QUARTZ CRYSTAL GLOSSARY OF TERMS

Nominal frequency: The specified center frequency of the crystal. Unit of frequency is Hertz (Hz). Quartz crystals are specified in kHz or MHz.

Crystal equivalent circuit: The crystal equivalent circuit of the quartz crystal consists of a motional capacitance C1, the motional inductance L1, a series resistance R1, and a shunt capacitance C0. The first three parameters are known as the "motional parameters". See figure 1.

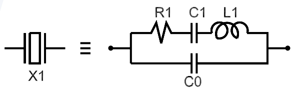


Fig. 1

Operating mode: The quartz crystal could operate at its Fundamental mode or harmonic modes. The fundamental mode is always the preferred oscillating mode. Odd harmonics such as 3rd, 5th, 7th, etc. are overtone modes.

Frequency tolerance: The maximum allowable frequency deviation from a specified nominal frequency at ambient room temperature (25°C ± 3°C). Frequency tolerance is expressed in percent (%) or parts per millions (ppm).

Frequency stability: The maximum allowable frequency deviation from the ambient temperature over the temperature range. Frequency stability is expressed in percent (%) or parts per millions (ppm). The frequency stability is determined by cut type, angle cut, angle cut tolerance, mode of operation, package styles, and mechanical dimensions of the quartz blank.

Series vs. Parallel resonance: When a crystal is operating at series resonance (Fs), it looks resistive in the circuit. At this point \XL\ = \XC\. In series resonance, load capacitance does not have to be specified.
The antiresonant frequency (Fa) occurs when the reactance in the series branch is equal to C0.
When a crystal is operating at parallel resonance, it looks inductive in the circuit. The crystal equivalent circuit can be simplified as a series resistance Re with a reactance Xe.
The difference in frequency between the Fs and Fa depends on the C0/C1 ratio of the crystal unit, and the inductance L1. In parallel resonance, the load capacitance shall be specified.

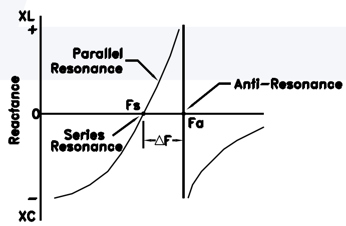


Fig. 2

Equivalent Series Resistance (ESR): The value of impedance the crystal exhibits in the operating resonant circuit.

Aging: The relative frequency change over a certain period of time and is typically expressed as a maximum value in parts per million per year (ppm/year). Typically, aging is computed within the first 30 days to 90 days and predicted exponentially over a longer period usually a year.

Operating temperature: The minimum and maximum temperatures within which crystal unit operates under specified conditions.

Storage temperature: The minimum and maximum temperatures that the crystal unit can be safely stored.

Drive level: A function of the driving or excitation current flowing through the crystal. The drive level is the amount of power dissipated in the crystal and is expressed in milliwatts or microwatts. Drive level should be kept at a safe minimum condition to assure proper start-up. Excessive drive level will result in possible long-term frequency drift or crystal fracture.

Figure 4 shows the relationship between drive level and circuit load capacitance and optimum value guarantee for start-up condition.

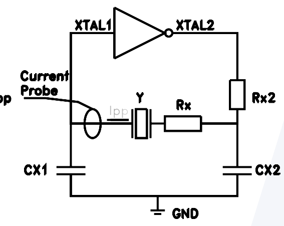


Fig. 3

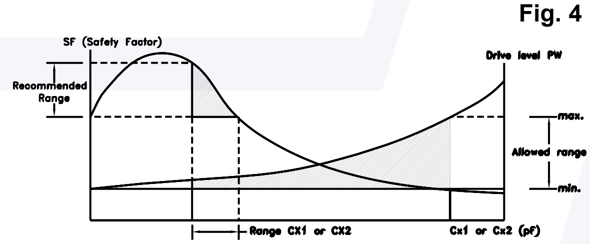
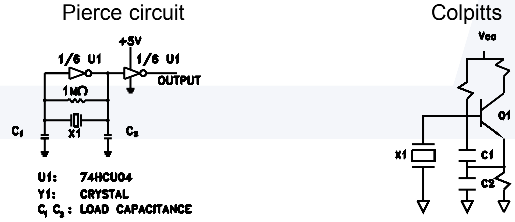


Fig. 4

Load capacitance: Load capacitance (CL) is the amount of capacitance that the oscillator exhibits when looking into the circuit through the two crystal terminals. Load capacitance needs to be specified when the crystal is used in a parallel mode. Load capacitance is calculated as follows:

Pierce circuit Colpitts



$$CL = \frac{(C1 \times C2)}{(C1 + C2)} + Cstray$$

Fig. 5

Spurious responses: Unwanted resonance usually above the operating mode, specified in dB max. or number of times of main mode ESR value. Frequency range is specified within couple of hundreds kilohertz.

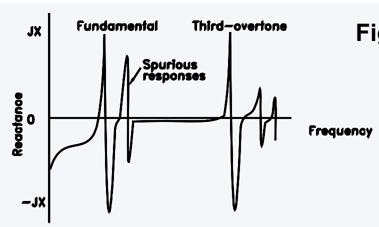


Fig. 6

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QUARTZ CRYSTAL GLOSSARY OF TERMS

Crystal cuts: A blank wafer is obtained by cutting the quartz bar at specific angles to the various axes. The choice of axis and angle cut determines the physical and electrical parameters of the resonator. Figure 7 shows combinations of X, Y, and Z rotational cuts which are labeled in industry as AT, BT, CT, DT cut, etc. The most two common cuts in Abracon crystals are AT and BT-cuts. There are differences in temperature coefficients of the two cuts.

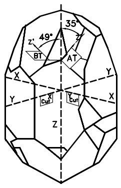

Fig. 7

Vibration modes: The crystal vibrates and produces a steady signal when it is excited with a voltage. The mode of vibration depends on crystal cuts such as thickness shear for AT and BT cuts, length-width flexure for tuning fork, Face shear for CT, DT cuts, etc. Figure 8 shows a thickness-shear mode.

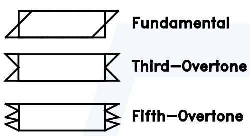

Fig. 8

Shunt capacitance C0: The static capacitance between the electrodes (Ce) together with holder capacitance (Ch).

$$Co = Ce + Ch$$

Ch varies between 0.6pF to 0.8pF depending on mounting method.

Motional capacitance C1: The capacitance of the nominal arm of the equivalent circuit. C1 results from the elasticity of the quartz blank.

$$C1\ (pF) = 0.22 \times A\ (m^2) \times F\ (Hz) / 1670$$

Where A = area of electrode in m^2

Quality factor Q: The factor that represents the sharpness of the resonant curve. Quartz crystal has a very high Q compared to other resonators typically in 10,000 to 100,000s.

$$Q = \frac{2 * \pi * Fs * L1}{R1} = \frac{1}{2 * \pi * Fs * C1 * R1}$$

Pullability: When a crystal is operating at parallel resonance, it looks inductive in the circuit. As the reactance changes, the frequency changes correspondingly, thus change the pullability of the crystal. The difference in frequency between the Fs and Fa depends on the C0/C1 ratio of the crystal unit and the load capacitance CL.

Delta F from series resonant to parallel resonant in ppm:

$$\frac{FL - Fs}{Fs} = \frac{\Delta F}{Fs} = \frac{C1}{2\,(C0 + CL)}$$

Pullability can be expressed in terms of load sensitivity (TS) in ppm/pF.

$$TS\ (ppm/pF) = \frac{10^6 * C1}{2\,(C0 + CL)^2}$$

Negative resistance (-R): Negative resistance is used to evaluate circuit oscillation allowance. Lack of negative resistance could lead to initial circuit start-up and and unstable oscillation at steady state.

Procedure:

1. Connect the external resistance Ri in series with the crystal.
2. Adjust Ri value until oscillation stops.
3. Record Ri value.
4. Negative resistance –R = Ri + R1
5. Recommended - R value to be at least 5 to 10 times greater than Re.

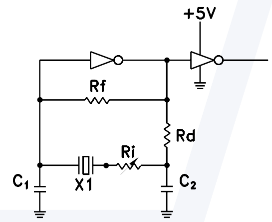

Fig. 9

See figure 9.

Frequency vs. temperature characteristics: Figure 10 shows the frequency – temperature characteristics for a thickness-shear AT cut crystal. The AT-cut curve has an S-shape symmetrical to room temperature.

Quartz crystals manufacturing process: Quartz crystals are

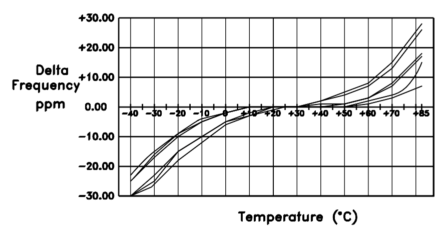

Fig. 10

manufactured in a clean environment to assure high-precision. Highlights of the major steps in manufacturing process of the AT-Cut crystal are described below:

As grown quartz bars – Lumbering – Cutting – Measurement of angle – Precision lapping – Beveling – Etching and Cleaning – Base coating – Mounting – Fine frequency adjusting – Annealing – Sealing – Aging – Final tests and Inspections.

Crystal mounting methods: Quartz blank unit is mounted on holder mounts with conductive epoxy or solder (tuning fork). Precise amount of silver epoxy is applied with automounter

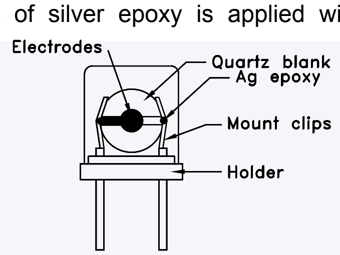

Fig. 11

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