CROVEN CRYSTALS
Wenzel International, Inc.

PRECISION QUARTZ RESONATORS

COMPANY BACKGROUND

CROVEN CRYSTALS has provided high quality and reliability products to the frequency control industry for more than fifty 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) & **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 large 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 Coven 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.

Since that time our name has changed several times as the Company went through a variety of management and organizational changes however the commitment to manufacturing the finest crystals for the most demanding applications has been unwavering.

In 2006 the company was acquired by Wenzel Associates and the CROVEN CRYSTALS name has been resurrected in recognition of our origins and long tradition of serving the crystal resonator market.

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.

Welcome to the new CROVEN CRYSTALS!
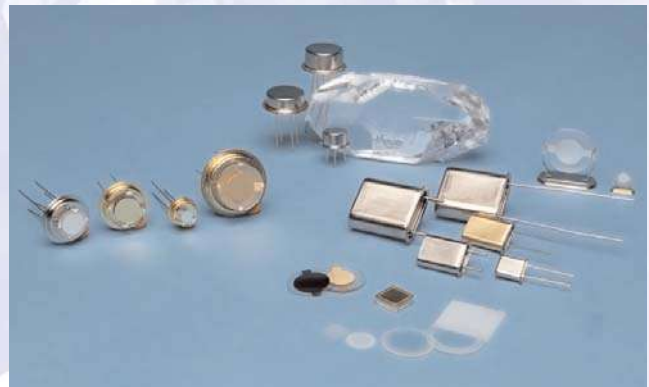
A BRIEF HISTORY OF PIEZO-ELECTRIC QUARTZ AND ITS SPECIAL PROPERTIES

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 another Frenchman, Professor P. 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 few years later a quartz piezoid was used to control the frequency of an oscillator 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 at the end of the Second World War, naturally occurring quartz candles are rarely 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 almost 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.

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, the Y and the Z. The theoretically ideal quartz crystal, as formed in nature, would be a hexagonal prism with six cap faces at each end. A cross section taken from that prism is shown in Figure 1.

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 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.
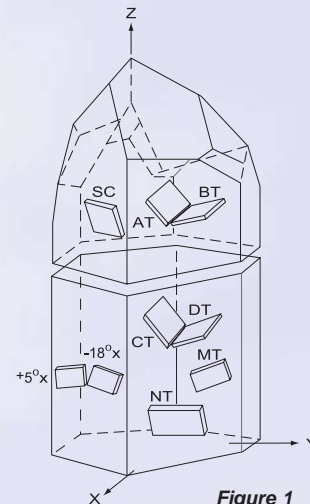

Figure 1

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.

As a result of its good temperature vs frequency characteristic, the AT-cut crystal is the most popular cut in use today. It is a slab cut at approximately 35° 15' from the Z-axis.

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.

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 2. 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.
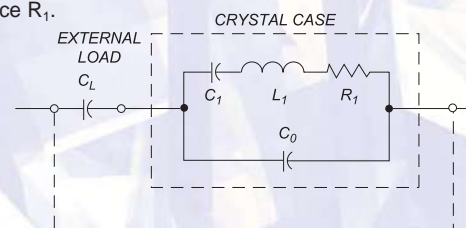

Figure 2

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 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.

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 dimension 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 circuit.

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 3). Alternatively, by altering 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.
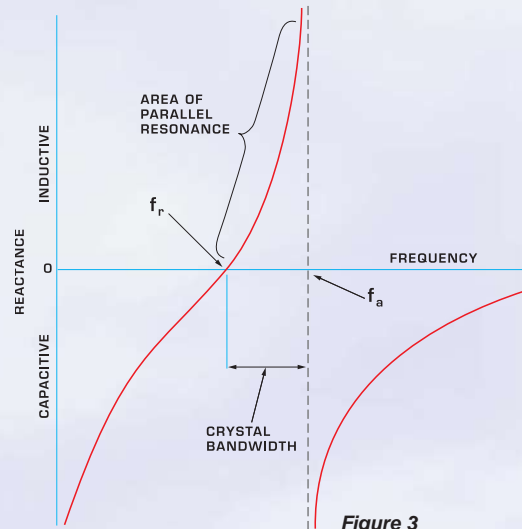
Figure 3

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. 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 3).

If pullability is a factor in the 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 C0 and C1 are known then the pullability in ppm between two load capacitances can be obtained using the formula:

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

i.e.
$C_1 = 0.020$ pF
$C_0 = 4.5$ pF
$C_{L1} = 20$ pF
$C_{L2} = 30$ pF

$$ppm = \frac{0.02(30-20)10^6}{2(4.5 + 30)(4.5 + 20)} = 118 \text{ ppm}$$

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

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

i.e. Using the above figures and a C_L of 30 pF:

$$ppm/pF = \frac{0.02 \cdot 10^6}{2 \cdot (4.5 + 30)^2} = 8.4 \text{ ppm/pF average}$$

FREQUENCY STABILITY

The overall frequency stability of a crystal oscillator is dependent upon the stability of all the parameters influencing the crystal circuit. These in turn are dependent upon the stability of the power source and the load, as well as the ambient conditions under which the oscillator is required to operate. The over-all stabilizing ability of the crystal is dependent upon both the stability of the crystal parameters when the crystal is exposed to changes in temperature or drive level, and the ability of the crystal to minimize the change in frequency that occurs when the parameters of the external circuit deviate. It is the latter quality of the crystal that makes the crystal oscillator superior to other types of oscillators.

TEMPERATURE STABILITY

Initially, the temperature stability of the crystal is determined by the angle at which the quartz plate or blank is cut from the mother stone. The family of curves on page 5 reflects the theoretical deviations of frequency with temperature for AT-cut crystals. These curves are produced by slightly different orientations of the crystal plate with reference to the crystallographic axis. In order to achieve a specific frequency-temperature stability it is necessary to cut the quartz at a particular angle. In practice, the actual angle of cut within a group of crystals will vary due to limitations in the manufacturing equipment and processes. Typically, a tight stability requirement allows a very narrow range of crystal angles (i.e. a tight "angle spread") and as a result the crystal cost increases. Some stabilities are simply not practical on a production basis and must be achieved with compensation or by placing the crystal in an oven. With these methods, frequency stabilities can be improved by several orders of magnitude.

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 million (ppm) 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 characteristics. 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. Usually the first effects of aging can be traced to changes at the surface of the crystal and can be avoided or greatly diminished through proper design and manufacturing techniques.

Aging normally follows an exponential 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.

The type of seal used in the manufacture of the crystal can have a dramatic effect on the aging characteristics of the crystal. Typical aging rates for Resistance Weld parts are on the order of 2 ppm/year while Cold Weld parts are typically 1-1.5 ppm/year. These rates are without pre-aging or conditioning which would improve these figures further.

CROVEN CRYSTALS has developed a wide range of low aging rate products for demanding applications. Our extensive clean room production capacity and 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.

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 6. For crystals resistances lower than these values please consult the factory.

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 high frequency crystals to several mW for lower frequency devices. For your specific requirements please contact our sales and engineering staff.

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.

CROVEN CRYSTALS 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.

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 shows a strong dependence 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 instead of fundamental resonators

- resonators designed to operate at the optimized Q for a given frequency

- SC-cut resonators rather than AT-cut resonators

CROVEN CRYSTALS 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

Accurate phase noise measurements are necessary to obtain ultimate noise performance. We use two methods: the oscillator method and the resonator bridge or residual method.

In the oscillator method, the crystal phase noise is measured in a customer supplied oscillator of the type that would be used in the customer's equipment. Therefore it is not necessary to measure the loaded Q of the resonator to predict the oscillator noise, it may be measured directly. This method provides for direct correlation between CROVEN CRYSTALS and the customer, but a suitable customer supplied oscillator assembly is required.

Most of our phase noise measurements are done using the bridge method on a Femtosecond FSS-600 Phase Noise Detector. The loaded Q of the crystal resonator in the test fixture can be different from that in the customer oscillator and therefore some scaling is necessary for accurate prediction of phase noise in the oscillator. The scaling factor is $(Q1/Q1m)^2$, where Q1 is the loaded Q of the resonator in our test fixture, and Q1m is the loaded Q of the resonator in the customer oscillator. It is our common practice to establish phase noise measurement correlation with the customer on the initial order wherever low noise requirements are specified. 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 half that of AT-cut resonators of the same frequency, overtone and holder style. Nominal vibration sensitivity attainable with four-point mount HC-35/U holders is 1×10^{-9}/g for AT-cut crystals and 5×10^{-10}/g for SC-cut and IT-cut crystals. CROVEN CRYSTALS has extensive experience in the design and development of crystals optimized for low vibration sensitivity in many holders and frequency ranges.

For your specific requirements, please contact our engineering staff.

For other technical information please visit our website at:
www.crovencrystals.com

AT-CUT FREQUENCY – TEMPERATURE CURVES

"AT" CUT FREQUENCY - TEMPERATURE CURVES

Note: This family of curves is theoretical and should be used for reference only.

"Quietly the Best"
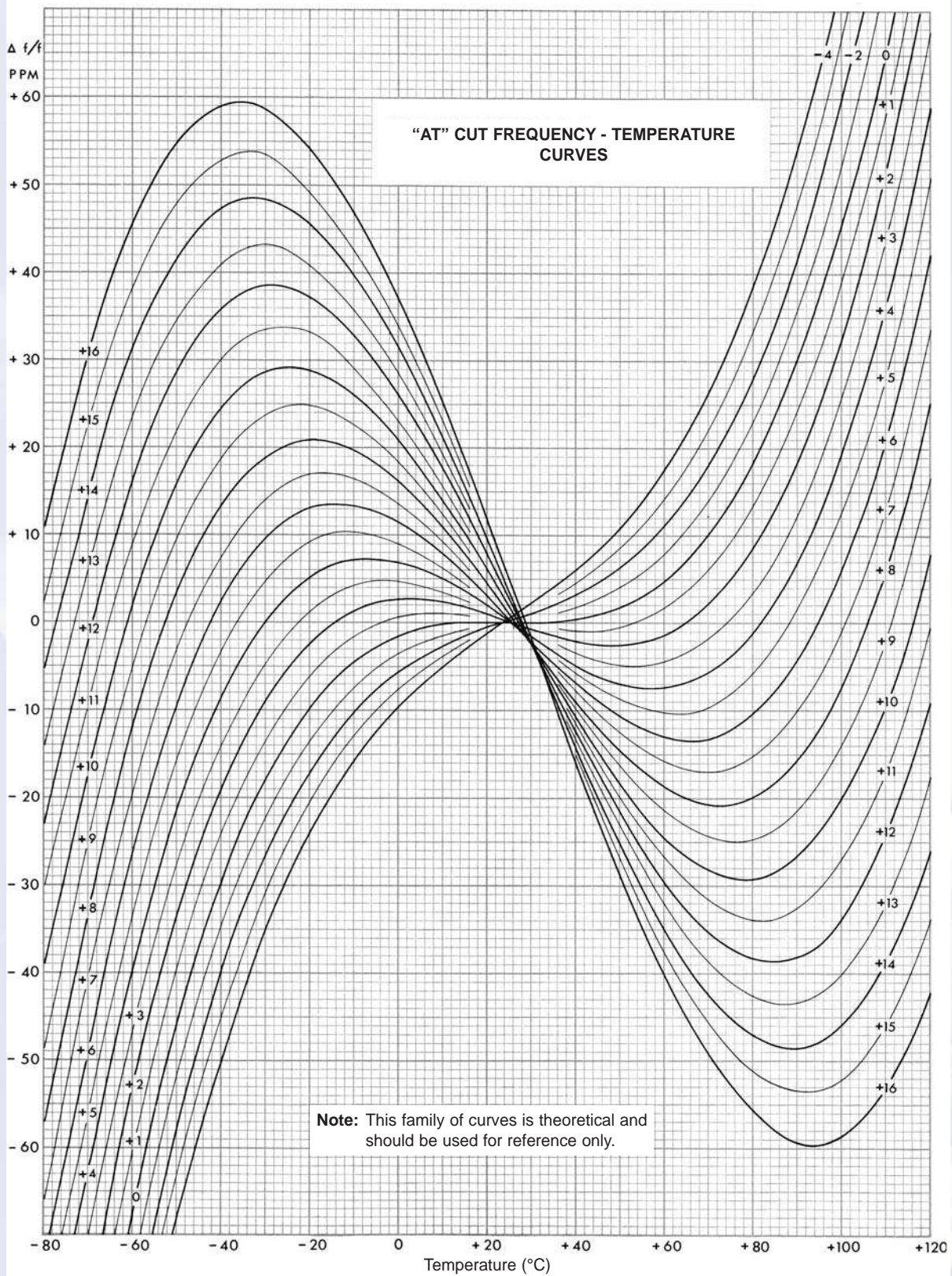
CROVEN CRYSTALS

HOLDER	FREQUENCY RANGE (MHz)	MODE OF OPERATION	RESISTANCE OHMS
HC-36/U	1.000 - 1.199	Fundamental	400
HC-36/U	1.200 - 1.349	Fundamental	340
HC-36/U	1.350 - 1.497	Fundamental	300
HC-36/U	1.498 - 1.599	Fundamental	280
HC-36/U	1.600 - 1.849	Fundamental	220
HC-36/U	1.850 - 1.999	Fundamental	190
HC-36/U	2.000 - 2.499	Fundamental	150
HC-36/U	2.500 - 2.999	Fundamental	90
HC-36/U	3.000 - 4.999	Fundamental	37
HC-36/U	5.000 - 6.999	Fundamental	25
HC-36/U	7.000 - 9.999	Fundamental	20
HC-36/U	10.000 - 14.999	Fundamental	18
HC-36/U	15.000 - 33.000	Fundamental	20
HC-49/U	2.900 - 3.324	Fundamental	150
HC-49/U	3.325 - 3.499	Fundamental	90
HC-49/U	3.500 - 6.999	Fundamental	50
HC-49/U	7.000 - 9.999	Fundamental	30
HC-49/U	10.000 - 14.999	Fundamental	25
HC-49/U	15.000 - 33.000	Fundamental	20
HC-35/U	10.000 - 33.000	Fundamental	25
HC-45/U	10.000 - 14.999	Fundamental	30
HC-45/U	15.000 - 17.999	Fundamental	25
HC-45/U	18.000 - 33.000	Fundamental	20
ALL HOLDERS	33.001 - 220.000	Fundamental	Consult Factory
HC-36/U	10.000 - 61.000	3rd overtone	40
HC-36/U	61.001 - 84.000	3rd overtone	60
HC-49/U	15.000 - 61.000	3rd overtone	40
HC-49/U	61.001 - 84.000	3rd overtone	60
HC-35/U	30.000 - 61.000	3rd overtone	40
HC-35/U	61.001 - 84.000	3rd overtone	60
HC-45/U	30.000 - 61.000	3rd overtone	50
HC-45/U	61.001 - 84.000	3rd overtone	50
HC-36/U	90.000 - 125.000	3rd overtone	60
HC-36/U	125.001 - 165.000	5th overtone	65
HC-49/U	45.000 - 89.999	5th overtone	50
HC-49/U	90.000 - 125.000	5th overtone	60
HC-49/U	125.001 - 165.000	5th overtone	65
HC-35/U	50.000 - 89.000	5th overtone	50
HC-35/U	90.000 - 125.000	5th overtone	60
HC-35/U	125.001 - 165.000	5th overtone	65
HC-45/U	50.000 - 125.000	5th overtone	60
HC-45/U	125.001 - 165.000	5th overtone	65
ALL HOLDERS	80.000 - 196.000	7th overtone	120
ALL HOLDERS	162.000 - 216.000	9th overtone	200

NOTES:

(1) Unless otherwise specified, the standard drive level is 200 mW.

(2) The above values apply to other holders in a particular holder group (i.e. HC-36/U covers HC-48/U, HC-47/U and HC-51/U; HC-49/U covers HC-43/U, HC-42/U and HC-50/U; HC-45/U covers HC-52/U; HC-35U covers the SM1 package).

(3) For resistance values that are lower than the maximum values indicated, please contact our engineering staff.

HOW TO SPECIFY A QUARTZ CRYSTAL

Most crystals may be fully specified with the following information:

1) **Crystal Frequency** (i.e. 1.000 to 360 MHz).

2) **Mode of Operation** (i.e. - Fund, 3rd, 5th etc) (see page 1).

3) **Holder Style** The holder style depends on your individual application and crystal frequency. (see pages 10 - 12).

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, 2 ppm, etc.) 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 2).

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_o, motional capacitance C_1, equivalent resistance R_1, spurious mode suppression, aging characteristics, drive level, etc.)

THE CROVEN CRYSTALS CODE

We have reduced items 2 through 7 to a nine digit alpha-numeric code that can be used to describe the crystal required. A typical code would be **A357DFE-32 @ 20.000000 MHz** and is translated as follows:

A	fundamental mode of operation
35	HC-35/U holder
7	four point mount for improved g-sensitivity
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	when present, these two digits specify parallel resonance operation and the load capacitance in pF (i.e. 32 pF)

Nominal frequency of 20.000000 MHz

The table below 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 deviation number will be assigned by the factory.

MODE		HOLDER				CALIBRATION TOLERANCE AT REFERENCE TEMPERATURE		TEMPERATURE STABILITY OR TOTAL TOLERANCE		OPERATING TEMPERATURE RANGE (ºC)		CIRCUIT CONDITION	
CODE	DESC	CODE	DESC	CODE	DESC	CODE	DESC	CODE	DESC	CODE	DESC	CODE	DESC
A	Fund	35	HC-35/U (TO-5)	0	Standard			X	± 2 ppm stability	X	+15 to +35		
B	3rd OT	36	HC-36/U	1	Surface Mount	X	± 1.5 ppm	Y	± 3 ppm stability	Y	+10 to +40		
C	5th OT	37	HC-37/U (TO-8)	2	Surface Mount	A	± 2 ppm	Z	± 4 ppm stability	Z	+5 to +45		
D[1]	7th OT	40	HC-40/U (EO-7)	3	Slimline	B	± 5 ppm	B	± 5 ppm stability	A	0 to +50	00	Series resonance.
E[1]	9th OT	42	HC-42/U	4	Modifed can height	C	± 7 ppm	C	± 7 ppm stability	B	-5 to +55		
F[1]	11th OT	43	HC-43/U	5	Modifed can height	D	± 10 ppm	D	± 10 ppm stability	D	-10 to +60		
		45	HC-45/U	6	Modifed can height	E	± 15 ppm	E	± 15 ppm stability	E	-15 to +65	01	Parallel resonance
		47	HC-47/U	7	Four point mount	F	± 20 ppm	F	± 20 ppm stability	F	-20 to +70		load capacity of
		48	HC-48/U	8	Modifed can height	G	± 25 ppm	G	± 25 ppm stability	G	-25 to +75		100 pF or more.
		49	HC-49/U	9	Modifed can height	H	± 30 ppm	H	± 30 ppm stability	H	-30 to +80		Advise actual
		50	HC-50/U			J	± 40 ppm	J	± 40 ppm stability	J	-40 t0 +90		value.
		51	HC-51/U			M	± 50 ppm	M	± 50 ppm stability	M	-55 to +105		
		52	HC-52/U					L	± 75 ppm stability	U	+50 to +60 Oven	10 to 90	Parallel resonance
		90	SM1			K	± 100 ppm	K	± 100 ppm stability	L	+55 to +65 Oven		load capacity in pF.
								N	± 150 ppm stability	T	+60 to +70 Oven		
								S	Specific curve	N	+65 to +75 Oven		
								T	± 20 ppm(4) (B)†	P	+70 to +80 Oven		
								U	± 25 ppm(4) (C)†	R	+75 to +85 Oven	99	Calibration at
								V	± 30 ppm(4) (D)†	S	+80 to +90 Oven		reference
								W	± 50 ppm(4) (F)†	V	+85 to +95 Oven		temperature in
								P	± 100 ppm(4) (H)†	W	+90 to +100 Oven		customer's
								R	± 200 ppm(4) (M)†	X	+95 to +105 Oven		oscillator.
										0	Not specified		
								0	Turn Over Point in Oven Range		Calibration frequency is at the mid-point of the above ranges.		
									† - Corresponding calibration codes				

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.

(5) For RoHS compliant parts add 'R' to the end of the part number.

For your specific requirements, please contact our engineering staff.

"Quietly the Best"

DOUBLY ROTATED CRYSTALS

CROVEN CRYSTALS has extensive experience in the design and manufacture of doubly rotated crystal resonators such as FC-cut, IT-cut and SC-cut crystals. These crystal cuts have significantly different operating characteristics than the popular AT-cuts and can provide some performance advantages in certain applications.

The frequency-temperature curves of doubly rotated resonators are very similar to those of AT-cuts and the major difference is the inflection temperature (Ti). This is the temperature at which the second derivative of the frequency-temperature curve becomes zero and is typically in the area of 25°C to 30°C for AT-cuts depending on design and frequency. The inflection temperature for doubly rotated cuts is in the area of 45°C to 55°C for FC-cuts, 70°C to 80°C for IT-cuts and 85°C to 95°C for SC-cut. Curves of these resonators are also flatter than corresponding AT-cuts.

The temperature stability advantage is valid only for higher temperatures where doubly rotated resonators can show up to a 10 times improvement in stability over their AT-cut counterparts. For wide temperature ranges which include temperatures below 0°C, better stability can be obtained with AT-cut resonators.

The main advantages of these resonators, and in particular the SC-cut (Stress Compensated) type are:

- improved frequency-temperature stability for ovenized applications with operating temperatures in the 60°C to 110°C temperature range

- reduced amplitude frequency effect which allows higher drive levels and improved signal to noise ratio

- superior thermal transient characteristics resulting in improved short term stability and faster warm up times in oven operation

- improved 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 changes

- higher Q-factor (typically 10 - 15% better than equivalent AT-cut resonators)

For your specific requirements please consult our engineering staff.

DOUBLY ROTATED CRYSTALS FOR OCXO APPLICATIONS

Doubly rotated resonators are the right choice for oven controlled crystal oscillators (OCXOs) and their use is increasing due to the substantial improvement they provide in temperature stability and aging over their AT-cut counterparts. Development and use of doubly rotated resonators has significantly improved achievable OCXO performance but the presence of the strong B-mode (typically 8 - 10% above the main mode frequency) somewhat complicates oscillator design. The more complex processes and increased testing requirements of the doubly rotated resonators contribute to their higher costs and longer manufacturing times.

Some typical doubly rotated parameters are listed on the following page.

For your specific requirements please consult our engineering staff.
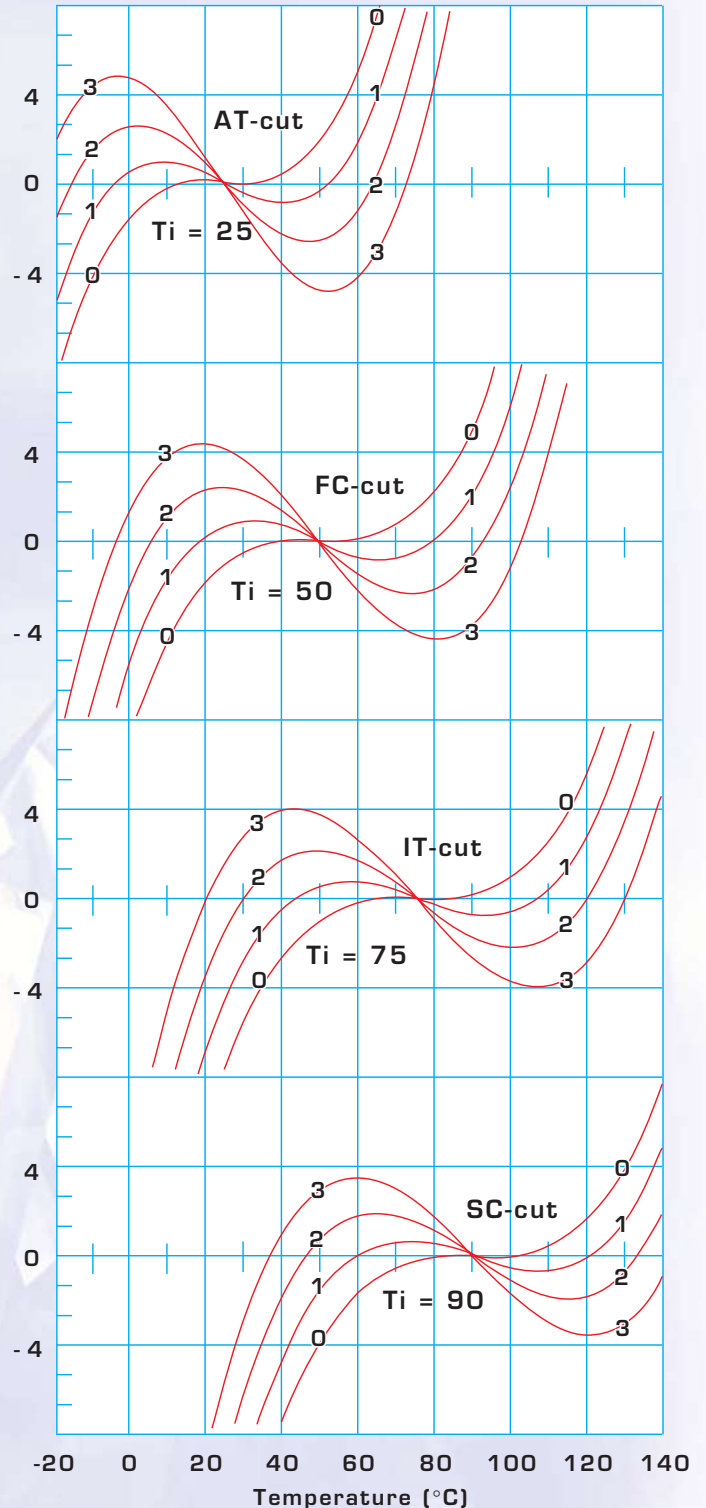
TYPICAL PARAMETERS OF DOUBLY ROTATED CRYSTAL CUTS

FREQUENCY (MHz)	MODE of OPERATION	HOLDER	CUT	$R_1 (\Omega)$ (MAX)	C_0 (pF) (NOM)	C_1 (fF) (NOM)	Q (MIN)	ALSO AVAILABLE IN HOLDER (1)
4.000000	Fundamental	HC-47/U	IT	15	5.0	3.7	700,000	HC-40/U
5.000000	Fundamental	HC-47/U	FC	10	4.5	15.0	200,000	HC-40/U
5.000000	Fundamental	HC-37/U	SC	10	3.2	2.5	1,300,000	HC-40/U, HC-47/U
7.000000	Fundamental	HC-37/U	SC	15	2.8	2.4	600,000	HC-40/U, HC-43/U, HC-47/U
10.000000	Fundamental	HC-37/U	SC	10	4.3	5.5	800,000	HC-40/U, HC-47/U
13.000000	Fundamental	HC-43/U	SC	10	4.4	6.8	200,000	HC-37/U, HC-47/U
13.000000	Fundamental	HC-35/U	FC	20	3.8	11.0	55,000	HC-43/U
20.000000	Fundamental	HC-35/U	SC	30	1.8	2.4	100,000	HC-43/U
24.000000	Fundamental	HC-35/U	SC	15	3.5	5.0	90,000	HC-43/U
4.500000	3rd OT	HC-40/U	SC	130	2.4	0.18	1,500,000	HC-47/U
5.000000	3rd OT	HC-40/U	SC	130	2.8	0.15	1,600,000	HC-37/U, HC-47/U
6.000000	3rd OT	HC-47/U	SC	120	3.8	0.17	1,300,000	HC-40/U
8.192000	3rd OT	HC-37/U	SC	85	3.4	0.25	900,000	HC-40/U, HC-47/U
10.000000	3rd OT	HC-37/U	SC	80	3.7	0.22	900,000	HC-40/U, HC-43/U, HC-47/U
10.000000	3rd OT	HC-37/U	IT	80	3.0	0.24	800,000	HC-40/U, HC-47/U
13.000000	3rd OT	HC-37/U	SC	85	4.3	0.21	700,000	HC-40/U, HC-43/U, HC-47/U
15.000000	3rd OT	HC-37/U	SC	80	2.2	0.28	500,000	HC-40/U, HC-43/U, HC-47/U
16.384000	3rd OT	HC-43/U	SC	80	3.4	0.23	550,000	HC-37/U, HC-40/U, HC-47/U
20.000000	3rd OT	HC-43/U	SC	60	3.4	0.44	300,000	HC-35/U, HC-37/U, HC-47/U
25.000000	3rd OT	HC-37/U	SC	60	2.6	0.38	280,000	HC-35/U, HC-43/U
30.000000	3rd OT	HC-43/U	SC	50	3.9	0.44	250,000	HC-35/U, HC-37/U
40.000000	3rd OT	HC-43/U	SC	40	3.5	0.53	180,000	HC-35/U, HC-37/U
50.000000	3rd OT	HC-35/U	SC	50	3.0	0.42	150,000	HC-37/U, HC-43/U, SM1
50.000000	3rd OT	HC-35/U	IT	50	2.2	0.33	200,000	HC-37/U, HC-43/U, SM1
80.000000	3rd OT	HC-35/U	SC	45	3.2	0.45	100,000	HC-43/U, SM1
100.000000	3rd OT	HC-35/U	SC	50	2.8	0.38	80,000	HC-43/U, SM1
115.000000	3rd OT	HC-35/U	SC	50	3.2	0.40	70,000	HC-43/U, SM1
40.000000	5th OT	HC-37/U	SC	100	3.0	0.13	300,000	HC-47/U
50.000000	5th OT	HC-35/U	SC	90	3.8	0.22	150,000	HC-37/U, HC-43/U, SM1
60.000000	5th OT	HC-35/U	SC	90	3.8	0.20	150,000	HC-43/U, SM1
80.000000	5th OT	HC-35/U	SC	90	3.8	0.20	100,000	HC-43/U, SM1
80.000000	5th OT	HC-35/U	IT	80	3.2	0.20	120,000	HC-43/U, SM1
100.000000	5th OT	HC-35/U	SC	100	3.8	0.20	80,000	HC-43/U, SM1
100.000000	5th OT	HC-35/U	IT	80	3.3	0.22	90,000	HC-43/U, SM1
120.000000	5th OT	HC-35/U	SC	100	3.8	0.17	70,000	HC-43/U, SM1
120.000000	5th OT	HC-35/U	IT	90	4.0	0.19	70,000	HC-43/U, SM1
140.000000	5th OT	HC-35/U	SC	115	4.0	0.14	70,000	HC-43/U, SM1
140.000000	5th OT	HC-35/U	FC	80	2.8	0.19	75,000	HC-43/U, SM1
160.000000	5th OT	HC-35/U	SC	120	4.0	0.16	50,000	HC-43/U, SM1

Notes: The typical electrical parameters in these holders may be different, consult our engineering staff for data on these and other doubly rotated crystals.

DOUBLY ROTATED CRYSTAL SELECTION

The choice of which doubly rotated crystal cut to use is dependent upon a number of factors including the desired operating temperature. As can be seen from the frequency-temperature curves on page 8, FC-cut, IT-cut and SC-cut crystals have widely different lower and upper turning point temperatures and therefore the choice of crystal cut and oven temperature should be closely coordinated.

Typical turning point temperature ranges for the most popular cuts are provided in the following table. In addition, data are also provided for modified SC-cuts (i.e. SCM1, SCM2 and HSC) which are preferred

for higher oven temperatures. It should be noted that the electrical values for the modified cuts will differ slightly from the regular SC-cut.

Type of Cut	Turning Point	Typical Turning Point Temperature Range
FC	Upper	+55°C to +75°C
IT	Upper	+85°C to +105°C
SC	Lower	+60°C to +80°C
SCM1	Lower	+65°C to +85°C
SCM2	Lower	+85°C to +100°C
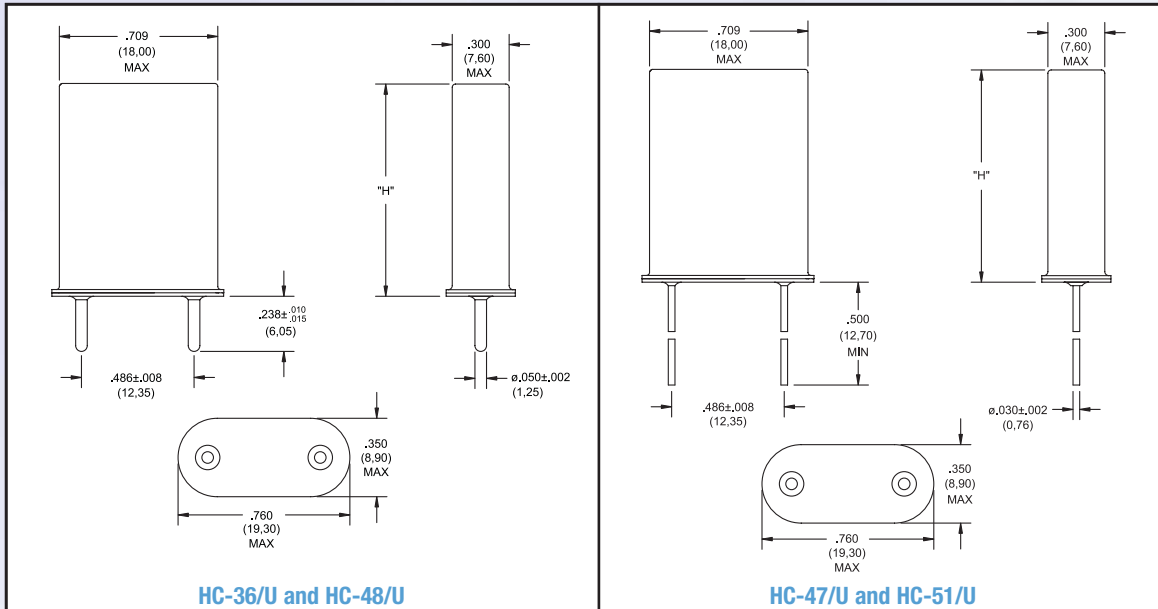
HC-36/U and HC-48/U

HC-47/U and HC-51/U

TYPE	SEAL	CODE	HEIGHT 'H' IN (mm)	Frequency Range (MHz)					
				Fund	3rd	5th	7th	9th	11th
HC-36/U	Cold Weld	360	0.775 (19,69) Max	1 - 35	4 - 105	10 - 165	80 - 230	160 - 300	216 - 360
HC-48/U	Resistance Weld	480	0.775 (19,69) Max	1 - 35	4 - 105	10 - 165	80 - 230	160 - 300	216 - 360
HC-47/U	Cold Weld	470	0.775 (19,69) Max	1 - 35	4 - 105	10 - 165	80 - 230	160 - 300	216 - 360
HC-51/U	Resistance Weld	510	0.775 (19,69) Max	1 - 35	4 - 105	10 - 165	80 - 230	160 - 300	216 - 360
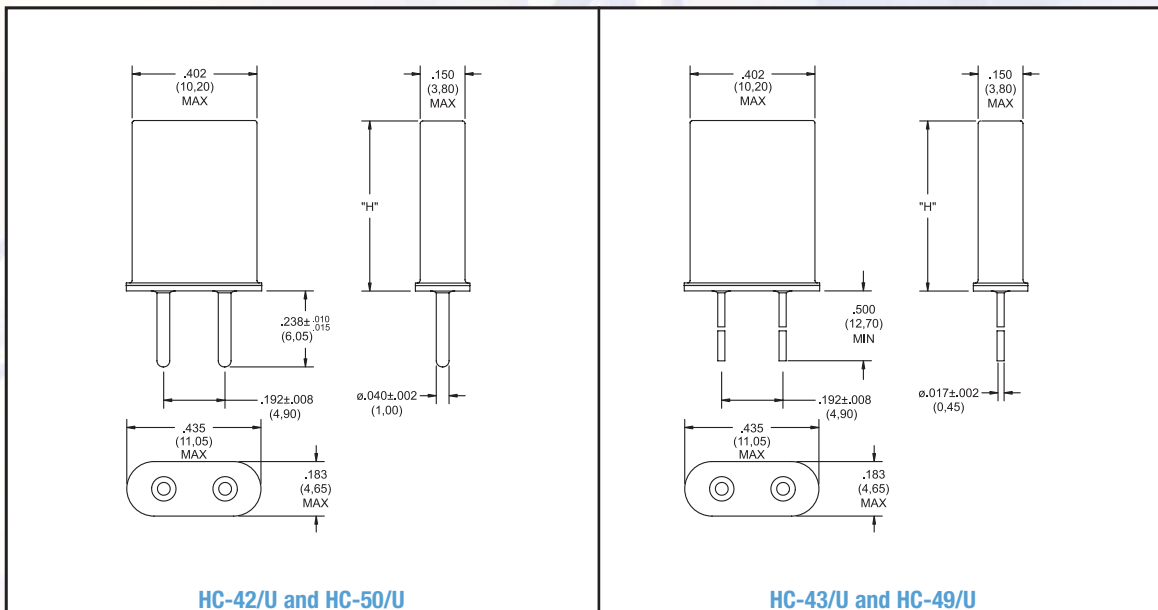
HC-42/U and HC-50/U

HC-43/U and HC-49/U

TYPE	SEAL	CODE	HEIGHT 'H' IN (mm)	Frequency Range (MHz)					
				Fund	3rd	5th	7th	9th	11th
HC-42/U	Cold Weld	420	0.530 (13,46) Max	2.9 - 35	10 - 105	30 - 165	80 - 230	160 - 300	216 - 360
HC-42/U	Cold Weld	425	0.438 (11,13) Max	6 - 35	35 - 105	40 - 165	80 - 230	160 - 300	216 - 360
HC-50/U	Resistance Weld	500	0.530 (13,46) Max	2.9 - 35	10 - 105	30 - 165	80 - 230	160 - 300	216 - 360
HC-50/U	Resistance Weld	506	0.455 (11,56) Max	6 - 35	35 - 105	40 - 165	80 - 230	160 - 300	216 - 360
HC-43/U	Cold Weld	430	0.530 (13,46) Max	2.9 - 35	10 - 105	30 - 165	80 - 230	160 - 300	216 - 360
HC-43/U	Cold Weld	435	0.438 (11,13) Max	6 - 35	35 - 105	40 - 165	80 - 230	160 - 300	216 - 360
HC-49/U	Resistance Weld	490	0.530 (13,46) Max	2.9 - 35	10 - 105	30 - 165	80 - 230	160 - 300	216 - 360
HC-49/U	Resistance Weld	496	0.455 (11,56) Max	6 - 35	35 - 105	40 - 165	80 - 230	160 - 300	216 - 360
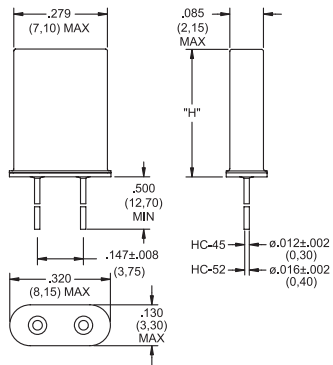
HC-45/U and HC-52/U
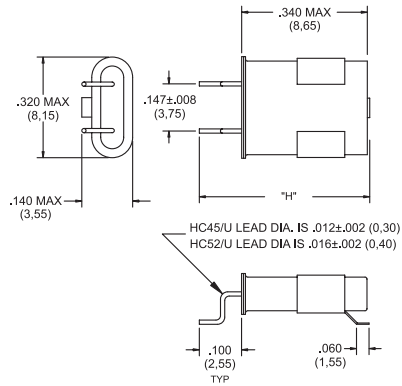
HC-45/U SMD and HC-52/U SMD

TYPE	SEAL	CODE	HEIGHT 'H' IN (mm)	Frequency Range (MHz)					
				Fund	3rd	5th	7th	9th	11th
HC-45/U	Cold Weld	450	0.342 (8,69) Max	9 - 175	27 - 360	40 - 360	80 - 360	160 - 360	216 - 360
HC-52/U	Resistance Weld	520	0.342 (8,69) Max	9 - 175	27 - 360	40 - 360	80 - 360	160 - 360	216 - 360
HC-45/U SMD	Cold Weld	451	0.445 ± 0.020 (11,30 ± 0,51)	9 - 175	27 - 360	40 - 360	80 - 360	160 - 360	216 - 360
HC-52/U SMD	Resistance Weld	521	0.445 ± 0.020 (11,30 ± 0,51)	9 - 175	27 - 360	40 - 360	80 - 360	160 - 360	216 - 360
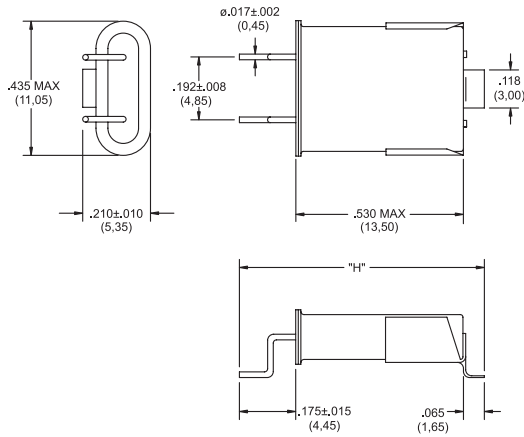
HC-43/U SMD and HC-49/U SMD
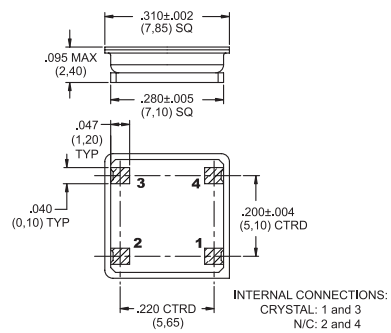
SM1

TYPE	SEAL	CODE	HEIGHT 'H' IN (mm)	Frequency Range (MHz)					
				Fund	3rd	5th	7th	9th	11th
HC-43/U SMD	Cold Weld	431	0.660 ± 0.015 (16,76 ± 0,38)	6 - 35	35 - 105	40 - 165	80 - 230	160 - 300	216 - 360
HC-43/U SMD	Cold Weld	432	0.725 ± 0.015 (18,42 ± 0,38)	2.9 - 35	10 - 105	30 - 165	80 - 230	160 - 300	216 - 360
HC-49/U SMD	Resistance Weld	491	0.660 ± 0.015 (16,76 ± 0,38)	6 - 35	35 - 105	40 - 165	80 - 230	160 - 300	216 - 360
HC-49/U SMD	Resistance Weld	492	0.725 ± 0.015 (18,42 ± 0,38)	2.9 - 35	10 - 105	30 - 165	80 - 230	160 - 300	216 - 360
SM1	Resistance Weld	900	0.095 (2,41) Max	7 - 175	20 - 360	40 - 360	80 - 360	160 - 360	216 - 360

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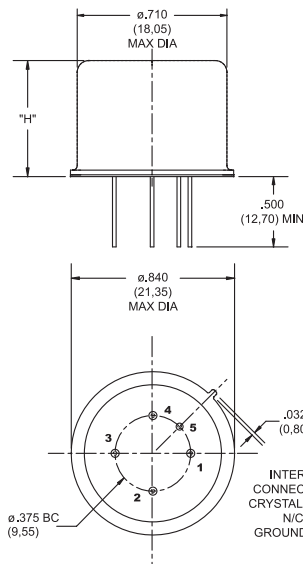
HC-40/U (EO-7) (also available in pin version)
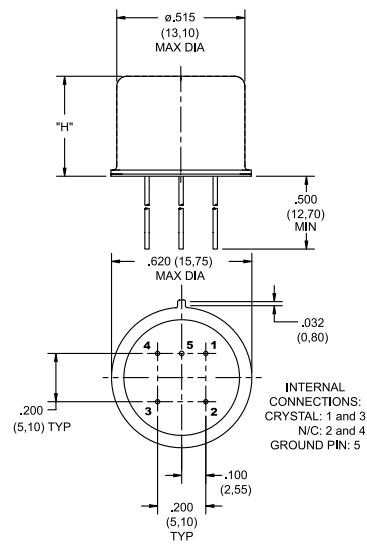
HC-37/U (TO-8) (also available in pin version)

TYPE	SEAL	CODE	HEIGHT 'H' IN (mm)	Frequency Range (MHz)					
				Fund	3rd	5th	7th	9th	11th
HC-40/U	Cold Weld	400	0.355 (9,01) Max	1 - 10	4 - 30	8 - 50	n/a	n/a	n/a
HC-37/U	Cold Weld	370	0.265 (6,73) Max	2.5 - 25	5 - 60	10 - 100	25 - 125	n/a	n/a
HC-37/U	Cold Weld	375	0.235 (5,95) Max	2.5 - 25	5 - 60	10 - 100	25 - 125	n/a	n/a
HC-37/U	Cold Weld	379	0.160 (4,06) Max	4 - 20	10 - 60	10 - 100	25 - 125	n/a	n/a
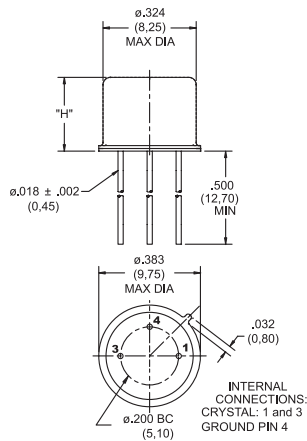
HC-35/U (TO-5)

In addition to the providing sealed crystals in standard enclosures, CROVEN CRYSTALS also provides custom hybrid blanks for oscillator, sensor and other applications. These blanks are available in a variety of shapes, sizes and electrode finishes. Consult the factory for your particular requirements.
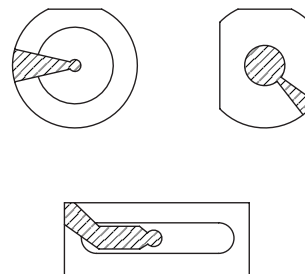
Hybrid Blanks

TYPE	SEAL	CODE	HEIGHT 'H' IN (mm)	Frequency Range (MHz)					
				Fund	3rd	5th	7th	9th	11th
HC-35/U	Cold Weld	350	0.265 (6,73) Max	7 - 175	20 - 360	40 - 360	80 - 360	160 - 360	216 - 360
HC-35/U	Cold Weld	355	0.220 (5,59) Max	7 - 175	20 - 360	40 - 360	80 - 360	160 - 360	216 - 360
HC-35/U	Cold Weld	356	0.208 (5,28) Max	7 - 175	20 - 360	40 - 360	80 - 360	160 - 360	216 - 360

NOTES:

(1) HC-37/U and HC-40/U have 4-point internal mount construction. HC-35/U is also available as 4-point mount when specified.

(2) For holder styles and sizes not illustrated in this catalogue, please consult the factory.

MILITARY AND SPACE PRODUCTS

CROVEN CRYSTALS 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 included below.

ITAR COMPLIANCE and CLASSIFIED PROGRAMS

For products and information governed by ITAR regulations CROVEN CRYSTALS 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 CROVEN CRYSTALS has valid site security clearances recognized by the United States Department of Defense which enable us to provide services for programs where clearances are required.

MILITARY CR-TYPE	MIL-PRF SPEC. NO.	FREQUENCY RANGE IN MHz
CR-76A/U	3098/53	24.000 - 61.000
CR-77/U	3098/55	24.000 - 62.000
CR-78A/U	3098/62	3.700 - 20.000
CR-79/U	3098/63	3.700 - 20.000
CR-80/U	3098/57	50.000 - 125.000
CR-81/U	3098/58	24.000 - 62.000
CR-83/U	3098/60	50.000 - 125.000
CR-83/U	3098/60	50.000 - 125.000
CR-84/U	3098/61	24.000 - 61.000
CR-89/U	3098/67	2.120 - 6.200
CR-97/U	3098/72	8.000 - 10.000
CR-106/U	3098/82	10.500 - 11.500
CR-117/U	3098/93	30.000 - 62.000
CR-139/U	3098/118	20.000 - 22.000
CR-140/U	3098/119	9.500 - 12.500
CR-141/U	3098/122	50.000 - 90.000
CR-157/U	3098/137	1.800 - 20.000

MILITARY CR-TYPE	MIL-PRF SPEC. NO.	FREQUENCY RANGE IN MHz
CR-5A/U	3098/78	2.000 - 10.000
CR-6A/U	3098/78	2.000 - 10.000
CR-8A/U	3098/111	1.000 - 10.000
CR-18A/U	3098/3	1.000 - 20.000
CR-19A/U	3098/4	1.000 - 20.000
CR-52A/U	3098/30	15.000 - 61.000
CR-55A/U	3098/33	24.000 - 62.000
CR-56A/U	3098/34	50.000 - 125.000
CR-58A/U	3098/36	1.000 - 20.000
CR-59A/U	3098/37	50.000 - 125.000
CR-60A/U	3098/38	5.000 - 20.000
CR-61/U	3098/39	24.000 - 61.000
CR-64/U	3098/42	3.700 - 20.000
CR-65/U	3098/43	15.000 - 61.000
CR-67A1U	3098/45	24.000 - 62.000
CR-69A/U	3098/47	3.700 - 25.000
CR-72/U	3098/50	24.000 - 25.000

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.