Technical Dictionary

Frequency Tolerance

The deviation from the nominal frequency expressed in Parts Per Million (PPM) at room temperature (+25°C) Frequency tolerance is sometimes expressed as a percentage of frequency deviation, rather than as Parts Per Million (PPM) The conversion is as follows:

.01 % = 100 PPM
.005% = 50 PPM
.001 % = 10 PPM etc.

As frequency tolerances are tightened, costs increase incrementally.

Aging

A change in the frequency and/or the resistance of a quartz crystal unit with the passage of time. Attributable to the relaxation of strain in the resonator and to mass transfer mechanisms within the resonator package due to contamination. Other factors include drive level, ambient temperature, wire fatigue, and frictional wear.

These factors are minimized by design considerations, including the mechanical design of the mounting structure, and by the design and control of certain manufacturing processes. Most of the aging effects of a crystal occur within the first 60 days of operation leading to slower aging characteristics through the first year. The integrity of the hermetic characteristics of the crystal package are a major factor in determining how well a crystal will age.

Absolute Clock Jitter

The maximum variation in the period of a clock signal, measured at an interval of 1 period from the reference (trigger) edge.

Calibration Tolerance

The Calibration Tolerance is defined as the accuracy of the initial calibration of the crystal or oscillator, as compared to a reference source with zero error to the NBS standard.

Center Frequency

Midpoint in the pass band, or the arithmetic mean between high and low cut off frequencies of the filter.

Current Consumption

The Current Consumption Current is defined as the current drawn by the oscillator when it is enabled, measured in mA.

Drive Level

The amount of power dissipated by the oscillating crystal unit. Usually expressed in terms of milliwatts (mW), and is usually specified in terms of current through the resonator or power dissipated by the resonator. The latter is preferable. The drive level of a crystal is a function of the reactance of the input and output capacitance of the inverter or microprocessor and all other external components including the crystal. To calculate drive level, "ohm's law" for power is used.

Drive level should be held to a minimum to avoid problems with stability, aging, nonlinear coupled modes and other nonlinear effects. However, the phase noise performance of an oscillator can be increased by increased drive level, so a compromise is sometimes in order. The maximum power dissipation is specified for each type of crystal in the oscilent specifications. Drive level is most critical in tuning fork crystals because of the comparably lower maximum drive levels. Circuits utilizing tuning fork crystals should be designed in such a way that avoids over driving the crystal.

Enable / Disable Time

Defined as the time an Oscillator takes to reach it's specified output amplitude and frequency upon assertion of the output Enable or Disable (output is stabilized)

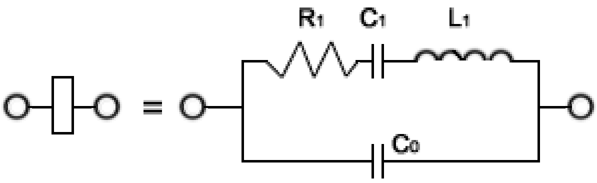
Useful Equations

Equations	Definitions
fS = (Series) frequency = $\frac{1}{2\pi\sqrt{L_1C_1}}$	C0 = Static Capacitance in farads
CL = Load capacitance = $\frac{C_1}{2 \times \Delta f} - C_0$	C1 = Motional capacitance in farads
Co = Shunt capacitance = $\frac{C_1}{2 \times \Delta f} - C_L$	CL = Load capacitance in farads
C1 = Motional capacitance = $2(C_0 + C_L)\Delta f$	f = Nominal frequency in Hz
L1 = Motional inductance = $\frac{1}{4x^2 fs^2 C_1}$	fL = Anti-resonant frequency in Hz
R1 = Series resistance = $\frac{2\pi \times fs \times L_1}{Q}$	fS = Series resonant frequency in Hz
Q = Quality factor = $\frac{2\pi \times fs \times L_1}{R_1}$	L = Inductance into Henrys
fL - fS = Δf = $\frac{C_1}{2(C_0 + C_L)}$	PL = Pullability (ppm/pF)
PL = Pullability = $\frac{C_1 \times 10^6}{2(C_0 + C_L)^2}$	Q = Quality factor
	R1 = Series resistance in ohms

Equivalent Circuit

The equivalent circuit (shown in Figure A) depicts electrical activity of a quartz crystal unit operating at its natural resonant frequency. The shunt capacitance

(Co), represents the capacitance of the crystal electrodes plus the capacitance of the holder and leads. R1, C1, and L1 compose the "motional arm" of the crystal, and are referred to as the motional parameters. The motional inductance (L1) represents the vibrating mass of the crystal unit. The motional capacitance (C1) represents the elasticity of the quartz, and the resistance (R1), represents bulk losses occurring within the quartz.



Equivalent Series Resistance/ Mode Of Oscillation

Mode Of Oscillation:

A quartz crystal is designed to vibrate on its fundamental frequency or one of its overtones. Generally, fundamental frequencies up to 30 Mhz are attainable using standard crystal designs and processes. For frequencies above 30 Mhz, overtone modes are recommended. Fundamental mode crystals, at these frequencies, become more expensive because the quartz blank is extremely thin and subject to a higher rate of breakage during production. The ability to use the overtone crystal, instead of the fundamental, produces significant cost savings. As the frequency range is extended, the oscillation mode of the crystal changes to other overtones. Normal overtone modes are 3rd, 5th, 7th, and 9th and can be referred to as "multiples" of the fundamental frequency. As an example, a 60 Mhz 3rd overtone crystal would look like a 20 MHz crystal at it's fundamental. A 20 Mhz crystal can be made to oscillate at 3, 5, 7, etc times the fundamental frequency. A frequency of 60 Mhz is achieved by optimizing certain electrical parameters in an overtone oscillator circuit derived from a 20 Mhz crystal. Crystals in the range of 60-110MHz are generally 5th overtones, while crystals in the range of 110-175MHz generally are 7th overtones. Never attempt to use a fundamental mode crystal unit operating at an overtone frequency.

Equivalent Series Resistance (ESR):

The equivalent series resistance is the resistive element (R1) of the quartz crystal equivalent circuit. (see Equivalent Circuit below) This resistance represents the equivalent impedance of the crystal at natural resonant frequency (series resonance) ESR is measured by a Crystal Impedance (CI) meter.

ESR values are generally stated as maximum values expressed in ohms. The ESR values vary with frequency, mode of operation, holder type, crystal plate size, electrode size, and mounting structure.

It is worth noting that the ESR value at a given frequency for an AT- strip crystal design is generally higher than that of the standard (round blank) design. This becomes more significant at lower frequencies. When transitioning from a series resonant through-hole HC-49/U type crystal to a smaller surface mount type utilizing an AT-strip crystal, some consideration may be given to the difference in the ESR values produced by different cuts.

The ESR becomes critical when resistance values reach a point were the oscillator circuit cannot adequately drive the crystal. Sluggish start-up or unwanted modes of operation may result.

Equivalent Circuit:

The equivalent circuit (shown in Figure A) depicts electrical activity of a quartz crystal unit operating at its natural resonant frequency. The shunt capacitance (Co), represents the capacitance of the crystal electrodes plus the capacitance of the holder and leads. R1, C1, and L1 compose the "motional arm" of the crystal, and are referred to as the motional parameters. The motional inductance (L1) represents the vibrating mass of the crystal unit. The motional capacitance (C1) represents the elasticity of the quartz, and the resistance (R1), represents bulk losses occurring within the quartz.

Rise Time / Fall Time

Rise Time (TR):

Amount of time it takes the output voltage to go from 10% of the Logic "1" level to 90% of the Logic "1" level.. Measured in nS.

Fall Time (TF):

The time required for the output voltage to go from 90% of the Logic "1" level to 10% of the Logic "1" level.. Measured in nS.

Frequency Accuracy

The absolute accuracy of a crystal or oscillator, as compared to the NBS standard.

Frequency Adjustment

TCXO products come equipped with a frequency adjustment feature that allows for adjustments to the center frequency. This feature allows compensation for initial frequency calibration and aging, and is accomplished via the internal trimmer. This adjustment can also be provided by a control voltage via an external lead on the TCXO The oscillator utilizing this technique is referred to as a Temperature Compensated Voltage Controlled Crystal Oscillator or TCVCXO.

Frequency Control Range

The maximum range over which a VCXO can be tuned.

Frequency Linearity

The Frequency Linearity in a VCXO is defined by the change in Voltage Control divided by the resultant change in output frequency.

Frequency Pulling Range

The Frequency Pulling range of a VCXO is defined as the maximum change in output frequency that can be attained via the Control Voltage.

Frequency Range

The frequency band that a particular crystal or oscillator product can be offered as a standard in manufacturing. Wherever possible, we have listed standard and/or common frequencies in the Data Sheets. Other frequencies are available and can be constructed in the Part Number Guide.

Frequency Tolerance / Stability Over Temperature

The Frequency Tolerance of a crystal or oscillator is defined as the initial deviation of the crystal or oscillator frequency as compared to the absolute at 25°C. The Frequency Stability over temp is defined as the frequency deviation compared to the measured frequency at 25°C OVER the defined operating temperature range (I.E. 0°C to +70°C). Stability tolerance is sometimes expressed as a percentage of frequency deviation rather than as Parts Per Million (PPM) The conversion is as follows:

.01 % = 100 PPM
.005% = 50 PPM
.001 % = 10 PPM etc.

The stability tolerance of a crystal or oscillator needs to be specified, along with the operating temperature range. For instance, a crystal may be specified as having a frequency stability tolerance of ±50 PPM over an operating temperature of -45°C to + 85°C, and having a frequency tolerance of ±50 PPM at +25°C.

Guaranteed Attenuation

The maximum guaranteed reduction in power, ranging outside a specified frequency span. Attenuation usually specified in decibels (dB)

Input Current (IDD)

Maximum specified current for electrical/operational characteristics to remain within specifications. Usually specified in mA.

Input / Output Impedance

The complex combination of Resistance and Reactance, usually specified in Ohms.

Insertion Loss

Power loss of the filter in the passband expressed in dB. Point of maximum output of the filter is 0 dB reference unless otherwise specified. Insertion loss is equal to 10 Log Pin/Pout.

Insulation Resistance

The DC resistance between the pins of a crystal, usually expressed in MegOhms.

Internal Capacitance (C1) (C2)

The internal capacitance C1, also known as the motional capacitance Cm, is the electronic equivalence of the mechanical elasticity of the unit.

Load Capacitance

The Capacitance external to the crystal contained within the feedback loop of the oscillator circuit. For "parallel" resonant crystals (see below for discussion on parallel vs. series resonant crystals), the value of load capacitance needs to be specified by the customer to insure initial Frequency Tolerance. For "series" resonant crystals, load capacitance is not used. Load capacitance can be measured as the amount of capacitance across the crystal terminals on the PCB. A parallel resonant mode crystal needs to have a load capacitance (CL) specified when ordering (this was already said above). The approximate crystal loading for a given circuit can be determined from the formula (SEE below for more useful equations):

$$C_L = \frac{C_1 \times C_2}{C_1 + C_2} + C_S$$

CS is the stray capacitance of the circuit and the input/output capacitance of the inverter or microprocessor chip at the Crystal 1 (C1) and Crystal 2 (C2) pins, plus any parasitic capacitances. CS may be assumed to equal 5 pF. Most crystal manufacturers will specify standard parallel resonant load capacitances of either 18 or 20 pF. These values have been found to provide for good Frequency Tolerance in most circuits. Changes in load capacitance will result in changes in the output frequency. .

Series vs. Parallel:

Parallel resonant crystals are intended for circuits which contain reactive components (capacitors) in the oscillator feedback loop. These circuits depend on the reactive components and the crystal to achieve the phase shift needed to start and maintain ocsillation at a specified frequency. Series resonant crystals are intended for circuits that contain no reactive components in the oscillator feedback loop. Please see Figure A for Series and Figure B for Parallel resonant crystals:

Figure A - Series

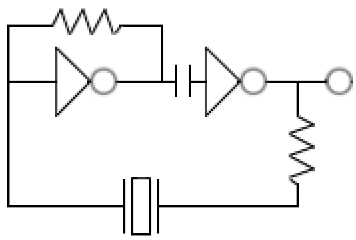
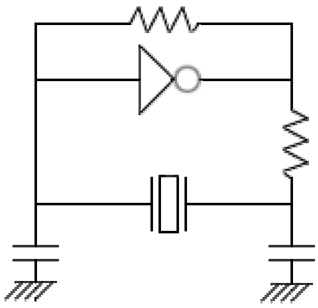


Figure B - Parallel



Logic "0" / Logic "1"

Logic "0" Level:

The Logic "0" level is defined as the low voltage portion of the output clock cycle of the oscillator.

Logic "1" Level:

The Logic "1" level is defined as the high voltage portion of the output clock cycle of the oscillator

Nominal Frequency

The desired center frequency of a crystal or oscillator. The midpoint in the pass band, or the arithmetic mean between high and low cut off frequencies of the filter.

Operating Temperature

Range of temperature in which output frequency and other electrical and environmental characteristics meet the product specifications.

Output Current

Output Low Current (IOL):

Assuming proper loading, the maximum Logic "0" current at the output of the oscillator.

Output High Current (IOH):

Assuming proper loading, the maximum Logic "1" current at the output of the oscillator.

Input / Output Impedance

The complex combination of Resistance and Reactance, usually specified in Ohms.

Output Load

Maximum load that different oscillator products can drive is defined as the output load driving capability. The load driving capability (fan-out) of each oscillator is specified by the number of gates of a particular logic type (i.e., HC, HCT, etc..) that can de driven.

Output Logic

The output of an oscillator is designed to meet various specified logic, such as TTL, HCMOS, ECL, Sine, Clipped-Sine (DC cut).

Output Symmetry

The Output Symmetry (also known as Duty Cycle) is defined as the ratio of the time interval of the positive portion of the output waveform to the total period of the output waveform. It is usually defined in %.

Output Voltage

Output High Voltage (VOH):

Assuming proper loading, the minimum Logic "1" voltage at an output of the oscillator.

Output Low Voltage (VOL):

Assuming proper loading, the maximum Logic "0" voltage at an output of the oscillator.

Number Of Poles

Refers to the number of sections in a filter, where the selectivity or Q of the filter is greater with the greater number of poles.

Q-Factor

Quality Factor (Q):

A measurement used to determine the units relative quality, or efficiency of operation. In a crystal resonator it is the reactance of the motional inductance or capacitance divided the motional resistance (See useful equations below) The maximum attainable short tern stability of a crystal depends on the "Q" value. In Figure 7, the separation between the series and parallel frequencies is called the bandwidth. As the bandwidth gets smaller, the value of "Q" rises, and the reactance slope gets steeper. Changes in the reactance of external circuit components have less effect (less "pullability") on high "Q" crystals, hence, there is more short term stability.

Resonant Resistance

The equivalent series resistance of a crystal at it's center, or resonant frequency.

Ripple

The peak to peak deviation in the pass band attenuation of a filter. Usually defined in dB.

Selectivity

Selectivity, also known as Q, is defined as (F/BW), where F is the center frequency, and BW is the bandwidth, usually the 3dB bandwidth.

Series vs. Parallel

Parallel resonant crystals are intended for circuits which contain reactive components (capacitors) in the oscillator feedback loop. These circuits depend on the reactive components and the crystal to achieve the phase shift needed to start and maintain ocsillation at a specified frequency. Series resonant crystals are intended for circuits that contain no reactive components in the oscillator feedback loop. Please see Figure A for Series and Figure B for Parallel resonant crystals:

Figure A - Series

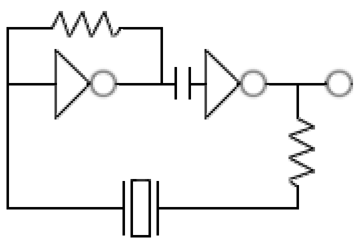
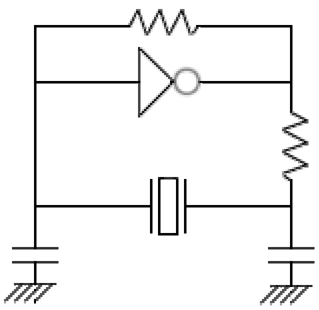


Figure B - Parallel



Shock Resistance

The Shock Resistance of a crystal or oscillator is defined as the maximum single impulse shock for which the crystal or oscillator can maintain it's performace characteristics, usually defined in G's.

Shunt Capacitance

Used to identify the capacitance resulting from the presence of the electrodes plus stray capacitance associated with the holder. This feature is specified by the manufacturer and is not a customer specified option.

Start-Up Time (Ts)

Defined as the time an Oscillator takes to reach it's specified output amplitude and frequency (output is stabilized)

Stopband

Also called a reject band, this is the area of frequency where the minimum transmission of signals is desired.. Expressed as a range of frequencies attenuated by more than a specified minimum. The part of the frequency spectrum that is subjected to a specified attenuation of signal strength by a filter.

Storage Temperature

The temperature at which the unit is safely stored or kept without damaging or changing the performance characteristics of the unit. The storage temperature is typically -40° - +85°, and is not a customer specified feature in Oscilent's product selection.

Supply Voltage

Voltage required for the oscillator to operate within specification, or the maximum voltage which can safely be applied to the VCC lead with respect to the ground lead. Specified in VDC.

Temperature Coefficient

The Temperature Coefficient is defined as the change in center frequency of a crystal or oscillator divided by the change in temperature. This is usually defined in PPM/Deg C.

Terminating Impedance

Load Impedance or Output Termination refers to the impedance that must be connected to the output terminals of the filter in order to achieve proper response. Source Impedance or Input Termination refers to the output impedance of the circuit that drives the filter.

Turnover Temperature

The Turnover Temperature is the temperature at which the Frequency Stability over temp characteristic of a crystal or oscillator changes polarity.

Voltage Control

The Voltage Control of a VCXO is defined as the port that controls the output frequency of the oscillator. Usually measured in Volts.

Withstanding Voltage

The DC voltage at which the insulation of the crystal can maintain it's specified resistance without voltage creep.

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