max. R_1 Ω
1,600000 – 1,869999	220
1,870000 – 1,999999	185
2,000000 – 2,119999	165
2,120000 – 2,249999	150
2,250000 – 2,599999	125
2,600000 – 2,999999	90
3,000000 – 3,399999	70
3,400000 – 3,749999	52
3,750000 – 3,999999	45
4,000000 – 4,999999	37
5,000000 – 6,999999	25
7,000000 – 9,999999	20
10,000000 – 14,999999	18
15,000000 – 25,000000	15

Table 2, Frequency tolerance in different temperature ranges with respect to + 25 °C

frequency range MHz	temperature range °C	frequency tolerance		
		class 0	class I	class II
1,6 - 25	–5/+ 45 –10/+ 50 –15/+ 70	$\pm 5 \times 10^{-6}$ $\pm 7{,}5 \times 10^{-6}$ $\pm 10 \times 10^{-6}$	$\pm 7{,}5 \times 10^{-6}$ $\pm 10 \times 10^{-6}$ $\pm 15 \times 10^{-6}$	$\pm 10 \times 10^{-6}$ $\pm 15 \times 10^{-6}$ $\pm 20 \times 10^{-6}$
1,6 - 2,3 2,3 - 7 7 - 25	–55/+ 105 –55/+ 105 –55/+ 105	$\pm 30 \times 10^{-6}$ $\pm 32{,}5 \times 10^{-6}$ $\pm 25 \times 10^{-6}$	$\pm 35 \times 10^{-6}$ $\pm 35 \times 10^{-6}$ $\pm 30 \times 10^{-6}$	$\pm 40 \times 10^{-6}$ $\pm 40 \times 10^{-6}$ $\pm 40 \times 10^{-6}$
1,6 - 25	$T_{nom} \pm 5$		$\pm 2{,}5 \times 10^{-6}$	$\pm 5 \times 10^{-6}$

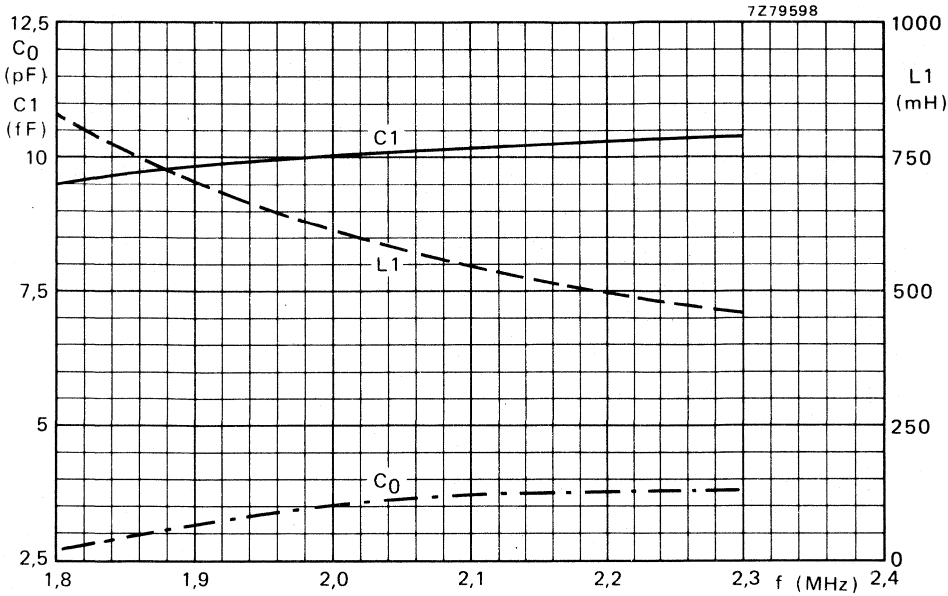


Fig. 1 Typical values for C_0, C_1 and L_1 for frequencies from 1,8 to 2,3 MHz.

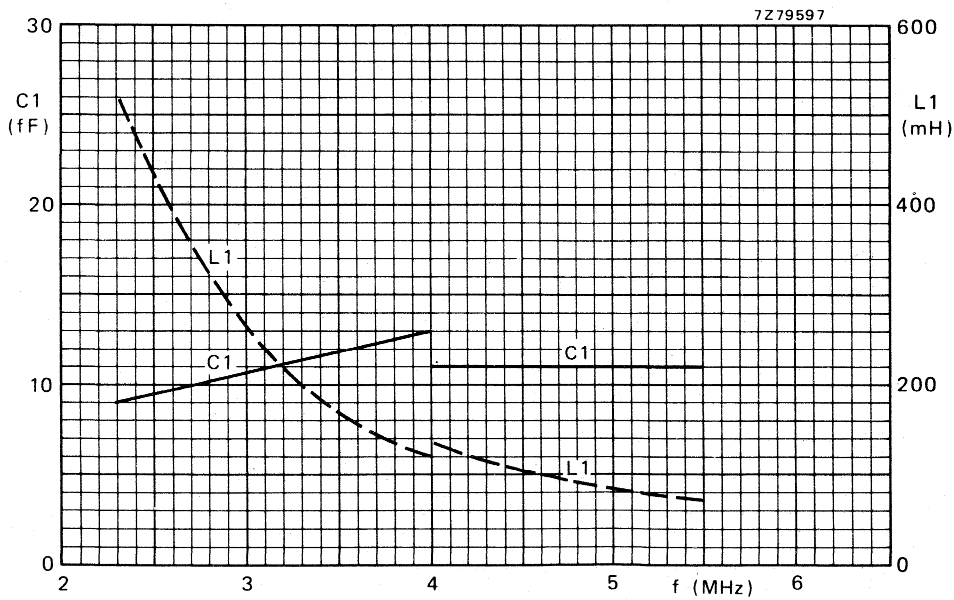


Fig. 2 Typical values for C_1 and L_1 for frequencies from 2,3 to 5,5 MHz.

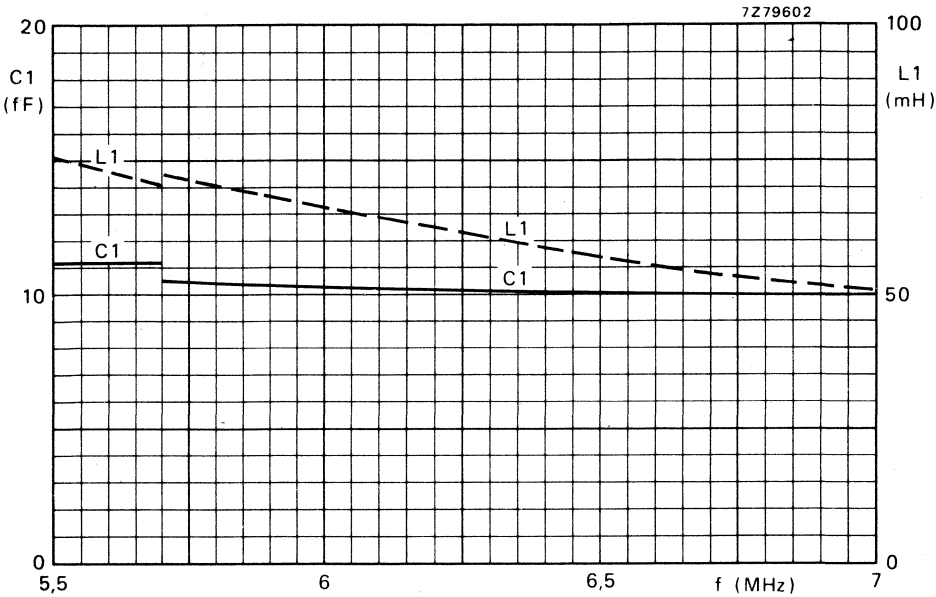


Fig. 3 Typical values for C_1 and L_1 for frequencies from 5,5 to 7 MHz.

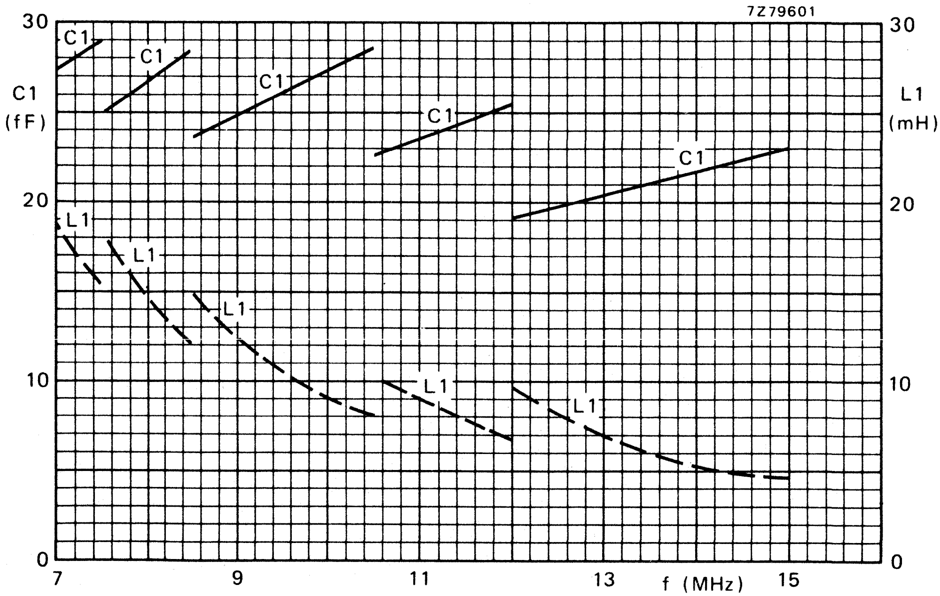


Fig. 4 Typical values for C_1 and L_1 for frequencies from 7 to 15 MHz.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	4 to 25 MHz
Mode of vibration	fundamental
Type of holder	HC-26/U or HC-29/U

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 0,8 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	± 10 x 10^{-6}
Load capacitance C_L*	30 pF
Level of drive	0,5 mW
Motional capacitance C_1	see Figs 1 and 2
Parallel capacitance C_0	see Figs 1 and 2
Motional inductance L_1	see Figs 1 and 2
Resonance resistance R_1	see Table 1
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table 2
Maximum permissible d.c. voltage between terminations	100 V
Aging after 90 days non-operative at + 85 ± 2 °C	(–0,5 to + 1) x 10^{-6}

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

* Data at other C_L values and for series resonance available on request.

Table 1 Resonance resistance R_1

frequency MHz	max. R_1 Ω
4,000000 – 4,749999	110
4,750000 – 5,999999	70
6,000000 – 6,999999	45
7,000000 – 9,999999	30
10,000000 – 14,999999	25
15,000000 – 25,000000	20

Table 2 Frequency tolerance in different temperature ranges with respect to + 25 °C

frequency range MHz	temperature range °C	frequency tolerance		
		class 0	class I	class II
4 - 25	–5/+ 45 –10/+ 50 –15/+ 70	$\pm 5 \times 10^{-6}$ $\pm 7,5 \times 10^{-6}$ $\pm 10 \times 10^{-6}$	$\pm 7,5 \times 10^{-6}$ $\pm 10 \times 10^{-6}$ $\pm 15 \times 10^{-6}$	$\pm 10 \times 10^{-6}$ $\pm 15 \times 10^{-6}$ $\pm 20 \times 10^{-6}$
4 - 6 6 - 12 12 - 25	–55/+ 105 –55/+ 105 –55/+ 105	$\pm 30 \times 10^{-6}$ $\pm 32,5 \times 10^{-6}$ $\pm 25 \times 10^{-6}$	$\pm 40 \times 10^{-6}$ $\pm 35 \times 10^{-6}$ $\pm 30 \times 10^{-6}$	$\pm 50 \times 10^{-6}$ $\pm 40 \times 10^{-6}$ $\pm 40 \times 10^{-6}$
4 - 25	$T_{nom} \pm 5$		$\pm 2,5 \times 10^{-6}$	$\pm 5 \times 10^{-6}$

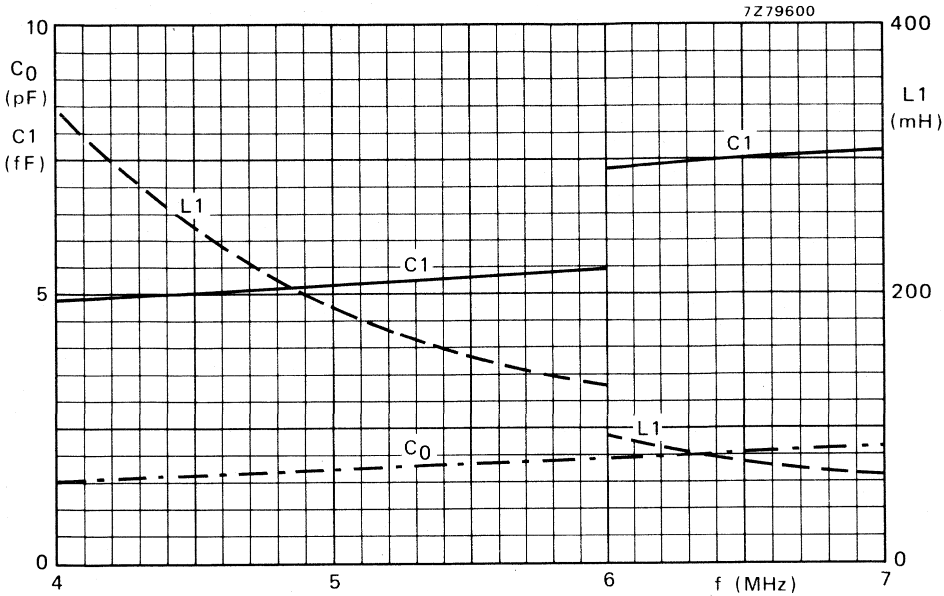


Fig. 1 Typical values of L_1, C_0 and C_1 for frequencies from 4 to 7 MHz.

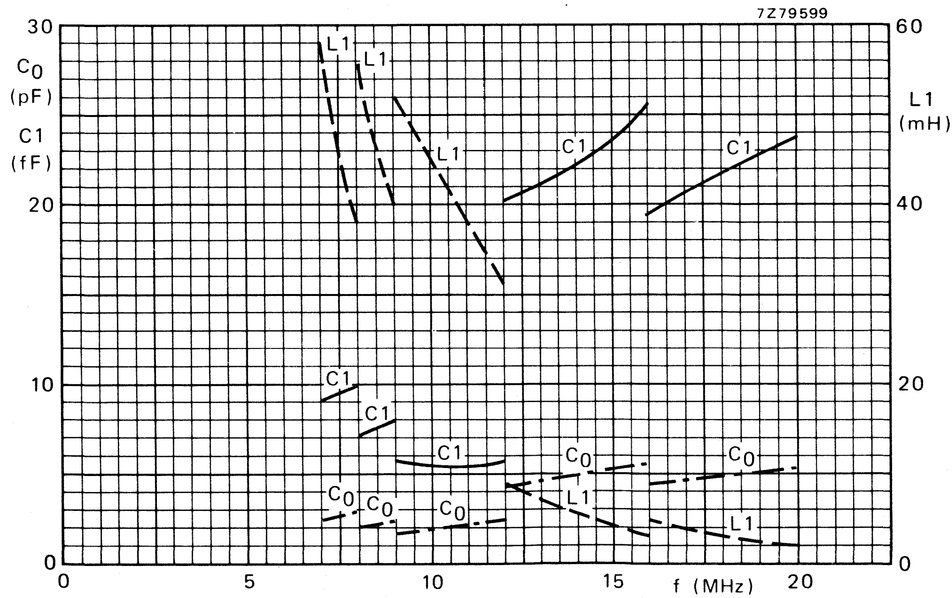


Fig. 2 Typical values of L_1, C_0 and C_1 for frequencies from 7 to 20 MHz.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	4 to 25 MHz
Mode of vibration	fundamental
Type of holder	RW-43 or RW-42

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 1 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	± 20 x 10^{-6}
Load capacitance C_L *	30 pF
Level of drive	0,5 mW
Motional capacitance C_1	5 to 30 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	
4 to 7 MHz	max. 80 Ω
7 to 25 MHz	max. 40 Ω
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table
Maximum permissible d.c. voltage between terminations	100 V
Aging	within adjustment tolerance

* Data at other C_L values and for series resonance available on request.

Table Frequency tolerance in different temperature ranges with respect to + 25 °C

temperature range °C	frequency tolerance class 0	frequency tolerance class I	frequency tolerance class II
−5/+ 45	$\pm 5 \times 10^{-6}$	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$
−10/+ 50	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$	$\pm 15 \times 10^{-6}$
−15/+ 70	$\pm 10 \times 10^{-6}$	$\pm 15 \times 10^{-6}$	$\pm 20 \times 10^{-6}$
−55/+ 105	$\pm 25 \times 10^{-6}$	$\pm 30 \times 10^{-6}$	$\pm 40 \times 10^{-6}$
$T_{nom.} \pm 5$	$\pm 5 \times 10^{-6}$		

TESTS AND REQUIREMENTS

test	IEC-122 clause	IEC-68-2 test method	procedure	requirements
aging	2.5.17	–	30 days + 85 °C	$\Delta f/f \pm < 10 \times 10^{-6}$
damp heat, accelerated	2.5.12 2.5.13 2.5.14	D	–	$\Delta f/f \pm < 10 \times 10^{-6}$ $R_{ins} > 20$ MΩ at 50 V d.c.
temperature cycling	–	Na	−20/+ 50 °C, 15 cycles, 1 h/cycle	$\Delta f/f \pm < 5 \times 10^{-6}$
shock	2.5.2	Ea	100g sawtooth 6 directions, 1 blow/direction	$\Delta f/f \pm < 5 \times 10^{-6}$ $\Delta R \pm < 15\%$
vibration	2.5.3	Fc	10-55-10 Hz 2 h *	$\Delta f/f \pm < 5 \times 10^{-6}$ $\Delta R \pm < 15\%$
soldering**	2.5.10	T	–	no visible damage, terminals well-tinned $\Delta f/f \pm < 2 \times 10^{-6}$
bending of terminations**	2.5.6	Ub	1 x 90°, 5 N	no visible damage

* The batch is divided into 3 equal parts, each part is tested in 1 of the 3 perpendicular directions.
** Holder RW-43 only.

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	10 to 61 MHz
Mode of vibration	third overtone
Type of holder	HC-6/U

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 4 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 20 \times 10^{-6}$
Level of drive	0,5 mW
Motional capacitance C_1	typ. 1,5 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	max. 60 Ω
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table
Maximum permissible d.c. voltage between terminations	100 V
Aging	within adjustment tolerance

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

Table Frequency tolerance in different temperature ranges with respect to + 25 °C

temperature range °C	frequency tolerance		
	class 0	class I	class II
−5/+ 50	$\pm 5 \times 10^{-6}$	$\pm 7{,}5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$
−10/+ 60	$\pm 7{,}5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$	$\pm 15 \times 10^{-6}$
−20/+ 70	$\pm 10 \times 10^{-6}$	$\pm 13 \times 10^{-6}$	$\pm 20 \times 10^{-6}$
−55/+ 105	$\pm 25 \times 10^{-6}$	$\pm 30 \times 10^{-6}$	$\pm 40 \times 10^{-6}$
$T_{nom} \pm 5$	$\pm 5 \times 10^{-6}$		

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	10 to 61 MHz
Mode of vibration	third overtone
Type of holder	HC-27/U

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 2,5 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 10 \times 10^{-6}$
Level of drive	0,5 mW
Motional capacitance C_1	typ. 1,5 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	max. 40 Ω
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table
Maximum permissible d.c. voltage between terminations	100 V
Aging after 90 days non-operative at + 85 ± 2 °C	$(-0,5 \text{ to } +1) \times 10^{-6}$

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

Table Frequency tolerance in different temperature ranges with respect to + 25 °C

temperature range °C	frequency tolerance		
	class 0	class I	class II
−5/+ 50	$\pm 5 \times 10^{-6}$	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$
−10/+ 60	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$	$\pm 15 \times 10^{-6}$
−20/+ 70	$\pm 10 \times 10^{-6}$	$\pm 13 \times 10^{-6}$	$\pm 20 \times 10^{-6}$
−55/+ 105	$\pm 25 \times 10^{-6}$	$\pm 30 \times 10^{-6}$	$\pm 40 \times 10^{-6}$
$T_{nom} \pm 5$		$\pm 2,5 \times 10^{-6}$	$\pm 5 \times 10^{-6}$

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	20 to 61 MHz
Mode of vibration	third overtone
Type of holder	HC-26/U or HC-29/U

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 0,8 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 10 \times 10^{-6}$
Level of drive	0,5 mW
Motional capacitance C_1	typ. 1,5 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	max. 30 Ω
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table
Maximum permissible d.c. voltage between terminations	100 V
Aging after 90 days non-operative at + 85 ± 2 °C	$(-0,5 \text{ to } +1) \times 10^{-6}$

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

Table Frequency tolerance in different temperature ranges with respect to + 25 °C

temperature range °C	frequency tolerance		
	class 0	class I	class II
−5/+ 50	$\pm 5 \times 10^{-6}$	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$
−10/+ 60	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$	$\pm 15 \times 10^{-6}$
−20/+ 70	$\pm 10 \times 10^{-6}$	$\pm 13 \times 10^{-6}$	$\pm 20 \times 10^{-6}$
−55/+ 105	$\pm 25 \times 10^{-6}$	$\pm 30 \times 10^{-6}$	$\pm 40 \times 10^{-6}$
$T_{nom} \pm 5$		$\pm 2,5 \times 10^{-6}$	$\pm 5 \times 10^{-6}$

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	17 to 61 MHz
Mode of vibration	third overtone
Type of holder	RW-43 or RW-42

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 1 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 20 \times 10^{-6}$
Level of drive	0,5 mW
Motional capacitance C_1	typ. 1,5 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	max. 40 Ω
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table
Maximum permissible d.c. voltage between terminations	100 V
Aging	within adjustment tolerance

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

Table Frequency tolerance in different temperature ranges with respect to + 25 °C

temperature range °C	frequency tolerance		
	class 0	class I	class II
−5/+ 50	$\pm 5 \times 10^{-6}$	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$
−10/+ 60	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$	$\pm 15 \times 10^{-6}$
−20/+ 70	$\pm 10 \times 10^{-6}$	$\pm 13 \times 10^{-6}$	$\pm 20 \times 10^{-6}$
−55/+ 105	$\pm 25 \times 10^{-6}$	$\pm 30 \times 10^{-6}$	$\pm 40 \times 10^{-6}$
$T_{nom} \pm 5$	$\pm 5 \times 10^{-6}$		

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	10 to 61 MHz
Mode of vibration	third overtone
Type of holder	RW-36

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 4 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 20 \times 10^{-6}$
Level of drive	0,5 mW
Motional capacitance C_1	typ. 1,5 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	max. 60 Ω
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table
Maximum permissible d.c. voltage between terminations	100 V
Aging	within adjustment tolerance

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

Table Frequency tolerance in different temperature ranges with respect to + 25 °C

temperature range °C	frequency tolerance		
	class 0	class I	class II
−5/+ 50	$\pm 5 \times 10^{-6}$	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$
−10/+ 60	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$	$\pm 15 \times 10^{-6}$
−20/+ 70	$\pm 10 \times 10^{-6}$	$\pm 13 \times 10^{-6}$	$\pm 20 \times 10^{-6}$
−55/+ 105	$\pm 25 \times 10^{-6}$	$\pm 30 \times 10^{-6}$	$\pm 40 \times 10^{-6}$
$T_{nom} \pm 5$	$\pm 5 \times 10^{-6}$		

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	50 to 125 MHz
Mode of vibration	fifth overtone
Type of holder	HC-6/U

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 4 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 20 \times 10^{-6}$
Level of drive	0,5 mW
Motional capacitance C_1	typ. 0,5 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	20 to 100 Ω
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table
Maximum permissible d.c. voltage between terminations	100 V
Aging	within adjustment tolerance

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

Table Frequency tolerance in different temperature ranges with respect to + 25 °C

temperature range °C	frequency tolerance		
	class 0	class i	class ii
−5/+ 50	$\pm 5 \times 10^{-6}$	$\pm 7{,}5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$
−10/+ 60	$\pm 7{,}5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$	$\pm 15 \times 10^{-6}$
−20/+ 70	$\pm 10 \times 10^{-6}$	$\pm 13 \times 10^{-6}$	$\pm 20 \times 10^{-6}$
−55/+ 105	$\pm 25 \times 10^{-6}$	$\pm 30 \times 10^{-6}$	$\pm 40 \times 10^{-6}$
$T_{nom} \pm 5$	$\pm 5 \times 10^{-6}$		

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	50 to 125 MHz
Mode of vibration	fifth overtone
Type of holder	HC-27/U

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 2,5 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 10 \times 10^{-6}$
Level of drive	0,5 mW
Motional capacitance C_1	typ. 0,5 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	max. 50 Ω
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table
Maximum permissible d.c. voltage between terminations	100 V
Aging after 90 days non-operative at + 85 ± 2 °C	$(-0,5 \text{ to } +1) \times 10^{-6}$

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

Table Frequency tolerance in different temperature ranges with respect to + 25 °C

temperature range °C	frequency tolerance		
	class 0	class I	class II
−5/+ 50	$\pm 5 \times 10^{-6}$	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$
−10/+ 60	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$	$\pm 15 \times 10^{-6}$
−20/+ 70	$\pm 10 \times 10^{-6}$	$\pm 13 \times 10^{-6}$	$\pm 20 \times 10^{-6}$
−55/+ 105	$\pm 25 \times 10^{-6}$	$\pm 30 \times 10^{-6}$	$\pm 40 \times 10^{-6}$
$T_{nom} \pm 5$		$\pm 2,5 \times 10^{-6}$	$\pm 5 \times 10^{-6}$

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	50 to 125 MHz
Mode of vibration	fifth overtone
Type of holder	HC-26/U or HC-29/U

MECHANICAL DATA

Outlines See general section (A) "Holders"

Mass 0,8 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	± 10 x 10^{-6}
Level of drive	0,5 mW
Motional capacitance C_1	typ. 0,5 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	
50 to 90 MHz	max. 50 Ω
90 to 125 MHz	max. 70 Ω
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table
Maximum permissible d.c. voltage between terminations	100 V
Aging after 90 days non-operative at + 85± 2 °C	(–0,5 to + 1) x 10^{-6}

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

Table Frequency tolerance in different temperature ranges with respect to + 25 °C

temperature range °C	frequency tolerance		
	class 0	class I	class II
–5/+ 50	± 5 x 10^{-6}	± 7,5 x 10^{-6}	± 10 x 10^{-6}
–10/+ 60	± 7,5 x 10^{-6}	± 10 x 10^{-6}	± 15 x 10^{-6}
–20/+ 70	± 10 x 10^{-6}	± 13 x 10^{-6}	± 20 x 10^{-6}
–55/+ 105	± 25 x 10^{-6}	± 30 x 10^{-6}	± 40 x 10^{-6}
T_{nom} ± 5		± 2,5 x 10^{-6}	± 5 x 10^{-6}

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	50 to 125 MHz
Mode of vibration	fifth overtone
Type of holder	RW-43 or RW-42

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 1 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 20 \times 10^{-6}$
Level of drive	0,5 mW
Motional capacitance C_1	typ. 0,5 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	
50 to 90 MHz	max. 60 Ω
90 to 125 MHz	max. 80 Ω
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table
Maximum permissible d.c. voltage between terminations	100 V
Aging	within adjustment tolerance

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

Table Frequency tolerance in different temperature ranges with respect to + 25 °C

temperature range °C	frequency tolerance		
	class 0	class I	class II
−5/+ 50	$\pm 5 \times 10^{-6}$	$\pm 7{,}5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$
−10/+ 60	$\pm 7{,}5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$	$\pm 15 \times 10^{-6}$
−20/+ 70	$\pm 10 \times 10^{-6}$	$\pm 13 \times 10^{-6}$	$\pm 20 \times 10^{-6}$
−55/+ 105	$\pm 25 \times 10^{-6}$	$\pm 30 \times 10^{-6}$	$\pm 40 \times 10^{-6}$
$T_{nom} \pm 5$	$\pm 5 \times 10^{-6}$		

QUARTZ CRYSTAL UNIT

QUICK REFERENCE DATA

Frequency range	50 to 125 MHz
Mode of vibration	fifth overtone
Type of holder	RW-36

MECHANICAL DATA

Outlines See general section (A) "Holders".

Mass 4 g

ELECTRICAL DATA

Adjustment tolerance at + 25 °C	$\pm 20 \times 10^{-6}$
Level of drive	0,5 mW
Motional capacitance C_1	typ. 0,5 fF
Parallel capacitance C_0	max. 7 pF
Resonance resistance R_1	20 to 100 Ω
Frequency tolerance in different temperature ranges with respect to + 25 °C	see Table
Maximum permissible d.c. voltage between terminations	100 V
Aging	within the adjustment tolerance

TESTS

Mechanical and climatic tests according to MIL and IEC procedures.

Table Frequency tolerance in different temperature ranges with respect to + 25 °C

temperature range °C	frequency tolerance		
	class 0	class i	class ii
−5/+ 50	$\pm 5 \times 10^{-6}$	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$
−10/+ 60	$\pm 7,5 \times 10^{-6}$	$\pm 10 \times 10^{-6}$	$\pm 15 \times 10^{-6}$
−20/+ 70	$\pm 10 \times 10^{-6}$	$\pm 13 \times 10^{-6}$	$\pm 20 \times 10^{-6}$
−55/+ 105	$\pm 25 \times 10^{-6}$	$\pm 30 \times 10^{-6}$	$\pm 40 \times 10^{-6}$
$T_{nom} \pm 5$		$\pm 5 \times 10^{-6}$	

TEMPERATURE COMPENSATED CRYSTAL OSCILLATORS D

Survey of types	D2
Data sheets	D3

SURVEY OF TYPES

frequency range MHz	temperature range °C	frequency tolerance x 10^{-6}	supply voltage 12 V ± . . %	adjustable with external trimmer	basic catalogue number
4,5 to 15	0 to + 50	± 1	20	no	4322 190
	−10 to + 60	± 1,5	20		
	−20 to + 70	± 2	20		
4,5 to 15	0 to + 50	± 1	20	yes	4322 191
	−10 to + 60	± 1,5	20		
	−20 to + 70	± 2	20		
20 to 50	0 to + 50	± 1	2	yes	4322 195
	−20 to + 70	± 2	2		
	0 to + 50	± 2	10		
	−20 to + 70	± 3	10		

TEMPERATURE COMPENSATED CRYSTAL OSCILLATOR

QUICK REFERENCE DATA

Frequency range	4,5 - 15 MHz *
Frequency tolerance	
0 to + 50 °C	± 1 x 10^{-6}
−10 to + 60 °C	± 1,5 x 10^{-6}
−20 to + 70 °C	± 2 x 10^{-6}
Aging	± 1 x 10^{-6} per year
Correction on aging (fixed step)	typ. −2 x 10^{-6}

APPLICATION

Temperature compensated crystal oscillators (TCXOs) are used in mobilophones, electronic timing devices, measuring equipment, synthesizers, etc.

DESCRIPTION

A TCXO module comprises a quartz crystal oscillator, and a thermally controlled circuit that compensates for frequency changes over the whole temperature range. The metal housing is filled with dry nitrogen and hermetically sealed. The unit is provided with 5 connecting pins which are arranged to fit printed-wiring boards with a grid pitch of 2,54 mm (see Fig. 1).

MECHANICAL DATA

Dimensions (mm) and terminal location

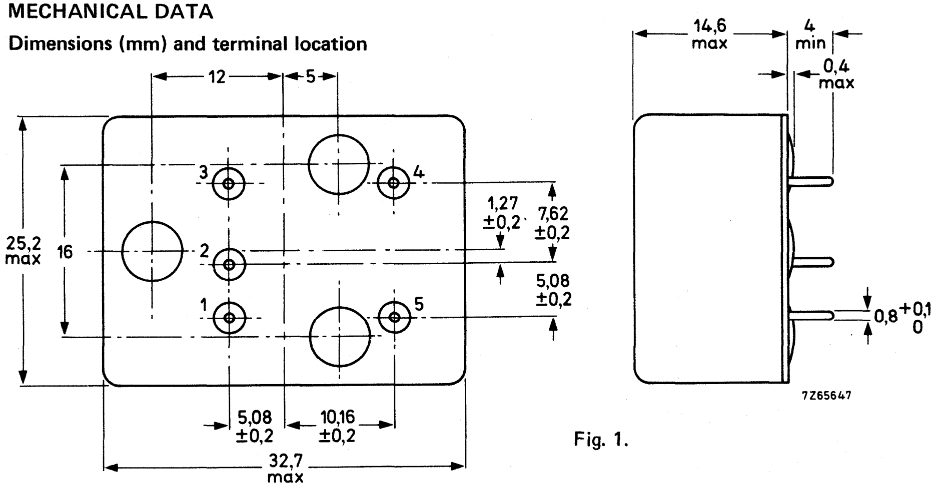


Fig. 1.

* A 5 MHz TCXO can be ordered under catalogue number 4322 190 00010;
an 8 MHz TCXO can be ordered under catalogue number 4322 190 00020;
a 10 MHz TCXO can be ordered under catalogue number 4322 190 00000.
TCXOs with other frequencies can be ordered under number 4322 190 stating the required frequency.

Mass

25 g approximately

Marking

The units are provided with a label showing the following information:

TCXO	Type 4322 190
Frequency	MHz
Δf 25 °C	Hz
Range	°C
No.	

ELECTRICAL DATA

Supply voltage, V_s	+ 12 V ± 10% via R_1 = 470 Ω (see Fig. 2) + 12 V ± 20% via R_1 = 330 Ω
Power consumption	max. 200 mW
Frequency range	4,5 - 15 MHz
Frequency tolerance at specified V_s, Z_L, and at a temp. rate of max. 1 °C/min.	
0 to + 50 °C	$\pm 1 \times 10^{-6}$
−10 to + 60 °C	$\pm 1{,}5 \times 10^{-6}$
−20 to + 70 °C	$\pm 2 \times 10^{-6}$
Aging	$\pm 1 \times 10^{-6}$ per year
Correction on aging influence by connecting pin 3 to pin 2	$-2\,^{+1}_{-0{,}5} \times 10^{-6}$
Internal resistance, R_i	2800 Ω ± 5%
Internal capacitance, C_i	5,5 pF ± 5%
Internal voltage source, V_i	600 mV ± 40%
Load impedance, Z_L	min. 500 Ω
Output voltage, V_o	see Figs 3 and 4
Storage temperature range	−40 to + 85 °C

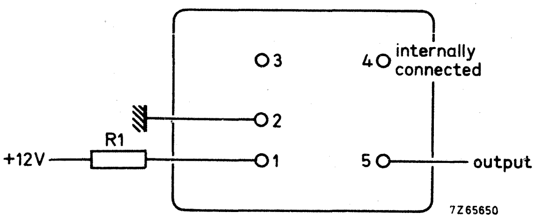


Fig. 2 Connection diagram.

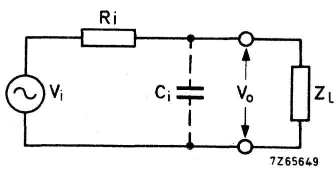


Fig. 3 Equivalent circuit.

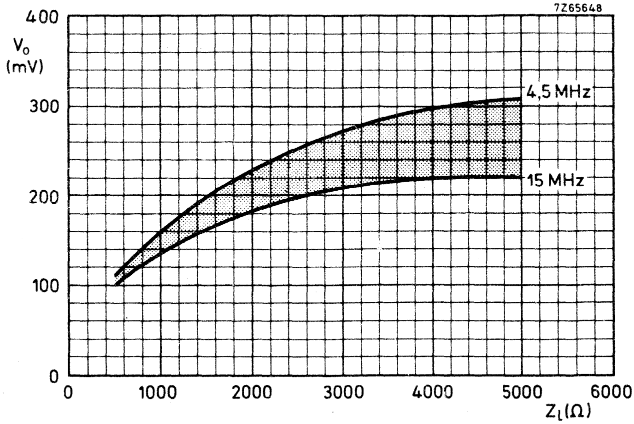


Fig. 4 Output voltage as a function of load impedance (typical values).

ENVIRONMENTAL TESTS AND REQUIREMENTS

IEC 68-2 test method	test	procedure	requirements
Ea	shock	50g, 1 x, in 6 directions	$\Delta f/f$ max. 5×10^{-7}
F	vibration	10 to 500 Hz, 10g, in 3 directions, 30 min per direction	$\Delta f/f$ max. 5×10^{-7}
T	soldering		
D	climatic		$\Delta f/f$ max. 5×10^{-7}

Note

Other specifications for TCXOs with respect to temperature range and for frequency tolerance can be made available on request.

TEMPERATURE COMPENSATED CRYSTAL OSCILLATOR

QUICK REFERENCE DATA

Frequency range	4,5 to 15 MHz *
Frequency tolerances	
0 to + 50 °C	$\pm 1 \times 10^{-6}$
−10 to + 60 °C	$\pm 1{,}5 \times 10^{-6}$
−20 to + 70 °C	$\pm 2 \times 10^{-6}$
Aging	$\pm 1 \times 10^{-6}$ per year
Frequency adjustable with external trimmer	

APPLICATION

Temperature compensated crystal oscillators (TCXOs) are used in mobilophones, electronic timing devices, measuring equipment, synthesizers, etc.

DESCRIPTION

A TCXO module comprises a quartz crystal oscillator, and a thermally controlled circuit that compensates for frequency changes over the whole temperature range. The metal housing is filled with dry nitrogen and hermetically sealed. The unit is provided with 5 connecting pins which are arranged to fit printed-wiring boards with a grid pitch of 2,54 mm (see Fig. 1).

MECHANICAL DATA

Dimensions (mm) and terminal location

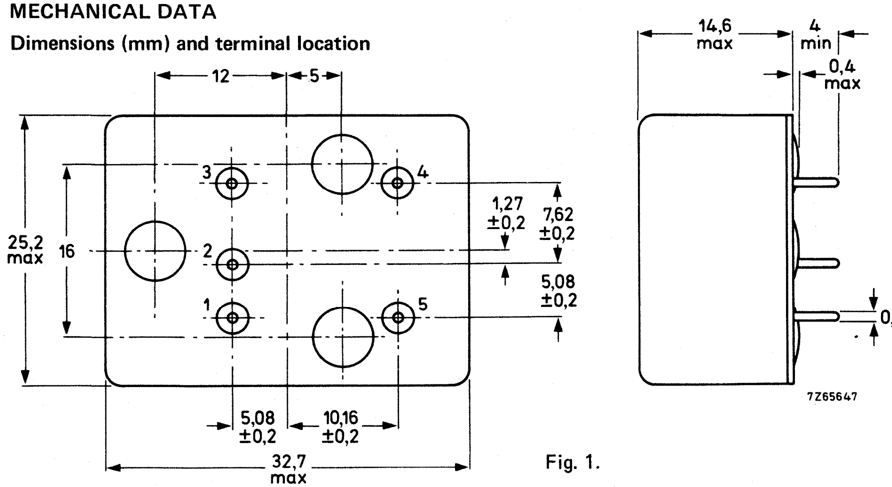


Fig. 1.

* A 5 MHz TCXO can be ordered under catalogue number 4322 191 00011;
an 8 MHz TCXO can be ordered under catalogue number 4322 191 00021;
a 10 MHz TCXO can be ordered under catalogue number 4322 191 00001.
TCXOs with other frequencies can be ordered under number 4322 191 stating the required frequency.

Mass

25 g approximately

Marking

The units are provided with a label showing the following information:

TCXO	Type 4322 191
Frequency	MHz
Δf 25 °C	Hz
Range	°C
No.	

ELECTRICAL DATA

Supply voltage, V_s	+ 12 V ± 10% via R_1 = 470 Ω (see Fig. 2) + 12 V ± 20% via R_1 = 330 Ω
Power consumption	max. 200 mW
Frequency range	4,5 - 15 MHz
Frequency tolerance after adjustment (see note), at specified V_s, Z_L, and at a temperature rate of max. 1 °C/min	
0 to + 50 °C	± 1 x 10^{-6}
−10 to + 60 °C	± 1,5 x 10^{-6}
−20 to + 70 °C	± 2 x 10^{-6}
Aging	± 1 x 10^{-6} per year
Correction on aging influence	± 2 x 10^{-6} (see note below)
Internal resistance, R_i	2800 Ω ± 5%
Internal capacitance, C_i	5,5 pF ± 5%
Internal voltage source, V_i	600 mV ± 40%
Load impedance, Z_L	min. 500 Ω
Output voltage, V_o	see Figs 3 and 4
Storage temperature range	−40 to + 85 °C

Note

It is not guaranteed that the nominal frequency occurs at room temperature. The nominal frequency can be shifted by connecting a variable capacitor of max. 60 pF externally between pin 2 and 3. For optimum stability over the whole temperature range the oscillator should be adjusted at room temperature to a frequency which deviates from the nominal one by an amount mentioned as "Δf 25 °C ... Hz" on the label on the module. After this adjustment a trimming range of ± min. 2 x 10^{-6} is still available to correct aging influences.

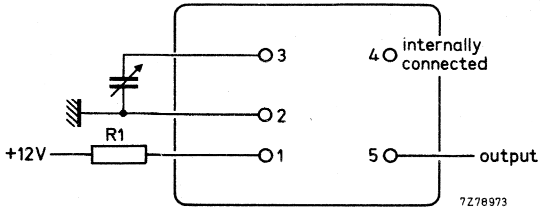


Fig. 2 Connection diagram.

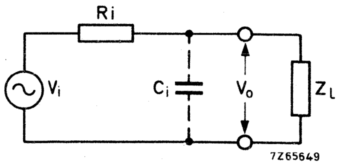


Fig. 3 Equivalent circuit.

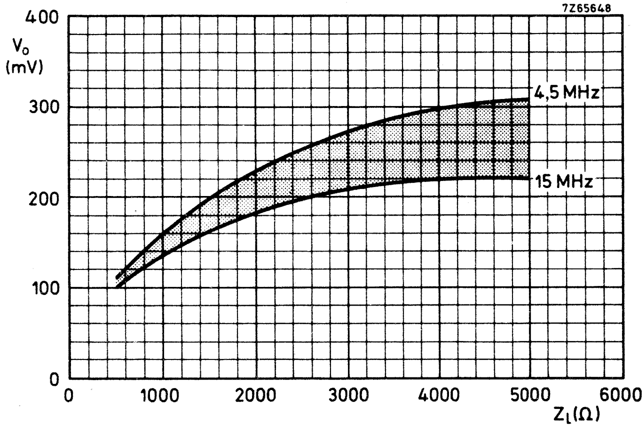


Fig. 4 Output voltage as a function of load impedance (typical values).

ENVIRONMENTAL TESTS AND REQUIREMENTS

IEC 68-2 test method	test	procedure	requirements
Ea	shock	50g, 1 x, in 6 directions	$\Delta f/f$ max. 5×10^{-7}
F	vibration	10 to 500 Hz, 10g, in 3 directions 30 min per direction	$\Delta f/f$ max. 5×10^{-7}
T	soldering		
D	climatic		$\Delta f/f$ max. 5×10^{-7}

Note

Other specifications for TCXOs with respect to temperature range and for frequency tolerance can be made available on request.

TEMPERATURE COMPENSATED CRYSTAL OSCILLATOR

QUICK REFERENCE DATA

Frequency range	20 to 50 MHz	
Supply voltage	12 V ± 2%	12 V ± 10%
Frequency tolerance		
0 to + 50 °C	$\pm 1 \times 10^{-6}$	$\pm 2 \times 10^{-6}$
−20 to + 70 °C	$\pm 2 \times 10^{-6}$	$\pm 3 \times 10^{-6}$
Aging	$\pm 1 \times 10^{-6}$ per year	
Frequency is adjustable with external trimmer		

APPLICATION

Temperature compensated crystal oscillators (TCXOs) are used in mobilophones, electronic timing devices, measuring equipment, synthesizers, etc.

DESCRIPTION

A TCXO module comprises a quartz crystal oscillator, and a thermally controlled circuit that compensates for frequency changes over the whole temperature range. The metal housing is filled with dry nitrogen and hermetically sealed. The unit is provided with 5 connecting pins which are arranged to fit printed-wiring boards with a grid pitch of 2,54 mm (see Fig. 1).

MECHANICAL DATA

Dimensions (mm) and terminal location

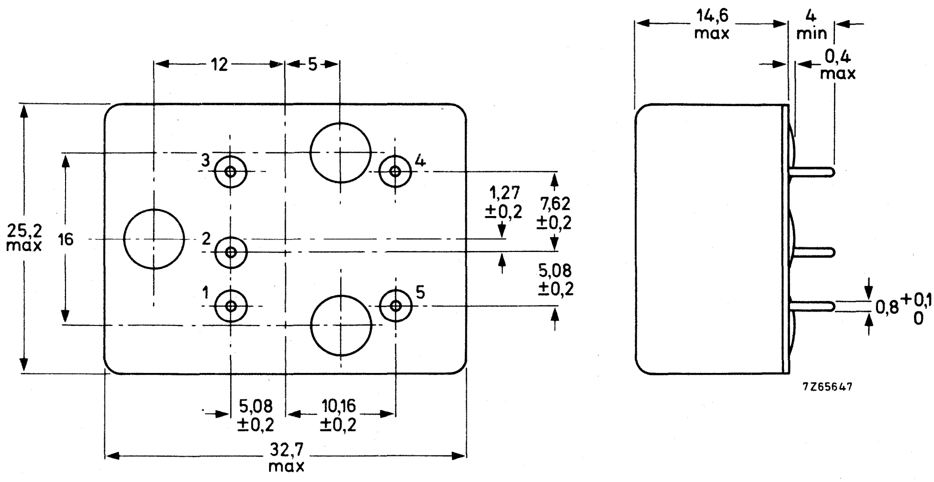


Fig. 1.

Mass

25 g approximately

Marking

The units are provided with a label showing the following information:

TCXO	Type 4322 195
Frequency	MHz
Δf 25 °C	Hz
Range	°C
No.	

ELECTRICAL DATA

Supply voltage, V_s	+ 12 V ± max. 10% via R_1 = 390 Ω, see Fig. 2
Power consumption	typ. 160 mW, max. 180 mW
Frequency range	20 to 50 MHz
Frequency tolerance after adjustment (see note), at specified V_s, Z_L, and at a temperature rate of 1 °C/min	see Fig. 4
Aging	± 1 x 10^{-6} per year
Correction on aging influence	± > 2 x 10^{-6}, see note
Internal resistance, R_i	2800 Ω ± 5%
Internal capacitance, C_i	5,5 pF ± 5%
Internal voltage source, V_i	600 mV ± 40%
Load impedance, Z_L	min. 500 Ω
Output voltage, V_o	see Fig. 5
Storage temperature range	−40 to + 85 °C

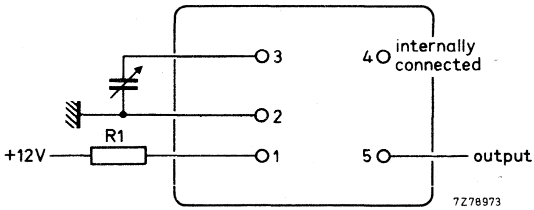


Fig. 2 Connection diagram.

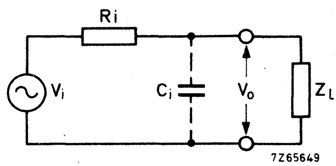


Fig. 3 Equivalent circuit.

Note

It is not guaranteed that the nominal frequency occurs at room temperature. The nominal frequency can be shifted by connecting a variable capacitor of max. 20 pF externally between pins 2 and 3. For optimum stability over the whole temperature range the oscillator should be adjusted at room temperature to a frequency which deviates from the nominal one by an amount mentioned as "Δf 25 °C ... Hz" on the label on the module. After this adjustment a trimming range of ± min. 2 x 10^{-6} is still available to correct aging influences.

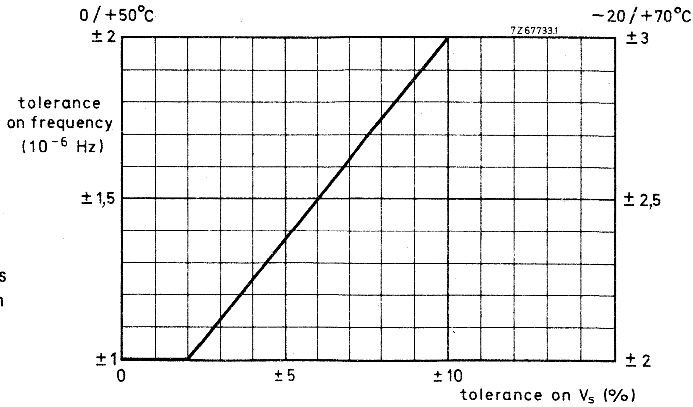


Fig. 4 Frequency tolerance as a function of the tolerance on supply voltage.

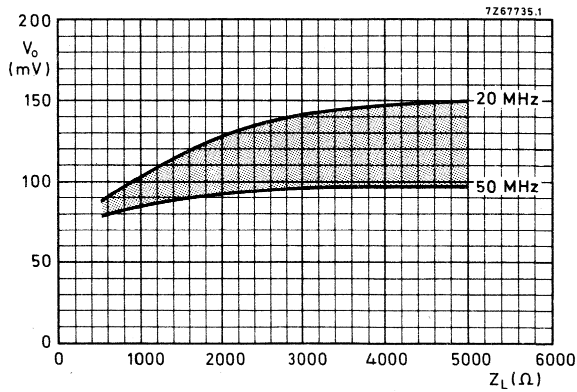


Fig. 5 Output voltage as a function of load impedance (typical values).

ENVIRONMENTAL TESTS AND REQUIREMENTS

IEC 68-2 test method	test	procedure	requirements
Ea	shock	50g, 1 x, in 6 directions	$\Delta f/f$ max. 5×10^{-7}
F	vibration	10 to 500 Hz, 10g, in 3 directions, 30 min per direction	$\Delta f/f$ max. 5×10^{-7}
T	soldering		
D	climatic		$\Delta f/f$ max. 5×10^{-7}

Note

Other TCXO specifications concerning supply voltage, temperature range and frequency tolerance can be made available on request.

PIEZOELECTRIC QUARTZ DEVICES

A QUARTZ CRYSTAL UNITS GENERAL

B QUARTZ CRYSTAL UNITS FOR SPECIAL APPLICATIONS

C QUARTZ CRYSTAL UNITS FOR GENERAL FREQUENCY STABILIZATION

D TEMPERATURE COMPENSATED CRYSTAL OSCILLATORS

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Australia: PHILIPS INDUSTRIES HOLDINGS LTD., Elcoma Division, 67 Mars Road, LANE COVE, 2066, N.S.W., Tel. 427 08 88.
Austria: ÖSTERREICHISCHE PHILIPS BAUELEMENTE Industrie G.m.b.H., Triester Str. 64, A-1101 WIEN, Tel. 62 91 11.
Belgium: M.B.L.E., 80, rue des Deux Gares, B-1070 BRUXELLES, Tel. 523 00 00.
Brazil: IBRAPE, Caixa Postal 7383, Av. Brigadeiro Fari Alima, 1735 SAO PAULO, SP, Tel. (011) 211-2600.
Canada: PHILIPS ELECTRONICS LTD., Electron Devices Div., 601 Milner Ave., SCARBOROUGH, Ontario, M1B 1M8, Tel. 292-5161.
Chile: PHILIPS CHILENA S.A., Av. Santa Maria 0760, SANTIAGO, Tel. 39-40 01.
Colombia: SADAPE S.A., P.O. Box 9805, Calle 13, No. 51 + 39, BOGOTA D.E. 1., Tel. 600 600.
Denmark: MINIWATT A/S, Emdrupvej 115A, DK-2400 KØBENHAVN NV., Tel. (01) 69 16 22.
Finland: OY PHILIPS AB, Elcoma Division, Kaivokatu 8, SF-00100 HELSINKI 10, Tel. 1 72 71.
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