

Quartz Crystal Glossary of Terms

Rev B

Activity Dip

An unwanted crystal characteristic that exhibits a sudden change in the crystal resistance and resonant frequency, followed by an equally sudden return to the prior values. Activity dips are strongly influenced by crystal drive level and load capacitance.

Aging

The systematic change in frequency with time due to internal changes in the quartz crystal resonator. Aging is often expressed as a maximum value in parts per million per year (ppm/year). The rate of aging is logarithmic in nature. The following factors effect crystal aging: adsorption and desorption of contamination on the surfaces of the resonator, stress relief of the mounting and bonding structures, material outgassing, and seal integrity.

Angle

The angle (specified in degrees, minutes, and seconds) at which the resonator blank is cut from the quartz material in relation to the main crystallographic axis. The cut angle is a primary factor controlling the frequency versus temperature performance of the quartz crystal unit.

AT Cut Crystal Unit

A classification of a specific type of quartz crystal cut. The AT cut is the most popular cut type manufactured today for crystal units in the MHz range. The AT cut is classified as a thickness-shear bulk acoustic wave (BAW) crystal unit and has a cubic frequency versus temperature with inflection point near room temperature. It is widely popular due to its excellent temperature versus frequency characteristics.

Base

Often called a holder or header, a base is a subcomponent of a quartz crystal unit package.

Blank

A semi-processed quartz resonator without its holder or base.

BT Cut Crystal Unit

A classification of a specific type of quartz crystal cut. The BT cut is processed at an angle approximately opposite that of the AT cut and is classified as a thickness-shear crystal unit with a parabolic frequency versus temperature curve with its inflection point near room temperature. Thus, over a given operating temperature range, the BT cut crystal will exhibit a greater frequency shift than the AT cut crystal.

Capacitive Ratio

The crystal shunt capacitance divided by the crystal motional capacitance. An indicator of the change in a parallel load resonant frequency as a direct result of a given change in crystal load capacitance. In VCXO applications

where variations in the crystal parallel resonant frequency are desired for frequency modulation, the capacitive ratio, symbol 'r', may be specified. The value of this ratio has limitations when it is realized in a physical quartz crystal design.

Ceramic Package

Often called a header or leadless chip carrier (LCC), this is a type of surface mount crystal package fabricated using ceramic as its primary packaging material. Integrated with a metal lid or cover, this package provides a hermetically seam-sealed enclosure for the quartz crystal.

Crystal Cut

The crystal blank plate is cut with respect to the crystallographic axis of a quartz bar. The type of crystal cut influences the crystal's aging frequency stability and other parameters.

Crystal Equivalent Circuit

A crystal device consists of a quartz resonator blank with metal plating. This plating is located on both sides of the crystal 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 crystal equivalent circuit consisting of the following components: motional capacitance, motional inductance, motional resistance, and shunt capacitance.

Crystal Oscillator

A timing device that consists of a quartz crystal resonator and an oscillator sustaining circuit incorporated into a single package, providing an output waveform at a specified reference frequency. This term is often abbreviated as XO or SPXO (Simple Packaged Crystal Oscillator).

Crystal Unit

A timing device that consists of a quartz crystal resonator and its associated package.

Drive Level

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

Equivalent Series Resistance (ESR)

The resistive element, measured in ohms, of a crystal device. At the series resonant frequency of a crystal, 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 they cancel one another and only a resistance remains in the series leg of the equivalent circuit. The ESR measurement is made only at the series resonant frequency (F_s), not at some predetermined parallel resonant frequency (F_L).

Flexure Vibration

A vibration mode of a tuning fork crystal resonator, in which a flexure motion of the vibrating plate is used as the oscillation source. This type of vibration is suited for low-frequency (kHz) crystal devices.

Frequency

Measured in Hertz (Hz), it is a periodic repetition of an event within a unit of time. In an electrical circuit, it is the number of times a resonator plate oscillates or vibrates in one second.

Frequency Stability

The amount of frequency deviation from the ambient temperature frequency over the operating temperature range. This term is expressed as a minimum and maximum percent (%) or parts per million (ppm) and is determined by the following primary factors: Type of quartz cut and angle of the quartz cut. Some of the secondary factors include: mode of operation, load capacitance, and drive level.

Frequency Tolerance

Often called Calibration Accuracy, it is the amount of frequency deviation from the specified nominal frequency at room temperature (25°C). This term is expressed as a minimum and maximum percent (%) or parts per million (ppm).

Fundamental Mode

The first and lowest frequency vibration order a resonator plate will oscillate, determined by the physical dimensions of the plate.

Hertz (Hz)

The basic unit of measurement of frequency. It is a measurement used to denote one complete occurrence of an event in one second. The frequency of a crystal is measured in megahertz (MHz) or kilohertz (kHz).

Insulation Resistance

The resistance, expressed as a minimum value, between the leads of the crystal and between the crystal leads and the base.

Load Capacitance

A capacitance, specified in picofarads (pF), presented to the crystal. The parallel load resonant frequency (F_L) is a function of the load capacitance.

Mode of Operation

A quartz crystal is designed to vibrate either on its fundamental mode or one of its overtones. For AT cut quartz crystals, overtone modes are at odd frequency harmonics. The mode of operation of a quartz device is one of the factors that will determine the frequency of oscillation.

Motional Capacitance

The equivalent electrostatic capacitance component in a crystal unit. The motional capacitance (C_1) and the motional inductance (L_1) of a crystal resonate at a series resonance frequency (F_S). The actual value of C_1 has physical limitations when it is realized in a quartz crystal design. These constraints include mode of operation, crystal cut, mechanical design, and nominal frequency.

Motional Inductance

The equivalent inductive component in a crystal unit. The motional inductance (L_1) and motional capacitance (C_1) of a crystal resonate at a series resonance frequency (F_S). The actual value of L_1 has physical limitations when it is realized in a quartz crystal design. These constraints include mode of operation, crystal cut, mechanical design, and nominal frequency.

Nominal Frequency

The specified reference or center frequency of the crystal, typically expressed in megahertz (MHz) or kilohertz (kHz). The desired frequency for which the crystal is designed and manufactured.

Operating Temperature Range

The minimum and maximum temperatures that a device can be exposed to during oscillation. Over this temperature range, all of the device specified operating parameters are guaranteed.

Overtone Mode

An odd-numbered multiple of the fundamental vibration order.

Package

Holder or header used to contain the quartz crystal blank. The package facilitates the blank mounting and maintains an inert atmosphere in order to sustain the internal crystal's oscillation performance. Packaging includes materials such as metal or ceramic, and are classified as through-hole or surface mount (SMD).

Parabolic Temperature Curve

A frequency versus temperature curve showing a decrease in frequency as the temperature goes above or below the turnover temperature.

Parallel Load Resonance

A crystal employed in a typical oscillator application operates in either of two resonant modes: Series Resonance or Parallel Load Resonance. The crystals used in these two types of modes are physically the same crystal, but are calibrated to slightly different frequencies. When a crystal is placed into an oscillator circuit, the crystal and oscillator circuit components resonate together at a tuned frequency. This frequency is dependent upon the crystal design 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 circuit's 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.

Parallel Resonant Frequency

The resonant frequency of a crystal unit operating with a specified value of load capacitance.

Piezoelectric Effect

The electric charge generated in a particular axial direction when pressure is applied to a defined axial direction on a quartz crystal. By contrast, the mechanical stress that results when a charge is applied in the same axial direction is called a converse piezoelectric effect.

PPM

The abbreviation for Parts Per Million, a method of calculation used to specify the frequency tolerance or stability of a crystal unit.

Pullability

A specification for the change in the parallel load resonant frequency, expressed in ppm, as a function of change in crystal load capacitance. The frequency can be pulled in a parallel resonant circuit by changing the value of load capacitance.

Quartz Crystal Unit

An electronic component, consisting of a resonator plate with electrodes and a hermetically sealed package with suitable mounting structures, used in frequency control applications. Synthetic quartz crystals are hexagonal mono-crystals composed of Silicon and Oxygen (SiO_2) and are cultured in autoclaves under high pressure and temperature. Quartz crystals exhibit piezoelectric properties and can be used to stabilize the frequency of an oscillator circuit.

Reflow Profile

The reflow profile specifies the temperatures and time periods to be used when mounting electronic components onto printed circuit boards.

Resistance Weld

A crystal package sealing process involving pressure sealing with electricity to reflow the metal joint interface of a cover and base.

Resonant Frequency

The natural frequency at which a crystal device vibrates.

Resonance

The creation of vibrations in a system by applying a periodic force. Resonance occurs when the frequency of the applied force is equal to the natural frequency of the system.

Resonator

A device, operating at some resonant frequency, capable of being set into resonance by the application of a periodic electrical force.

SAW Resonator

A crystal device that employs a SAW (surface acoustic wave) blank. A SAW device consists of a structure that has alternating positive and negative electrodes on the surface of a quartz element creating a wave-like vibration emitting from the surface.

Series Resonant Frequency

The resonant frequency of a crystal unit operating without the presence of load capacitance resulting in a crystal frequency lower than the parallel resonant frequency. The motional capacitance (C_1) and the motional inductance (L_1) of a crystal resonate at a series resonance frequency (F_s).

Shunt Capacitance

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.

SMD Package

An acronym for surface mount device, it is a package with pads that mount to the surface of a printed circuit board.

Spurious Response

An unwanted non-harmonic signal found in the frequency response of a quartz crystal, occurring at some point higher than the desired mode but lower than the next overtone.

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 any temperature over this range, all of the specifications are guaranteed over the operating temperature range. Exceeding the storage temperature range may result in device failure or internal component damage.

Strip Crystal or Resonator

A crystal unit processed and manufactured in the shape of a rectangular. It typically has a higher crystal resistance as compared with a round crystal and is smaller in size, thus allowing it to be placed into a smaller packaging.

Synthetic Quartz Crystal

The product result of a high quality artificial manufacturing process called hydrothermal synthesis. This process 'grows' quartz over a period of time in an autoclave.

Thickness Shear Vibration

A classification of the type of vibration motion of a bulk acoustic mode (BAW) crystal unit. For this vibration mode, the top and bottom surfaces along the crystal plate's thickness direction move opposite to each other. This mode is prevalent in AT cut crystal units.

Through-hole Package

A package that is mounted by insertion of pins into holes of a printed circuit board.

Trim Sensitivity

Amount by which the parallel resonant frequency of a crystal oscillating with a specific value of load capacitance will vary if that load capacitance is varied one picofarad about its nominal value.

Tuning Fork

A type of low frequency (kHz) crystal device that uses a tuning fork-shaped crystal blank.

Turnover Temperature

The temperature at which the frequency is at the vertex of the parabolic curve.