Precision Quartz Crystal Resonators

Product Catalog

Quantic™ Croven

Company Background

Croven Crystals has provided high quality and reliability products to the frequency control industry for more than seventy years and has been continually recognized as a world leader and supplier of precision frequency control devices.

Founded in 1954 as W. Gary-Wright Electronics of Canada to assemble crystal products for various military communications programs, the Company name was later changed to Croven Ltd., an acronym for the products then manufactured:

CR (for quartz crystal) and **OVEN** (for the temperature controlled ovens developed for use with the crystals in precision applications).

By 1959, Croven's crystal and oven products were in great demand and the facility at 500 Beech Street was erected. At that time, due to the large demand for oven products, the Company founded Ovenaire in Charlottesville, VA, which went on to become a world leader in the manufacture of precision ovens and ovenized oscillators. The Company was further expanded in 1963 when the Filtaire division was established to support the growing demand for specialized crystal filter products.

In 1967 the Companies were purchased by Walter Kidde & Co. of Belleville, NJ. By then, Croven had grown greatly and the Whitby facility had been expanded to its current 25,000 sq. ft.

In 1975 Croven Ltd. founded Croven Europe (later to be known as Dantronic), a wholly owned subsidiary in Denmark to manufacture crystal products for the European market.

By 1979, Croven Ltd. had moved all manufacturing of oscillators and hybrid modules to its other locations, and the Whitby operation from that time has focused exclusively on the design and development of precision quartz crystal resonators. The name was then changed to Croven Crystals Ltd. to better reflect our product and market orientation.

Over the ensuing years Croven was partnered with various companies in the frequency control industry but we remained focused on maintaining our position as the premier supplier of precision quartz crystals.

In 2006 the company was acquired by Wenzel Associates, a leader in the design and manufacture of low noise oscillators and integrated microwave assemblies. The synergies achieved through the joining of these two industry leaders served to accelerate product development and resulted in significant advancement of low noise quartz resonator and oscillator capability.

In 2021, Croven Crystals was acquired by Quantic Electronics. Quantic Electronics brings together the industry's most distinguished electronics and manufacturing experts, in an elite portfolio of complementary design, engineering and manufacturing businesses. Our teams collaborate closely with customers, consulting engineer-to-engineer, on the most mission-critical applications in RF & Microwave, power, sensing and magnetics.

We hope that this catalogue serves not only to inform you of our capabilities, but that it will also provide some insight into the technology of crystal design and manufacture and be a useful reference.

* This catalogue has been prepared as a general guide to the customer and every effort has been made to ensure that the information provided is correct at the time of printing. Quantic Croven reserves the right to change any of the information or specifications without prior notice.

Precision Quartz Crystal Resonators

A Brief History of Piezo-Electric Quartz and Its Special Properties

Piezo comes from the Greek word piezein meaning "to press" and piezo-electricity is described as "electric polarity due to pressure, especially in a crystalline substance". Therefore the piezo-electric effect can be described as the behavior of certain materials, among them quartz, which produce an electrical charge on their surface when they are distorted or subjected to pressure. Conversely, and more importantly from our point of view, these materials will distort and produce a mechanical vibration when an alternating electric current is applied.

The Curie brothers of France discovered the piezo-electric phenomenon in quartz around 1880 but very little practical use was made of it until 1917 when French physicist Paul Langevin used X-cut plates of quartz to generate and detect sound waves in water. His work led to the development of sonar and prompted others to investigate the phenomenon further. A quartz piezoid was first used to control the frequency of an oscillator in 1921 by Walter Cady and the age of the quartz resonator was born.

Quartz is one of the several forms of silicon dioxide (SiO_2) found in nature and even though approximately 15% of the earth's crust is comprised of SiO_2, electronic grade quartz of reasonable size and acceptable purity is rare. More than 90% of such quartz comes from Brazil. However, since the development of man-made or cultured quartz in the late 1940s, naturally occurring quartz candles are no longer used in the fabrication of quartz resonators

Cultured quartz is produced by placing small chips of quartz in an autoclave or pressure chamber, mixed with an aqueous alkaline solution. This solution is then subjected to high temperature and pressure (350°C and 12,500 PSI) causing the quartz to dissolve and eventually reform around seeds (thin slices of quartz) suspended toward the top of the autoclave. This process takes from 30 to 45 days, depending on the quality and size of the quartz bars required. Cultured quartz has now entirely replaced natural quartz in the fabrication of finished crystals.

The thing that makes quartz so attractive as a material for piezoelectric crystals is its excellent mechanical, thermal and chemical characteristics. The low friction loss in quartz assures the generation of electro-mechanical vibrations with a high quality factor (Q). Because of its high Q and excellent stability, the quartz crystal has become an indispensable frequency determining device when precision frequency control or time standards are required.

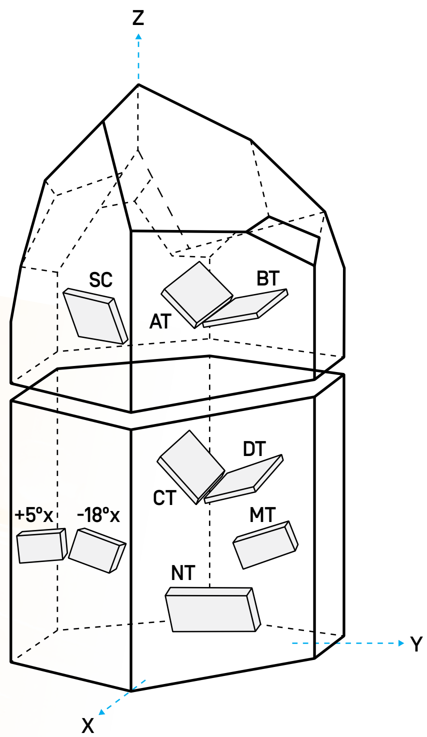


Figure 1. Cross Section of a Theoretically Ideal Quartz Crystal from Nature

Quartz Crystal Cuts

Unlike non-crystalline materials, many of the physical properties of crystals are dependent on direction. It is therefore necessary to choose reference directions within the crystals in order to specify the values of these physical properties. These directions are called "axes". There are three axes in quartz, the X, Y, and Z. The theoretically ideal quartz crystal, as formed in nature, would be a hexagonal prism with six cap faces at each end. Figure 1 shows a cross section from such a prism.

The Z-axis is known as the "optical" axis and is an axis of threefold symmetry. All physical properties repeat each 120° as the crystal is rotated about the Z-axis.

The X-axis is parallel to a line bisecting the angles between adjacent prism faces. This axis is called the "electrical" axis, since electrical polarization occurs in this direction when mechanical strain is applied. An X-cut is a slab of quartz cut from that portion of the main bar that is perpendicular to the X-axis. The X-cut was the original quartz plate investigated by the Curies and was later used as an ultrasonic wave transducer. The most popular use of this cut today is for digital watches which use a tuning fork design at 32.768 kHz.

The Y-axis, which is known as the "mechanical" axis, runs at right angles through the prism face as well as at right angles to the X-axis. Crystals in this group vibrate primarily in their "shear modes"; face shear for the low frequency elements such as the CT-cuts and DT-cuts, and thickness shear for the high frequency elements such as the AT-cuts and BT-cuts.

Crystal Cutting Angle

The term "cutting angle" or just "angle" refers to the specific angular orientation of a quartz plate with respect to the reference axes. Since the discovery of the usefulness of the Y-cut crystal plate for frequency control in 1917 there has been a large body of research conducted into many different types of crystal cuts. Today the majority of quartz-based oscillators make use of the AT-cut which is one of a family of cuts which exhibit a zero temperature-coefficient. The ideal AT-cut plate is a slab of quartz cut at an angle of 34° 15' from the Z-X plane and such a crystal will have a slope of 0 ppm/°C around 25 deg C. This orientation is therefore referred to as the "zero angle". As a result of its good temperature vs. frequency characteristic, the AT-cut crystal is the most popular cut in use today.

Frequency vs. Temperature Curves

The frequency-temperature characteristic of the AT-cut crystal is a polynomial of the form $F_r = A_3 \cdot [T-T_{ref}]^3 + A_2 \cdot [T-T_{ref}]^2 + A_1 \cdot [T-T_{ref}] + A_0$ where T_{ref} is a reference temperature, which is typically specified as 25°C. The F-T curve described by this function has several points of interest for cutting angles, which are greater than the zero angle:

Inflection Temperature: The temperature at which the 2nd order derivative of the polynomial has a value of zero occurs where the slope changes from negative to positive. This is referred to as the inflection temperature and the theoretical F-T curve is anti-symmetric around this temperature. The ideal AT-cut has an inflection temperature around 25°C but the actual inflection temperature of a particular resonator is influenced by the crystal design, including the specific cutting angle, frequency (thickness), overtone, and blank geometry.

Lower and Upper Turning Points: For cutting angles which are higher than the zero angle the F-T curve will exhibit turning points which are local maxima or minima frequencies. The temperatures at which the turning points occur are found as the roots of the 1st order derivative of the F-T polynomial.

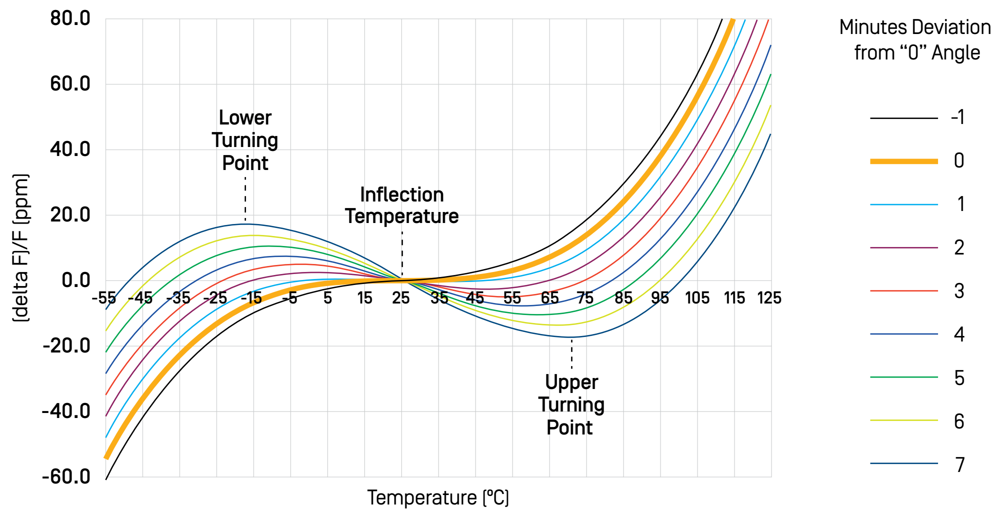


Figure 2. AT-cut Frequency vs. Temperature Curves

Angle Tolerance and Temperature Stability

Figure 2 illustrates a range of AT-cut frequency vs. temperature curves for various cutting angles. The thick orange line shows the zero angle (theoretically 34° 15' from the Z-axis) and additional F-T curves are shown for angles above and below this angle in 1' increments. To achieve a specific frequency-temperature stability it is necessary to cut the quartz plate at a particular angle. For example, from the curves shown, we see that an AT-cut resonator with a quartz blank cut at an angle which is 4.5' above the zero angle (i.e. 34° 19' 30") would have an F-T stability of ± 9 ppm from -40 to +85°C (the typical industrial operating temperature range). In practice, the actual angle of cut within a group of crystals will vary due to limitations in the quartz cutting equipment and processes. Additionally, the realized F-T stability is influenced by the crystal design and assembly variations. As a result the actual F-T stability is reduced and, for example, for a temperature range of -40 to 85 °C the tightest practical specification for F-T stability of an AT-cut crystal is in the range of ± 15 ppm, which allows a quartz plate angle variation of around 40 seconds of arc. If a tight F-T stability is specified, then only a very narrow range of crystal angles (i.e. a “tight angle spread”) will work and as a result the crystal cost can increase significantly. Some stabilities are simply not practical on a production basis and must be achieved with compensation (as in a TCXO or VCXO) or by placing the crystal in an oven—typically at one of the turning points (as in an OCXO). With these methods, frequency stabilities can be improved by several orders of magnitude.

Singly and Doubly Rotated Crystal Cuts

There are an infinite variety of crystal orientations that can be cut from a slab of quartz and a method of describing these cuts is needed. Various terminologies or reference systems have been employed over the years but a standardized system was developed by the I.R.E. (now IEEE) in the 1940s and this system is still used for quartz plates today. In this terminology any crystal cut can be described by specifying the thickness and length directions of the plate and then specifying the angular orientation of that plate using three rotations in a right-handed X-Y-Z frame. These three angles are denoted as (Φ, Θ, Ψ). The popular AT-cut crystal is a member of the Y-group of cuts and is a “singly” rotated cut with angular rotations of (0°, 35.25°, 0°). There are a variety of singly rotated cuts belonging to the Y-group which have zero temperature-coefficients and which are useful for various purposes and some of these are illustrated in Figure 3. These various cuts were named as they were discovered, AT, BT, CT, etc., where “T” denotes their “temperature-compensated” characteristic.

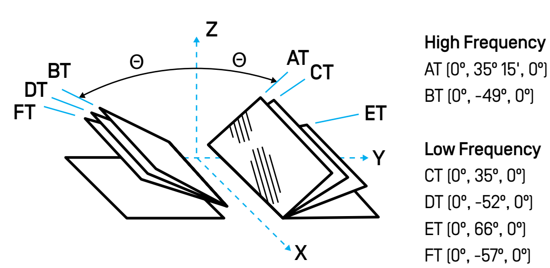


Figure 3. Singly-Rotated Zero Temperature-Coefficient Resonators

All of these singly rotated cuts have some sensitivity to mechanical and thermal strain and a significant amount of research has been devoted to searching for quartz cuts that have lower sensitivities. The earliest cut with significantly reduced sensitivity to strain and possessing a zero temperature-coefficient was identified in the 1950s and called the IT-cut and it is made with two cutting rotations. The IT-cut and others like it are referred to as "doubly" rotated cuts since they require that two separate rotations (Φ and Θ) be employed in the cutting process as illustrated in Figure 4.

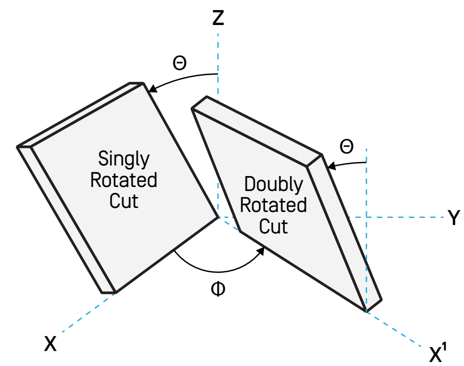


Figure 4. Singly- and Doubly-Rotated Crystal Cuts

The frequency-stress behavior of doubly rotated cuts depends almost entirely upon the first angle of rotation Φ while the frequency-temperature behavior is determined almost entirely by the second rotation Θ. Doubly rotated orientations achieving various degrees of freedom from stress bias and which have zero temperature-coefficients are illustrated in Figure 5. Cuts of interest in oscillator design have a Θ value near 34° and a Φ value ranging from 15 to 24° with an ideal orientation for stress compensation around 22°. This theoretically ideal orientation has been referred to as a TS-cut (thermal strain compensated) or TTC-cut (thermal transient compensated) but the most common name employed today is the SC-cut (stress compensated). In practice the stress compensation is not complete and even the so-called "true SC-cut" orientation has some degree of stress sensitivity. Therefore a variety of Φ orientations are commonly employed and SC-cuts are generally considered to be a family of cuts near Φ = 22°.

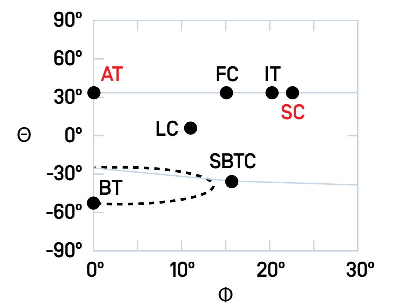


Figure 5. Various degrees of freedom-from-stress bias for doubly-rotated orientations that have zero temperature-coefficients

Quantic Croven has extensive experience in the design and manufacture of doubly rotated crystals such as the FC-cut, IT-cut and SC-cut family. The frequency-temperature curves of these cuts are very similar to those of AT-cuts and the major difference is the inflection temperature (Ti). The inflection temperature for doubly rotated cuts is in the area of 50°C for FC-cuts, 75°C for IT-cuts and 90°C for SC-cuts but the inflection temperatures can vary widely due to the plate thickness and geometry.

The main advantages of these resonators, and in particular the SC-cuts, are:

- Flatter frequency-temperature curves in the vicinity of the turning points enables better frequency stability for a given oven temperature stability
- Reduced amplitude frequency effect allows higher drive levels and improved signal to noise ratio
- Superior transient frequency-temperature characteristics resulting in improved short-term stability and faster warm-up times in oven operation
- Greatly reduced planar stress sensitivity resulting in improved long-term aging characteristics
- Improved vibration sensitivity (up to 2–3 times better than equivalent AT-cut resonators)
- Higher C_0/C_1 ratio resulting in reduced sensitivity to circuit component variations
- Higher Q-factor (typically 10–15% better than equivalent AT-cut resonators)
- Fewer activity dips and coupled modes

The main disadvantages are:

- More complicated manufacturing processes resulting in higher costs
- More complicated mode spectra and larger spurious modes
- Reduced pulling range necessitates tighter calibration tolerances and complicates use in TCXO and VCXO applications
- Tighter Θ tolerances are required to achieve specified turn over point ranges
- A strong b-mode response 8–10% above the main mode requires additional oscillator circuitry to avoid mode jumping

Doubly rotated resonators are the right choice for high precision oven-controlled crystal oscillators (OCXOs) and their use is increasing due to the substantial improvement they provide in frequency-temperature stability, aging, phase noise, g-sensitivity and other characteristics over their AT-cut counterparts.

The choice of which doubly rotated cut to use is dependent upon a number of factors including the desired oven operating temperature.

Type of Cut	Turning Point	Typical Turning Point Temperature Range
FC	Upper	+ 55 °C to + 75 °C
IT	Upper	+ 85 °C to + 105 °C
S0	Upper	+ 92 °C to + 110 °C
SC	Lower	+ 65 °C to + 85 °C
S1	Lower	+ 75 °C to + 90 °C
S2	Lower	+ 80 °C to + 100 °C
S3	Lower	+ 90 °C to + 110 °C

Some typical doubly rotated crystal parameters are listed on page 15. For your specific requirements please consult our engineering staff.

The Quartz Crystal as an Electrical Circuit

The complex electromechanical system that is formed by a vibrating quartz resonator operating in the fundamental mode can be described by the simplified equivalent circuit of Figure 7. The circuit elements L_1, C_1 and R_1 are referred to as the motional parameters of the crystal. The vibrating mass of the crystal is equivalent to a series motional inductance L_1, which has an effective inductance value ranging from thousands of henries for low frequency crystals to millihenries for high frequency resonators. The mechanical elasticity of the quartz is represented as a motional capacitance C_1 and the mechanical losses of the crystal appear as an equivalent series resistance R_1.

The electrodes plated on the surface of the crystal form a parallel plate capacitor with quartz as the dielectric. This, combined with stray capacitance from the crystal holder, creates the static capacitance C_0, which is typically on the order of a few pF for AT-cut and SC-cut crystals.

C_L is the load capacitance of the circuit into which the crystal is installed. The crystal is designed to operate at a specific load capacitance which is defined by the customer for parallel resonant applications.

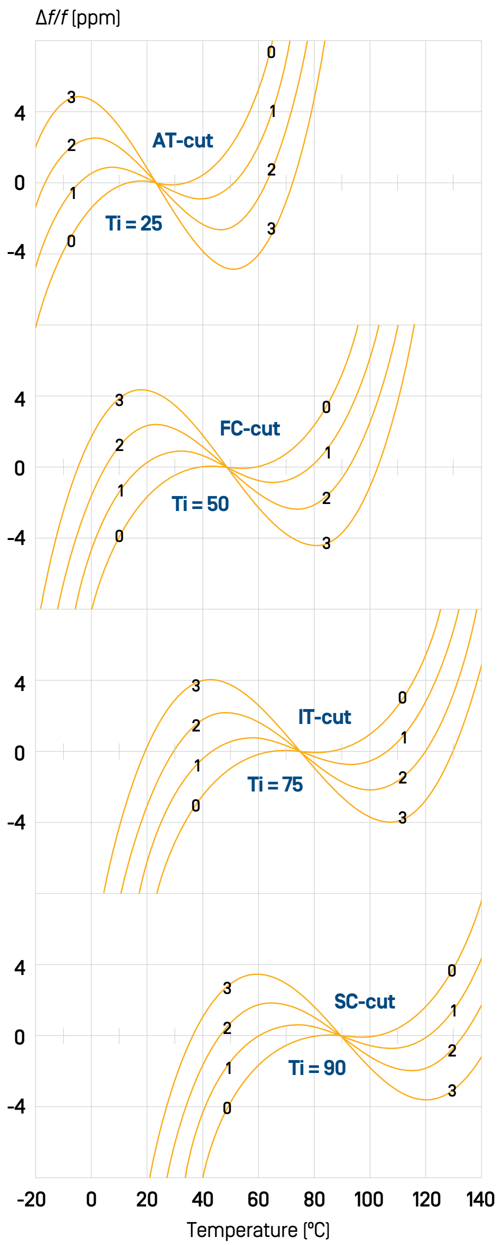


Figure 6. Generalized F-T curves for standard crystal cuts illustrating typical inflection temperatures

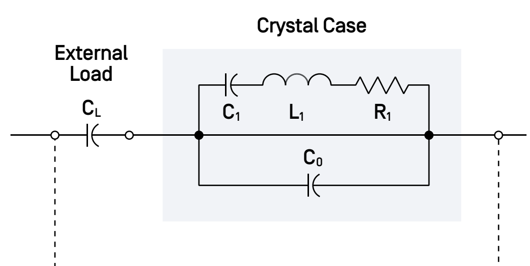


Figure 7. Simplified Equivalent Circuit

Equivalent Resistance

MIL-PRF-3098 defines equivalent resistance as follows:

A. For crystals designed to operate at series resonance, equivalent resistance is the equivalent ohmic resistance of the unit when operating in the specified crystal impedance meter adjusted for the rated drive level and tuned to the specified crystal unit frequency.

B. For crystal units designed to operate at parallel or anti-resonance, equivalent resistance is the equivalent ohmic resistance of the unit and a series load capacitor of the specified load value, when operating in the specified crystal impedance meter adjusted for rated drive level and tuned to the specified crystal unit frequency.

Generally, the lower the resistance value of a crystal, the more active it is and less drive is required to activate it. If the equivalent resistance is too high then the crystal may not oscillate.

Resistance can be represented by the formula:

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

where Q is the quality factor of the crystal resonator. Typical specification limits for standard AT-cuts are provided for a variety of crystal frequencies and holders in the table on page 14. For crystals with resistances lower than these values please consult the factory.

Spurious or Unwanted Modes

Vibrations at frequencies which are not fundamental or overtone modes are referred to as spurious or unwanted modes. These unwanted responses are influenced by many factors including the dimensions of the quartz wafer, the surface finish, the size and thickness of the electrode and the mounting technique. In a poorly designed crystal resonator, the equivalent series resistance of the crystal at the spurious mode can be less than the main mode resistance and this can result in spurious oscillations or frequency jumps in the oscillator output.

Spurious modes can be specified in the following ways: in terms of minimum resistance of the spurious mode, in terms of a minimum resistance ratio between the spurious mode and the main mode, or in terms of the transmission response in dB. These unwanted modes may be more or less important to you depending upon your application. For example, a filter manufacturer generally would be much more concerned about spurious modes than would an oscillator manufacturer.

When considering spurious mode suppression it should be noted that it can add dramatically to the crystal cost and cannot be done without affecting other parameters, such as motional capacitance and series resistance.

Parallel vs. Series Resonant Operation

Crystals are designed to resonate at either a series resonant frequency f_r, or a parallel resonant frequency f_a that is slightly higher than f_r (see Figure 8). Alternatively, by changing the capacitive load for the parallel-resonant circuit, you can operate the crystal at some frequency between f_a and f_r (i.e. f_l). At series resonance, the reactances of the motional capacitance C_1 and motional inductance L_1 are equal and opposite, and the net reactance of the series circuit is zero. The series resonant circuit is then equivalent to R_1 in parallel with the static capacitance C_0. R_1 is very small compared to the reactance of C_0 and therefore series resonance occurs at minimum impedance and with zero phase shift.

At a frequency slightly higher than f_r the inductive reactance of L_1 increases and the capacitive reactance of C_1 decreases. Then C_0 and L_1 form a parallel resonant circuit. When the net inductive reactance equals that of C_0 the crystal vibrates at frequency f_a where the crystal has very high impedance and an inductive reactance. Any external capacitance, such as a load capacitor C_L, then becomes a portion of the frequency determining network and the actual working frequency is slightly decreased from that of the theoretical parallel resonant frequency. The difference or delta frequency in Hz between the series resonant point and anti-resonant point can be obtained from the equation:

$$f_a - f_r = 0.5 f_r (C_1/C_0)$$

Parallel resonant crystals are most commonly used for applications where the frequency of the oscillator may need to be trimmed because the frequency shift can then be obtained by varying the value of the load capacitor. The load capacitance may be in series or parallel with the crystal but it must be specified if the crystal is to be used in the parallel resonant mode. Typical values of load capacitance range from 18–35 pF but other values can be accommodated in the crystal design.

Pullability

The pullability of a crystal describes how the operating frequency may be changed by varying the load capacitance. The pullability specification helps you decide how much trimming will be required to compensate for circuit component variations.

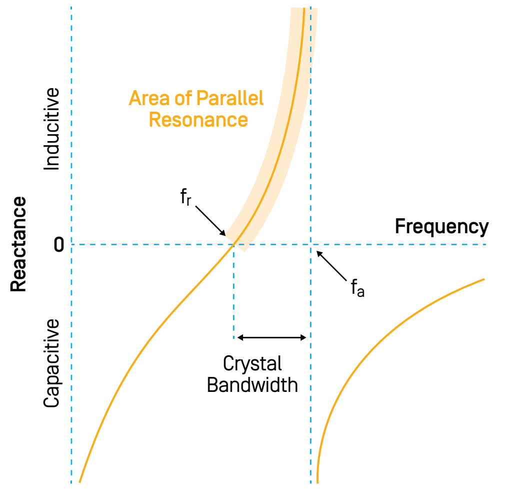


Figure 8. Crystal impedance - series vs parallel resonance

It also aids in the design of circuits for voltage control. The bandwidth over which the frequency can be varied is bounded by the series resonant frequency at one end and the parallel resonant frequency at the other (see Figure 8).

If pullability is a factor in the oscillator design collaboration with our engineers is advisable as bandwidth can be controlled to some extent during fabrication by varying the crystal parameters. An approximation of the pulling limits for standard crystals can be found from the formula:

$$\Delta f = \frac{0.5\, f_s \cdot C_1}{(C_0 + C_L)}$$

The exact limits also depend upon the Q of the crystal as well as associated stray capacitances. Pullability can be approximately doubled by modified crystal fabrication and by adding capacitance or inductance external to the crystal. If the C_0 and C_1 are known then the pullability in ppm between two load capacitances can be obtained using the formula:

$$ppm = \frac{C_1 \cdot (C_{L2} - C_{L1}) \cdot 10^6}{2 \cdot (C_0 + C_{L2})(C_0 + C_{L1})}$$

To obtain the average pulling per pF about a known load capacitance, use the following formula:

$$ppm/pF = \frac{C_1 \cdot 10^6}{2 \cdot (C_0 + C_L)^2}$$

Activity Dips

An activity dip is a sudden increase in crystal resistance accompanied by a change in resonant frequency that occurs at a specific temperature. Activity dips are also referred to as coupled modes because the origin of the perturbation is usually another quartz resonant mode and the dip occurs when the two modes overlap at the same temperature and the coupled mode then saps energy from the desired mode. The two modes usually overlap over only a very narrow temperature range but this can cause significant problems in TCXOs and in OCXOs when the coupling occurs near the oven temperature. When the resistance increases above the ability of the oscillator to sustain oscillation then the oscillator will cease to operate. Activity dips can also be caused by crystal manufacturing defects but in either case the frequency and resistance changes as a function of temperature are usually quite repeatable. As a result it is possible to test for such defects by measuring the crystal performance in small temperature steps and specifying a limit in terms of the frequency deviation or rate of resistance change.

The magnitude of an activity dip and the temperature at which it occurs is also influenced by the crystal drive level and load capacitance since the interfering mode has a C_1 value which differs from the desired mode. SC-cut crystals are relatively immune to couple modes as compared to AT-cut crystals.

Long-Term Stability (Aging)

Long-term stability is a measure of the frequency stability of the crystal over an extended time period and is usually expressed in terms of parts per billion (ppb) per day or year. Aging is a general term applying to any cumulative process which contributes to the deterioration of the crystal unit and which results in a gradual change in its operating frequency. There are many interrelated factors involved in aging, such as minute leakage through the holder, adsorption of moisture, corrosion of the electrodes, wire fatigue, small irreversible changes in the crystal lattice, out-gassing of the materials, presence of foreign matter, over-driving the crystal, thermal effects, mounting stresses and erosion of the crystal surface. With proper design and manufacturing processes, these aging factors can be controlled and aging rates as low as a few parts per billion (ppb) per year can be achieved.

Aging normally follows a logarithmic progression so that most aging takes place within the first few weeks of manufacture. This process can be accelerated by operating the crystal at an elevated temperature for an extended period, by temperature cycling or by high temperature bake or burn-in.

Quantic Croven has developed a wide range of low aging rate products for demanding applications. Our extensive clean room production capacity and manufacturing experience, coupled with our low phase noise processes, make us the leader in low aging rate crystals for OCXO applications.

Short-Term Stability

Short-term stability relates to frequency changes due to random noise, incidental modulation and any other frequency fluctuations in time intervals of a few seconds or less. The measurement of short-term stability can be accomplished in both the time and frequency domain. The most frequently used terms for short-term stability are Allan Variance in the time domain and Phase Noise in the frequency domain. Conversion formulas between these two measurement domains can be found in the literature. We typically measure this parameter in the frequency domain as it is more convenient.

Microphonic Noise

Microphonic noise is vibration-induced noise in the otherwise frequency-independent noise floor range (to 30 kHz). It consists of discrete spurious peaks that are usually the result of crystal resonator and support resonances. Microphonic noise can be significantly reduced by proper choice of resonator cut and geometry, bonding techniques and support configuration. We have several techniques for reducing or eliminating microphonic noise when specified by the customer. For your specific requirements please contact our sales and engineering staff.

Drive Level

The rated drive level is the power dissipation level at which the crystal resonator is designed to operate. Operating the crystal at drive levels which are too high or too low can result in improper performance. For example, if the drive level is too low, the crystal may fail to oscillate or have degraded phase noise performance (this is exhibited to a greater degree in SC-cut crystals). On the other hand, if the crystal is driven at too high a level, the results could include frequency shifts (permanent or temporary), crystal activity dips (frequency-temperature discontinuities), excessive aging or, in extreme cases, physical failure of the resonator. In addition, the maximum specified equivalent resistance of the crystal is affected by and is measured at a predetermined drive level. Therefore it is important to understand the effect of drive level on crystal performance and to operate the resonator at a suitable drive level.

Our standard drive level is 200 µW but drive levels can vary from a few microwatts for some low frequency designs to several mW for some higher frequency devices. For your specific requirements please contact our sales and engineering staff.

Phase Noise

Phase noise is a term used to describe instability in the phase or frequency of a crystal unit in periods of time of a few seconds or less. It is measured as the ratio of power in the noise to that in the carrier at a specified offset frequency (Fourier frequency) in a specified bandwidth. The measurement bandwidth is usually normalized to 1 Hz. The phase noise characteristic of a crystal is important for resonators intended for use in crystal oscillators for radar, navigation, communication, electronic warfare and RF test and measurement systems. High phase noise brings about a loss of weak signal detection and can cause other problems such as high error rates, loss of radar sensitivity at low Doppler shifts and lack of definition in ultrasound imaging systems. By knowing the inherent phase noise of a crystal resonator, oscillator designers can predict the lowest oscillator phase noise attainable using that resonator.

The dominant source of noise in a well designed crystal oscillator is resonator 1/f frequency fluctuation known as flicker frequency noise. This noise is typically related to internal losses in the resonator due to thermal interactions and is dependent on the Q factor of the resonator ($\sim 1/Q^4$). However this is strictly true only for resonators designed to operate at the highest possible Q. For resonators operating well below the optimum Q, the means by which the Q is decreased is important to the level of 1/f noise.

Burst Noise

Burst or “popcorn” noise is the other significant noise process in crystal resonators. This type of noise is distinct in character from 1/f noise and its source is confined to a very small area of the crystal. It is believed that burst noise is connected to surface defects of the resonator (deep pits and scratches). In order to attain the ultimate noise level for a given frequency it is necessary to use:

- Overtone resonators rather than fundamental mode resonators
- Resonators designed to operate at the optimized Q for a given frequency
- SC-cut resonators rather than AT-cut resonators

Quantic Croven has established an excellent reputation as a manufacturer of low phase noise crystals and crystals which exhibit very low burst noise. It is a combination of our extensive design experience and unique processes which yield crystals with superior low noise performance.

Phase Noise Measurement

There are several techniques available to measure the noise characteristic of a quartz crystal using passive methods however these techniques are not accurate at very low noise levels and do not provide results that correlate well with oscillator noise production data.

In order to properly assess crystal resonator noise it is necessary to install the crystal in a well designed low noise oscillator and stabilize the crystal at the proper operating temperature and drive level. Quantic Croven has a variety of state of the art phase noise analyzer equipment and makes use of the highest quality low noise test oscillators from Quantic Wenzel. As a result we are able to accurately measure crystal noise and provide our customers with product screened to their particular requirements. This allows for significant improvements in oscillator performance and production yields.

For the best possible correlation between crystal and oscillator noise measurements it is desirable to test the crystals in a customer supplied oscillator in order to exactly replicate the circuit conditions which can impact close in noise. It should be noted that correlation is only possible if the resonators exhibit low burst noise.

Vibration Sensitivity

Vibration sensitivity (also known as g-sensitivity or acceleration sensitivity) refers to the degradation of the close in noise performance of a crystal under the influence of external mechanical vibrations. Phase noise of otherwise quiet crystal resonators can be significantly degraded when the crystal is operated in environments such as fixed and rotary wing aircraft, ships, missiles and other applications where the quartz blank is excited by mechanical vibration.

Sinusoidal vibration produces spurious sidebands which are offset from the carrier signal by the frequency of vibration while random vibration produces sidebands which appear as an overall increase in the phase noise level. The magnitude of vibration-induced sidebands is dependent upon the frequency and magnitude of vibration, the output frequency of the crystal resonator or oscillator, the vibration sensitivity of the crystal resonator and the mechanical resonances in the crystal and the oscillator. Proper oscillator design and internal mounting of the crystal is essential to achieve optimum performance. The performance of the oscillator under vibration will be limited by the crystal design providing that the method in which the crystal is installed into the oscillator does not contribute to its vibration sensitivity.

Doubly rotated SC-cut and IT-cut resonators have a vibration sensitivity which is typically 2-3 times lower than that of AT-cut resonators of the same frequency, overtone and construction. Nominal vibration sensitivity attainable with four-point mount HC-35/U holders is 1×10^{-9}/g for AT-cut crystals and 3×10^{-10}/g for SC-cut and IT-cut crystals. Quantic Croven has extensive experience in the design and development of crystals optimized for low vibration sensitivity in many holders and frequency ranges.

Modes of Vibration

Quartz crystals naturally vibrate in several simultaneous resonance modes referred to as the fundamental or overtone modes. Usually, one of these modes is designed to be dominant at the desired operating frequency. The fundamental frequency of vibration is a function of the resonator physical dimensions and angle of cut while the overtone modes occur at odd numbered harmonics of the fundamental mode and include the 3rd, 5th, 7th, 9th, and 11th harmonics. It should be noted that the harmonic frequencies of vibration are not integral multiples of the fundamental mode but will differ slightly.

Typical AT-cut resonators are designed to operate in the fundamental mode from 1 MHz to 35 MHz and from 5 MHz to 360 MHz as overtone crystals.

High Frequency Fundamental Mode Crystals

Conventional crystal lapping processes limit the highest fundamental mode frequency which may be reliably achieved to around 60 MHz above which excessive breakage and other problems occur. Nevertheless there is a need for even higher fundamental frequencies because of the larger values of motional capacitance (C_1) that can be achieved versus overtone mode crystals of the same frequency. High Frequency Fundamental (HFF) mode crystals are therefore useful for applications where greater pullability is required and in filter applications where they provide better spurious mode response than overtone crystals at the same frequency.

Quantic Croven uses various chemical milling processes to manufacture blanks with fundamental frequencies of >170 MHz and can provide blanks for hybrid applications or sealed crystals in a variety of holders. Please consult our sales and engineering staff to discuss your particular requirements.

How To Specify AT-Cut Crystals

Most AT-cut crystals may be fully specified with the following information:

1. **Crystal Frequency** (i.e. 1 to 360 MHz)

2. **Mode of Operation** (i.e. Fund, 3rd, 5th, etc.)

3. **Holder Style** The holder style depends on your individual application and crystal frequency. (See pages 16–18.)

4. **Calibration Tolerance at Reference Temperature** The allowable frequency deviation from the nominal frequency at the fixed calibration temperature (i.e. ± 20 ppm @ 25°C, ± 5 ppm @ 75°C, etc.).

5a. **Temperature Stability** The allowable frequency deviation over a specified temperature range, with reference to the actual frequency measured at the calibration temperature (i.e. ± 15 ppm over temperature vs FR or FL as applicable), or ...

5b. **Total Tolerance** The allowable deviation over a specified temperature range, with reference to the nominal frequency (i.e. calibration tolerance and temperature stability combined).

6. **Operating Temperature Range** This is the specified temperature range over which the temperature stability or the total tolerance is to be effective.

7. **Circuit Condition** The circuit condition will be either parallel or series resonance. If parallel resonance, please state the load capacitance (see page 8).

Optional information may include any other parameters that are important to you and which are not covered by, or differ from, MIL-PRF-3098 (such as shunt capacitance C_0, motional capacitance C_1, equivalent resistance R_1, or spurious mode suppression, etc.).

The Quantic Croven Code

We have reduced items 2 through 7 to a nine-digit alpha-numeric code that, along with the frequency, can be used to describe the crystal required.
A typical code would be:

A350DFE-32 @ 20.000000 MHz

and is translated as follows:

A	Fundamental mode of operation
357	HC-35/U holder in standard height
D	Calibration tolerance of ± 10 ppm at the reference temperature
F	Temperature stability of ± 20 ppm, with respect to the frequency measured at the reference temperature
E	Temperature range of -15°C to +65°C, over which the temperature stability is effective
-32	These two digits specify parallel resonance operation and the load capacitance in pF (i.e. 32 pF), 00 denotes series resonance)

Nominal frequency of 20.000000 MHz

The table on the next page lists the many values of these six essential parameters that can be covered by the Crystal Code. Note that the nine digit Crystal Code addresses only the six parameters outlined above. Unless otherwise specified by the customer, the values of any additional parameters will be per the latest revision of MIL-PRF-3098.

If the crystal requirements cannot be fully described by the nine digit code, a unique part number will be assigned by the factory.

Mode

Code	Desc
A	Fund
B	3rd OT
C	5th OT
D[1]	7th OT
E[1]	9th OT
F[1]	11th OT

Holder

Code	Desc
18	HC-43/U or 49/U
25	HC-42/U or 50/U
33	HC-51/U
35	HC-35/U
36	HC-35/U LP or LPS
37	HC-37/U
40	HC-40/U
42	HC-40/U
46	TO-6
80	HC-52/U
90	SM1

Code	Desc
0	Standard
1	Modifed can height
2	Modifed can height
3	SMD
4	Modifed can height
5	Modifed can height
6	Modifed can height
7	Cold weld
8	SMD
9	Resistance weld

Calibration Tolerance at Reference Temperature

Code	Desc
X	± 1.5 ppm
A	± 2 ppm
B	± 5 ppm
C	± 7 ppm
D	± 10 ppm
E	± 15 ppm
F	± 20 ppm
G	± 25 ppm
H	± 30 ppm
J	± 40 ppm
M	± 50 ppm
K	± 100 ppm

Temperature Stability or Total Tolerance

Code	Desc
X	± 2 ppm stability
Y	± 3 ppm stability
Z	± 4 ppm stability
B	± 5 ppm stability
C	± 7 ppm stability
D	± 10 ppm stability
E	± 15 ppm stability
F	± 20 ppm stability
G	± 25 ppm stability
H	± 30 ppm stability
J	± 40 ppm stability
M	± 50 ppm stability
L	± 75 ppm stability
K	± 100 ppm stability
N	± 150 ppm stability
S	Specific curve
T	± 20 ppm[4] [B]†
U	± 25 ppm[4] [C]†
V	± 30 ppm[4] [D]†
W	± 50 ppm[4] [F]†
P	± 100 ppm[4] [H]†
R	± 200 ppm[4] [M]†
0	Turn Over Point in Oven Range

†Corresponding calibration codes

Operating Temperature Range [°C]

Code	Desc
X	+15 to +35
Y	+10 to +40
Z	+5 to +45
A	0 to +50
B	-5 to +55
D	-10 to +60
E	-15 to +65
F	-20 to +70
G	-25 to +75
H	-30 to +80
J	-40 to +90
M	-55 to +105
U	+50 to +60 Oven
L	+55 to +65 Oven
T	+60 to +70 Oven
N	+65 to +75 Oven
P	+70 to +80 Oven
R	+75 to +85 Oven
S	+80 to +90 Oven
V	+85 to +95 Oven
W	+90 to +100 Oven
X	+95 to +105 Oven
0	Not specified

Calibration frequency is at the mid-point of the above ranges.

Circuit Condition

Code	Desc
00	Series resonance
01	Parallel resonance load capacity of 100 pF or more. Advise actual value.
8 to 90	Parallel resonance load capacity in pF
99	Calibration at reference temperature in customer's oscillator

Notes:

1. 7th, 9th, and 11th overtone modes are available at series resonance only.
2. Standard holder types for all codes are as per MIL-H-10056.
3. Not all holders are available with all modifications.
4. These codes indicate the total tolerance (i.e. calibration and temperature stability) measured from the nominal frequency. They are to be used with the calibration code indicated.

For your specific requirements please contact our engineering staff.

AT-cut Equivalent Resistance by Holder

Holder	Frequency Range (MHz)	Mode of Operation	Maximum Resistance (Ohms)
HC-40/U and HC-51/U	1.000–1.199	Fundamental	400
HC-40/U and HC-51/U	1.200–1.349	Fundamental	340
HC-40/U and HC-51/U	1.350–1.497	Fundamental	300
HC-40/U and HC-51/U	1.498–1.599	Fundamental	280
HC-40/U and HC-51/U	1.600–1.849	Fundamental	220
HC-40/U and HC-51/U	1.850–1.999	Fundamental	190
HC-40/U and HC-51/U	2.000–2.499	Fundamental	150
HC-40/U and HC-51/U	2.500–2.999	Fundamental	90
HC-40/U and HC-51/U	3.000–4.999	Fundamental	37
HC-40/U and HC-51/U	5.000–6.999	Fundamental	25
HC-40/U and HC-51/U	7.000–9.999	Fundamental	20
HC-40/U and HC-51/U	10.000–14.999	Fundamental	18
HC-40/U and HC-51/U	15.000–33.000	Fundamental	20
HC-43/U and HC-49/U	2.900–3.324	Fundamental	150
HC-43/U and HC-49/U	3.325–3.499	Fundamental	90
HC-43/U and HC-49/U	3.500–6.999	Fundamental	50
HC-43/U and HC-49/U	7.000–9.999	Fundamental	30
HC-43/U and HC-49/U	10.000–14.999	Fundamental	25
HC-43/U and HC-49/U	15.000–33.000	Fundamental	20
HC-35/U and SM1	10.000–33.000	Fundamental	25
HC-45/U and HC-52/U	10.000–14.999	Fundamental	30
HC-45/U and HC-52/U	15.000–17.999	Fundamental	25
HC-45/U and HC-52/U	18.000–33.000	Fundamental	20
ALL HOLDERS	33.001–220.000	Fundamental	Consult the factory
HC-40/U and HC-51/U	10.000–61.000	3rd overtone	40
HC-40/U and HC-51/U	61.001–84.000	3rd overtone	60
HC-43/U and HC-49/U	15.000–61.000	3rd overtone	40
HC-43/U and HC-49/U	61.001–84.000	3rd overtone	60
HC-35/U and SM1	30.000–61.000	3rd overtone	40
HC-35/U and SM1	61.001–100.000	3rd overtone	60
HC-45/U and HC-52/U	30.000–61.000	3rd overtone	50
HC-45/U and HC-52/U	61.001–100.000	3rd overtone	50
HC-43/U and HC-49/U	45.000–89.999	5th overtone	50
HC-43/U and HC-49/U	90.000–125.000	5th overtone	60
HC-43/U and HC-49/U	125.001–165.000	5th overtone	65
HC-35/U and SM1	50.000–89.000	5th overtone	50
HC-35/U and SM1	90.000–125.000	5th overtone	60
HC-35/U and SM1	125.001–165.000	5th overtone	65
HC-45/U and HC-52/U	50.000–125.000	5th overtone	60
HC-45/U and HC-52/U	125.001–165.000	5th overtone	65
ALL HOLDERS	80.000–196.000	7th overtone	120
ALL HOLDERS	162.000–250.000	9th overtone	200

Notes:
1. Unless otherwise specified the standard drive level is 200 μW.
2. For resistance values lower than the maximum values indicated please contact our engineering staff.

Standard SC-cut Crystal Specifications

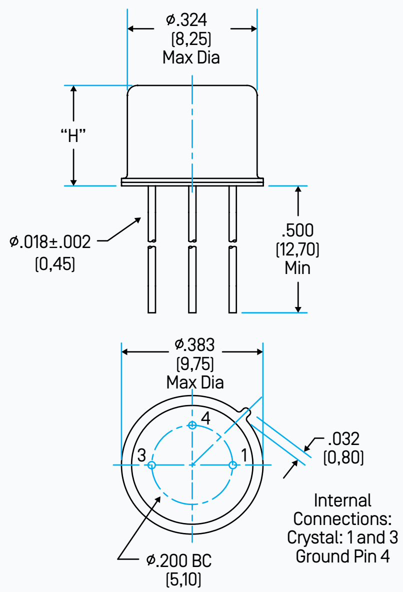
Number	Frequency (MHz)	Holder	Calibration Tolerance (ppm @ turn over temp)	Turn Over Temp (°C)	Load Capacitance (pF)	Overtone	Typical Motional Capacitance (fF)	Maximum Resistance (ohms)	Maximum Aging (ppb/ year after 30 days)
CC31730	5	HC-37	± 1.5	90–100	20	3rd	0.13	175	20
CC3174-5	5	HC-37	± 1.5	80–90	20	3rd	0.13	175	20
CC4018-5	5	HC-40	± 1.5	80–90	20	3rd	0.13	140	10
CC3169-10	10	HC-37	± 1.5	80–95	22	3rd	0.16	100	30
CC3175-10	10	HC-37	± 1.5	90–102	20	3rd	0.18	80	30
CC4019-10	10	HC-40	± 1.5	75–85	20	3rd	0.18	80	30
CC5062	10	HC-43	± 2	80–90	20	3rd	0.17	100	50
CC5087-10	10	HC-43	± 2	92–105	20	3rd	0.18	100	50
CC6064-10	10	HC-45	± 3	80–95	17	Fund	1.80	40	200
CC5071	10.23	HC-43	± 3	80–95	20	3rd	0.16	100	50
CC1349-20	20	HC-35	± 2	90–102	20	3rd	0.17	80	100
CC1352-25.6	25.6	HC-35	± 3	90–102	20	3rd	0.44	40	100
CC5099-40	40	HC-43	± 4	90–104	Series	3rd	0.40	50	100
CC6045-40	40	HC-45	± 5	94–104	20	3rd	0.41	50	100
CC1039-50	50	HC-35	± 5	80–90	Series	3rd	0.38	60	200
CC1277-50 LPS	50	HC-35 LPS	± 4	95–105	20	5th	0.21	80	100
CC1331-50 LPS	50	HC-35 LPS	± 4	90–104	Series	3rd	0.38	50	100
CC5100-50	50	HC-43	± 4	90–104	Series	3rd	0.40	50	100
CC6066-50	50	HC-45	± 4	90–104	20	3rd	0.44	50	100
CC1144-LP	60	HC-35 LP	± 5	80–95	Series	3rd	0.34	50	100
CC1233-60	60	HC-35	± 3	80–90	20	3rd	0.34	60	100
CC1280-60	60	HC-35	± 3	85–95	Series	5th	0.15	110	80
CC1162-80 LP	80	HC-35 LP	± 4	90–100	Series	5th	0.17	90	100
CC1184-80 LPS	80	HC-35 LPS	± 4	85–95	Series	5th	0.17	90	100
CC1277-80 LPS	80	HC-35 LPS	± 4	95–105	Series	5th	0.19	100	100
CC9012-80	80	SM1	± 4	80–95	Series	3rd	0.35	100	300
CC1352-90	90	HC-35	± 4	80–95	Series	5th	0.16	95	100
CC9013-90	90	SM1	± 4	80–95	Series	5th	0.15	100	300
CC1037-LP	91.858	HC-35 LP	± 4	80–95	Series	5th	0.16	110	100
CC1075	100	HC-35 LP	± 5	80–95	Series	5th	0.17	100	100
CC1200-100 LPS	100	HC-35 LPS	-7/3	85–95	Series	5th	0.15	100	100
CC1253-100	100	HC-35	± 4	80–95	Series	5th	0.15	100	100
CC1284-100 LPS	100	HC-35 LPS	± 5	92–106	Series	5th	0.17	110	100
CC1319-100	100	HC-35	-2/4	90–103	Series	5th	0.19	90	100
CC5088-100	100	HC-43	0/10	80–90	Series	5th	0.15	100	200
CC6008	100	HC-45	± 5	80–90	Series	5th	0.15	110	250
CC6062-100	100	HC-45	± 5	92–106	Series	5th	0.17	110	200
CC9007	100	SM1	± 5	80–95	Series	5th	0.15	100	300
CC1250-102.4 LP	102.4	HC-35 LP	± 5	85–95	Series	5th	0.15	110	100
CC1043	120	HC-35	± 5	80–95	Series	5th	0.15	100	120
CC1163-120 LP	120	HC-35 LP	± 5	90–100	Series	5th	0.19	100	120
CC1183-120 LPS	120	HC-35 LPS	± 5	85–95	Series	5th	0.15	110	120
CC1284-120 LPS	120	HC-35 LPS	± 5	92–106	Series	5th	0.18	100	100
CC6023	120	HC-45	± 5	92–106	Series	5th	0.18	100	100
CC9014-120	120	SM1	± 5	80–95	Series	5th	0.16	100	300

Quantic Croven is a world leader in the design and manufacturing of SC-cut crystals for use in ovenized oscillators and our portfolio contains more than 2,000 different SC-cut designs in the frequency range of 4 to 250 MHz. A selection of our standard SC-cut offerings are listed above. **Please contact our engineering staff for your unique requirements.**

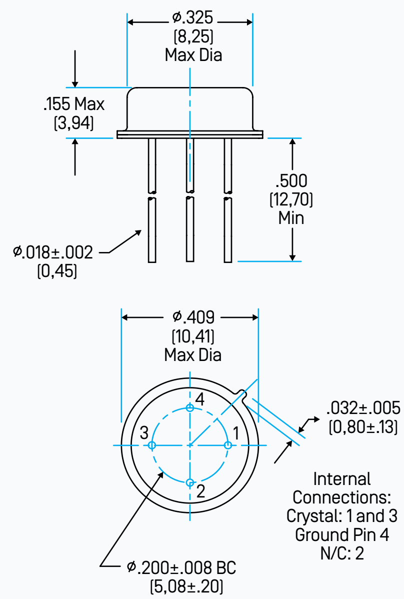
Holder Specifications

Type	Seal	Code	Height 'H' in [mm]	Frequency Range [MHz]				
				Fund	3rd	5th	7th	9th
HC-35/U	Cold Weld	350	0.265 [6,72] Max	7–135	18–230	35–230	120–260	160–300
HC-35/U	Cold Weld	355	0.220 [5,58] Max	7–135	18–230	35–230	120–260	160–300
HC-35/U LPS	Cold Weld	356	0.208 [5,28] Max	7–135	18–230	35–230	120–260	160–300
HC-35/U LPS	Cold Weld	360	0.155 [3,93] Max	7–135	18–230	35–230	120–260	160–300
HC-35/U LP	Cold Weld	360	0.155 [3,93] Max	7–135	18–230	35–230	120–260	160–300
SM1	Resistance Weld	909	0.095 [2,40] Max	7–135	18–230	35–230	120–260	160–300

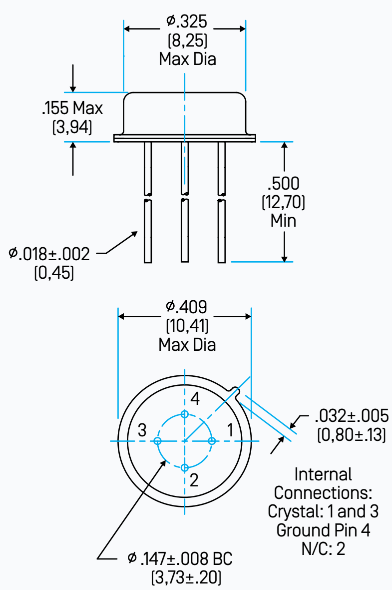
HC-35/U



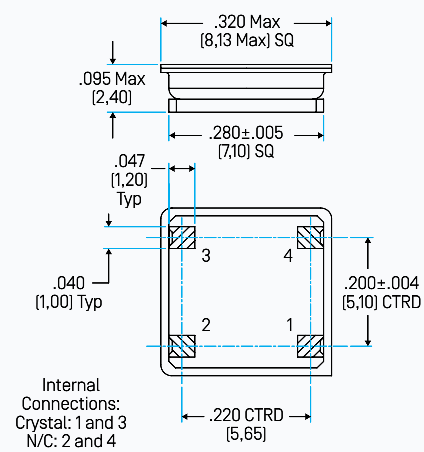
HC-35/U LPS



HC-35/U LP



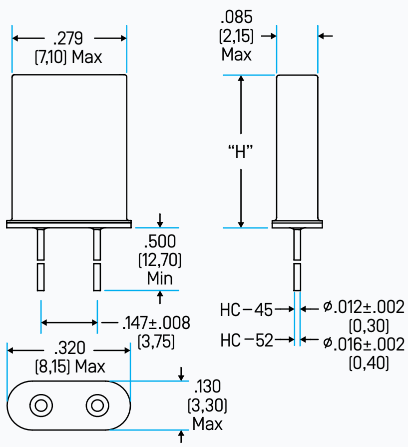
SM1



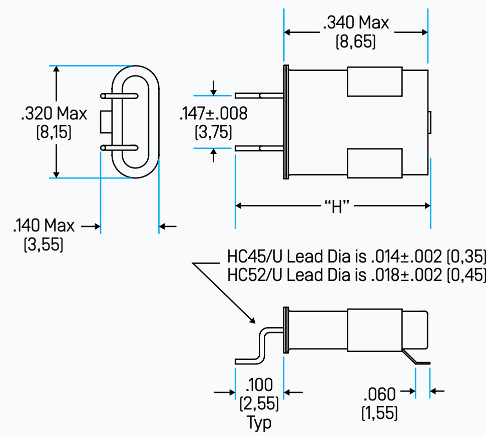
Holder Specifications

Type	Seal	Code	Height 'H' in [mm]	Frequency Range [MHz]				
				Fund	3rd	5th	7th	9th
HC-45/U	Cold Weld	807	0.342 [8,69] Max	10–175	18–225	40–260	80–260	100–300
HC-52/U	Resistance Weld	809	0.342 [8,69] Max	10–175	18–225	40–260	80–260	100–300
HC-45/U SMD	Cold Weld	803	0.445 ± 0.020 [11,30 ± 0,51]	10–175	18–225	40–260	80–260	100–300
HC-52/U SMD	Resistance Weld	803	0.445 ± 0.020 [11,30 ± 0,51]	10–175	18–225	40–260	80–260	100–300
HC-43/U	Cold Weld	187	0.530 [13,46] Max	3–35	8–105	30–165	80–230	100–300
HC-49/U	Resistance Weld	189	0.530 [13,46] Max	3–35	8–105	30–165	80–230	100–300
HC-49/U	Resistance Weld	186	0.455 [11,56] Max	6–35	10–105	30–165	80–230	100–300
HC-43/U SMD	Cold Weld	183	0.660 ± 0.015 [16,76 ± 0,38]	3–35	8–105	30–165	80–230	100–300
HC-43/U SMD	Cold Weld	188	0.725 ± 0.015 [18,42 ± 0,38]	3–35	8–105	30–165	80–230	100–300
HC-49/U SMD	Resistance Weld	183	0.660 ± 0.015 [16,76 ± 0,38]	3–35	8–105	30–165	80–230	100–300
HC-49/U SMD	Resistance Weld	188	0.725 ± 0.015 [18,42 ± 0,38]	3–35	8–105	30–165	80–230	100–300

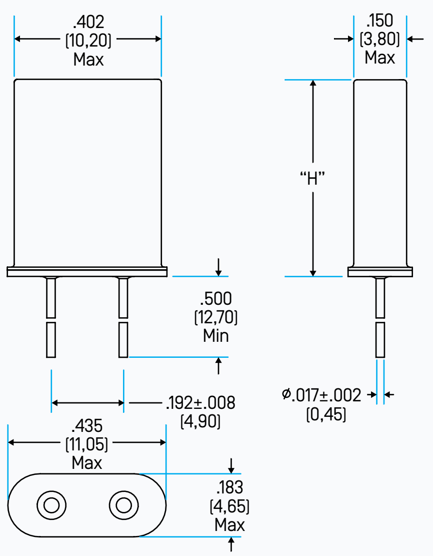
HC-45/U and HC-52/U



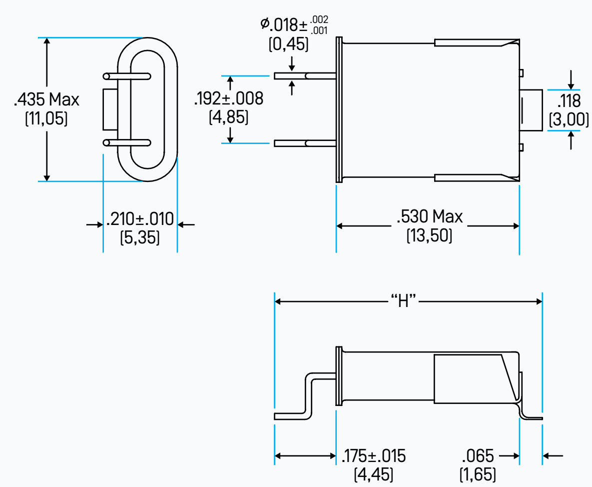
HC-45/U and HC-52/U SMD



HC-43/U and HC-49/U



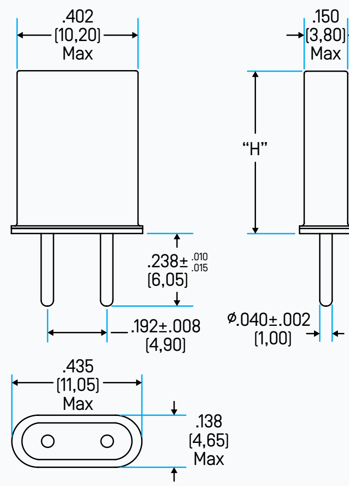
HC-43/U and HC-49/U SMD



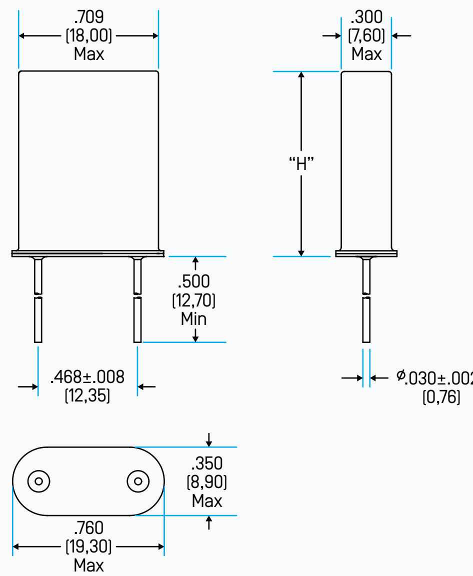
Holder Specifications

Type	Seal	Code	Height 'H' in [mm]	Frequency Range [MHz]				
				Fund	3rd	5th	7th	9th
HC-42/U	Cold Weld	257	0.530 [13,46] Max	3–35	8–105	30–165	80–230	100–300
HC-42/U	Cold Weld	256	0.455 [11,56] Max	6–35	10–105	30–165	80–230	100–300
HC-51/U	Resistance Weld	339	0.775 [19,95] Max	1–15	4–60	10–75	—	—
HC-37/U	Cold Weld	371	0.235 [5,95] Max	2.5–25	4–60	10–100	—	—
HC-37/U	Cold Weld	372	0.200 [5,08] Max	2.5–25	4–60	10–100	—	—
HC-37/U	Cold Weld	374	0.160 [4,06] Max	4–25	10–60	18–100	—	—
HC-40/U	Cold Weld	405	0.355 [9,03] Max	1–10	4–30	10–50	—	—
HC-40/U	Cold Weld	420	0.250 [6,35] Max	3–25	10–75	30–100	—	—

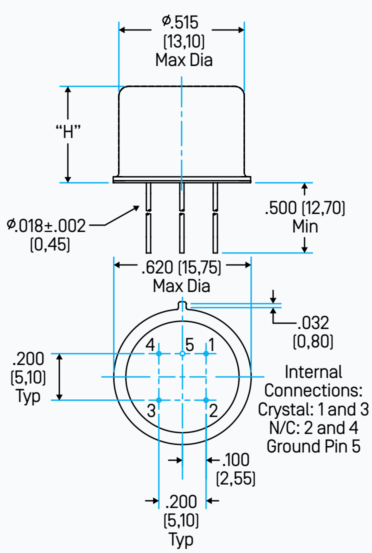
HC-42/U



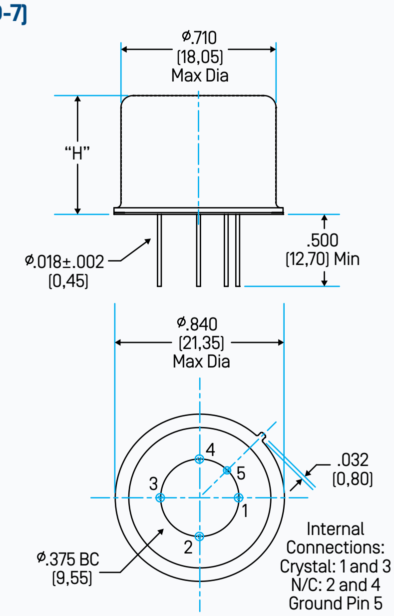
HC-51/U



HC-37/U [TO-8]



HC-40/U [EO-7]



Military and Space Products

Quantic Croven has been a leading supplier of precision quartz resonators for space, military and other hi-rel applications since the 1960's. Our crystals can be found in the deepest regions of space and the most hostile environments closer to home. Complete in house testing capabilities enable us to provide full qualification and reliability assurance processing for the most demanding applications.

In addition we have been QPL approved since 1967 and offer a full range of standard crystals per MIL-PRF-3098. A list of the existing standard parts is shown here.

ITAR Compliance and Classified Programs

For products and information governed by ITAR regulations Quantic Croven maintains registration with the Canadian Controlled Goods program which enables our customers to take advantage of the ITAR exemptions as proscribed under 22 CFR 126.5. This makes it very easy to transfer ITAR related materials and documents from and to our facility.

In addition Quantic Croven has valid site security clearances recognized by the United States Department of Defense which enable us to provide services for programs where security clearances are required.

RoHS Compliance

All crystals may be ordered as RoHS compliant. Please specify your requirement at time of order entry.
If RoHS compliance is not specified then the crystal leads may be coated with a Pb bearing solder.

Standard Crystals per MIL-PRF-3098

Military CR-Type	MIL-PRF SPEC. NO.	Frequency Range in MHz
CR55/U	3098/33	24.000–62.000
CR56/U	3098/34	50.000–125.000
CR59/U	3098/37	50.000–125.000
CR60/U	3098/38	5.000–20.000
CR61/U	3098/39	24.000–61.000
CR64/U	3098/42	2.900–20.000
CR67/U	3098/45	24.000–62.000
CR69/U	3098/47	2.900–25.000
CR72/U	3098/50	24.000–25.000
CR76/U	3098/53	24.000–61.000
CR80/U	3098/57	50.000–125.000
CR81/U	3098/58	24.000–62.000
CR82/U	3098/59	50.000–125.000
CR83/U	3098/60	50.000–125.000
CR84/U	3098/61	24.000–61.000
CR97/U	3098/72	8.000–10.000
CR101/U	3098/103	7.000–20.000
CR102/U	3098/104	50.000–125.000
CR103/U	3098/105	17.000–61.000
CR106/U	3098/82	10.500–11.500
CR117/U	3098/93	30.000–62.000
CR139/U	3098/118	20.000–22.000
CR141/U	3098/122	50.000–90.000

Quantic™ Croven

Quantic Croven has been a leader in the design and development of precision quartz resonators since our founding in 1954. With extensive capabilities related to low noise, low aging rate and high-reliability resonators we service the telecommunications, instrumentation, metrology, data telemetry, military, avionics, space and industrial markets.

www.quanticcroven.com

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Fax: 905-668-5003
E-mail: sales@quanticcroven.com

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Since 1978, Quantic Wenzel has set the standard for ultra-low phase noise crystal oscillators, a portfolio complemented by a range of advanced frequency sources and integrated microwave assemblies to 30 GHz and beyond. Quantic Wenzel's frequency control and timing products are designed into mission-critical military, space and commercial applications, and perform in the most extreme environments.

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E-mail: sales@quanticwenzel.com

2215 Kramer Lane, Austin, TX, 78758, USA

Quantic™ MWD
MICROWAVE DYNAMICS

Founded in 1993, Quantic MWD (Microwave Dynamics) designs and manufactures free running and phase-locked oscillators, amplifiers, frequency converters, and frequency multipliers with a focus on the singular characteristic that matters most: performance. Quantic MWD offers a portfolio of best-in-class solutions that maximize stability and minimize noise under extreme environmental conditions, ensuring optimal precision and reliability for mission-critical and industrial defense applications.

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