QUARTZ CRYSTAL

DSL Corporation has been a leading quartz crystal producer in China since 1983. DSL's main poducts are Quartz Crystal Units, Oscillators and Filters. The full scale operations include every step from purchasing the rw materials as grow quartz crystal bars through lumbering, cutting, lapping and other finishing steps to the finished quartz crystal units, oscillators and filters. The manufacturing process flow is shown below, for your reference.

As grown quartz bars	Y-bar and Z-plate
Lumbering	Y-bars and pure Z-bars
Cutting	AT-Cut crystal wafers and blanks
Lapping	GC # 1000 to # 4000 lapping and / or beveling
Polishing	Remillox powder Polish mat
Cleaning	
Base Coating	
Adjusting	
Sealing	
Aging	
Production	

Quartz crystal units	**1 MHz ~ 250 MHz HC-49/U, HC-49/S UM-1 / UM-5**
Quartz crystal oscillator	**1 MHz ~ 100 MHz CXO, TCXO, VCXO**
Quartz crystal filter	**5 MHz ~ 150 MHz Monolithic crystal filter (MCF) Mobile phone filter**

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THE QUARTZ CRYSTAL

Quartz crystal, the chemical name silicon dioxide, S_iO_2, is a hard, and brittle crystal. The ideal quartz crystal is a hexagonal prism with six pyramidal face. Crystal consists of a Z-axis (also called optic axis) and three X-axes (also called electrical axes) which make an angle of 120° with each other and perpendicular to the Z-axis. The Y-axis (also call mechanical axis) is perpendicular to both the Z-axis and X-axis. X-axis is a polar axis since electrical polarization occurs in this direction upon mechanical strain. Thus crystals having one or more polar axes display the phenomenon of piezo electricity.

DSL consistently manufactures blanks and crystal units from grown quartz crystal. Crystal blanks and units are used as oscillator crystals and filter crystals in oscillators and filters. Crystal units should have the following specifications.

- The mode of vibration and orientation angle.
- Frequency - temperature characteristics
- Equivalent circuit parameters
- Characteristics of frequency vs. load capacitance.
- Frequency aging characteristics.
- Measurement instrumentation.

MODE OF VIBRATION AND ORIENTATION ANGLE

The vibration modes of crystal units are grouped into flexure, extensional, face shear, and thickness shear. (See table 1).

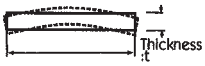
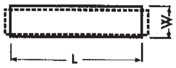
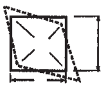
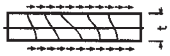
Mode of Vibration		Orientation Angle
Tuning Fork		+2°x
Flexure		XY NT
Extensional		+5°x -18,5°x
Face Shear		DT CT SL
Thickness Shear		AT Fundamental AT 3rd Overtone AT 5th Overtone AT 7th Overtone BT Fundamental

Table 1 shows the relationship between the mode of vibration, orientation angle and length or thickness dimensions. The mode of vibration and orientation angle usable for the desired frequency are determined from this table.

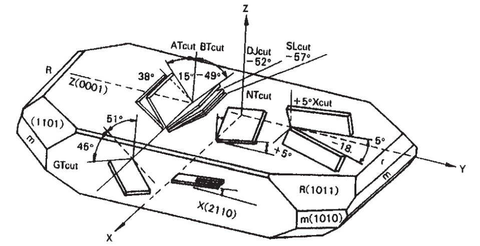


Fig.1 Orientation angle of a Z-plate quartz crystal.

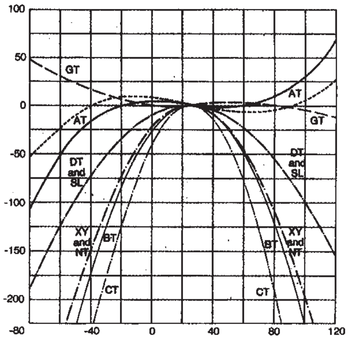


Fig. 2 Frequency-temperature characteristics of various quartz cuts.

Fig.1 and ***Fig.2*** show the orientation angle of a Z-plate quartz crystal at which the first frequency-temperature coefficient of crystal unit becoms zero near normal room temperature for the modes of vibration most often used.

FREQUENCY-TEMPERATURE CHARACTERISTICS

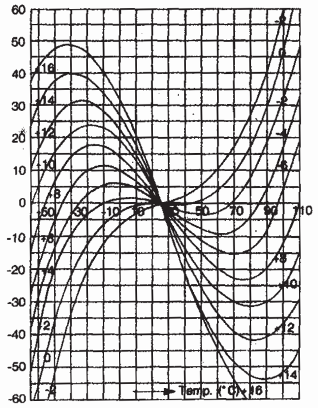


Fig.3 AT-Cut frequency-temperature characteristics

Fig. 3 shows the frequency-temperature characteristics for a thickness-shear mode At-Cut crystals with the angle of cut as a parameter. Since the AT-Cut frequency-temperature characteristics is equivalent to an equation of the third order, it displays excellent frequency stability over a wide temperature range.

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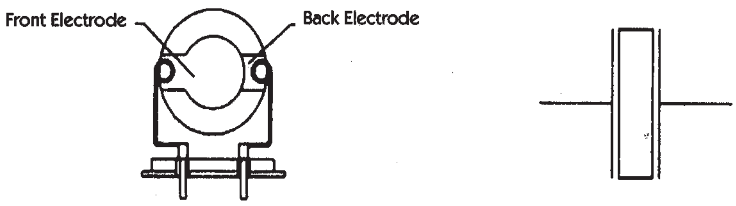
GLOSSARY OF TERMS

QUARTZ CRYSTALS

Quartz, composed of Silicon and Oxygen (Silicon Dioxide), exhibits piezoelectric properties. This device generates an electrical potential when pressure is applied on the surfaces of the crystal. Inversely, when an electrical potential is applied to the surfaces of a crystal, mechanical deformation or vibration is generated. These vibrations occur at a frequency determined by the crystal desing and oscillator circuit.

CRYSTAL EQUIVALENT CIRCUIT

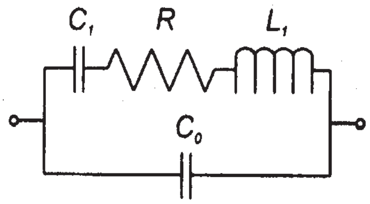
A crystal device consists of a quartz resonator with metal plating. This plating, as shown in ***Figure 1***, is located on both sides of the crastal and is connected to insulated leads on the crystal package. The device exhibits a piezoelectric response between the two crystal electrodes as expressed in the equivalent circuit shown in ***Figure 2*** below.



Front View

Schematic Symbol

Figure 1



Equivalent Circuit

Figure 2

NOMINAL FREQUENCY

The specified center frequency of the crystal and is typically specified in megahertz (MHz) or kilohertz (kHz).

FREQUENCY TOLERANCE OR CALIBRATION ACCURACY

The amount of frequency deviation from a specified nominal frequency at ambient temperature (referenced at 25°C). This parameter is specified with a maximum and minimum frequency deviation, expressed in percent (%) or parts per million (ppm).

FREQUENCY STABILITY

The amount of frequency deviation from the ambiente temperature frequency. This deviation is associated with a set of operating conditions including: Operating Temperature Range, Load Capacitance and Drive Level. This parameter is specified with a maximum and minimum frequency deviation, expressed in percent (%) or parts per million (ppm). The frequency stability is determined by the following factors: Type of quartz cut, angle of the quartz cut, mode of operation, and mechanical dimensions of the quartz blank.

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TYPE / ANGLE OF QUARTZ CUT

The type and angle of a quartz cut effects the crystal device operating parameters, the most significant being frequency stability. The temperature stability requirements and other electrical parameters required by the customer will determine the type of cut and angle of cut utilized.

SERIES VS. PARALLEL LOAD RESONANCE

Series Resonance or Parallel Load Resonance crystals are physically the same crystal, but calibrated to slightly different frequencies. When a crystal is placed into an oscillator circuit, theq oscillate together at a tuned frequency. This frequency is dependent upon the crystal desing and the amount of Load Capacitance, if any, the oscillator circuit presents to the crystal. Specified in picofarads (pF), Load Capacitance is comprised of a combination of the circuits discrete load capacitance, stray board capacitance, and capacitance from semiconductor miller effects. When an oscillator circuit presents some amount of load capacitance to a crystal, the crystal is termed „Parallel Load Resonant“, and a value of Load Capacitance must be specified. If the circuit does not exhibit any capacitive loading, the crystal is termed „Series Resonant“, and no value of Load Capacitance is specified. The „Parallel Load Resonant“ operating frequency of a quartz crystal is based on ***Equation 1*** below.

$$F_L = F_S \left\{ \frac{C_1}{2(C_0 + C_L)} + 1 \right\}$$

Equation 1

Where:

F_S = Series Resonant Frequency (MHz)
F_L = Parallel Load Resonant Frequency (MHz)
C_L = Crystal Load Capacitance (pF)
C_0 = Crystal Shunt Capacitance (pF)
C_1 = Crystal Motional Capacitance (pF)

MOTIONAL CAPACITANCE (C_1) AND MOTIONAL INDUCTANCE (L_1)

The motional capacitance and inductance are designated by C_1 and L_1 respectively, in the above equivalent circuit (***Figure 2***). For a „Series“ resonant crystal, the value of C_1 resonates with the value of L_1 at a frequency (F_S) as expressed in ***Equation 2***.

$$F_S = \frac{1}{2\pi \sqrt{L_1 C_1}}$$

Equation 2

Typically, L_1 is not mentioned when working with most crystals. Due to this absolute equation, it is only necessary to specify one motional component or the other. The industry standard is to specify a proper value of C_1 only. The actual value of C_1 has physical limitations when it is realized in a quartz crystal design. These constraints include the mode of operation, the quartz cut, the mechanical design, and the nominal frequency of the crystal.

SHUNT CAPACITANCE (C_0)

The static capacitance between the crystal terminals, measured in picofarads (pF), Shunt Capacitance is present whether the device is oscillating or not (unrelated to the piezoelectric effect of the quartz). Shunt Capacitance is derived from the dielectric of the quartz, the area of the crystal electrodes, and the capacitance presented by the crystal holder.

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EQUIVALENT SERIES RESISTANCE (ESR)

The resistive element, measured in ohms, of a crystal device. At the frequency found in ***Equation 2***, the motional inductance (***L_1***) and motional capacitance (***C_1***) are of equal ohmic value but are exactly opposite in phase. The net result is that cancel one another and only a resistance (***R***) remains in the series leg of the above equivalent circuit (***Figure 2***). The ESR measurement is made only at the series resonance frequency (***F_S***), not at some predetermined parallel resonant frequency (***F_L***). Crystal resistance measured at some parallel load resonant frequency is often called the „effective“ resistance.

DRIVE LEVEL

A function of the driving or excitation current flowing through the crystal. The Drive Level is the amount of power dissipation in the crystal, expressed in microwatts or milliwatts. Maximum power is the most power the device can dissipate while still maintaining operation with all electrical parameters quaranteed. Drive level should be maintained at the minimum levels necessary to assure proper start-up and steady state oscillation, thus avoiding poor aging characteristics and crystal damage.

AGING

The change in operating frequency over a specified time period and is typically expressed as a maximum value in parts per million per year (ppm/year). This frequency change as a function of time is due to many factors: Seal method and integrity, manufacturing processes, material type, operating temperature, and frequency of operation.

STORAGE TEMPERATURE RANGE

The minimum and maximum temperatures that the device can be stored or exposed to when in a non-oscillation state. After exposing or storing the device at the minimum or maximum temperatures for a length of time, all of the operating specifications are guaranteed over the specified Operating Temperature Range.

PULLABILITY

A specification for the change in frequency (expressed in ppm) for a „Parallel Load Resonant“ crystal as a function of chenge in Load Capacitance (expressed in pF). In certain applications (i.e. VCXO) where variations in the crystals parallel resonant frequency are mandatory, pullability is specified. The pullability of a quartz crystal is derived from ***Equation 1*** above and is calculated as shown in ***Equation 3*** below.

$$\frac{F_{CL1}-F_{CL2}}{F_{CL1}} = \frac{C_1}{2}\left\{\frac{1}{(C_0+C_{L1})} - \frac{1}{(C_0+C_{L2})}\right\}$$

Equation 3

As shown from the equation, a desired change in frequency (***F_{CL1}*** and ***F_{cl2}***) is a direct result of a given change in Load Capacitance (***C_{L1}*** and ***C_{L2}***).

METRIC TO ENGLISH CONVERSION

1” = 25.4 mm; 1 mm = 0.039”

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MECHANICAL CHARACTERISTICS

BEND TEST

Pins withstand max. bend of 90° ref. to base for 2 bends.

Ref. MIL - STD 202 F, Method 211A, Condition C.

VIBRATION

10 - 55 Hz, duration of 6 hours, displacement

1.5 mm 3 mutually perpendicular plans.

Ref. MIL - STD 202F, Method 201A.

SHOCK

1000 G, 0.35 ms, half sine - wave, 3 shocks of each plan.

Ref. MIL - STD 883 C, Method 2002. 3, Condition C.

SOLDERABILITY

95% coverage using 63/37 solder at 245°C for 5 sec. dipping after immersion in Alpha 611 flux 5 sec.

Ref. MIL - STD 883 C, Method 2003. 5.

SOLVENT RESISTANCE

Withstand of IPA, Tricholorethane, Freon TMC for 30 sec.

Ref. MIL - STD 202F, Method 215, Condition B.

ENVIROMENTAL CHARACTERISTICS

GROSS LEAK

All units 100% leak test of FC# 40 in 125°C ± 3°C

Ref. MIL - STD 883 C, Method 1012. 8, Condition C.

FINE LEAK

Mass spectrometer leak rate less than 2 x 10^{-8} atm. cc. / sec. of Helium.

Ref. MIL - STD 883 C, Method 1014. 8, Condition B.

TEMP CYCLING

-55°C to 125°C for 10 cycles, 1/2 hour dwell time max.

Ref. MIL - STD 883 C, Method 1010. 7, Condition B.

RESISTANCE TO SOLDERING HEAT

10sec. in a solder bath of 260°C up to 0.5 mm from the glass stand - off.

Ref. MIL - STD 202F, Method 210A, Condition B.

THERMAL SHOCK

-55°C to 125°C for 5 cycles, 10 min. stay in each extreme temperatures.

Ref. MIL - STD 883 C, Method 1010. 7, Condition B.

HUMIDITY

85% relative humidity at 85°C for 500 hours.

Ref. MIL - STD 883 C, Method 1004.6.

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