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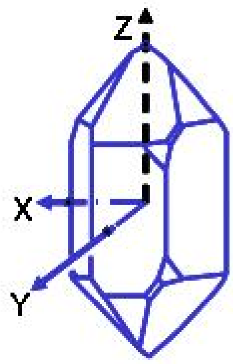
TZ MATERIAL AND FREQUENCY CONTROL PRODUCTS

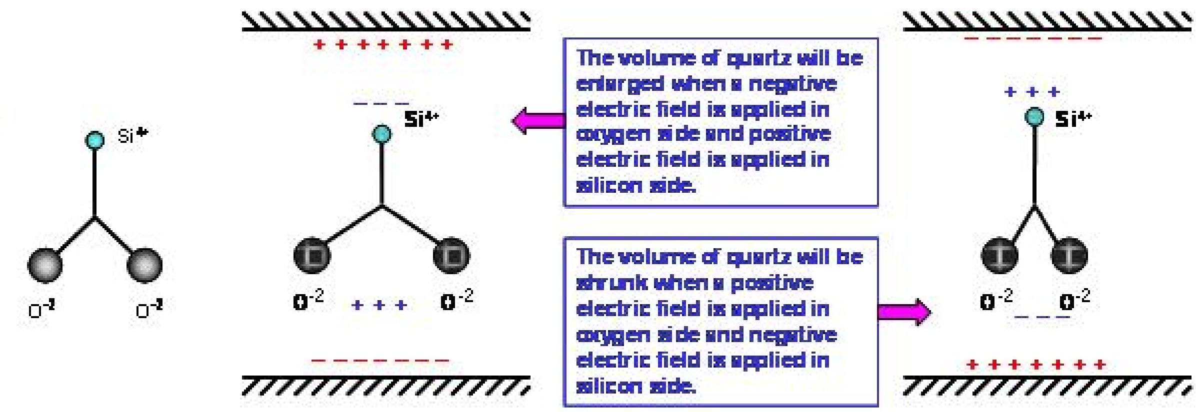
tz, a kind of crystallized Silicon Dioxide, SiO2, 32 symmetry group of trigonal system (Fig.1), exhibits piezoelectric y, which is the operating base of the electromechanical products. With its intrinstic high Q-value, the quartz based or and oscillator are the most wildly adopted as the reference signal source in circuitry for frequency control tions. Quartz frequency control products can be categorized into bulk acoustic wave application devices, such as /resonators, monolithic crystal filters and clock oscillators, and surface accoustic wave application devices, such as sonators and SAW filters. A piece of quartz crystal in a specific orientation cut, shape and dimensions is named wafer (blank). Such a crystal wafer with two deposited electrodes on both sides and housed in a holder is a crystal e-port resonator). By using the one-port resonators as impedance elements, crystal bandpass filters can be d. By incorporating the crystal resonator into a kind of electric circuit, one could get different kind of clock crystal ors (CXO), for example, Pierce Oscillator, Colpitts Oscillator, Simple Package Crystal Oscillator, Voltage Controlled Oscillatos, Temperature Compensated Crystal Oscillator, Oven Controlled Crystal Oscillator, and so on. Instead of ration of quartz crystals, a shorter wavelength (higher frequency) vibration can be achieved by surface wave jation with inter-digital-transducer (IDT) electrodes on the surface of quartz material. This vibration mechanism can d for resonator and filter applications .



(Fig.1) Crystallized quartz material

ELECTRICITY

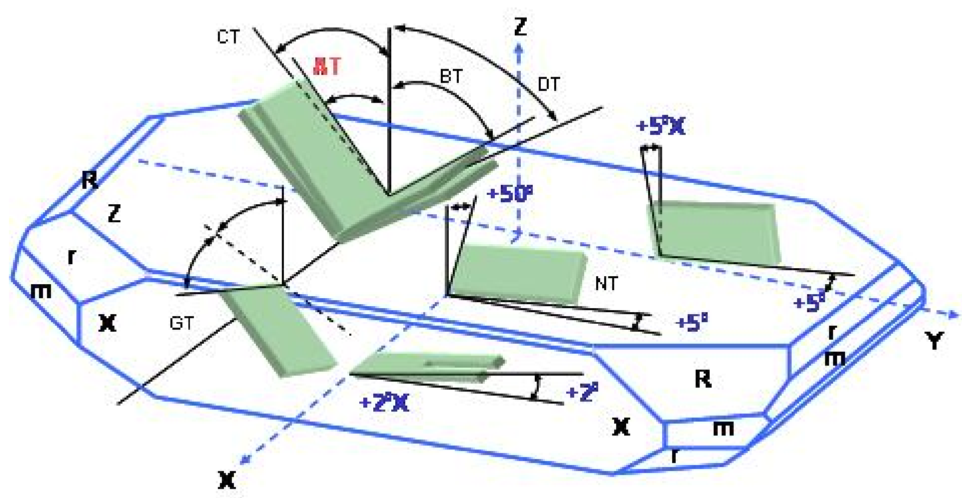
Silicon Dioxide atom is electrical natural in stable state. The electric dipole is along with silicon asix. Figure (2a) simplified two dimensional structure. When we apply an electric field along with dipole direction, with positive charged ilicon side and negative charged at the oxygen side, the oxygen ions will repel to each other creating an induced al field to balance the system. The oxygen ions will toward to each other if we apply a negative charged and positive d electric field to silicon and oxygen ions respectively. The oxygen ions will vibrate along horizontal direction in the equency as the alternative electric field along with vertical direction. The displacement of ions or the amplitude of n depends on the angle between the electrical field and the electric dipole of quartz. In practical three dimensional crystals, electrical field is supplied by electriodes coated on the surface of quartz wafer. The orientatin of dipole can ded through different kinds of cutting angles for quartz bar.



(Fig. 2) Simplified one dimensional piezoelectricity of SiO2

OF QUARTZ CRYSTAL CUT

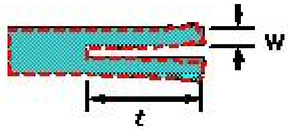
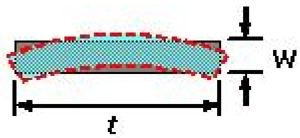
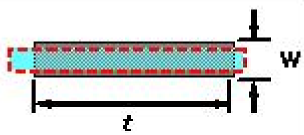
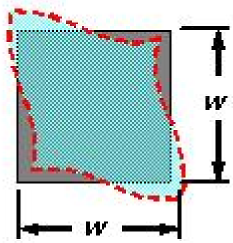
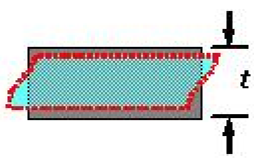
rding to different cut angles to quartz bars, there are different kinds of quartz plates, for examples, AT-, BT-, CT-, DT-, - cut plates Different types of quartz cuts, indicated by a set of Euler angles, have different available elastic, ectric and dielectric properties, which are the basic parameters for designing a quartz crystal device. The most often uartz-cut types are shown in (Fig. 3) schematically.



(Fig. 3) Orientation angle of a Z-plate quartz crystal.

OF VIBRATION

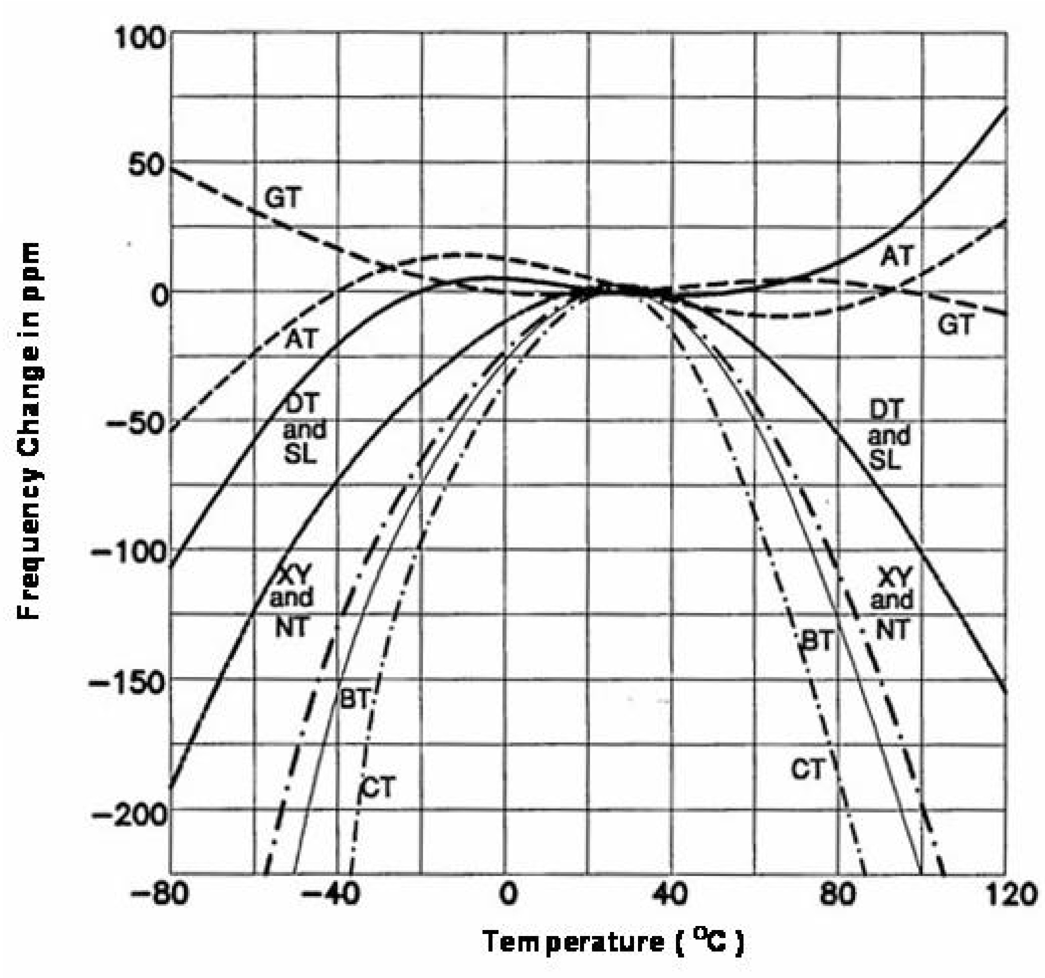
ibration modes of the quartz crystal units are grouped into flexure, extension, face shear and thickness shear The schematics of the vibration modes and the plate cuts usually used are listed in Table 1. Fundamental mode and e modes can be operated in any kinds of resonators. Fundamental mode is most often used, but for the thickness vices the overtone modes are often used as well, as shown in (Table 1)

Vibratoin Mode		Orienation Angle
Tuning Fork		+ 2 ° X
Flexure		XY NT
Extension		+ 5 ° X - 18.5 ° X
Face Shear		DT CT SL
Thickness Shear		AT Fundamental AT 3rd Overtone AT 5th Overtone BT Fundamental

﹝Table 1﹞Vibration Mode and Cut Angle.

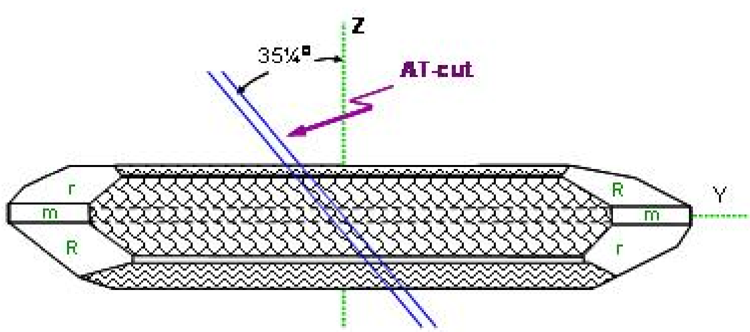
JENCY-TEMPERATURE CHARACTERISTICS

of the quartz products are used as an electrical circuit component for frequency selection and/or frequency control, requency-temperature characteristic of the devices is the most important parameter. This parts per million (ppm) ability of frequency-temperature characteristic is another merit of quartz frequency device that LCR discret ient oscillation circuitry can not be achieved in mass-production scale. For the usually used quartz crystal cuts, their icy-temperature characteristics are shown in (Fig. 4).



(Fig.4) Frequency-temperature characteristics of various quartz cuts.

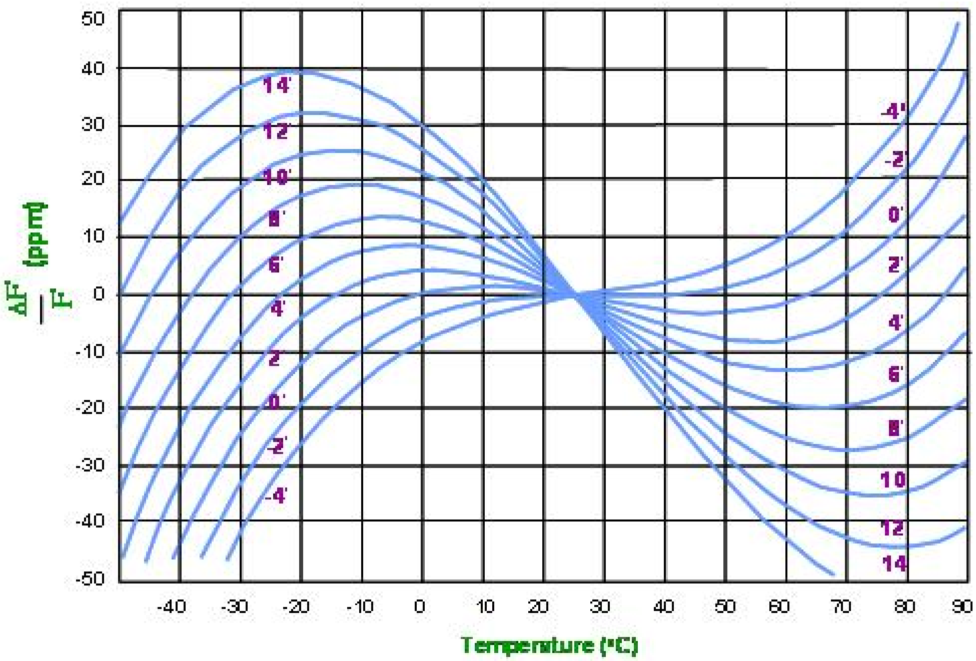
s the most popular crystal cut in the quartz devices for MHz applications. (Fig. 5) shows the orientation of AT plat
ɔ view of + X-axis.



(Fig.5) Orientation of AT plat

shows the frequency-temperature characteristics of the AT-cut crystal operating in thickness-shear mode, with the le deviation as a parameter. It is shown that AT-cut quartz has excellent frequency stability over a wide temperature ince the first-and second-order of the temperature coefficients go to zero in this range and the temperature ent is only dominated by a third-order function of the temperature deviation.

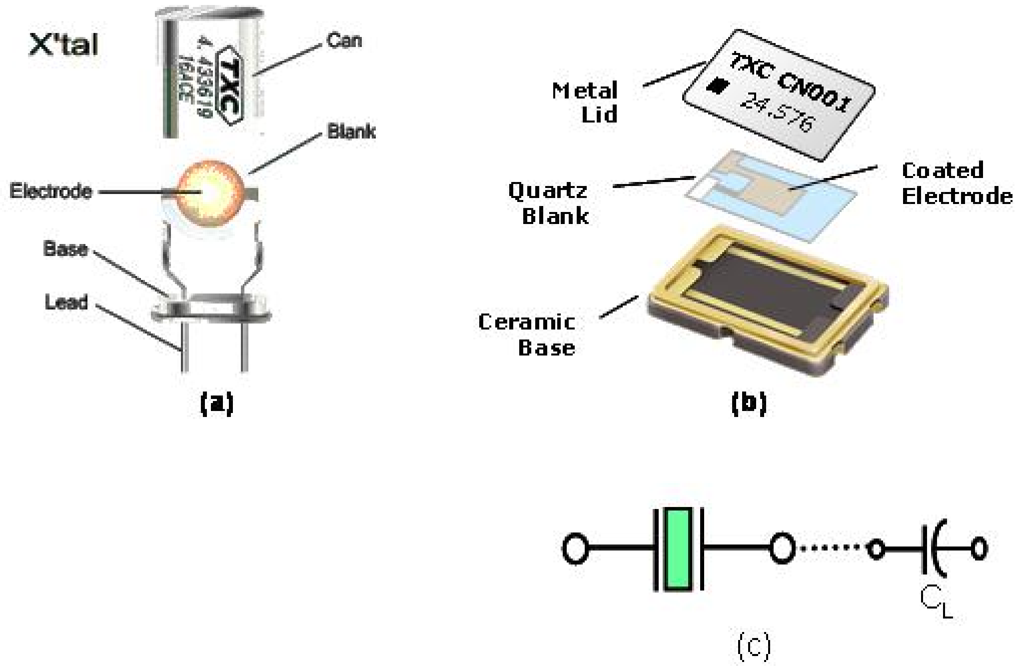
= A1 (Ti –25)3 + A2 (Ti –25)2 + A3 (Ti –25) + A4



(Fig. 6) AT - cut frequency-temperature characteristics.

ALENT CIRCUIT OF A CRYSTAL RESONATOR

7) shows the schematic of both metal can type and ceramic SMD type resonators and its symbol. The electrical ies of the unloaded resonator can be approximately expressed in Butterworth-Van Dyke (BVD) equivalent circuit as in Fig.5 when operating near a resonance frequency zone.

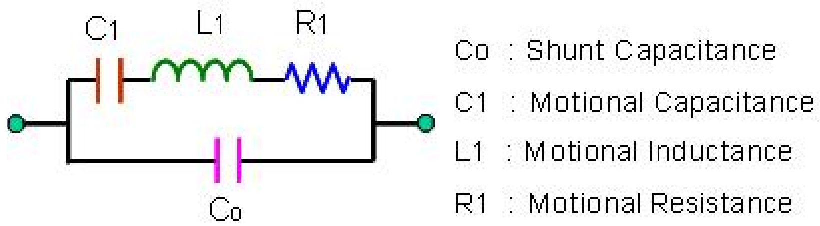


(Fig. 7) (a) Metal can type resonator

(b) Ceramic SMD type resonator

(c) Symbol of crystal usnit

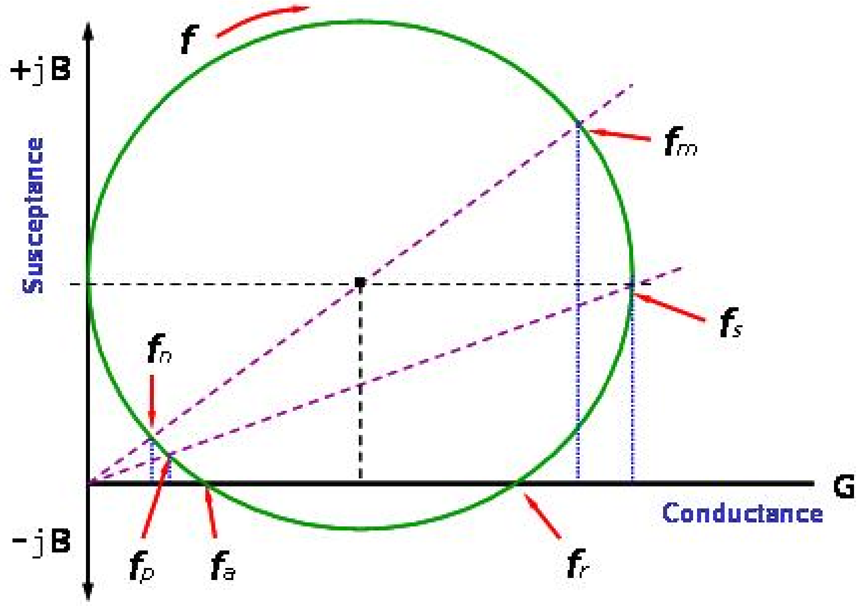
g the four parameters shown in (Fig .8) the major electrical properties of a crystal resonator and of a oscillator ng of the crystal resonator are described as follows.



（Fig.8）Effective Circuit of Crystal

NANCE FREQUENCY

ratures and product descriptions, there are three pairs of resonance frequencies, i,e., the "series resonance cy" and "parallel resonance frequency", (fs and fp) , the "resonance frequency" and "anti-resonance" frequency, (fr , and the "maximum and minimum total admittance located" frequencies, (fm and fn). All of them can be obtained e lumped equivalent circuit parameters as given in（Fig.9）The definitions and relationship of the resonance cy pairs can be clearly expressed in a complex admittance diagram given in (Fig. 9).



〔Fig.9〕 Complex Admittance of Resonators

ies and parallel resonance frequencies, fs and fp are determined by taking the input electrical conductance (real part dmittance) and resistance (real part of the electric input impedance) in maximum, respectively, as shown in (Fig. 9). onance frequency, fr and anti-resonance frequency, fa , are given by the two roots where the susceptance ary part of the input electric admittance) equals to zero, as shown in (Fig. 9). The resonance frequency and anti- nce frequency fr and fa are the frequencies of principal interest in two terminal applications. For evaluating the ent circuit of a resonator, however, the characteristic frequencies, fs and fp are more important. They are given by

$$f_s = \frac{1}{2\pi}\sqrt{\frac{1}{L_1 C_1}} \quad \text{----------(1)}$$

$$f_p = f_s\sqrt{1+(C_1/C_0)} \quad \text{------(2)}$$

C1and L1are the motional capacitance and motional inductance, respectively, and Co is the static capacitance ng in shunt branch (Fig. 7).

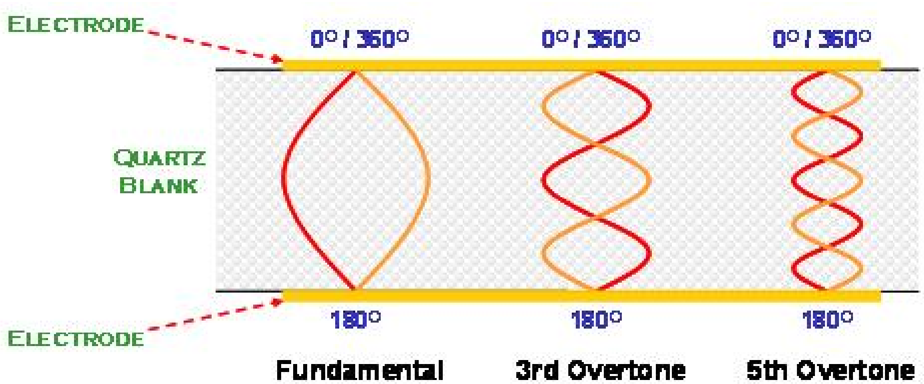
NOLOGIES

ominal Frequency and Its Tolerance or Calibration Accuracy

quency of a crystal resonator is typically specified in megahertz (MHz) or kilohertz (kHz). The normal frequency is the requency what we expect from the crystal oscillation circuitry with proper matching. There is an amount of frequency n from the nominal frequency at ambient temperature (referenced to 25oC) for a real device. The tolerance of the ntral frequency deviation, as a parameter of the device, is specified with a maximum value, expressed in percent (%) per million (ppm).

undamental and Overtone Vibrations

ckness shear vibration is the main vibration mode existed in AT cut. The high order harmonic vibrations are co- with fundamental vibration between electrode areas. Due to the reverse polarity of two electrodes, only odd number ic vibrations can be excited in piezoelectric quartz resonators.



(Fig.10) Only odd number harmonic vibrations can be excited in crystal resonator

oad Capacitance

apacitance, CL, is the amount of capacitance that the oscillator exhibits when looking into the circuit through the two the resonator. The load capacitance is formally in either series or parallel with the resonator. For parallel load case stence of CL will affect the parallel resonance frequency and the parallel-load resonance frequency, fL, is given by

$$f_L = f_s\sqrt{1 + C_1/(C_0 + C_L)} \quad \text{-------} \; (3)$$

rameter is necessary to be specified.

requency-Temperature Stability

ncy-Temperature stability is indicated by the amount of frequency variation from the value at the standard amblient ature (25oC, usually), caused by the operating temperature change. This parameter is specified by a curve showing uency variation (expressed in % or ppm) versus the temperature deviation from the reference temperature (25oC). nperature stability of a quartz device depends on the type of cut, the mode of vibration, and the dimension of the

›lank. Besides, the deviation value is associated with the operating temperature range, the load capacitance and the vel of the cryatal resonator.

quivalent Series Resistance (ESR)

ıistance R1 appearing in the series branch (fig. 5) can be measured at series resonance frequency, where the effects nd L1 are cancelled each other and the effective result of the branch is a resistive. R1 represents the mechanical :he crystal unit and the holder.

lotional Capacitance C1 and Motional Inductance L1

wo parameters are definitely related by the series resonance frequency, fs, as given in Eq.(1), and fs is a very sure ›ter in resonator design and in characterization. Only the value of C1 is specified in industry standard and L1 can be d from

$$L_1 = \frac{1}{4\pi^2 f_s{}^2 C_1} \quad \text{-------(4)}$$

ue of C1 is very small in comparison with capacitances usually used in oscillation circuits and can be evaluated from erial and geometry parameters of the crystal plate and electrodes.

tatic Capacitance Co (in Shunt)

ınt capacitance, Co , is a static capacitance, which is present whether the device is oscillating or not. The value of Co measured at very low frequency (less than or about 1.0 MHz), and theoretically is given by

$$C_0 = \varepsilon_{ij}^{s} \cdot \frac{A}{d} + C_{m+p} \quad \text{-------(5)}$$

A is the electrode area, d is the thickness of the blank, and ε is the dielectric constant of the corresponding crystal

ically, Co includes not only the static capacitance of plated quartz blank, but also the capacitance of conductive ȷ material and the capacitance of housing itself.

rive Level

ve level of a resonator is the amount of power dissipation, expressed in nanowatts, microwatts or milliwatts. ng level is the suitable power range to assure proper start and maintain a steady state oscillation. Drive level should ated at the minimum level to avoid long-term frequency drift and crystal fracture. Generally, the smaller the product ower the drive level should be applied without damanging the quartz resonators for long term usage. Generally, the vel from 10μW to 100 μW is good enough for most of the applications.

uality Factor-Q

sonator, quality factor-Q value is a very important parameter. In specification, unloaded and loaded Q values are d. The unloaded Q, or mechanical Q, can be expressed by

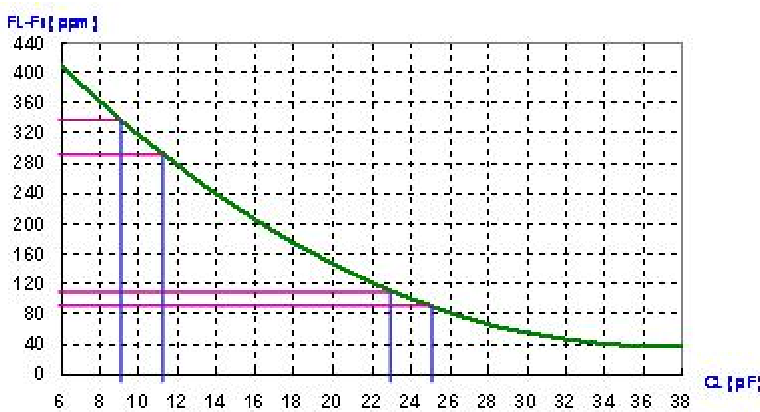
$$Q = \frac{2\pi f_s L_1}{R_1} = \frac{1}{2\pi f_s C_1 R_1} \quad \text{-------(6)}$$

R1 is the resistance appearing in the series branch.

ded Q value depends on the loaded circuit.

Pullability

allel-load capacitance oscillator, the oscillation frequency depends on the load capacitance, CL as shown in Eq.(3) g. 11). The frequency change (in ppm) as a function of the load capacitance change (in pF) is a specification. In applications where the variation of loaded resonance frequency is mandatory (VCXO, for example), pullability has to cified.



(Fig. 11) Frequency variation vs. load capacitance

AGING

s the relative change of operating frequency over a specified time period and is expressed in parts per million (ppm) ı specified period. This rate of frequency change is normally exponential in character. The highest aging rate occurs ıe first week of aging and decreases slowly after wards. Typically, aging is computed within first 30 days and is :ed over a long-term period (one year or ten years). Aging rate depends on many factors: seal method, integrity, cturing processes, material type, operating temperature, and frequency.

STORAGE TEMPERATURE RANGE

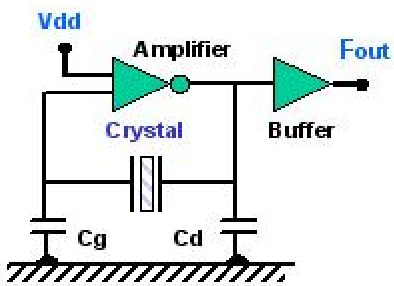
ecification indicates the minimum and maximum temperatures in which the devices can be stored or exposed in a erating state. After storing or exposing the devices at the specified temperature range for a long time, all of the ations are guaranteed over the specified operating temperature range.

Negative Resistance "-R"

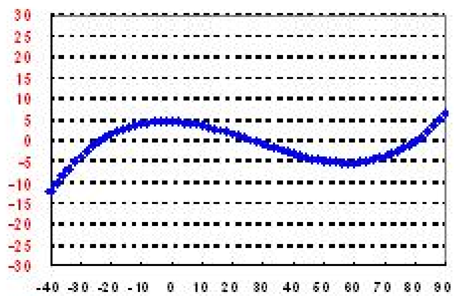
'e resistance is introduced to describe the electric property of an oscillator circuit, This is the amount of resistance oscillator circuit exhibits when looking into the circuit through the terminals of the resonator. One of the basic on conditions demands the amplifier have to supply enough gain to compensate the loss in the resonator. From or point of view, the load has to exhibit enough "negative resistance" to compensate the resistance of the resonator. an important parmeter in designing oscillators.

LATORS

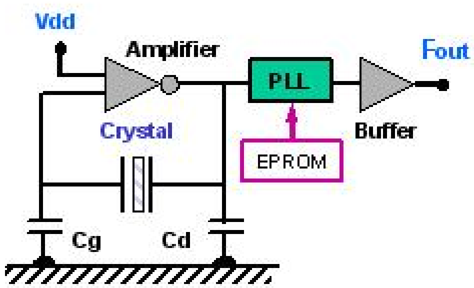
(a) Simple Package Crystal Oscillator



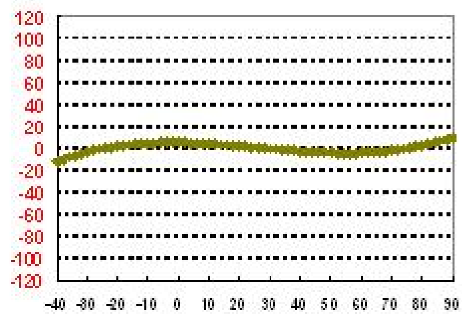
Frequency Stability



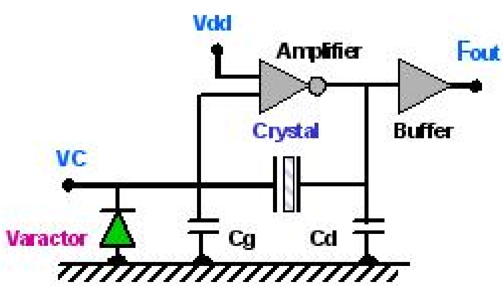
(b) Programmable Crystal Oscillators



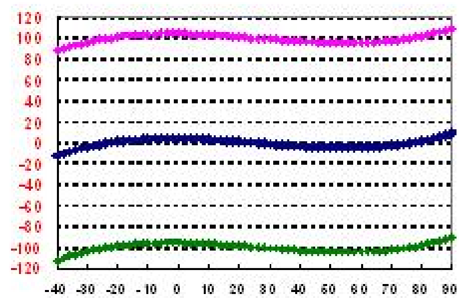
Frequency Stability



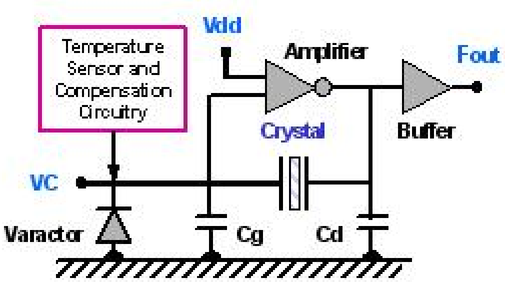
(c) Voltage Controlled Crystal Oscillator



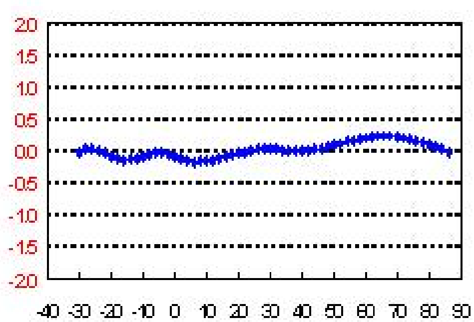
Frequency Stability



(d) Temperature Compensated Crystal Oscillator (TCXO / VCTCXO)



Frequency Stability



/e any questions please E-mail us.