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Quartz Crystal Theory

1. Technical Introduction

In their investigations, the brothers Pierre & Jacques Curie found that electrical charges were produced by mechanical stresses applied to various naturally occuring crystals. This phenomenon is called the “piezo-electric effect”, being derived from the Greek word “to press”.

Conversely it was found that the crystal was deformed by the application of an electrical charge, later the application of an alternating electrical field introduced mechanical vibrations.

The quartz crystal behaves as an electrical resonance circuit with very low attenuation.

2. Quartz

Quartz was found to be one of the naturally occuring crystaline substance that exhibited the “piezo-electric effect” and being very stable, both chemically and mechanically, it became of great interest to the early electronic experimenters. The chemical description of quartz is Silicon dioxide SiO_2.

Although approximately 14% of the earth's crust consists of SiO_2, it occurs relatively infrequently in usable crystaline form with the necessary purity and without physical defects, cracks etc. Raw quartz of quality suitable for the production of quartz crystal units is found in Brazil and Madagascar.

For this reason continuous attempts have been made to produce quartz synthetically; that is to grow by recrystalisation on to quartz seed plates. These processes are now commercially successful.

Quartz chippings are dissolved in an alkaline solution in steel autoclaves at approximately 400° C and a pressure of 10.000 N/cm^2, the desired direction of growth is ensured by the careful preorientation of the quartz seed plates.

The growth rate is normally approximately 1 mm/day. Slow growth-rates result in a more homogeneous material since fewer foreign atoms are being incorporated into the crystal lattice.

Synthetic quartz is now grown in suitable length ad cross sections to enable the subsequent processing steps to be carried out in the most efficient way, with minimum cutting losses. Grades available today are of very high purity and mechanical quality, so that synthetic quartz is used almost exclusively for the production of quartz crystal units.

3. AT-cut

Its outstanding physical properties have made the AT-cut the most used cut for oscillator crystal production.

The position of the AT-cut relative to the crystal axis can be seen from the marginal schematic presentation of a half quartz crystal (fig. 1).

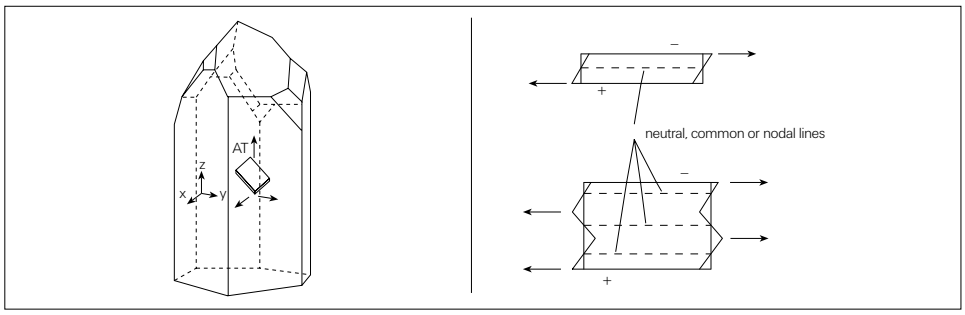


Fig. 1

AT-cut crystals are thickness shear vibrators. The crystal vibrator is usually a round disc. The thickness (d) of the disc is related to the fundamental mode frequency f by the equation:

$$f\,[kHz] = \frac{N}{d\,[mm]}$$

The constant for the AT-cut is N=1660 kHz·mm.

The crystal vibrator has thin metal electrodes deposited on both sides by evaporation, these electrodes are the means whereby the alternating electric field is applied thus stimulating the mechanical oscillation.

With overtone oscillation, only oddnumbered harmonics can be generated, as can be seen from the polarity diagram (fig. 2). With an even-numbered overtone, the electrodes would show identical polarity and consequently no electric field will develop for the stimulation of mechanical oscillation .

Normal overtone oscillations are the 3rd, 5th, 7th and 9th, the upper harmonic oscillation is not exactly an integral multiple of the crystal fundamental frequency but can differ from this up to some percents.

The principal advantage of AT-cut over other cuts is the low frequency sensitivity to change in temperature, it follows a 3rd degree curve, a so-called "cubical parabola" with an inflection point which lies between 25° and 35° C depending on the actual cut angle and mechanical construction.

$$\frac{\Delta f}{f} = A_t \cdot (T - T_{ref}) + A_2 \cdot (T - T_{ref})^2 + A_3 \cdot (T - T_{ref})^3$$

This equation can be reduced, if one refers to the inflection point temperature T_{inv} instead of the initial temperature T_{ref}.

$$\frac{\Delta f}{f} = a_1 \cdot (T - T_{inv}) + a_3 \cdot (T - T_{inv})^3$$

whereby $a_3 = 1{,}05 \cdot 10^{-4}$

$a_1 = 0{,}0085 \cdot \Delta\varphi$

$\Delta\varphi = \varphi_{zz} - \varphi$ oscillation in one-sixtieth of one angular degree

$\frac{\Delta f}{f}$ in ppm [$=10^{-6}$] and temperatures in °C

The steepness at the inversion point depends on the angle of cut is the difference in cut angle between the so-caled zero angle where the T.K. curve has a horizontal tangent at the inflection point.

By the choice of the appropriate cutting angle, two inversion points appear in the T.K. curve, a maximum below 25°C and a minimum above this temperature. At each of these inversion points the temperature gradient is zero.

This property is, at the upper inversion point, utilised where crystals are operating in a thermostatically controlled environment (oven), judicious choice of the cutting angle will cause the zero temperature gradient point to coincide with the thermostat temperature, thus the thermostat or oven temperature must be clearly sated when ordering crystals for this particular use.

From fig. 3 it can be seen that symetrical ranges of temperature with respect to the inflection point, e.g. -20°C to +70°C or 0° to +50° C are meaning full. A one-sided limitation, such as e.g. at 0° to 70° C means no relief for the manufactured in general, due to the symetry of the curves the suggested tolerance – in our case down to -20°C – is only observed with opposite (plus or minus) signs.

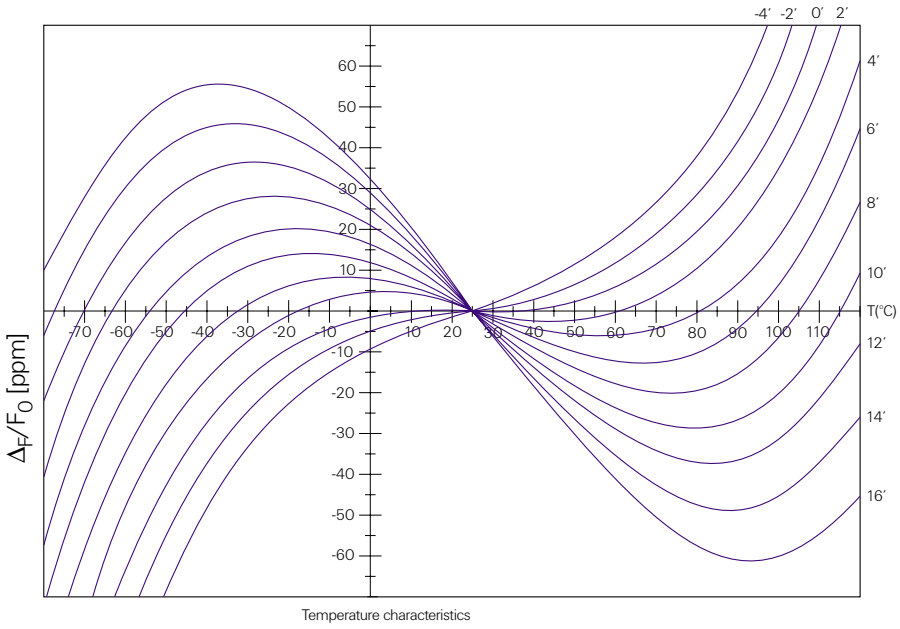


Fig.3

Temperature characteristics

Cutting angles of approximately 10 arc seconds can be accurately maintained, however other mechanical effects can influence the variation of frequency over the temperature range, thus technical as well as physical limitations are imposed on minimizing the temperature coefficient.

For the determination of the frequency temperature coefficient it is sufficient – for simple requirements – to measure the frequencies at three temperatures. For higher accuracy, five measuring points or more may be necessary. By means of these, the best adapted cubical parabola is applied and the appropriate coefficients a_1, and a_3 determined.

A correctly designed resonator should produce a smooth curve for its temperature coefficient with the value of a_3 within ±20 of the value indicated above.

4. Encapsulation, resistance welding technique

The quartz vibrator is mounted in a lowloss holder system (fig. 4a) in order to obtain high Q.

Electrical energy is applied to the resonator via the mounting and the thin, evaporated electrodes.

For higher mechanical demands, in particular shock and vibration resistance, special installation styles with three or four point fixing have been developed (fig.4)

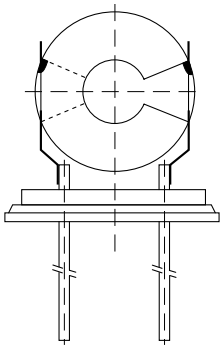


Fig.4a

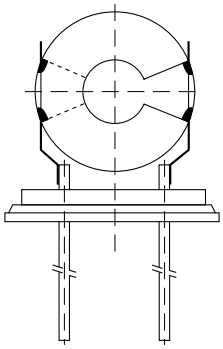


Fig.4b

The quartz vibrator is protected from outside influences in a hermetically sealed casing, either filled with protective gas. A pre-condition for a low ageing rate is a maximum cleanliness of the protective gas and the inner housing, as well as an impeccable hermetic seal. For that reason, sealing technique is of the utmost importance.

A technically simple type of sealing is by soldering together the housing can and base, however when soldering, fluxing agents and other gases released by the heating reach the inner casing and deteriorate the ageing characteristics of the crystal. This technique is therefore seldom used today.

A type of sealing not subject to these disadvantates is called resistance welding. In this case, can and base are pressed together and welded by means of a current impulse.

5. Equivalent circuit and motional parameters

The electrical properties of the oscillator crystal as a function of the frequency can be depicted in the vicinity of the resonance frequency by an equivalent circuit diagram (fig. 5a).(compare IEC-Public. 122–2).

The oscillating mass is symbolized by the dynamic inductance L_1 , whereas the elasticity is represented by the dynamic capacitance C_1.

Overtone resonance, as well as spurious resonances can be depicted by additional, parallel connected series resonance circuits.

At higher frequencies (above 100 MHz), a parallel conductance value G_0 may be required for modelling the behavoir. The insulation resistance is also modelled in this. The insulation resistance may be impaired by the following influences:

1. Fine leak of the glass feedthrough due to insufficient glass quality.
2. Long-term effect: trough the migration of electrode material (silver) along so-called etching channels which can form due to non-homogenities in the crystal growth. This migration can only occur when a DC voltage is applied between the crystal pins over an extended period (several years) and has so far only been observed occasionally. The insulation resistance can collapse down to a few kΩ. the result of this is that the DC operating point of the capacitance diode connected to the crystal is displaced in VCXO circuits, which in turn leads to a greater frequency shift occurring.

It is therefore recommended to operate quartz crystals free of DC voltage by connecting a blocking capacitor (a few nF) in series to the crystal unit.

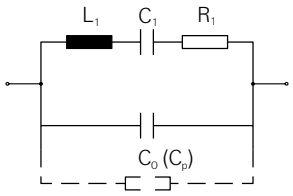


Fig.5a

In addition, a parallel capacitance C_p which differs from the static capacitance C_0 measurable at low frequencies acts at high frequencies owing to the influences of the lead and leakage reactances.

The value of the dynamic capacitance C_1 is very small in comparison with capacitances normally found in oscillating circuits in telecommunications and is calculated for a plano parallel quartz disc as follows:

$$C_1\,[F] = 0{,}1 \cdot k_c d_{el}^2 \left[mm^2\right] \cdot \frac{f_s\,[MHz]}{n^3}$$

f_s = resonance frequency
d_{el} = electrode diameter
n = ordinal number of the harmonics (1,3,5)
k_c = correction constant
k = 1 for fundamental oscillation
k = 0.85 for 3rd overtone
k = 0.75 for 5th and higher overtones

With a given resonance frequency it can be seen that the C_1 can be varied by changing the electrode diameter, this variation is limited by the actual diameter of the quartz vibrator.

For frequences lower than 1.8 MHz in enclosures HC-48/U, and HC-51/U, also below 4.3 MHz for enclosures HC-50/U and HC-49/U and also below 8 MHz in enclosure HC-52/U, it is no longer practicable tu use a plano parallel resonator as the losses introduced by the mounting system become intolerable.

In these cases by using the grinding techniques of the optical industry either plano-convex or bi-convex resonators are employed.

This technique substancially reduces the values of C_1 (the dynamic capacitance) that are obtained when using a plano parallel resonator.

This is the reason for the non-linearity of the C_1 graph shown on our data sheets for fundamental resonators in these holder styles.

For fundamental frequencies above 20 MHz, the value of C_1 is limited by the unacceptable increase in superious resonances if the value of C_1 is increased above 35 fF.

L_1 and C_1 are related by Thomson's formula:

$$L_1 = \frac{1}{\omega_s^{\,2} C_1}$$

The dynamic resistance of the crystal unit R_1 represents the mechanical losses due to molecular friction within the resonator plus the damping induced by the mounting system and the accoustical damping of the gasfilled housing.

The static capacitance C_0 represents the capacitance between the evaporated electrodes using the quartz resonator material as the dielectric.

$$C_{0q}\,[pF] = 0.02 \cdot d_{el}^{\,2}\left[mm^2\right] \cdot \frac{f_s\,[MHz]}{n}$$

Thus the capacitances of the mounting system and the casing have to be added (0.5 pF to 2 pF), which leads to a new equivalent circuit (as shown in fig. 5b).

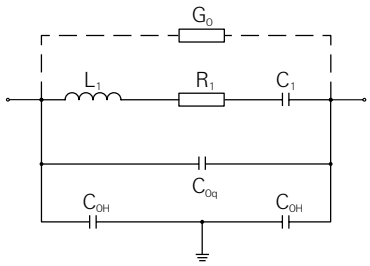


Fig.5b

Depending on the particular enclosure type C_0 normally lies between 1 pF and 9 pF, oscillator crystals are normally designed with C_0 less than 7 pF.

Its value can be influenced by an appropriate electrode diameter.

For exact measurement of C_1 it is essential to indicate if the measurement must be made with the crystal housing grounded or not. Likewise the frequency at which the measurement of C_0 is performed must be off the resonance frequency of the crystal to be measured (usually 1 MHz). Measurement near to the resonance frequency indicates the parallel capacitance C_p which may differ from C_0, particularly at high frequencies.

The quality Q of the quartz crystal units is specified as

$$Q = \frac{2\pi f_s L_1}{R_1} = \frac{1}{2\pi f_s R_1 C_1}$$

In fig. 6, the curve of the reactance of a lossless crystal resonator is shown.

There are 2 resonance frequencies, the series resonance frequency f_s and the resonance frequency f_s.

$$f_s = \frac{1}{2\pi\sqrt{L_1 C_1}} \qquad f_p = \frac{1}{2\pi\sqrt{L_1 \frac{C_1 \cdot C_0}{C_1 + C_0}}} = f_s\sqrt{1+\frac{C_1}{C_0}}$$

The series and parallel resonance frequencies are related by the formula

$$\frac{f_p - f_s}{f_s} \approx \frac{1}{2} \cdot \frac{C_1}{C_0}$$

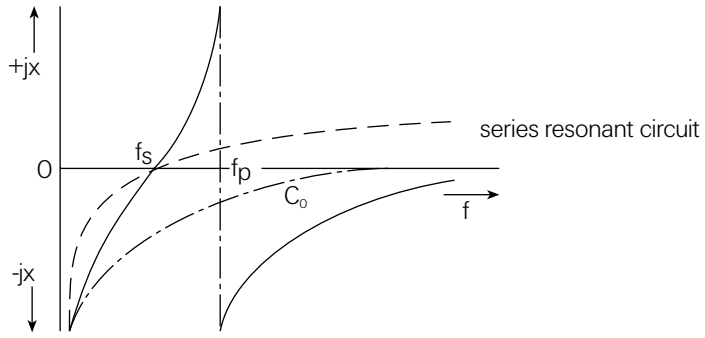


Fig.6

However, for a "lossy" crystal the dynamic branch of the equivalent circuit compries L_1,C_1 and R_1 which are in parallel with C_0. Thus the impedance of this combination is only real at the resonance frequency f_r above f_s.

Furthermore the complex impedance is given by:

$$Z_S = \frac{R_1 \cdot jX_0}{R_1 + jX_0}, \quad \text{with} \quad X_0 = \frac{-1}{\omega C_0}$$

$$Z_S = \frac{R_1 \cdot X_0^{\,2}}{R_1^{\,2} + X_0^{\,2}} + j\frac{R_1^{\,2} \cdot X_0}{R_1^{\,2} + X_0^{\,2}}$$

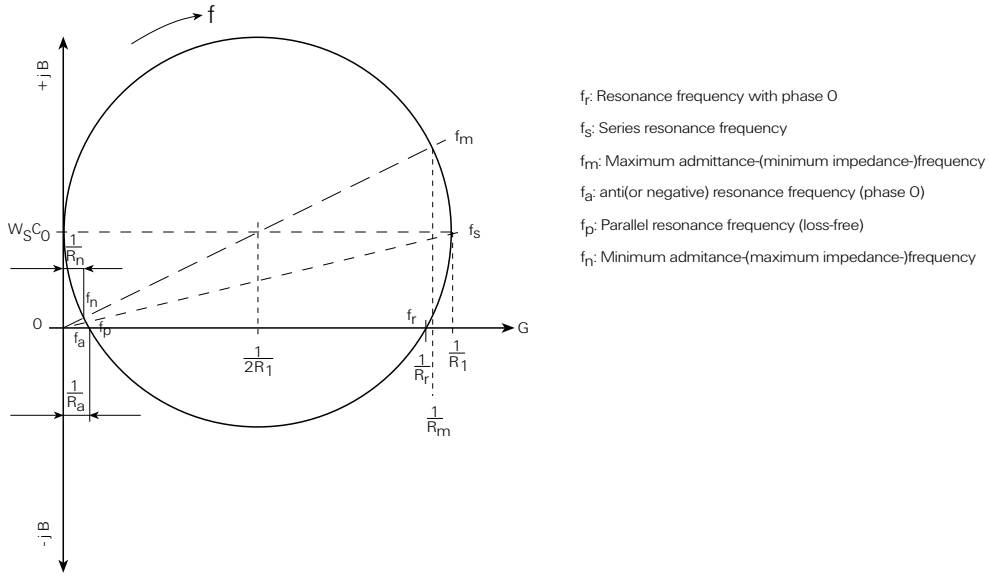
The phase angle at the series resonant frequency f_s is given by

$$\omega = \arctan\left(\frac{R_1}{X_0}\right) = \arctan\left(-R_1\omega C_0\right) = -\arctan\left(R_1\omega C_0\right)$$

The series resonant frequency of L_1 and C_1 is not the only frequency of the quartz crystal, as can be seen from the polar diagram (fig. 7) representing the admittance of the circuit.

The most important frequency for practical application is the resonance frequency f_r at phase 0. The measurement technique in accordance with IEC 444 also refers to this frequency. The frequencies f_a,f_p and f_n lying at the high-impedance end of the circle cannot be excited in oscillators.

The centre of the circle is defined by the angle $\varphi_m=\arctan(2R_1\omega C_0)$ and its distance from the real axis given by $B_0=\omega C_0$.



f_r: Resonance frequency with phase 0

f_s: Series resonance frequency

f_m: Maximum admittance-(minimum impedance-)frequency

f_a: anti(or negative) resonance frequency (phase 0)

f_p: Parallel resonance frequency (loss-free)

f_n: Minimum admitance-(maximum impedance-)frequency

Fig.7

With increasing frequency the angle between the centre of the circle and the G-axis increases, thus the frequency differences between f_r, f_s and f_m also increase. Likewise the resistance R_r at zero phase also increases in comparison with R_1. The so-called figure of merit

$$M=\frac{1}{\omega C_0 R_1}$$

shows on the diagram as the difference between fr and fs (or R_r and R_1).

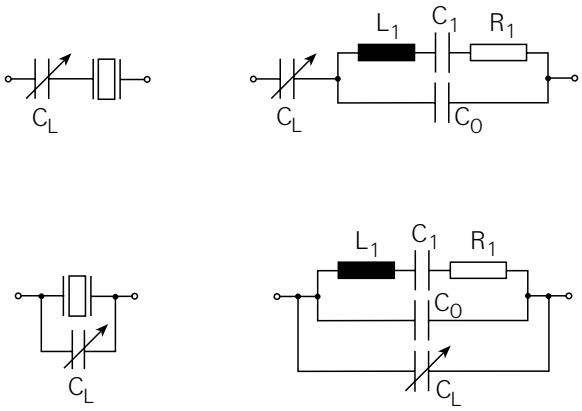
At frequencies above 120 MHz, M can become smaller than 2, so that the locus no longer cuts the G-axis, thus f_r disappears and is no longer seal.

6. Quartz crystal with load capacitance C_L

Fundamental mode quartz crystals are normally operated with a load capacitance, which allows the circuit capacitance variations to be compensated.

The load capacitance is normally in series or parallel (fig. 8) with the resonator and this causes it to oscillate at a new frequency, which sometimes is called "parallel resonance frequency", even though the load resonance frequency f_L should always lie far nearer the resonance frequency f_r (or f_s) than the parallel resonance frequency f_p and the load resonance resistance R_L which acts in this case is only slightly than R_r (or R_1) and far lower than R_p.

Overtone crystals in application without frequency modulation and FSK (Frequency Shift Keying) are often used at (series) resonance without load capacitance as the circuit normally contains a tuned (LC) circuit and the necessary compensation can be achieved by slightly detuning this element.



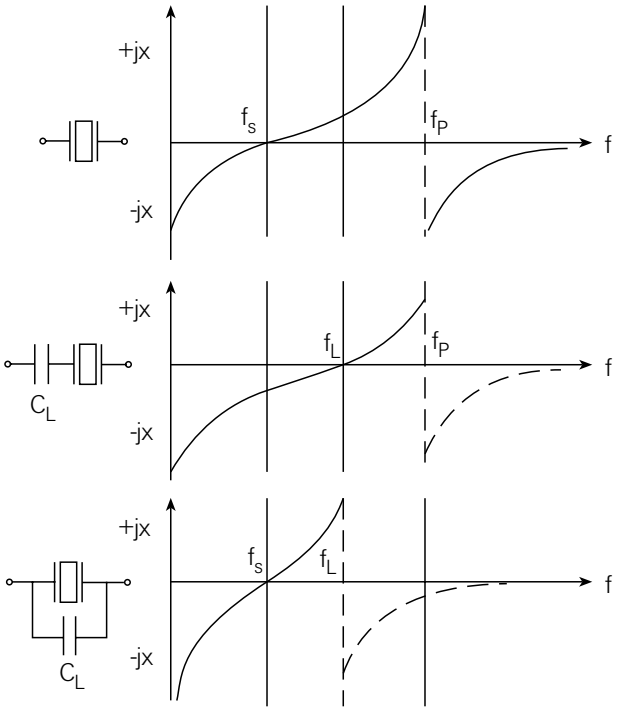


Fig.8

Fig.9

In fig. 9 we show the reactance curves for a quartz crystal, then with a load capacitance in series and then in parallel with quartz resonator.

$$f_L = f_s \cdot \sqrt{1+\frac{C_1}{C_0+C_1}} \approx f_s\left(1+\frac{C_1}{2(C_0+C_L)}\right)$$

In the two latter cases it can be seen that a new frequency is produced.

It can be seen that the difference between f_s and f_L is the same whether the capacitance is placed in series or in parallel with the crystal unit. The resistance R_L with series load capacitor is naturally higher than R_1.

$$R_L = R_1\left(1+\frac{C_0}{C_L}\right)^2$$

If one defines the difference in frequency between f_L and f_s as load resonance frequency offset D_L, then we have

$$D_L = \frac{f_L - f_S}{f} \approx \frac{C_1}{2\cdot(C_0 + C_L)}$$

The pulling range of the element is defined as the change in frequency produced by changing the load capacity from one value to another (e.g. from maximum to minimum of a trimmer capacitor):

$$D_{L_1,L_2} = \frac{f_{L_1} - f_{L_2}}{f} = \frac{C_1\,(C_{L_2} - C_{L_1})}{2\cdot(C_0 + C_{L_1})\cdot(C_0 + C_{L_2})}$$

Finally, we can define pulling sensitivity S as the frequency change in parts per million per pF change in the load capacitance:

$$S = \frac{1}{f_r}\cdot\frac{df_L}{dC_L} \approx -\frac{C_1}{2\,(C_0 + C_L)^2}$$

From the above formulae we can deduce:

With low value load capacitances, the change/pF would make S very large and thus the practical minimum value lies in the range between 8 and 10 pF.

Conversely, with high load capacitances the pulling sensitivity is very small, so probably 100 pF represents, approximately, the upper limit.

The pulling sensitivity of the crystal unit can be considerably increased if the C_0 is compensated (see fig. 10).

The formula for compensation is:

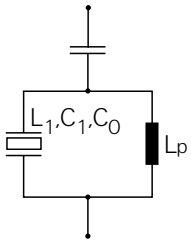
$$L_p = \frac{1}{\omega_r^{\,2} C_0}$$

Which gives us:

$$f_L = f_S\sqrt{1+\frac{C_1}{C_L}} \approx f\cdot\left(1+\frac{C_1}{2\cdot C_L}\right)$$

Thus the pulling range between the two values C_{L1}, and C_{L2} becomes

$$D_{L_1,L_2} \approx C_1\frac{(C_{L_2} - C_{L_1})}{2\cdot C_{L_1}\cdot C_{L_2}}$$



and the pulling sensitivity is

$$S = -\frac{C_1}{2 \cdot C_L^{\,2}}$$

There is another possibility to increase the pulling sensitivity and this is to replace the series load capacitor with a series tuned circuit comprising L_1, C_L when we have the new formula

$$f_L = f_S \left(1 + \frac{C_1}{2 \cdot \left(C_0 - \frac{1}{\omega_S^2 L_L - \frac{1}{C_L}} \right)} \right)$$

There is however a potential disadvantage to this method, the effective Q of the combination is dramatically reduced due to the relatively low Q of the inductance employed. Further more there is also an additional tuned circuit created, consisting of L_L, C_L and the C_0 of the quartz element, this potential parasitic frequency is not quartz controled.

In practice it is very important to determine accurately the load capacitance or input capacitance of the circuit into which the quartz crystal is to be introduced, as the pulling sensitivity at C_L=30 pF is about 10ppm/pF.

This load capacitance is defined during the manufacture of the quartz crystal and in its operational circuit comprises the sum of whatever actual capacitances form the oscillator network plus the stray capacitances of wireing and adjacent semiconductor elements, as well as the phase changes introduced by the latter which have an effect, however small.

The most simple way to determine the load capacitance suitable for a particular circuit is to measure an operational frequency in the middle of the pulling range with an available crystal of approximately the correct frequency. This frequency is then transferred to a passive measuring network in the factory and the operational frequency reproduced by variations of the load capacity in the network, which can then be accurately determined.

The current valid method of measuring load resonance frequencies is described in IEC 444-4.

7. Measurement of quartz crystal parameters

There are basically two methods, normally called either active or passive.

In the active method the crystal unit is used in an oscillator as the frequency determining unit. These oscillators have become know in the industry as 'test sets' and have been developed to cover specific frequency ranges. In a test set the quartz crystal oscillates largely independently of its resonance resistance and its other parameters, C_1, L_1 and C_0. The resonance resistance is determined by the substitution of an equivalent resistor to obtain the same output level from the oscillator.

The absolute measurement accuracy of a test set is generally considered to be between 10 and $15 \cdot 10^{-6}$.

However, with careful adjustment and measurement this can be reduced to be $5 \cdot 10^{-6}$ between different test sets.

Today however, adjustment tolerances often are as low as 5 or $10 \cdot 10^{-6}$ and this then precludes the use of 'test sets' for measurement purposes.

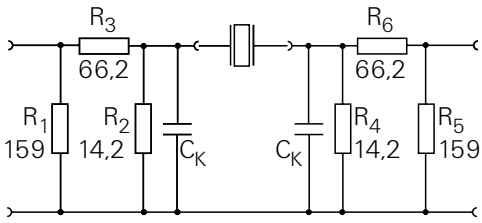
The passive or Pi-network method according to IEC-publication 444-1, which claims an accuracy of at least ten times better, is nowadays in general usage.

For this reason, the frequency must be determined to within an accuracy of approximately $5 \cdot 10^{-7}$.

This requirement is met with the passive measurement method in accordance with IEC 444. The classic method taken from IEC 444-1 IEC 444-4 is described below.

7.1 Passive measurement up to 125 MHz according to IEC 444–1 and 444–2

The crystal is in a double Pi-network as shown in fig. 11, which has the effect of isolating the crystal unit from the measuring devices.



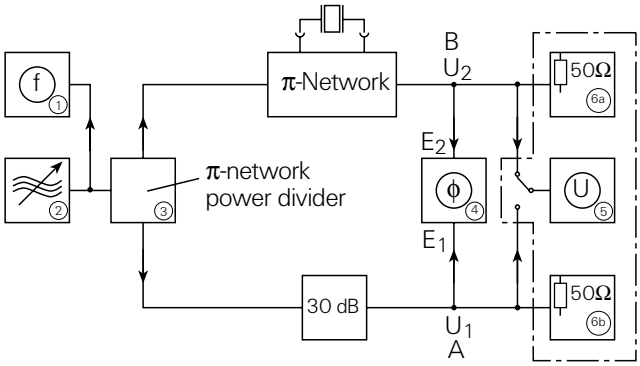


Fig.11 Fig.12

Seen from the crystal unit, the network impedance amounts to 12.5 ohms on both sides. It is therefore loaded with 25 ohms nominally.

Figure 12 shows the measuring arrangements. The frequency generator or synthesizer (2) is tuned in to the frequency required, which shows phase 0 between the points 'A' and 'B' measured with a vector-voltmeter or network analyzer (3).

The frequency is indicated by the frequency counter (1) and from the ratio of the voltages at points 'A' and 'B' we can calculate the resonance ressistance of the crystal. By variation of the generator output level the desired level of drive can be applied.

It is possible to partially automate this process, the frequency of the generator being controlled by either analogue or digital methods, whereby the phase of the generator is locked to the crystal by means of the phase proportional output voltage of (4).

8. Spurious resonances

All quartz crystals have spurious resonances (unwanted resonance responses) besides the main resonance frequency. They are represented in the equivalent circuit diagram (Fig. 5a-5b) by additional resonant circuits in parallel with R_1, L_1, C_1.

The ratio of spurious resonance resistance R_{NW} to resonance resistance R_r of the main wave is generally specified in the attenuation constant dB and is designated spurious attenuation a_{NW}:

$$a_{NW} = 20 \cdot \lg \frac{R_{NW}}{R_r}$$

For oscillator crystal 3 to 6 dB are normally sufficient. For filter crystals attenuations greater than 40 dB are often required. This can only be achieved by special design techniques and involves the use of very small values of the dynamic capacity C.

The achievable attenuation decreases with higher frequency and with higher orders of overtone. It is found generally that plano-parallel quartz resonators have better spurious attenuation than plano-convex resonators. In specifying spurious resonance parameters it is necessary to give an indication of both the acceptabble attenuation level desired and their frequencies relative to the main resonance frequency.

In the AT-cut the (so-called) "unharmonic resonances" exist only above the main resonance in the region of +40 to +150 kHz for plano parallel resonators between +200 to +400 kHz for biconvex or planoconvex resonators.

In the passive measurement method indicated above, spurious resonance attenuations up to 20 to 30 dB can be measured. With higher attenuations, C_0 compensation is necessary.

The usual method, as specified in IEC publ. 283, utilizes the method with hybrid coils which because of insufficient specification does not produce reproducible results.

It is somewhat better and more reproducible to use a 180° hybrid power divider in place of the hybrid coil in accordance with Fig. 4.

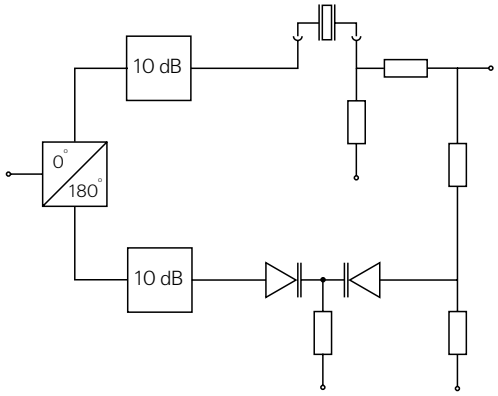


Fig.14

Using the above-described circle method in accordance with IEC 444–5 permits precise determination of the spurious resonances.

Standardisation for this is currently in preparation.

9. Drive level (DLD)

The amplitude of mechanical vibration of the quartz resonator increases proportionally to the amplitude of the applied current. The power dissipated in the resonance resistance is given by $P_c=I_q^2R_1$. High drive levels lead to the destruction of the resonator or the vaporisation of the evaporated electrodes. The upper limit for drive level is approximately 10 mW.

As the reactive power oscillating between L_1 and C_1 is represented by $Q_c=Q\times P_c$, for $P_c=1$ mW and with a Q of 100.00, Q_c is equal to 100 Watts.

The oscillation amplitude can be exceeted with relatively low level of drive P_c, thus resulting in the crystal frequency moving upwards.

This frequency dependence on drive level is more pronounced with increasing overtone order. Figure 15 shows typical effects but exact prediction of the effect is not possible as it is influenced by all the elements of crystal design and operation ie. mechanical blank parameters, electrode size, mounting arrangements and so on.

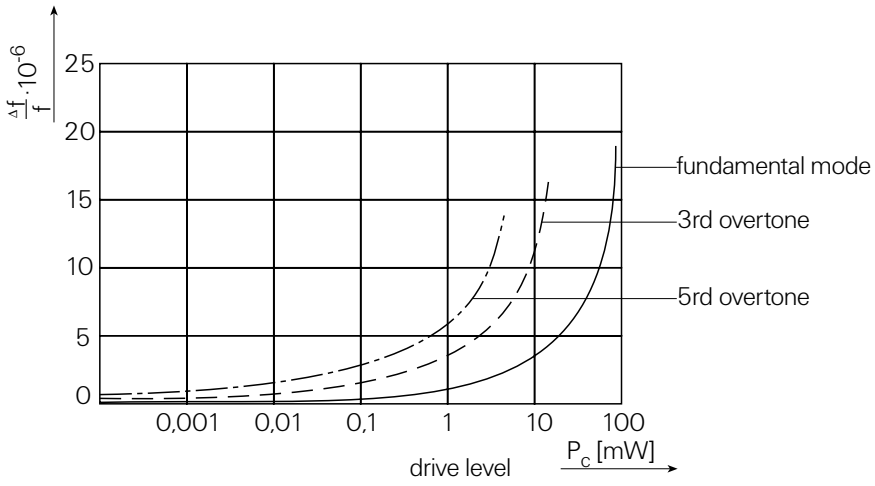


Fig.15

It can be seen that the drive level must be specified carefully, if there is to be good correlation between the frequency of the crystal at the end of its production and in the end use equipment.

Today with semiconductor oscillator circuits a drive level of approximately 0.1 mW appears normal, where this parameter is not specified, our production will use 0.1 mW.

A well performing crystal should start to oscillate easily and its frequency should be virtually independent of the variation of drive level from a starting level of about 1 nW. In todays semiconductor circuits with very low power consumption the crystal has to work well also at very low drive levels.

In fig. 16 we show the effect of crystal with and without the problem of frequency dependence on drive level.

Crystal that have badly adhering electrodes or on which the surface of the resonator is not fine enough, exhibit the curved effect ie. at low drive levels they have higher resistance.

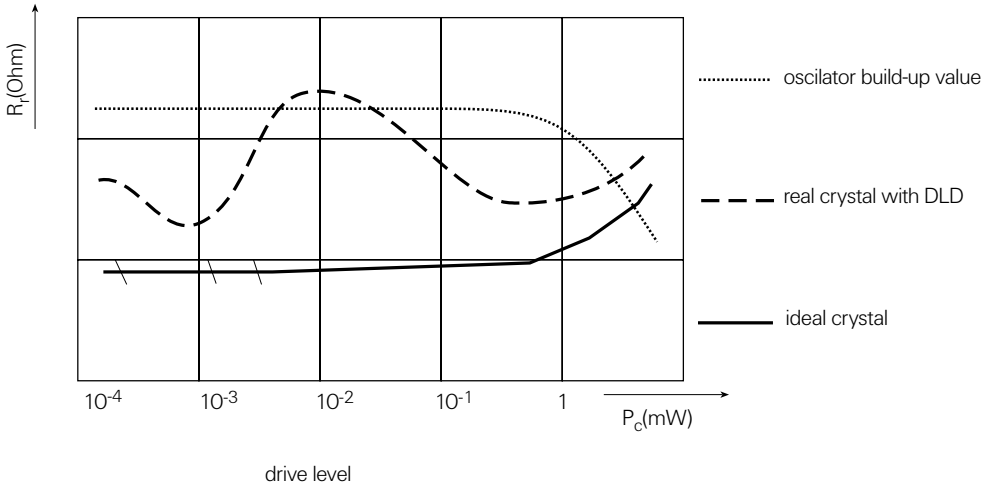


Fig.16

This effect is called the drive level dependence (DLD). Usually production test of DLD are performed between 1 and 10 microwatts and then at 1 mW and again at a low load. The relative change in resistance is then used as the test criterion. Needless to say, making more measurements at intermediate levels increases crystal production costs considerably.

Oscillation buil-up problems can very largely be eliminated by optimising the oscillator circuit by providing a sufficient feedback reserve and a "hard" switch-on pulse.

10.Frequency variation as function of time

This is normally considered in two ways. Short term stability (i.e. in the range of up to 10 seconds) and long term stability over days, months or years, often called ageing.

The short term stability of a quartz crystal depends on the actual oscillator design and manufacture. Only at low drive levels the short term stability of the oscillator is totally controlled by the quartz crystal.

The ageing rate is substantially influenced by the cleanliness of the resonator, the stability of the inert gas filling and the security of the final sealing process. Ageing is naturally greater during the first part of the life of the crystal unit. The frequency ageing can often be described by a logarithmic function of the form

$$\frac{\Delta f}{f} = a_0 + a_1 \cdot \lg(a_2 t + 1)$$

(see figure 17).

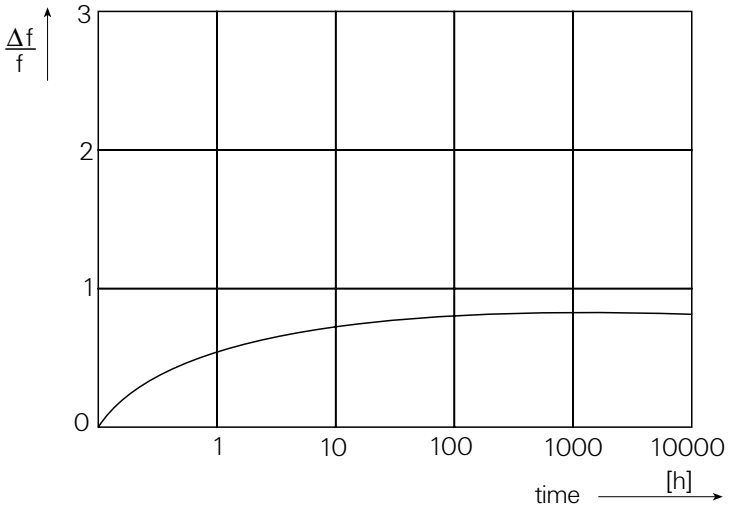


Fig.17

It is necessary to distinguish between active and passive ageing. Active ageing is the frequency shift, when the crystal works under operation conditions, ie. permanently oscillating in the circuit. Passive ageing is the frequency shift during storage. For accelerated ageing storage can be accomplished at elevated temperatures, e.g. 85° C.

Ageing rate is only meaningful if defined either as 'in operation' and under defined drive and temperature conditions ie. active, or in storage under defined temperature conditions ie. passive.

11.Mechanical and climatic tests

The tests mentioned here can be carried out at OMIG S.A. as approval tests if no special conditions are agreed or specified the following tests conditions are assumed to apply according to IEC publication 122-1.

a) Shock:

Tests Ea according to IEC 68-2-27, 3 shocks in each of the 3 axes, half sine 100 g, 6 ms.

b) Bump Test

Test Eb according to IEC 68-2-29, 4.000 bumps in one of the 3 axes, half sine 40 g, 6 ms.

c) Vibration (sinusoidal)

test Fc according to IEC 68–2–6, test B 1:10 ... 55 Hz amplitude ± 0.75 mm, 55 Hz ... 2 kHz, acceleration 10 g. 1 octave per minute. 2 hours in each of the three axes.

The permissible changes at the tests a) to c) are in each case:

$$\left|\frac{\Delta f}{f}\right| < 5\ \text{ppm} \qquad \left|\frac{\Delta R_r}{R_r}\right| < 10\%$$

For higher mechanical requirements, OMIG S.A. offers special crystal mounting methods.

d) Leak test:

The leakage is tested as a matter of routine in accordance to test Qk, method 2 in IEC 68–2–17 in the residual gas mass spectometer. Qualitative individual tests are also performed with the bubble test Qc, method 1 according to IEC 68–2–17.

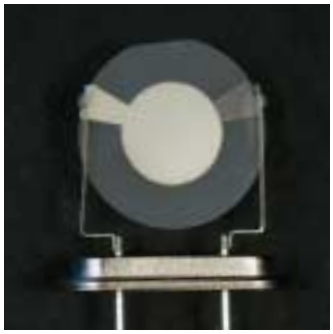
e) Solderability

Crystals with solder connections comply with test Ta, testing method 1 of IEC 68–2–20 (soldering bath 235 ±5)° C.

For specific requirements, other tests according to IEC 68, or according to IEC-Publication 68, or national standards can be applied. This needs in the individual case the coordination with OMIG S.A.

AT-cut Quartz Crystal

Freq. range 15 – 120 MHz



UM-5

RESISTANCE WELD PACKAGES;

Height	– 6.0mm
Terminals	– 2 or 3 wires,
SMD application	– on request (with "gull wing" and formed leads),
Packing	– on tape and reel on request

Standard Parameters

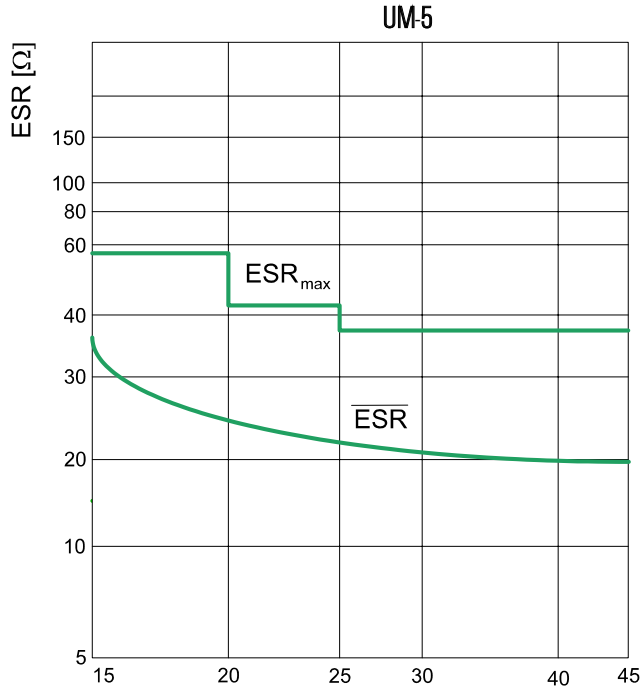
Temperature range	– from -55/+125°C.....to 0/50°C details – please see **Ordering Information**
Adjustment tolerance (at 25±3°C)	– ±5 ppm to ±100 ppm details – please see **Ordering Information**
Ageing (at 23°C)	– 1 ppm/y or 3 ppm/y or 5 ppm/y
Load Capacitance (CL)	– series to 150 pF details – please see **Ordering Information**
Shunt Capacitance (Co)	– 7 pF max
Packages	– details – please see **Packages – Crystal Units**

Non-standard Parameters (on request)

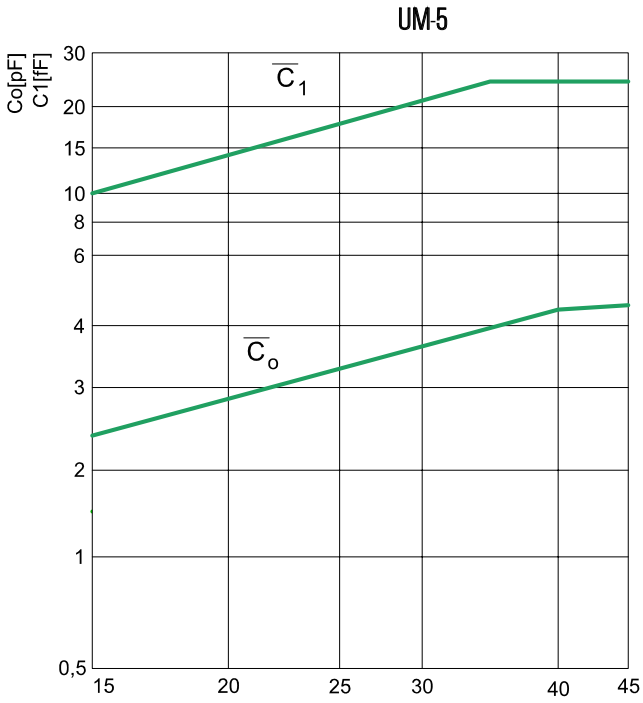
Extremal values of motional capacitances	– from about 5 fF up to the 30 fF
Temperature curve fit limit	– from ±0.25 ppm
Hysteresis	– from ±0.15 ppm
Spurious (for filter or oscillator applications)	– up to the 60 dB down
Special course of temperature characteristic	– on request for TCXOs and OCXOs

Mode	Frequency Range [MHz]	ESR (resistance) [Ω]	C_1 [fF]	C_0 [pF]	Temperature Range [°C] *	Temperature Stability [ppm] *
Fundamental	15 to 45	(see diagram 1)	(see diagram 2)	(see diagram 2)	-20 to +70 (*)	±5 (*)
3 rd ov.	40 to 90	(see diagram 3)	(see diagram 4)	(see diagram 4)	-20 to +70 (*)	±5 (*)
5 th ov.	70 to 120	(see diagram 5)	0.30	(see diagram 6)	-20 to +70 (*)	±5 (*)

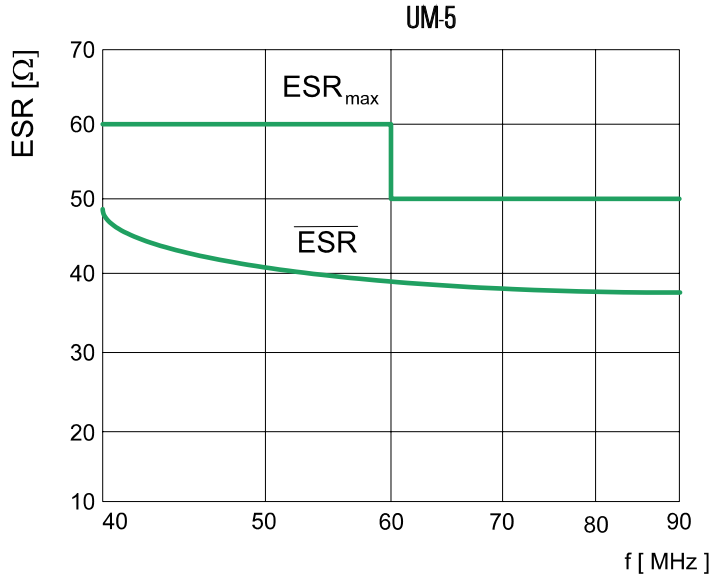
(*) It is an example only. Complete list is placed in the **Ordering Information** section.
(*) Crystals for oven applications available in temperature range 45°C to 85°C in 5°C steps.



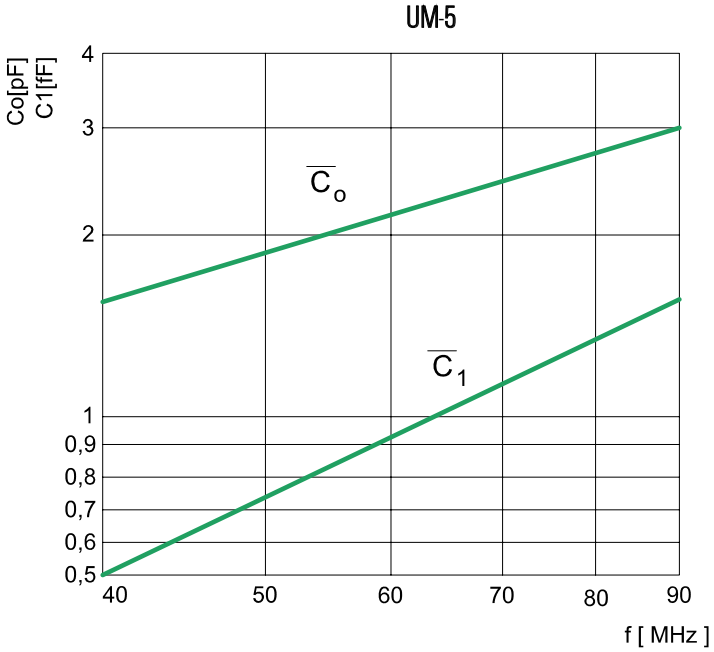
Diag. 1. Fundamental: Equivalent Series Resistance



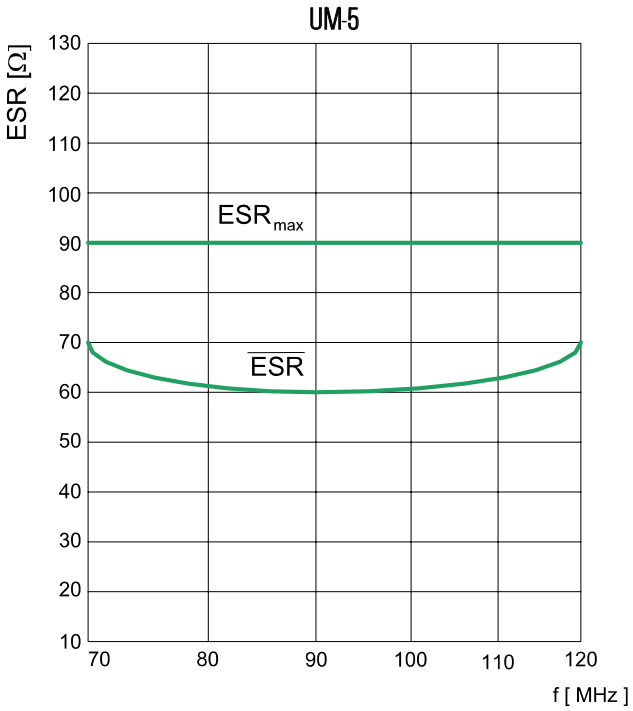
Diag. 2. Fundamental: Motional Capacitance, Shunt Capacitance



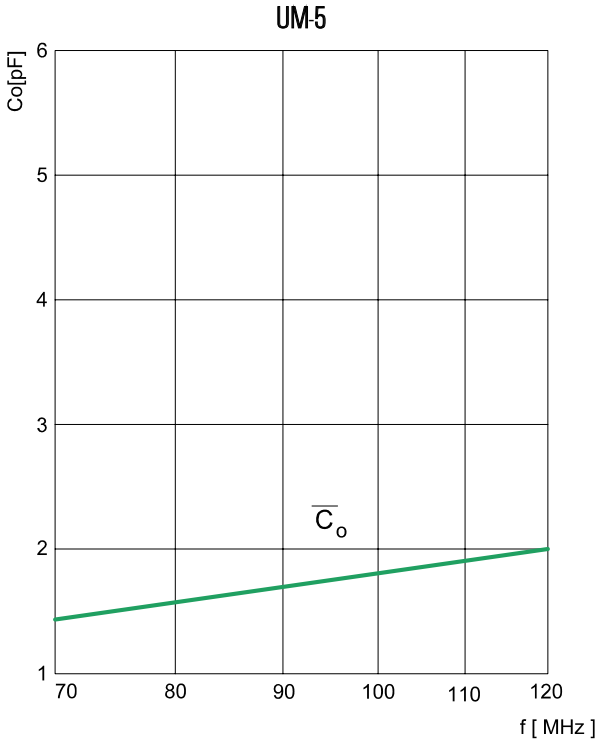
Diag. 3. 3rd Overtone: Equivalent Series Resistance



Diag. 4. 3rd Overtone: Motional Capacitance, Shunt Capacitance



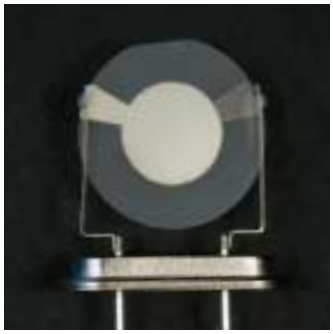
Diag. 5. 5th Overtone: Equivalent Series Resistance



Diag. 6. 5th Overtone: Shunt Capacitance

Quartz Crystal Units

Freq. range 8 - 200 MHz



UM-1; HC-52U ; HC-35 (TO-5)

RESISTANCE WELD PACKAGES;

Height – 6.6mm ; 8.0 mm and 8.8 mm
Terminals – 2 or 3 wires,
SMD application – on request (with "gull wing" and formed leads),
Packing – on tape and reel on request

Standard Parameters

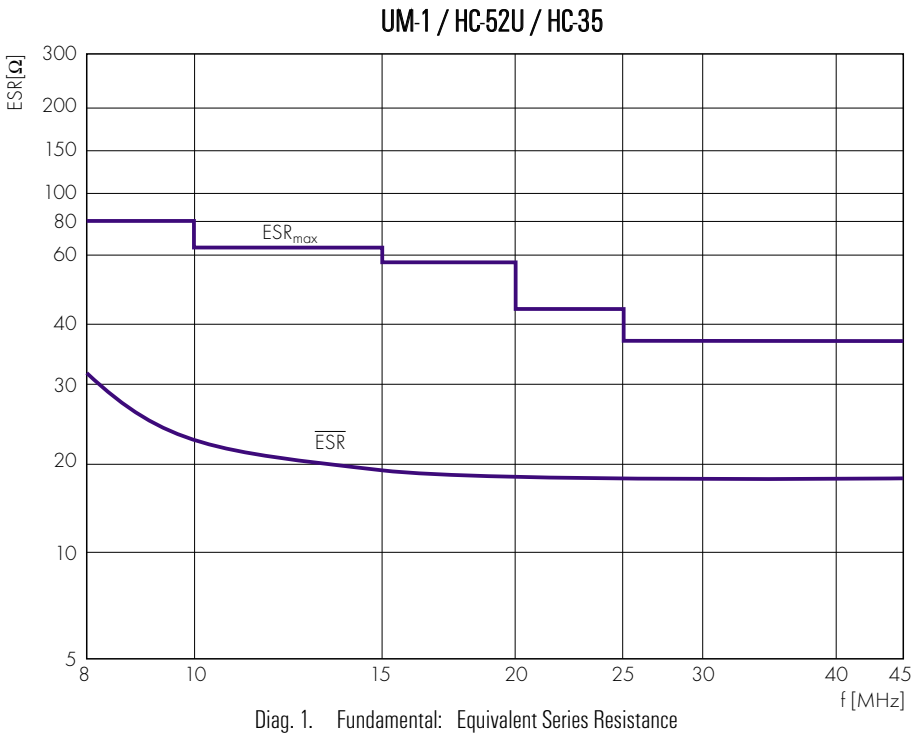
Temperature range	– from -55/+125°C.....to 0/50°C details – please see **Ordering Information**
Adjustment tolerance (at 25±3°C)	– ±5 ppm to ±100 ppm details – please see **Ordering Information**
Ageing (at 23°C)	– 1 ppm/y or 3 ppm/y or 5 ppm/y
Load Capacitance (CL)	– series to 150 pF details – please see **Ordering Information**
Shunt Capacitance (Co)	– 7 pF max
Packages	– details – please see **Packages – Crystal Units**

Non-standard Parameters (on request)

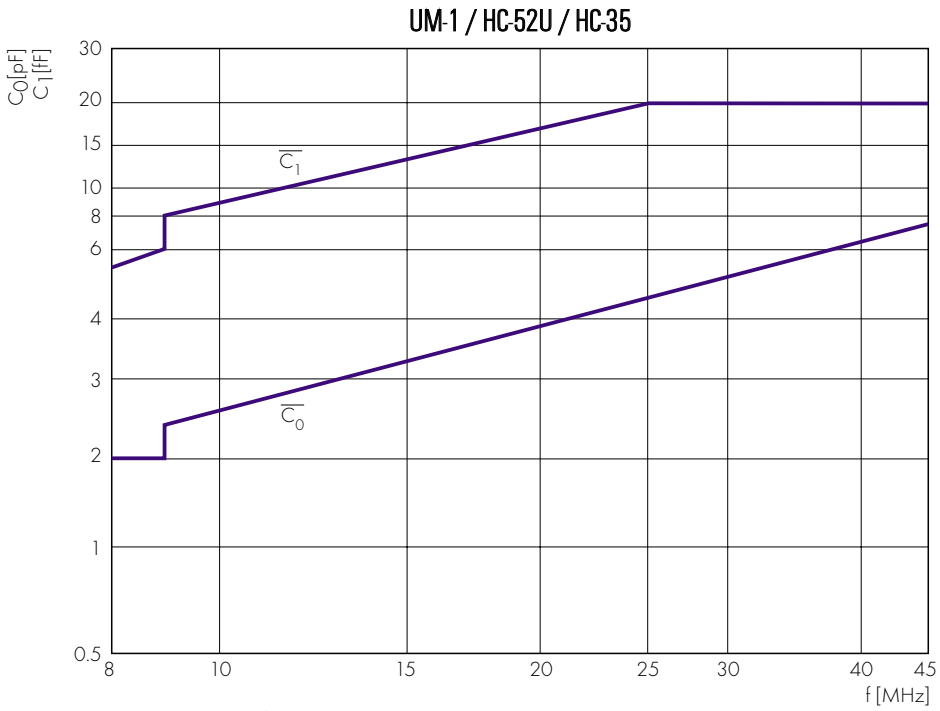
Extremal values of motional capacitances	– from about 5 fF up to the 35 fF
Temperature curve fit limit	– from ±0.20 ppm
Hysteresis	– from ±0.10 ppm
Spurious (for filter or oscillator applications)	– up to the 60 dB down
Special course of temperature characteristic for TCXOs and OCXOs	– on request

Mode	Frequency Range [MHz]	ESR [Ω]	C_1 [fF]	C_0 [pF]	Temperature Range [°C] *	Temperature Stability [ppm] *
Fundamental	8 to 50	(see diagram 1)	(see diagram 2)	(see diagram 2)	-20 to +70 (*)	±5 (*)
3 rd ov.	24 to 90	(see diagram 3)	(see diagram 4)	(see diagram 4)	-20 to +70 (*)	±5 (*)
5 th ov.	60 to 150	(see diagram 5)	0.35	(see diagram 6)	-20 to +70 (*)	±5 (*)
7 th ov.	125 to 200	(see diagram 7)	0.15	(see diagram 8)	-20 to +70 (*)	±5 (*)

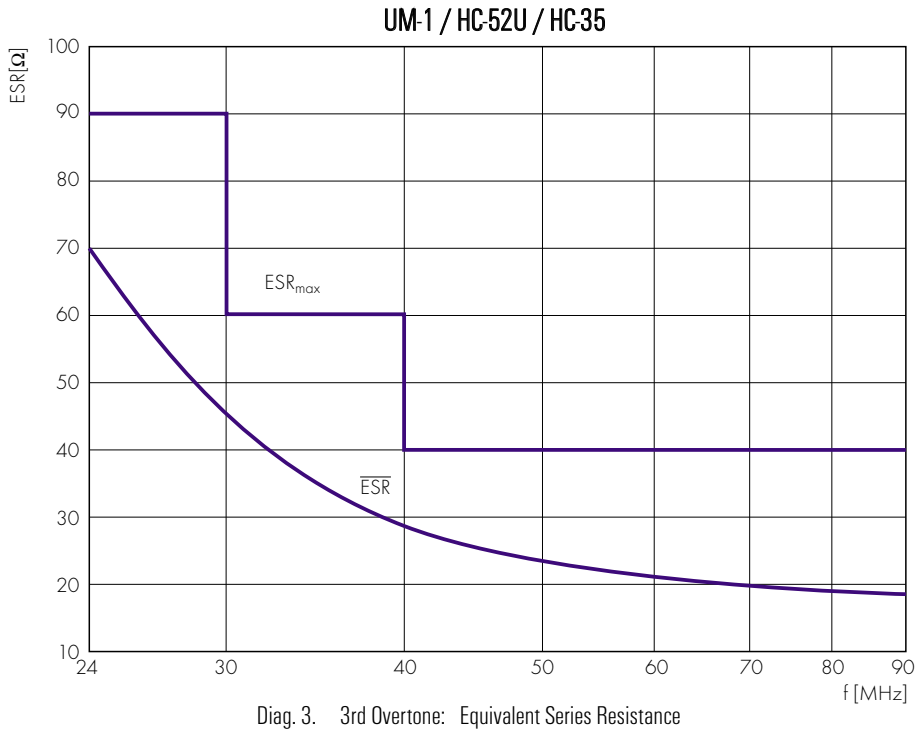
(*) It is an example only. Complete list is placed in the **Ordering Information** section.
(*) Crystals for oven applications available in temperature range 45°C to 85°C in 5°C steps.



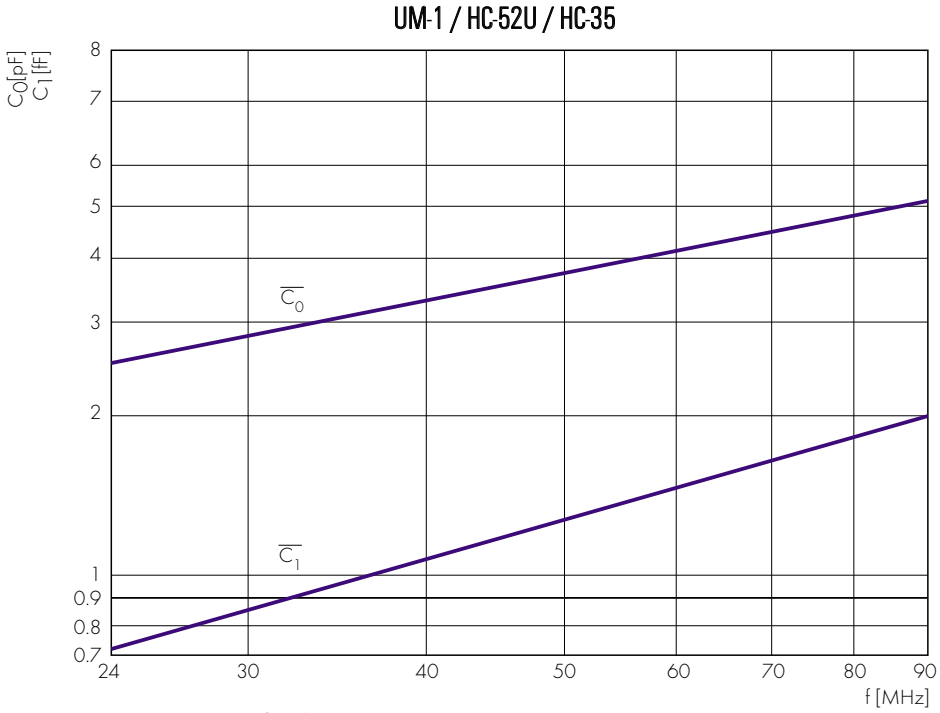
Diag. 1. Fundamental: Equivalent Series Resistance



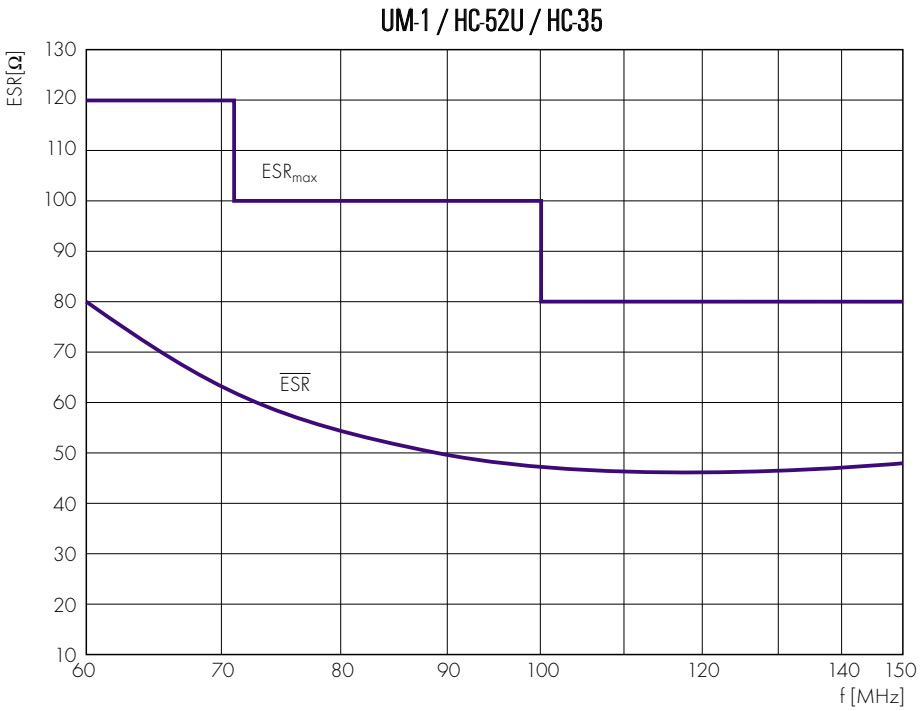
Diag. 2. Fundamental: Motional Capacitance, Shunt Capacitance



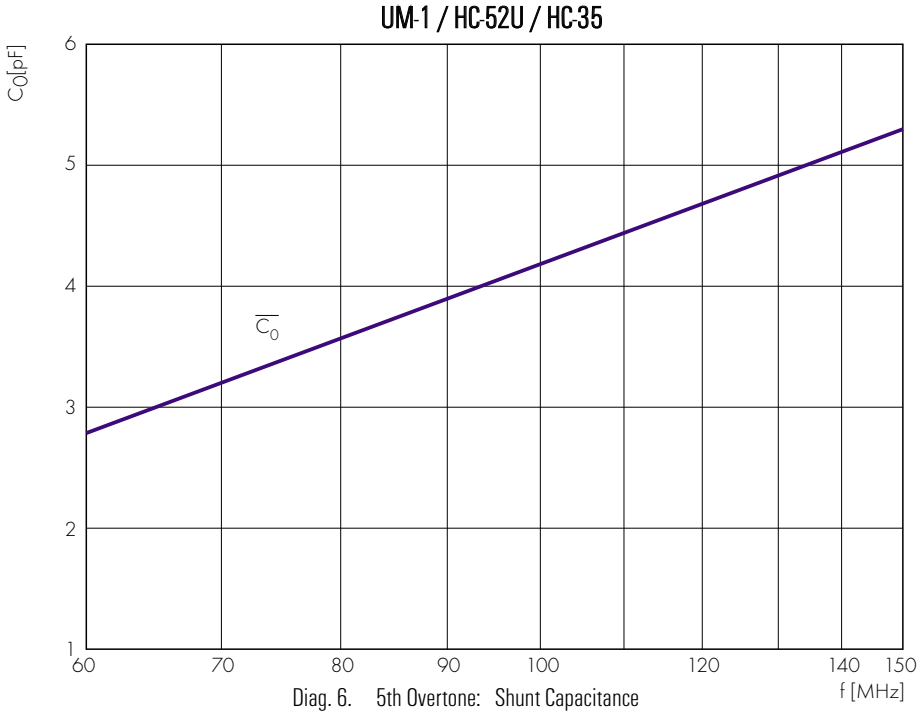
Diag. 3. 3rd Overtone: Equivalent Series Resistance



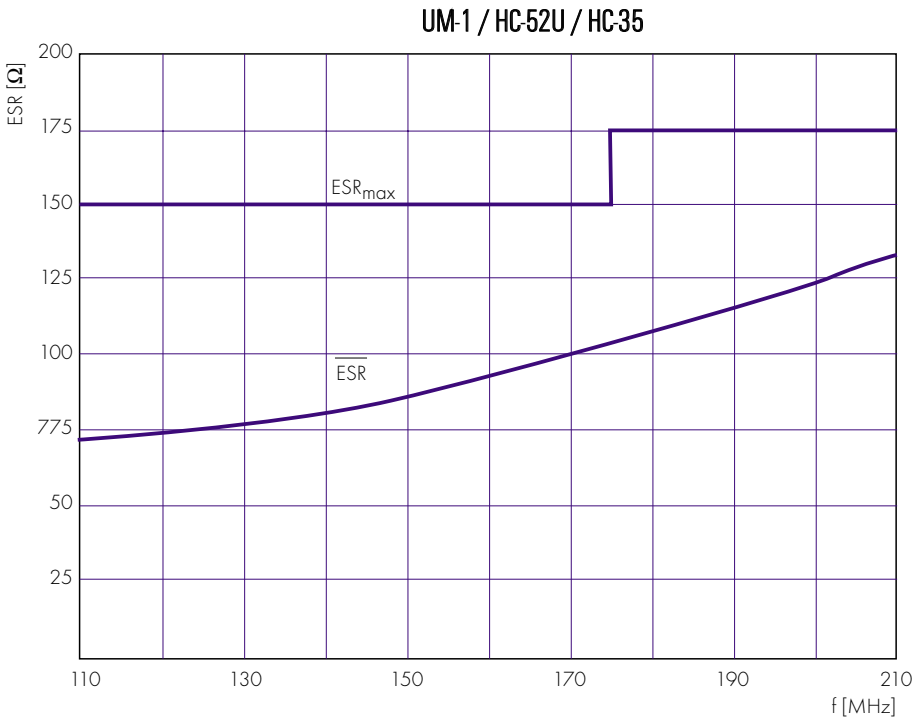
Diag. 4. 3rd Overtone: Motional Capacitance, Shunt Capacitance



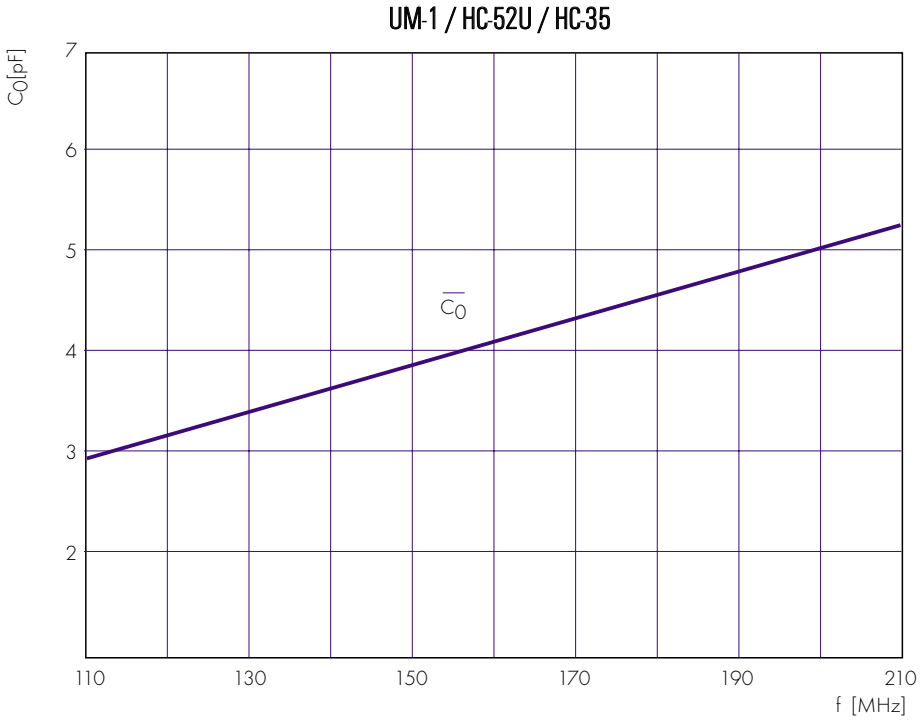
Diag. 5. 5th Overtone: Equivalent Series Resistance



Diag. 6. 5th Overtone: Shunt Capacitance



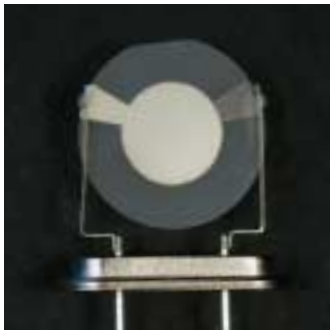
Diag. 7. 7th Overtone: Equivalent Series Resistance



Diag. 8. 7th Overtone: Motional Capacitance, Shunt Capacitance

Quartz Crystal Units

Freq. range 1.6 – 200 MHz



HC-49U ; HC-50U

RESISTANCE WELD ENCLOSURES

Height	– 11.5 mm and 13.5 mm (Note; Height 9.7 mm on the other page)
Terminals	– 2 or 3 wires (HC-49U) or 2 pins (HC-50U)
SMD application	– on request (with "gull wing" and formed leads)
Packing	– on tape and reel on request

Standard Parameters

Temperature range	– from -55/+125°C.....to 0/50°C details – please see **Ordering Information**
Adjustment tolerance (at 25±3°C)	– ±5 ppm to ±100 ppm details – please see **Ordering Information**
Ageing (at 23°C)	– 1 ppm/y or 3 ppm/y or 5 ppm/y
Load Capacitance (CL)	– series to 150 pF details – please see **Ordering Information**
Shunt Capacitance (Co)	– 7 pF max
Packages	– details – please see **Packages – Crystal Units**

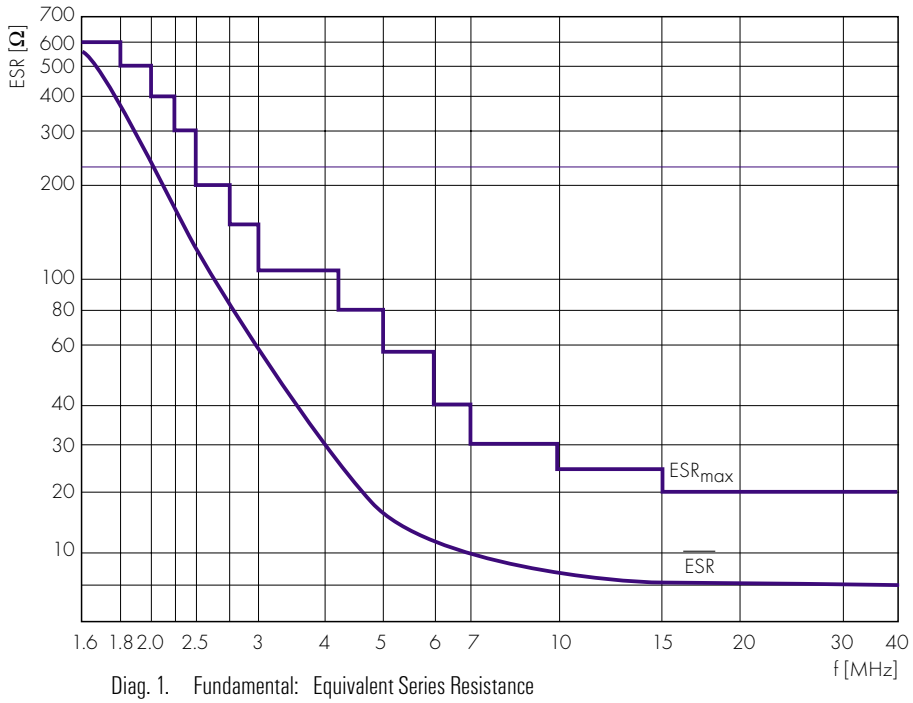
Non-standard Parameters (on request)

Extremal values of motional capacitances	– from about 5 fF up to the 45 fF
Temperature curve fit limit	– from ±0.20 ppm
Hysteresis	– from ±0.10 ppm
Spurious (for filter or oscillator applications)	– up to the 60 dB down
Special course of temperature characteristic for TCXOs and OCXOs	– on request

Mode	Frequency Range [MHz]	ESR (resistance) [Ω]	C_1 [fF]	C_0 [pF]	Temperature Range [°C] *	Temperature Stability [ppm] *
Fundamental	1.6 to 45	see diagram 1	see diagram 2	see diagram 2	-20 to +70 (*)	±5 (*)
3 rd ov.	13 to 90	see diagram 3	2.2	< 7 pF	-20 to +70 (*)	±5 (*)
5 th ov.	50 to 140	see diagram 5	0.5	< 7 pF	-20 to +70 (*)	±5 (*)
7 th ov.	110 to 200	see diagram 6	0.2	< 7 pF	-20 to +70 (*)	±5 (*)

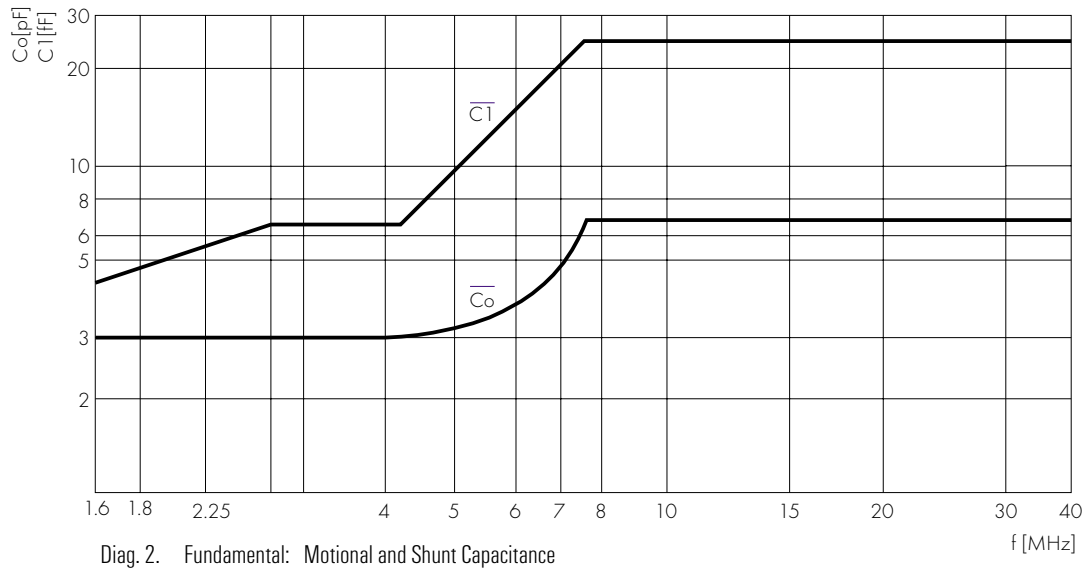
(*) It is an example only. Complete list is placed in the **Ordering Information** section.
(*) Crystals for oven applications available in temperature range 45° to 85°C in 5°c steps.

HC-49U / HC-50U height 11.5 and 13.5 mm

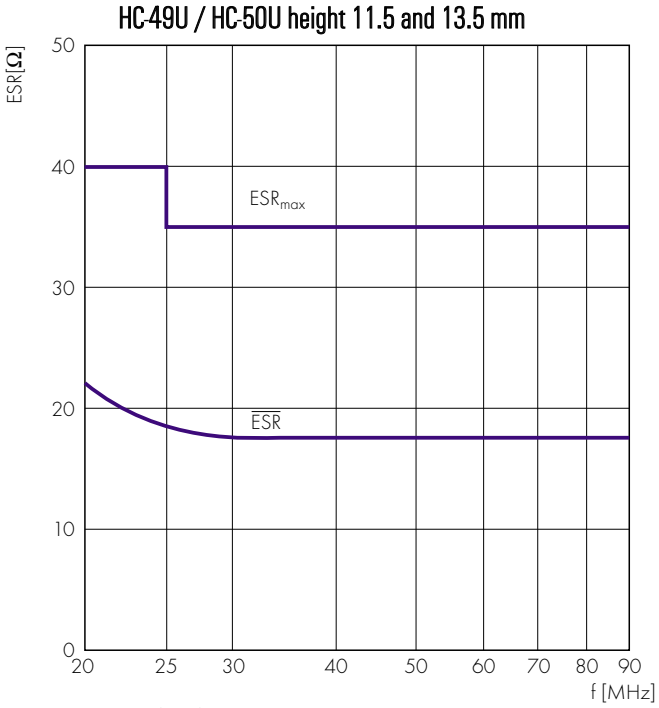


Diag. 1. Fundamental: Equivalent Series Resistance

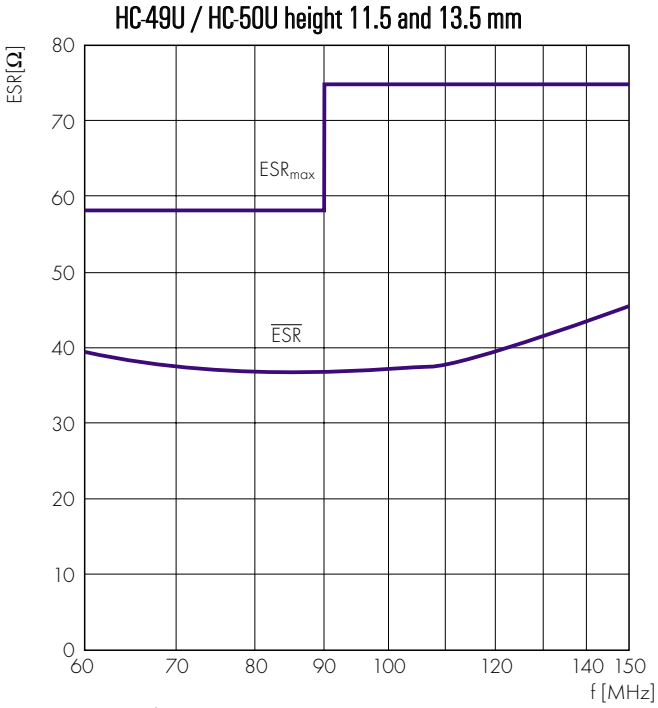
HC-49U / HC-50U height 11.5 and 13.5 mm



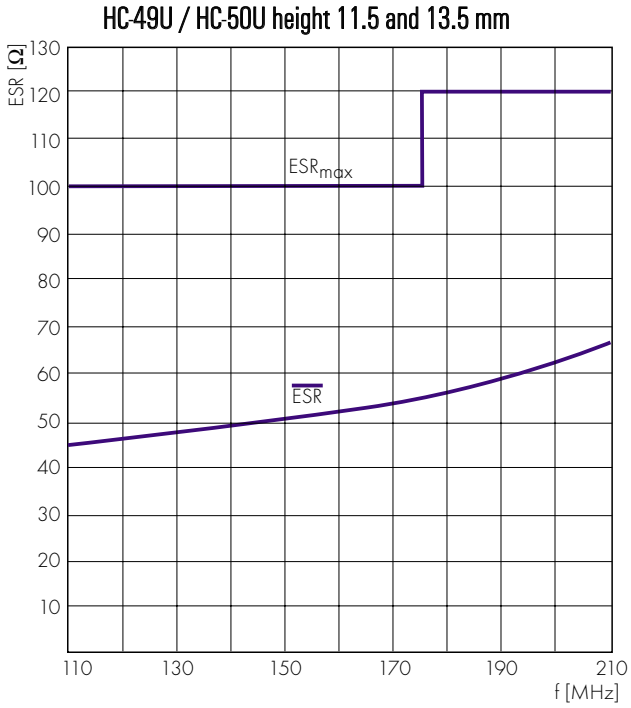
Diag. 2. Fundamental: Motional and Shunt Capacitance



Diag. 3. 3rd Overtone: Equivalent Series Resistance



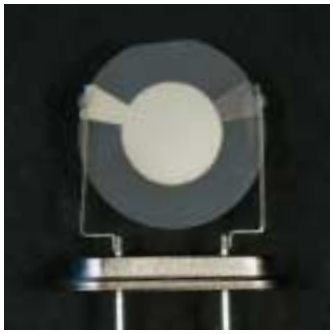
Diag. 4. 5th Overtone: Equivalent Series Resistance



Diag. 5. 7th Overtone: Equivalent Series Resistance

Quartz Crystal Units

Freq. range 8 – 200 MHz



HC-49U ; HC-50U

RESISTANCE WELD ENCLOSURES

Height – 9.7 mm
Terminals – 2 or 3 wires (HC-49U) or 2 pins (HC-50U)
SMD application – on request (with "gull wing" and formed leads)
Packing – on tape and reel on request

Standard Parameters

Temperature range	– from -55/+125°C.....to 0/50°C details – please see **Ordering Information**
Adjustment tolerance (at 25±3°C)	– ±5 ppm to ±100 ppm details – please see **Ordering Information**
Ageing (at 23°C)	– 1 ppm/y or 3 ppm/y or 5 ppm/y
Load Capacitance (CL)	– series to 150 pF details – please see **Ordering Information**
Shunt Capacitance (Co)	– 7 pF max
Packages	– details – please see **Packages – Crystal Units**

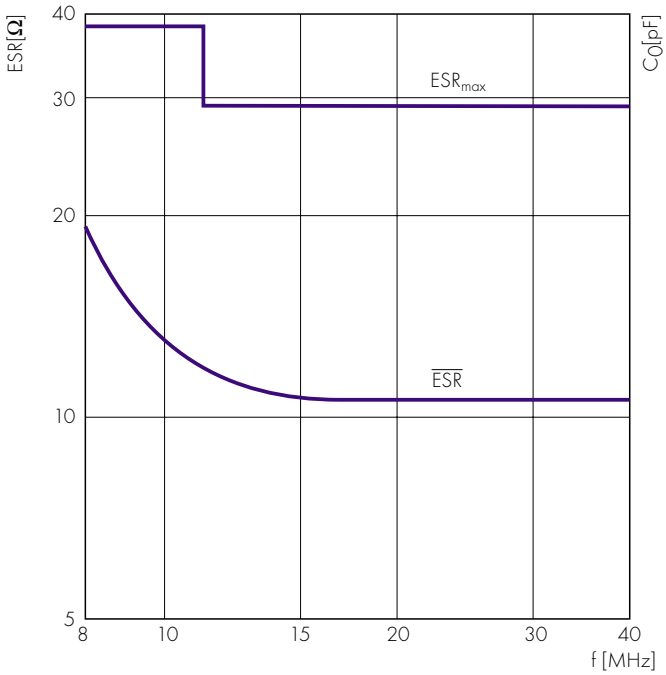
Non-standard Parameters (on request)

Extremal values of motional capacitances	– from about 5 fF up to the 45 fF
Temperature curve fit limit	– from ±0.20 ppm
Hysteresis	– from ±0.10 ppm
Spurious (for filter or oscillator applications)	– up to the 60 dB down
Special course of temperature characteristic for TCXOs and OCXOs	– on request

Mode	Frequency Range [MHz]	ESR [Ω]	C_1 [fF]	C_0 [pF]	Temperature Range [°C] *	Temperature Stability [ppm] *
Fundamental	8 to 40 (**)	see diagram 1	3 to 40	see diagram 2	-20 to +70 (*)	±5 (*)
3 rd ov.	24 to 90 (**)	see diagram 3	2.2 ± 30%	< 7	-20 to +70 (*)	±5 (*)
5 th ov.	60 to 150	see diagram 4	0.5 ± 30%	< 7	-20 to +70 (*)	±5 (*)

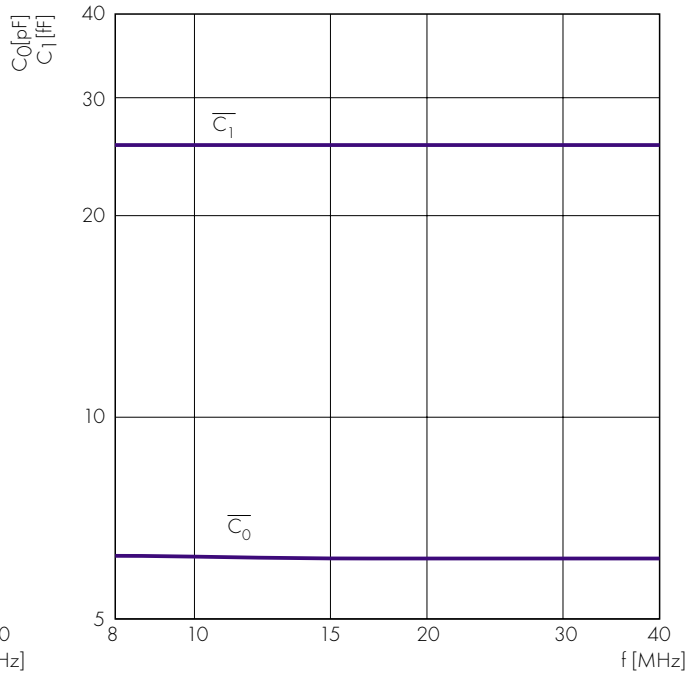
(*) It is an example only. Complete list is placed in the **Ordering Information** section.
(*) Crystal for oven applications available in temperature range 45° to 85°C in 5°C steps.
(**) These ranges are widther for package height 11.5 mm and 13.5 mm.

HC-49U / HC-50U height 9.7 mm



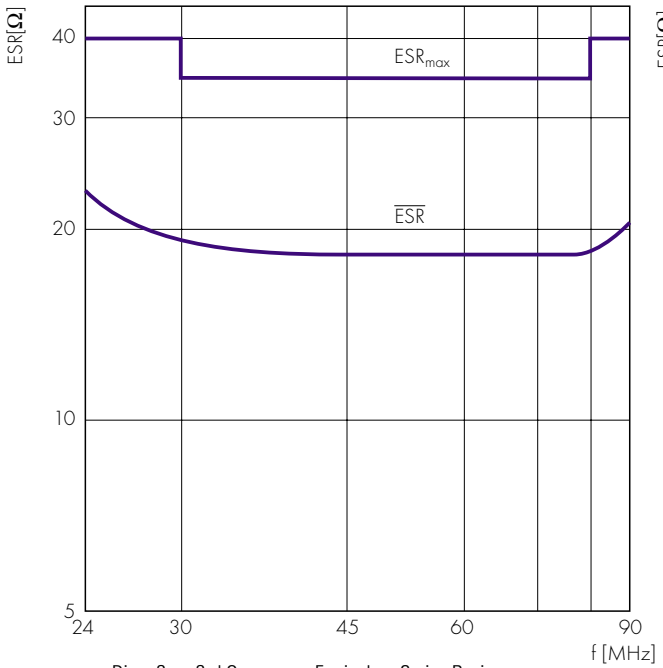
Diag. 1. Fundamental: Equivalent Series Resistance

HC-49U / HC-50U height 9.7 mm



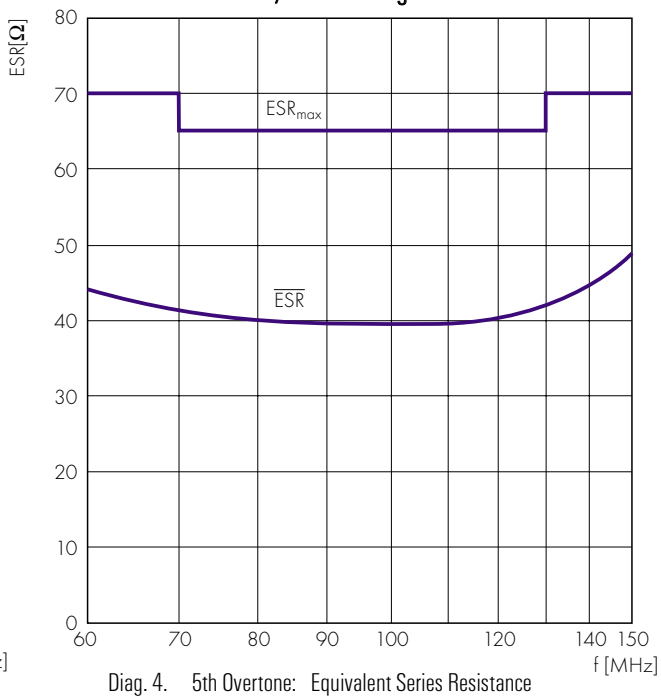
Diag. 2. Fundamental: Motional and Shunt Capacitance

HC-49U / HC-50U height 9.7 mm



Diag. 3. 3rd Overtone: Equivalent Series Resistance

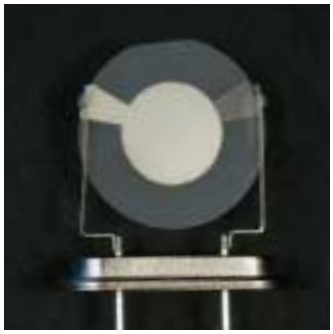
HC-49U / HC-50U height 9.7 mm



Diag. 4. 5th Overtone: Equivalent Series Resistance

Quartz Crystal Units for Consumer Electronics

Freq. range 1.6 – 80 MHz



HC-49U

RESISTANCE WELD ENCLOSURES

Height – 9.7 mm or 11.5 mm or 13.5 mm
Terminals – 2 or 3 wires (HC-49U)
SMD application – on request (with "gull wing" and formed leads)
Packing – on tape and reel on request

Standard Parameters

Temperature range	– from -20/70°C.....to 0/50°C details – please see **Ordering Information**
Adjustment tolerance (at 25 ± 3°C)	– ±20 ppm to ±100 ppm, details – please see **Ordering Information**
Ageing (at 23°C)	– 5 ppm/y
Load Capacitance (C_L)	– series to 150 pF details – please see **Ordering Information**
Shunt Capacitance (C_0)	– 7 pF max
Packages	– details – please see **Packages – Crystal Units**

Mode	Frequency Range (MHz)	ESR (Ω)	C_1 (fF)	C_0 (pF)	Temperature Range (°C) *	Temperature Stability (ppm) *
Fundamental	1.6 to 30	700 to 20	5 to 25	< 7	-20 to +70	±30 or ±50
3 rd ov.	20 to 80	40 to 60	2.2 ± 30%	< 7	-20 to +70	±30 or ±50

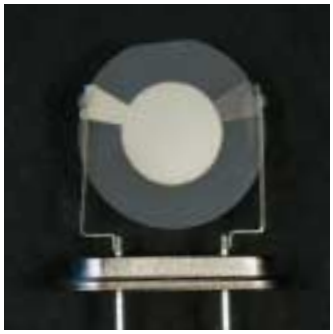
(*) Other temperature ranges and temperature stabilities on request.

Note:

Above parameters are for standard microprocessor units.
Please call our technical department for special requirements.

Quartz Crystal Units

Freq. range 0.8 - 100 MHz



HC-48U; HC-51U

RESISTANCE WELD PACKAGES

Height – 19.7 mm
Terminals – 2 wires (HC-48U) or 2 pins (HC-51U)

Standard Parameters

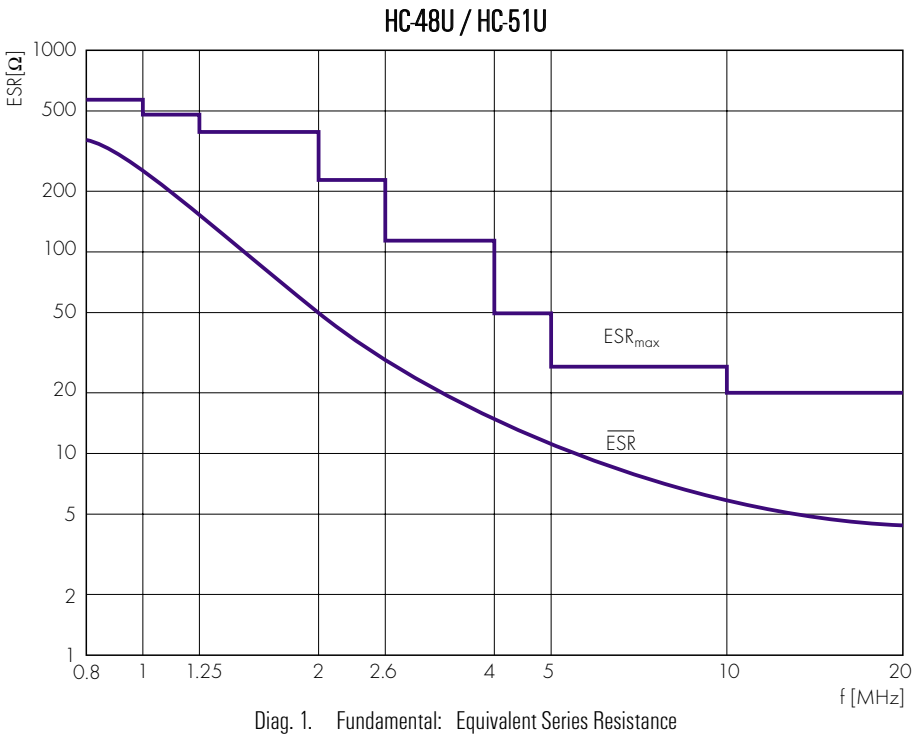
Temperature range	– from -55/+125°C.....to 0/50°C details – please see **Ordering Information**
Adjustment tolerance (at 25±3°C)	– ±5 ppm to ±100 ppm details – please see **Ordering Information**
Ageing (at 23°C)	– 1 ppm/y or 3 ppm/y or 5 ppm/y
Load Capacitance (CL)	– series to 150 pF details – please see **Ordering Information**
Shunt Capacitance (Co)	– 7 pF max
Packages	– details – please see **Packages – Crystal Units**

Non-standard Parameters (on request)

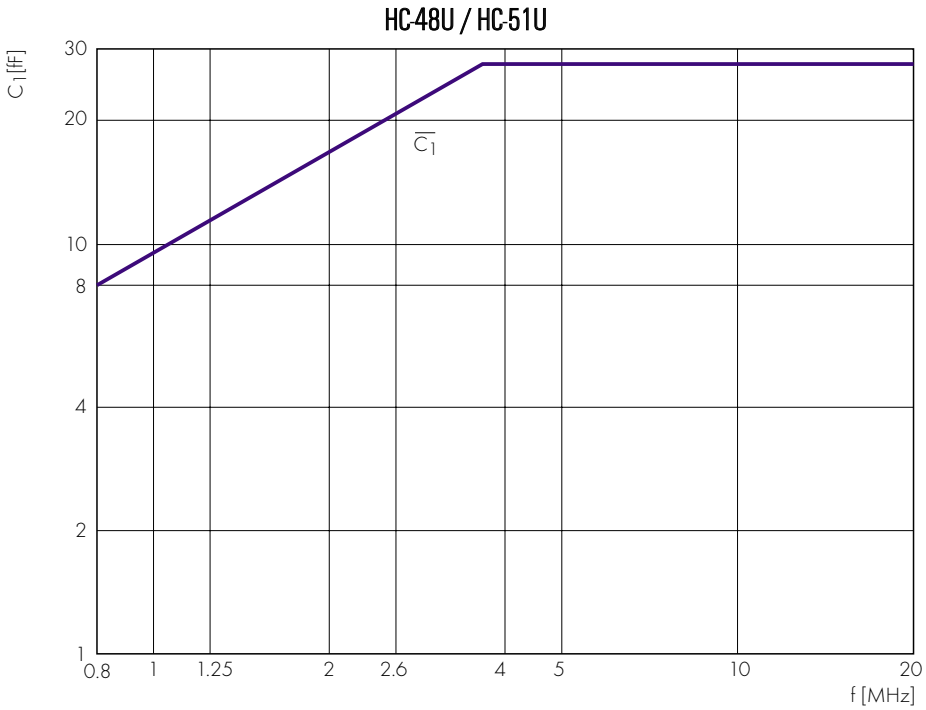
Extremal values of motional capacitances	– from about 5 fF up to the 45 fF
Temperature curve fit limit	– from ±0.20 ppm
Hysteresis	– from ±0.10 ppm
Spurious (for filter or oscillator applications)	– up to the 60 dB down
Special course of temperature characteristic for TCXOs and OCXOs	– on request

Mode	Frequency Range [MHz]	ESR [Ω]	C_1 [fF]	C_0 [pF]	Temperature Range [°C] *	Temperature Stability [ppm] *
Fundamental	0.8 to 20	see diagram 1	see diagram 2	see diagram 2	-20 to +70 (*)	±5 (*)
3 rd ov.	10 to 60	see diagram 3	2.2	< 7	-20 to +70 (*)	±5 (*)
5 th ov.	50 to 100	see diagram 4	0.50	< 7	-20 to +70 (*)	±5 (*)

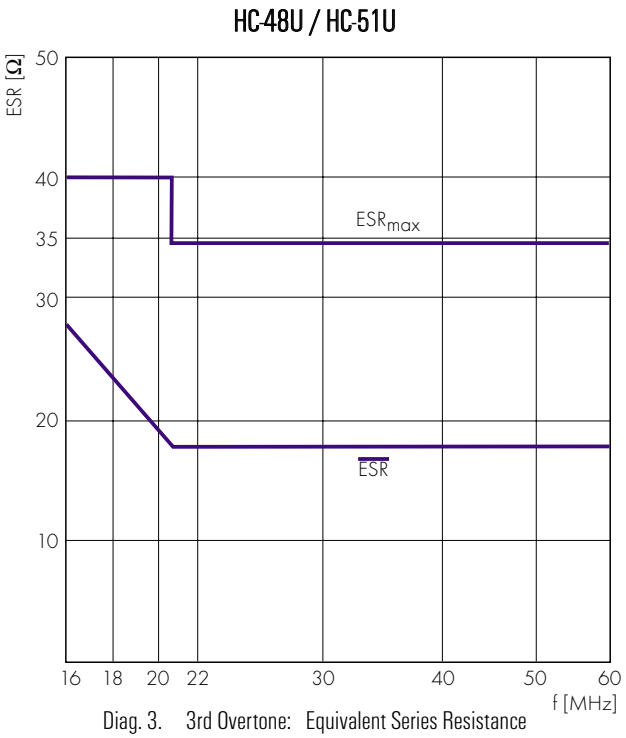
(*) It is an example only. Complete list is placed in the **Ordering Information** section.
(*) Crystals for oven applications available in temperature range 45° to 85°Cin 5°C steps.



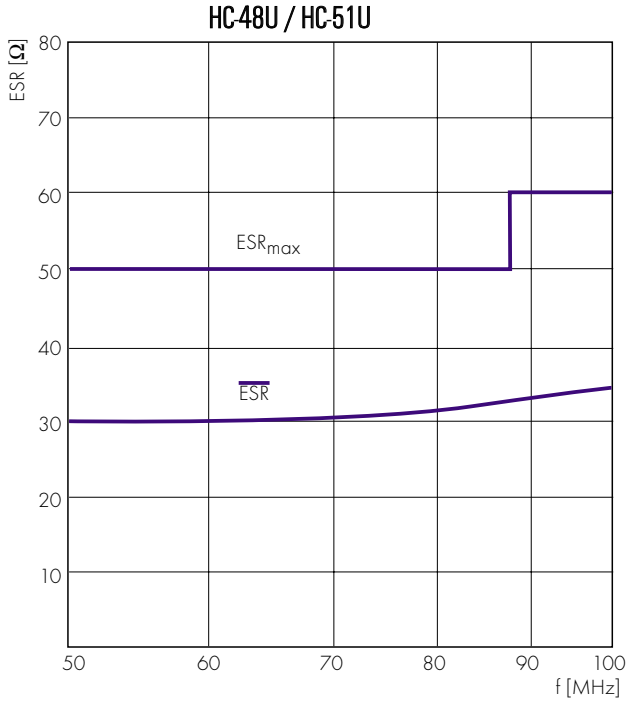
Diag. 1. Fundamental: Equivalent Series Resistance



Diag. 2. Fundamental: Motional Capacitance



Diag. 3. 3rd Overtone: Equivalent Series Resistance



Diag. 4. 5th Overtone: Equivalent Series Resistance

Informacje dla Zamawiającego Rezonatory kwarcowe

Wypełniając formularz **„Zapytanie Ofertowe (ZO)-rezonatory kwarcowe"** prosimy posługiwać się poniższymi **tablicami kodowymi** i szczegółowymi specyfikacjami wybranych rezonatorów.

Objaśnienia

1. **Częstotliwość nominalna** – Częstotliwość specyfikowana przez Zamawiającego
2. **Rząd drgań (owerton)** – Wartość specyfikowana przez Zamawiającego lecz zgodna z niniejszym katalogiem.

Uwaga; Wiele częstotliwości może być specyfikowane z sąsiadujących ze sobą rzędów drgań lecz zastępcze parametry takie jak pojemność dynamiczna ***C1****, rezystancja zastępcza* ***ESR*** *i inne będą się znacznie różnić od siebie co może mieć znaczny wpływ na pracę rezonatora w konkretnych warunkach.*

3. **Zastępcza rezystancja szeregowa [ESR]** – Prosimy specyfikować tylko wtedy gdy wartość podana w katalogu nie jest zgodna z Państwa wymaganiami

1. **Tolerancja dobrania (częstotliwości)** tj. tolerancja z jaką został wykonany rezonator w temp. odniesienia (23°C dla rezonatorów nietermostatowych lub temperatura termostatu dla rez. termostatowych) – Wartość zgodna z tablicą **Code III** lub inna zaproponowana przez Zamawiającego.

5. **Zakres temperatur pracy** tj. zakres temperatur pracy w którym rezonator spełnia określone wymagania – Wartość zgodna z tablicą **Code I** lub inna zaproponowana przez Zamawiającego.

6. **Temperaturowa stabilność częstotliwości** – tj. maksymalna względna dewiacja częstotliwości odniesiona częstotliwości w temp. odniesienia – Wartość zgodna z tablicą **Code II** (dla rez. nietermostatowych) lub tablicą **Code V** (dla rez. termostatowych).

7. **Moc znamionowa** tj. moc przy której mierzone są parametry rezonatora – Typową wartością jest 0.15mW. Inne wartości jak 0.50; 1.0; 2.0; 5.0 mogą być specyfikowane.

8. **Pojemność równoległa (Co)** tj. pojemność statyczna elektrod i obudowy – Typowe wartości podane są na wykresach lub w tabelach odnoszących się do danej specyfikacji.

9. **Pojemność dynamiczna (C1)** tj. szeregowa wartość pojemności wynikająca z zastępczego schematu rezonatora (w fF) – Typowe wartości podane są na wykresach lub w tabelach odnoszących się do danej specyfikacji.

10. **Pojemność obciążenia** tj. wartość pojemności (w pF) dla której rezonator spełnia określone wymagania (Tolerancję Dobrania i Temp. Stabilność Częstotliwości) – Wartość specyfikowana przez Zamawiającego wynikająca z warunków pracy rezonatora w określonej aplikacji zgodna ztablicą **CodeIV**.

11. **Starzenie** tj. maksymsalna zmiana częstotliwości w określonym okresie czsu (w ppm) – 1ppm/rok; 3ppm/rok lub 5 ppm/rok może być specyfikowana. *Uwaga; Wyższa wartość starzenia niższa cena rezonatora !!!*

12. **Obudowa** – Możliwe do wyboru obudowy podane są na początku kazdej specyfikacji a ich kształt i wymiary w rozdziale katalogu **„Obudowy-Rezonatory kwarcowe"**

13 **Aplikacje** – Można wybrać 3 rodzaje aplikacji:
Ogólna – do zastosowań umiarkowanych
Profesjonalna – do zastosowań odpowiedzialnych
Militarna – do zastosowań b. wymagających

14. **Dewiacja charakterystyki temperaturowej** tj. max. odchylenie charakterystyki temp. od jej aproksymacji przy pomocy funkcji matematycznej (najczęściej 3-stopnia) – Można wybierać od ±0.2 ppm w górę. *Uwaga; Stosuje się dla gen. TCXO i podobnych* aplikacji.

15.**Histereza** tj. max. różnica częstotliwości zmierzona w danej temp. na początku i po przejściu przez określoną temperaturę górną (dolną). – Można wybierać od ±0.1 ppm w górę. *Uwaga; Stosuje się dla gen. TCXO i podobnych aplikacji.*

Uwaga: Jeżeli Państwu nie odpowiadają proponowane przez nas parametry zastępcze rezonatora prosimy wstawić własne a my postaramy się je zapewnić, jeżeli to tylko będzie możliwe.

Code I	Operating temperature range (°C)
A	-55 ... +105
B	-40 ... +90
C	-30 ... +80
D	-25 ... +75
E	-20 ... +70
F	-15 ... +65
G	-10 ... +60
H	-5 ... +55
J	0 ... +50
K	+5 ... +45
L	+10 ... +40

Code II	Temperature frequency stability (ppm)
A	±200
B	±150
C	±100
D	±75
E	±50
F	±30
G	±25
H	±20
J	±15
K	±10
L	±7.5
M	±5
N	±4

Code III	Adjustment tolerance (ppm)
01	±50
02	±30
03	±20
04	±15
05	±10
06	±7.5
07	±5
08	+45 ... +65
09	+35 ... +55
10	+25 ... +45
11	+20 ... +40
12	+15 ... +35
13	+5 ... +25
14	0 ... +20
15	-5 ... +15
16	-15 ... +5
17	-20 ... +0
18	-25 ... -5
19	-30 ... -10
20	-35 ... -15
21	-40 ... -20
22	-45 ... -25
23	-50 ... -30
24	-55 ... -35
25	-60 ... -40
26	-65 ... -45
27	-70 ... -50
28	-75 ... -55

Code IV	Load capacitance (pF)
A	10
B	12
C	15
D	18
E	20
F	25
G	30
H	32
J	35
K	40
L	45
M	50
P	55
Q	60
R	65
S	series-resonance
T	70
U	75
V	80
W	90
X	100
Y	150

Ovenized crystals	
Code – complex	Oven temperature (°C)
TR	45
TS	50
TT	55
TU	60
TV	65
TW	70
TX	75
TY	80
TZ	85

Degree of Manufacturing Difficulty

		A	B	C	D	E	F	G	H	J	K	L	M	N
		±200	±150	±100	±75	±50	±30	±25	±20	±15	±10	±7.5	±5	±4
A	-55 ... +105													
B	-40 ... +90													
C	-30 ... +80													
D	-25 ... +75													
E	-20 ... +70													
F	-15 ... +65													
G	-10 ... +60													
H	-5 ... +55													
J	0 ... +50													
K	+5 ... +45													
L	+10 ... +40													

Low — Hight

Fig 1. Available combinations of operating temperature ranges and temperature stability

OMIG S.A.
Fax: (+48 22) 841 51 31
Tel : (+48 22) 841 05 34
E-mail: sales@omig.com.pl

Zapytanie ofertowe /ZO/
Rezonatory kwarcowe

Data :
.....

Nazwisko i imię	Telefon	Fax	E-mail

Firma :	Miasto :	Ulica :	Kod :

W celu ułatwienia wypełnienia poniższego formularza proponujemy pobrać **Rezonatory Kwarcowe** (w formacie PDF) i otworzyć rozdział ***Rezonatory Kwarcowe- Informacje dla Zamawiającego.***

Częstotliwość : [MHz]		Rząd drgań :		Rezystancja szeregowa : [Ohm]		Dokładność wykonania [ppm]:	
1 →		**2 →**		**3 →**		**4 →**	

Zakres temperatur pracy [°C]:		Temp. niestabilność [ppm]:		Moc maks. [mW] :	
5 →		**6 →**		**7 →**	

Pojemność równoległa: (Co) [pF]		Pojemność dynamiczna : (C1) [fF]:		Pojemność obciążenia (CL) : (C1) [fF]:	
8 →		**9 →**		**10 →**	

Starzenie [ppm/y] :		Obudowa :		Zastosowanie : *[Zakreślić właściwe]*			
11 →		**12 →**		**13 →**	*Ogólne*	*Profesionalne*	*Militarne*

Współczynnik kształtu krzywej temp. [ppm] : *Uwaga: Tylko dla spec. zastosowań*		Histereza [ppm] : *Uwaga: Tylko dla spec. zastosowań*	
14 →		**15 →**	

Warunki dostawy

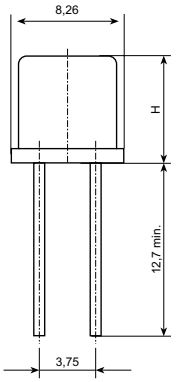
Ilość [sztuki] :		Wymagana data dostawy :	
16 →		**17 →**	

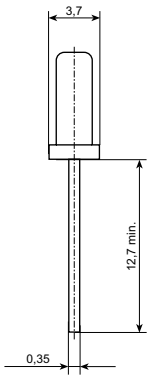
Uwagi :

- Koniec -

Obudowy – Rezonatory kwarcowe

HC - 52/U; UM - 1



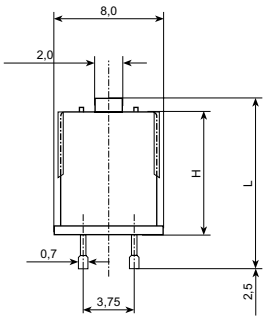


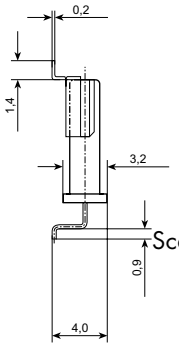
Scale 2:1

Scale 2:1

Omig enclosure type	H max mm	International type
QM-520	8,8	HC-52/U, UM-1
QM-521	8,0	HC-52/U, UM-1
QM-522	6,0	HC-52/U, UM-1

HC - 52/U; UM - 1 SMD

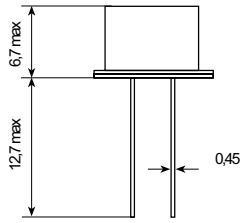


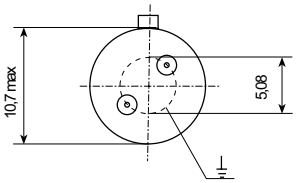


Scale 1.5:1

Omig enclosure type	H max mm	L mm	International type
QS-520	8,8	12,5±0,2	HC-52/U, UM-1 SMD
QS-521	8,0	11,8±0,2	HC-52/U, UM-1 SMD
QS-522	6,0	9,9±0,2	HC-52/U, UM-1 SMD

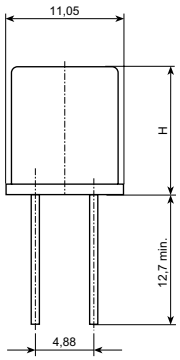
HC - 35/U

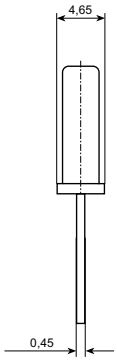




Omig enclosure type	H max mm	L mm	Internacional type
QM-350	6,7	12,7±0,2	HC-35/U, TO-5

HC - 49/U

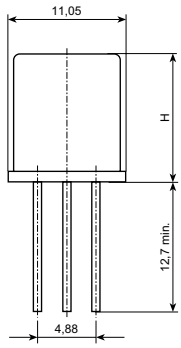




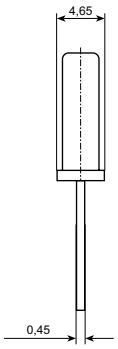
Omig enclosure type	H max mm	International type
QM-490	13,5	HC-49/U
QM-491	11,5	HC-49/U
QM-492	9,7	HC-49/U

Obudowy – Rezonatory kwarcowe

HC - 49/U



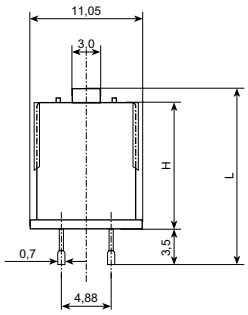
Scale 1.5:1

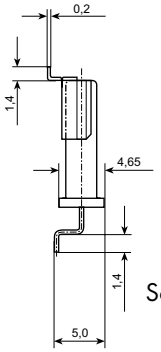


Scale 1.5:1

Omig enclosure type	H max mm	International type
QM-490 - 3	13,5	HC-49/U
QM-491 - 3	11,5	HC-49/U
QM-492 - 3	9,7	HC-49/U

HC - 49/U SMD

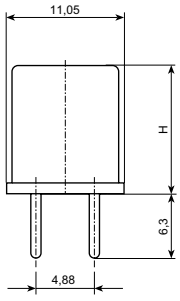


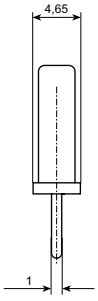


Scale 1:1

Omig enclosure type	H max mm	L mm	International type
QS-490	13,5	17,8±0,2	HC-49/U, SMD
QS-491	11,5	16,0±0,2	HC-49/U, SMD
QS-492	9,7	14,3±0,2	HC-49/U, SMD

HC - 50/U

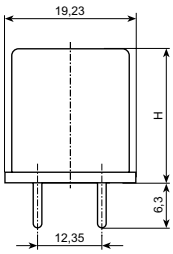


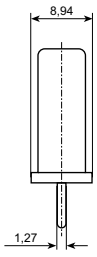


Scale 1:1

Omig enclosure type	H max mm	International type
QM-500	13,5	HC-50/U
QM-501	11,5	HC-50/U
QM-502	9,7	HC-50/U

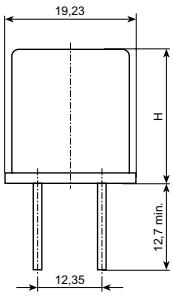
HC - 48/U

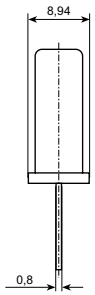




Omig enclosure type	H max mm	International type
QM-480	19,75	HC-48/U

HC - 51/U





Omig enclosure type	H max mm	International type
QM-510	19,75	HC-51/U