16 mhz crystal oscillator pdf

The crystalline oscillator Miniature quartz crystal 16 MHz, enclosed in an airtight HC-49/S package, used as a resonator in a crystal oscillator. TypeElectromechanicalWorking principlePiezoelectricity, ResonanceInventedAlexander M. Nicholson, Walter Guyton CadyFirst production1918Electronic symbol Crystal oscillator is an electronic oscillator chain that uses the mechanical resonance of the vibrating crystal of piezoelectric material to create an electrical signal with an exact frequency. This frequency is often used to track time, as in quartz wristwatches, to provide a stable clock signal for digital integrated circuits, as well as to stabilize frequencies for radio transmitters and receivers. The most common type of piezoelectric resonator is quartz crystal, so the oscillator chains that include them have become known as crystal oscillators, but other piezoelectric materials, including polycrystal ceramics, are used in similar circuits. The crystal oscillator, especially using quartz crystal, works by distorting the crystal with an electric field when the voltage is applied to the electrode near or on the crystal; a property known as electrostinence or reverse piezoelectricity. When the electric field is removed, the quartz, which fluctuates at an exact frequency, generates an electric field as it returns to its previous form and it can generate voltage. The result is that the quartz crystal behaves like an RLC circuit, but with much higher q. quartz crystals are produced for frequencies from a few dozen kilohertz to hundreds of megahertz. More than two billion crystals are produced each year. Most of them are used for consumer devices such as wristwatches, watches, radios, computers and mobile phones. Quartz crystals are also found inside test and measuring devices such as meters, signal generators and oscilloscopes. The terminological quartz crystalline resonator (left) and the quartz crystal oscillator (right) crystal oscillator is an electronic oscillator diagram that uses a piezoelectric resonator, a crystal, as an element that determines frequency. Crystal is a common term used in electronics for a frequency-defining component, made of quartz crystal or ceramics with electrodes connected to it. A more accurate term for it is the piezoelectric resonator. Crystals are also used in other types of electronic circuitry, such as crystal filters. Piezoelectric resonators are sold as separate components for use in crystal oscillator circuits. The example is shown in the picture. They often included in a single package with a crystal oscillator diagram shown on the right side. The history of 100 kHz crystal oscillators at the U.S. National Bureau of Standards, which served as the standard frequency for the United States in 1929 Very early Bell Labs crystals from Vectron International International Piezoelectricity was discovered in 1880 by The South and Pierre Curie. Paul Langevin first researched quartz resonators for use in sonar during World War I. The first crystal-controlled oscillator using the Rochelle salt crystal was built in 1917 and patented in 1918 by Alexander M. Nicholson at Bell Telephone Laboratories, although his priority was challenged by Walter Guyton Cady. Kadi built the first quartz crystal oscillator in 1921. Other early innovators in quartz crystal oscillators include G. W. Pierce and Louis Essen. The quartz crystal oscillators were developed for the high stability of frequency references in the 1920s and 1930s. Before the crystals, radio stations controlled their frequency using customized circuits that could easily move away from the frequency at 3-4 kHz. Since broadcasters were assigned frequencies only 10 kHz apart, interference between neighboring stations due to frequency drift was a common problem. In 1925, Westinghouse installed a crystal oscillator on its flagship station KDKA, and by 1926 quartz crystals were used to control the frequency of many broadcasting stations and were popular with amateur radio operators. In 1928, Warren Marrison of Bell Telephone Laboratories developed the first quartz crystal clock. With an accuracy of up to 1 second in 30 years (30 ms/g, or 0.95 ns/s), the quartz clock replaced the high-precision pendulum clock as the most accurate timekeepers in the world until the atomic clock was developed in the 1950s. Using early work at Bell Labs, ATT eventually established its own frequency control unit, later swirling and now known as Vectron International. At this time, a number of companies began production of quartz crystals for electronic use. Using what is now considered primitive methods, about 100,000 crystal units were produced in the United States in 1939. Through World War II, crystals were made from natural quartz crystal, almost all from Brazil. The shortage of crystals during the war, caused by the demand for precise control of the frequencies of military and marine radios and radars, spurred post-war research on the cultivation of synthetic quartz, and by 1950 Bell Laboratories had developed a hydrothermal process of growing quartz crystals on a commercial scale. By the 1970s, almost all of the crystals used in electronics were synthetic. In 1968, Juergen Staudte invented a photographic process for the production of quartz crystal oscillators while working in North American aviation (now Rockwell), allowing them to be small enough for portable products such as watches. Although crystal oscillators are still the most commonly used quartz, devices that use other materials, are becoming more common, such as ceramic resonators. The crystalline oscillation modes of Operation Crystal is solid, in which composite atoms, molecules or ions are packed in regularly ordered, ordered, pattern extending in all three spatial dimensions. Almost any object from the elastic material can be used as a crystal, with appropriate pre-ants, as all objects have natural resonant vibration frequencies. For example, steel is very elastic and has a high speed of sound. It was often used in mechanical filters in front of quartz. The resonant frequency depends on the size, shape, elasticity and speed of sound in the material. High-frequency crystals are usually cut as a simple rectangle or circular disk. Low-frequency crystals, such as those used in digital watches, are usually cut out as tuning forks. For applications that do not need a very precise time, instead of quartz crystal often used inexpensive ceramic resonator. When the quartz crystal is properly cut and mounted, it can be done to distort in the electric field by applying voltage to the electrode near or on the crystal. This property is known as electrostination or reverse piezoelectricity. When the field is removed, the quartz generates an electric field as it returns to its previous form and it can generate tension. As a result, the quartz crystal behaves like an RLC circuit consisting of an inductor, capacitor and resistor, with an accurate resonance frequency. The quartz has the further advantage that its elastic constants and its size vary in such a way that the frequency dependence on temperature can be very low. Specific characteristics depend on the method of vibration and angle of cutting quartz (relative to its crystallographic axes). Thus, the resonant frequency of the plate, which depends on its size, does not change much. This means that the quartz clock, filter or oscillator remain accurate. For critical applications, the quartz oscillator is installed in a temperature-controlled container called a crystal oven, and can also be installed on shock absorbers to prevent disturbance by external mechanical vibrations. Simulation of the electric model quartz crystal can be modeled as an electric network with low speed (series) and high imperials (parallel) resonance points, close to each other. Mathematically (with the laplace conversion) the movement of this network can be written as: Schematic symbol and equivalent scheme for quartz crystal in the oscillator (s) (1 s · C 1 s · L 1 and R 1) ‖ (1 s · C 0), (display style) (s) on the left ({1}'s'cdot C_{1}'cdot's'cdot L_{1}'R_{1}'right) on the left ({1}'s'cdot C_{0}) on the right. (s) s 2 s R 1 L 1 s 2 (s · C 0) s 2 s R ·1 L ·1 C 1 · C 0 x 1 x C 1 C 0 ≈ c (1 x C 1 1 2 C 0) (C 0 ≫ C 1) display style start (s) frac s{2} s.frac R_{1} L_{1}memehomeham (left) {2} on the left (s'cdot C_{0}'right {2}) _{\mathrm {p} }}^{2}\right]}}\\[2pt]\Rightarrow \omega _{\mathrm {s} }&={\frac {1}{\sqrt {L_{1}\cdot C_{1}}}},\quad \omega _{\mathrm {p} }={\sqrt {\frac {C_{1}+C_{0}}{L_{1}\cdot C_{1}\cdot C_{0}}}}=\omega _{s}{\sqrt {1+{\frac {C_{1}}{C_{0}}}}}\approx \omega _{s}\left(1+{\frac {C_{1}}{2C_{0}}}\right)\quad \left(C_{0}\gg C_{1}\right)\end{aligned}}} where s {\displaystyle s} is the complex frequency (s = j ω {\displaystyle s=j\ omega }), ω s {\displaystyle \omega _{\mathrm {s} }} is the series resonant angular frequency, and ω p {\displaystyle \omega _{\mathrm {p} }} is the parallel resonant angular frequency. Adding capacity through the crystal reduces the (parallel) resonance frequency. Adding induction through the crystal leads to an increase in the (parallel) resonance frequency. These effects can be used to adjust the frequency at which the crystal fluctuates. Manufacturers of crystals usually cut and trim their crystals to have a specified resonance frequency with a known load of capacity added to the crystal. For example, a crystal designed for a 6 pF load has a predetermined parallel resonance frequency when a 6.0 pF capacitor is placed on it. Without payload capacity, the resonance is higher. Resonant modes of the quartz crystal provides both inline and parallel resonance. The resonance of the series is several kilohertz below the parallel. Crystals below 30 MHz usually work between a series and a parallel resonance, which means that the crystal appears as an inductive reaction in the work, this induction forms a parallel resonance pattern with externally connected parallel capacity. Any small additional capacity in parallel with the crystal pulls the frequency below. In addition, the effective inductive reaction of the crystal can be reduced by adding a capacitor to a row with the crystal. This latter method can provide a useful method of trimming the oscillator frequency in a narrow range; in this case, inserting the capacitor into a row with the crystal increases the frequency of vibrations. In order for the crystal to work at a given frequency, the electronic circuit must be precisely indicated by the crystal manufacturer. Note that these points imply subtlety in relation to crystalline oscillators in this frequency range: the crystal usually does not fluctuate exactly on one of its resonant frequencies. Crystals above 30 MHz (up to 200 MHz) typically work in a resonance series where the momentum appears at a minimum level and equals the resistance of the series. For these crystals, the resistance of the series (100 euros) is defined instead of the parallel capacity. To reach higher frequencies, the crystal can be made to vibrate in one of its overtones modes that occur near multiples of fundamental resonance frequency. Only the odd measureded overtones are used. Such a crystal is called the third, 5th, or The 7th crystal overtone. To achieve this, the circuit oscillator usually includes additional LC circuits to select the desired overtone. The temperature effects of the crystal frequency depend on the shape or incision of the crystal. The tuning fork crystal is usually reduced in such a way that its frequency dependence on temperature is square, and the maximum is about 25 degrees Celsius, which means that the crystal oscillator tuning fork resonates close to its target frequency at room temperature, but slows down when the temperature either rises or decreases from room temperature. The total parabolic ratio for the tuning fork crystal of 32 kHz is 0.04 ppm/SM2: quote is necessary f e 0 x 1 0.04 ppm / ∘ C 2 · (T t 0) 2 . Display style ff_{0}1-0.04 textppm / circle (text C{2}'cdot (T-T_{0}){2} right. In the real application, this means that the watch, built using a conventional crystal tuning fork 32 kHz, , {2} right. Well spend time at room temperature, but lose 2 minutes per year at 10 degrees above or below room temperature and lose 8 minutes per year at a temperature 20 degrees above or below room because of the quartz crystal. Crystal oscillation circuit crystal used in the hobby radio control equipment to select the frequency. It includes a ceramic PCD base, oscillator, dispenser chip (/8), bypass capacitor and crystal cut AT. The crystal oscillator circuit supports vibrations, taking the voltage signal from the quartz resonator, amplifying it and feeding it back to the retriever. , fluctuations can be sustained. The oscillator crystal has two electrically conductive plates, with a slice or tuning of quartz crystal sandwiched between them. During the launch, the control chain places the crystal in an unstable equilibrium, and due to the positive feedback in the system, any tiny amount of noise is amplified by increasing vibrations. The crystalline resonator can also be seen as a high-frequency-selective filter in this system: it passes only a very narrow subdivided band of frequencies around the resonance, setting everything else up. After all, only the resonant frequency is active. As the oscillator strengthens, the signals coming from the crystal, the signals in the crystal frequency range become stronger, eventually dominating the oscillator output. A narrow resonant band of quartz crystal filtering out all unwanted frequencies. The frequency of quartz oscillator output can be either fundamental resonance or multiple, harmonic frequency. Harmonics are accurate integer a few Frequency. But like many other mechanical resonators, crystals have multiple oscillation modes, usually at roughly the odd multiple of fundamental frequency. They are called overtone modes, and oscillator chains can be designed to excite them. Oberton modes are at frequencies that are approximate but not accurate odd multiples, that of the fundamental mode, and the overtone frequencies are therefore not accurate fundamental harmonies. High-frequency crystals are often designed to work in the third, fifth or seventh overtones. Manufacturers have difficulty producing crystals thin enough to produce fundamental frequencies of more than 30 MHz. To produce higher frequencies, manufacturers make overtones crystals configured to put the 3rd, 5th or 7th overtone at the desired frequency because they are thicker and therefore easier to produce than a fundamental crystal that will produce the same frequency, although the exciting desired oberto frequency requires a slightly more complex oscillator chain. The fundamental circuit of the crystal oscillator is simpler and more efficient and more attractive than the third wrapper. Depending on the manufacturer, the highest available fundamental frequency can be from 25 MHz to 66 MHz. The main reason for the widespread use of crystal oscillators is their high quality ratio. The typical q value for a quartz oscillator ranges from 104 to 106, compared to perhaps 102 for the LC. The maximum q for high stability of the quartz oscillator can be estimated as q 1.6 and 107/f, where f is a resonance frequency in a megahertz. One of the most important features of quartz crystal oscillators is that they can exhibit very low phase noise. In many oscillators, any spectral energy at resonant frequency is amplified by the oscillator, resulting in a set of tones at different stages. In the crystal oscillator, the crystal mostly vibrates in one axis, so only one phase dominates. This low-phase noise property makes them particularly useful in telecommunications, where stable signals are needed, and in scientific equipment, where very precise references to time are needed. Environmental changes in temperature, humidity, pressure and vibration can alter the resonant frequency of quartz crystal, but there are several designs that reduce these environmental impacts. These include TCXO, MCXO and OCXO, which are defined below. These designs, especially the OCXO, often produce devices with excellent short-term stability. Restrictions in short-term stability are mainly due to noise from electronic components in oscillating circuits. Long-term stability is limited by the aging of the crystal. Due to ageing and environmental factors (such as temperature and vibration), it is difficult to keep even the best quartz quartz within one part in 1010 of their nominal frequency without constant adjustment. For this reason, atomic oscillators are used for applications that require better long-term stability and accuracy. False frequencies of 25 MHz crystal exhibit a false response For crystals operated in a series of resonance or broke away from the main mode by incorporating a series of inductor or capacitor, significant (and temperature-dependent) false answers may occur. While most false modes are usually a few dozen kilohertz above like a series of resonance their temperature ratio is different from the main mode and a false response can move through the main mode at certain temperatures. Even if the resistance of the series on false resonances seems higher than at the wanted frequency, a rapid change of resistance of the main mode series can occur at certain temperatures when the two frequencies are random. The consequence of these activity failures is that the oscillator can be fixed at a false frequency at certain temperatures. This is usually minimized, ensuring that maintaining the chain does not have enough benefits to activate unwanted modes. False frequencies are also generated by tossing the vibration crystal. This modulates the resonance frequency to a small extent in the frequency of vibrations. The crystals cut out by the UK are designed to minimize the frequency effect of increasing stress, and therefore they are less sensitive to vibration. Acceleration effects, including gravity, are also reduced by SC-cut crystals, as the frequency changes over time due to long-term voltage changes. There are drawbacks with the SC-cut shearing mode of crystals, such as the need to maintain an oscillator to discriminate against other closely related unwanted modes and an increase in the frequency of change due to temperature provided the full range of the environment. UK crystals are most beneficial where temperature control at zero temperature (turnover) is possible, in these conditions the overall stability from premium units can come closer to the stability of rubidium frequency standards. Commonly used crystalline frequencies Main article: Crystal frequency oscillator crystals can be manufactured for vibrations in a wide range of frequencies, from a few kilohertz to several hundred megahertz. Many applications require crystal oscillator frequencies conveniently associated with any other desired frequency, so hundreds of standard crystal frequencies are made in large quantities and supplied by electronics distributors. For example 3.579545 MHz crystals, which are made in large quantities for NTSC color television receivers, are popular for many non-television uses too. Using frequency dividers, frequency multipliers, and phase lock schemes with one reference frequency. Crystal Structures and Materials quartz Common types of packages for quartz crystal products Cluster of natural quartz crystals Synthetic quartz crystal, Grown as a result of hydrothermal fusion, about 19 cm long and weighing about 127 g tuning-fork crystal, used in modern quartz watches Simple quartz crystal Inside the design of the modern high-precision HC-49 packet quartz crystal Flexural and thick crystals. In the beginning, the technology used natural quartz crystals, but now synthetic crystal quartz, grown as a result of hydrothermal synthesis, prevails due to higher purity, lower cost and more convenient handling. One of the few remaining uses of natural crystals is the pressure of previews in deep wells. During World War II and for some time thereafter, natural quartz was considered a strategic material by the United States. Large crystals were imported from Brazil. Raw lascas, the source material of quartz for hydrothermal fusion, are imported into the U.S. or mined locally by Coleman quartz. The average cost of grown synthetic quartz in 1994 was $60/kg. Types 2 types of quartz crystals exist: left-handed and right-handed. These two differ in optical rotation, but they are identical in other physical properties. Both left and right crystals can be used for oscillators if the angle of the incision is correct. The right quartz is usually used in production. SiO4 tetraedras form parallel heligs; the direction of the spiral rotate determines the left or right orientation. The spirals are aligned along the z axis and are combined, dividing the atoms. The mass of the spiral forms a grid of small and large channels parallel to the z-axis. The large ones are large enough to allow some mobility of small ions and molecules through the crystal. The quartz exists in several stages. At 573 degrees Celsius at 1 atmosphere (and at higher temperatures and higher pressures) the quartz inversion undergoes quartz inversion, reversible transforms into quartz. The reverse process, however, is not exactly homogeneous and crystal sisterhood occurs. Manufacturing and processing must be taken care of to avoid phase transformation. Other phases, such as high-temperature tridim and cristobalite, are not significant for oscillators. All quartz oscillator crystals are quartz type. High-quality infrared spectrophotometry is used as a method of measuring the quality of grown crystals. Wave numbers 3585, 3500 and 3410 cm.1 are usually used. The measured value is based on the absorption bands of the OH radical and the infrared value is calculated. Class C electronic crystals have 1.8 million euros or Premium B crystals have 2.2 million euros, and special premium A crystals have 3.0 million euros. q q value Calculated only for the z region. crystals containing other regions may be negatively affected. Another indicator of quality is the density of the channel etch; When the crystal is etched, tubular channels are created along linear defects. For processing involving etching, for example, crystal plug settings of the wristwatch, the low density of channel etching is desirable. The channel etch density for noticeable quartz is about 10-100 and significantly more for unsmeanable quartz. The presence of etch channels and pit etch degrades the resonator's and introduces nonlineary. Production See also: Crystal growth of quartz crystals can be grown for specific purposes. AT-cut crystals are the most common in mass production of oscillator materials; Shape and sizes are optimized for the high yield of the required plates. High-purity quartz crystals are grown with a particularly low content of aluminum, alkaline metal and other impurities and minimal defects; the low amount of alkaline metals provides increased resistance to ionizing radiation. The crystals for the wristwatch, for cutting the tuning fork of crystals 32768 Hz, are grown with a very low density of grass canals. The crystals for SAW devices are grown as flat, with a large X-size seed with low channel etching density. Special high quality crystals, for use in high-end oscillators, are grown at a constant slow speed and have constant low infrared absorption across the axis. The crystals can be grown as a Y-bar, with a bar-shaped seed crystal and elongated along the Y axis, or as a plate grown from a seed plate with the length of the Y-axis and the width of the X-axis. The area around the seed crystal contains a large number of crystalline defects and should not be used for waffle crystals to grow anisously; growth along the axis up to 3 times faster than along the X axis. Y-bar crystals, or crystals with the Y long axis, have four growth areas, commonly called X, X, and S. The distribution of impurities during growth is uneven; different areas of growth contain different levels of pollutants. Regions No. Impurities have a negative effect on the hardness of radiation, susceptibility to sisterhood, loss of filter, and long and short-term stability of crystals. Different seeds of different orientations can provide other types of growth regions. The growth rate of the X direction is the slowest due to the effect of asorptation of water molecules on the surface of the crystal; aluminum impurities suppress growth in two other directions. The aluminium content is the lowest in the Higher in X, but higher in X, and highest in S; The size of the S regions is also increasing with the increase in aluminium gift. The hydrogen content is the lowest in the region, higher in Region X, but higher in Region S, and the highest in X. Aluminium inclusions are converted into color centers with gamma radiation, causing the crystal to darken in proportion to the dose and level of impurities; the presence of regions with different darkness shows different regions of growth. The dominant type of defect in quartz crystals is the replacement of the Al(III) atom with the Si (IV) atom in the crystal lattice. The aluminium ion has a bound interstitial charge compensator present nearby, which can be an XH ion (attached to nearby oxygen and forming a hydroxyl group called the Al-OH defect), Ion Lea, Ion Nae, Ion 3K (less common) or an electronic hole trapped in a nearby oxygen atom orbit. The composition of the growth solution, whether it is based on lithium or sodium alkaline compounds, determines the charge that compensates ions for aluminium defects. Ion impurities are of concern because they are not firmly connected and can migrate through the crystal, altering the elasticity of the local lattice and the resonant frequency of the crystal. Other common impurities of concern are, for example, iron (III) (interstitial), fluoride, boron (III), phosphorus (V), titanium (IV) (replacement, commonly present in magmatic quartz, less common in hydrothermal quartz), and germanium (IV) (replacement). Sodium and iron ions can cause the inclusion of akinite and elemeusitis crystals. Water inclusions can be present in fast-grown crystals; interstitial water molecules in abundance are located next to the crystal seed. Another important drawback is hydrogen, which contains a growth defect, where a pair of Si'OH HO-Si groups is formed instead of the Si-O'Si structure; essentially, communication is hydrolyzed. Fast-growing crystals contain more hydrogen defects than slow-grown. These sources of growth defects, like the supply of hydrogen ions for radiation processes and the formation of AL-OH defects. Germanium impurities tend to trap electrons created during exposure; Alkaline metal cats then migrate towards a negatively charged center and form a stabilizing complex. Matrix defects may also be present; Oxygen vacancies, silicon vacancies (usually compensated by 4 hydrogens or 3 hydrogens and a hole), peroxy groups, etc. Some defects produce localized levels in the prohibited strip serving as a charge trap; Al(III) and B(III) usually serve as traps for holes, while electronic vacancies, titanium atoms, germanium and phosphorus serve as electronic traps. Captured charge carriers may be released from heating; their recombination is the cause of thermoluminescence. The mobility of interstitial ions is strong From the temperature. Hydrogen ions are mobile to 10 K, but alkaline metal ions become mobile only at temperatures around and above 200 K. Hydroxyl defects can be measured measured infrared spectroscopy. Captured holes can be measured by the resonance of the rotation of electrons. Al-Nae defects are manifested as a peak of acoustic losses due to their stress-induced movement; Al-Lis defects do not form potential well, so are not detected in this way. Some of the radiation-induced defects during their thermal anneization produce thermoluminescence; defects associated with aluminum, titanium and Germanic can be identified. Swept crystals are crystals that have passed the solid state of the electrodiffusion cleaning process. The sweep involves heating the crystal above 500 degrees Celsius in a hydrogen-free atmosphere with a voltage gradient of at least 1 kV/cm for several hours (usually more than 12). The migration of impurities and the gradual replacement of alkaline metal ions with hydrogen (when displaced into the air) or electronic holes (when displaced in a vacuum) causes a weak electric current through the crystal; the disintegration of this current to a constant value signals the end of the process. The crystal then remains to cool down, while the electric field is supported. The impurities are concentrated in the cathode area of the crystal, which is then disconnected and discarded. Crystals of increased resistance to radiation, as the effects of the dose depend on the level of alkaline metallic impurities; they are suitable for use in devices prone to ionizing radiation, such as nuclear and space technology. Sweeping under a vacuum at higher temperatures and higher strengths of the field gives even more radiation crystals. The level and nature of impurities can be measured using infrared spectroscopy. The quartz can be seen in both the phase and the phase; radical in phase z faster, but phase transition can cause sisterhood. The twins can be reduced by exposing the crystal to a compression force in the direction of X, or an electric CHANGE or DC field along the X axis while the crystal cools through the phase conversion temperature area. Sweeping can also be used to inject one type of impurities into the crystal. Lithium, sodium and hydrogen crystals are used, for example, to study quartz behavior. Very small crystals for the treble can be made with photolithography. The crystals can be adjusted to precise frequencies using laser pruning. The technique used in the world of amateur radio to slightly reduce the frequency of crystals can be achieved by exposing crystals with silver electrodes to iodine vapors, which causes a slight increase in mass on the surface by forming a thin layer of silver iodide; such crystals however had a problematic long-term stability. Another method widely used is to electrochemically increase or reduce the thickness of a silver electrode by immersion in azures dissolved in water, citric acid in water or water with salt, and use a resonator as a single electrode and a small silver silver like the others. Choosing the direction of current, you can either increase, or reduce the mass of electrodes. The details were published in the journal Radio (3/1978) UB5LEV. Increasing the frequency by scratching parts of the electrodes is not recommended, as this can damage the crystal and reduce its ratio. Capacitor trimmers can also be used to adjust the frequency of the oscillator chain. Other materials Some other piezoelectric materials than quartz can be used. These include single crystals of lithium tantalat, lithium niobate, lithium borat, berlinite, gallium arsenide, lithium tetraborate, aluminum phosphate, bismuth oxide germanium, polycrystal circ titanium ceramics, highly-occidental ceramics, silicon-zinc oxide composite or dipot. Some materials may be more appropriate for specific applications. The oscillator crystal can also be manufactured by depositing the resonator material on the surface of the silicon chip. Gallium phosphate, langazite, langanite and langatate crystals are about 10 times more pulled than the corresponding quartz crystals and are used in some VCXO oscillators. Stability Stability Frequency is determined by the crystal. This back depends on the frequency, and on the constant, which depends on the particular cut. Other factors affecting q are the overtone, temperature, crystal driving level, surface finish quality, mechanical loads imposed on the crystal by bonding and mounting, crystal geometry and attached electrodes, clean material and crystal defects, type and pressure in the hull, intervention modes, and the presence and absorbed dose of ionization and neutron radiation. Temperature affects the operating frequency; various forms of compensation are used, from analog compensation (TCXO) and microcontroller compensation (MCXO) to temperature stabilization with a crystal furnace (OCXO). The crystals have temperature hysterical; the frequency at this temperature, achieved by raising the temperature, is not equal to the frequency at the same temperature achieved by lowering the temperature. The sensitivity of the temperature depends primarily on the incision; temperature offset reductions are chosen to minimize frequency/temperature dependence. Special incisions can be made with linear temperature characteristics; LC incision is used in quartz thermometers. Other factors are overtone, installation and electrodes, impurities in the crystal, mechanical voltage, crystalline geometry, temperature change rate, thermal history (due to hysterical), ionizing radiation and drive level. Crystals tend to suffer from abnormalities in their frequency/temperature and resistance/temperature characteristics known as activity failures. It's a small Frequency or or or The resistance of the excursion is localized at certain temperatures, with their temperature position depends on the value of load capacitors. Mechanical stress Mechanical stresses also affect the frequency. Tensions can be caused by the installation, bonding and application of electrodes, differential thermal expansion of the installation, electrodes and the crystal itself, differential thermal loads at present temperature gradient, expansion or shrinkage of binders during treatment, air pressure, which is transmitted to atmospheric pressure in the crystal body, voltages of the crystal lattice itself (non-uniform growth, impurities, dislocation), imperfections of the surface and damage, thus, the frequency may depend on the position of the crystal. Other dynamic stressors are beats, vibrations and acoustic noise. Some cuts are less sensitive to stress; PRIME may be a reduction in SC (stress compensation). Changes in atmospheric pressure can also lead to deformations in the hull, affecting the frequency by changing stray containers. Atmospheric humidity affects the thermal portable properties of the air and can alter the electrical properties of plastics by diffusing water molecules into their structure, altering the distant constants and electrical conductivity. Other factors influencing the frequency are power voltage, load, magnetic fields, electric fields (in the case of sensitive cuts, such as SC incisions), the presence and absorbed dose of particles and ionizing radiation, as well as the age of the crystal. The aging of crystals undergoes a slow gradual change in frequency over time, known as aging. There are many mechanisms. Installation and contacts can be a relief of built-in stresses. Pollution molecules either from the residual atmosphere, extracted from crystal, electrodes or packaging materials, or introduced at the compaction of the dwelling can be adsorbed on the crystalline surface, altering its mass; this effect is used in quartz crystalline microbalances. The composition of the crystal can be gradually altered by outgasing, diffusion of impurity atoms or migration from electrodes, or the lattice may be damaged by radiation. Slow chemical reactions can occur on either the crystal or the inside of the hull. Electrode material, such as chromium or aluminum, can react with a crystal, creating layers of metal oxide and silicon; these layers of the interface can change over time. The pressure in the case can change due to the variable atmospheric pressure, temperature, leaks or release of materials inside. Factors that do not depart from the crystal itself are, for example, the aging of the oscillator circuit (and, for example, a change in the and the drift of the crystal furnace parameters. The external composition of the atmosphere can also affect aging; hydrogen can spread through nickel shelter. Helium can cause similar problems when it dissipates through the glass hulls of rubidium standards. Gold is a favorite electrode material for low-cutting resonators; its pressure to quartz is strong enough to keep in touch even at strong mechanical shocks, but weak enough not to support significant deformation gradients (unlike chromium, aluminum and nickel). Gold also does not form oxides; It has adsorbs of organic contaminants from the air, but they are easy to remove. However, gold itself can pass delamination; thus, the chromium layer is sometimes used to enhance the strength of the binding. Silver and aluminum are often used as electrodes; however, both form layers of oxide over time, which increases the crystal mass and reduces the frequency. Silver can be transmitted by exposure to iodine vapors, forming a layer of silver iodide. Aluminium oxidizes easily, but slowly until about 5 nm thickness is reached; temperature increase in artificial aging does not significantly increase the rate of oxide formation; a thick layer of oxide can be formed during production by anodization. Exposure of silver crystal to iodine vapors can also be used in amateur conditions for a slight reduction in the frequency of the crystal; The frequency can also be increased by scratching off parts of the electrodes, but this carries the risk of damage to the crystal and loss of the DC voltage between the electrodes can accelerate the initial aging, probably by induced diffusion impurities through the crystal. Placing a capacitor in a row with a crystal and a resistor in a somewhat mega parallel can minimize such tension. Mechanical damage crystals are sensitive to shock. Mechanical stress causes a short-term change in the frequency of the oscillator due to the stress sensitivity of the crystal, and can introduce a permanent change in frequency due to shock-induced changes in installation and internal stresses (if the elastic limits of the mechanical parts are exceeded), desorption pollution from crystalline surfaces, or changes in the parameters of the circuit acill. High impacts can tear crystals away from their attachment (especially in the case of large low-frequency crystals suspended on thin wires), or cause crystal cracking. Crystals, free from superficial imperfections, are very shock-resistant; chemical polishing can produce crystals that can survive tens of thousands of G.G. The main causes of such noise are, for example, thermal noise (which limits the noise floor), the scattering of the phonon (influenced by lattice defects), the absorption/desorption of molecules on the surface of the crystal, noise chains, chains, shocks and vibrations, changes in acceleration and orientation, temperature fluctuations and the relief of mechanical stresses. Short-term stability is measured by four main parameters: Allan's variance (the most common indicated in the sheets of these oscillators), phase noise, spectral density of phase deviations and spectral density of fractional frequency deviations. The effects of acceleration and vibration tend to dominate other sources of noise; Surface acoustic wave devices tend to be more sensitive than volume acoustic waves (BAW), and stress-compensated incisions are even less sensitive. The relative orientation of the acceleration vector on the crystal dramatically affects the sensitivity of the crystal to vibration. Mechanical vibration insulation attachments can be used for high-resistance crystals. Phase noise plays a significant role in frequency synthesis systems using frequency multiplication; N frequency multiplication increases phase noise power on N2. Multiplying the frequency by 10 times increases the size of the phase error by 10 times. This could have disastrous consequences for systems using PLL or FSK technology. Radiation damage crystals are somewhat sensitive to radiation damage. Natural quartz is much more sensitive than artificially grown crystals, and sensitivity can be further reduced by sweeping the crystal - heating the crystal to at least 400 degrees Celsius in a hydrogen-free atmosphere in an electric field of at least 500 w/cm for at least 12 hours. Such crystals have a very low response to stable ionizing radiation. Some Si (IV) atoms are replaced by Al (III) impurities, each of which has a compensating bodice or cation Naz nearby. Ionization produces pairs of electron holes; the holes were trapped in a lattice near the Al Atom, as a result of whether and on the atoms are weakly trapped along the Kew axis; changing the lattice near the Al atom and corresponding to the elastic constant then causes a corresponding change in frequency. Sweeping removes the ions of La and Nae from the lattice, reducing this effect. The Al3 site can also trap hydrogen atoms. All crystals have a transient negative frequency shift after exposure to X-ray pulse; The frequency then gradually shifts backwards. Natural quartz reaches a stable frequency after 10-1000 seconds, with a negative bias to the frequency of pre-exposure, artificial crystals return to the frequency slightly lower or higher than before exposure, swept the crystals anneal almost back to the original frequency. Annealation is faster at higher temperatures. Sweeping under a vacuum at higher temperatures and field strength can further reduce the crystal's response to X-ray pulses. Resistance to a series of obbing increases after the X-ray dose, and the annals return to a slightly higher value for natural quartz (requiring an appropriate amplification reserve in the chain) and back to the value of prior exposure for Crystals. Resistance to the crystal series does not affect. Increased resistance to series is deteriorating; an increase that is too high can stop the oscillations. Neutron radiation causes changes in frequency by inserting dislocations into the lattice, knocking out atoms, one fast neutron can produce many defects; The SC and AT cut frequency increases roughly linearly with the absorbed dose of the neutron, while the frequency of BT contractions decreases. Neutrons also change temperature and frequency characteristics. The change in frequency at low ionizing radiation doses is proportionally higher than at higher doses. High-intensity radiation can stop the oscillator, causing photoconductivity in crystal and transistors; With a swept crystal and a properly designed circuit the vibrations can restart within 15 microseconds after a burst of radiation. Quartz crystals with high levels of alkaline metal impurities lose q when exposed; The question of sweeping artificial crystals does not affect. Exposure to higher doses (more than 105 rad) reduces sensitivity to subsequent doses. Very low doses of radiation (below 300 rad) have a disproportionately higher effect, but this nonlineity is saturated in higher doses. In very high doses, the radiation reaction of the crystal is saturated as well, due to the finmaline of impurities sites that may be affected. Magnetic fields have little effect on the crystal itself, as the quartz is diamagnetic; eddy currents or AC voltages can however be imposed in chains, and magnetic parts of fastening and housing can be affected. Once powered, the crystals take a few seconds to minutes to warm up and stabilize their frequency. OCXOs controlled by the oven usually require 3-10 minutes to heat up until the thermal equilibrium is achieved; Oven-less oscillators stabilize within seconds as a few milliwatts dissipated in the crystal cause a small but noticeable level of internal heating. Crystals do not have inherent failure mechanisms; some of them have been working in devices for decades. Failures may, however, introduce malfunctions in bonding, leaking enclosures, corrosion, frequency of shear as a result of aging, crystal disturbance too high by mechanical impact, or radiation-induced damage when non-laughing quartz is used. Crystals can also be damaged as a result of excessive damage. The crystals must be controlled at the appropriate level of drive. While AT abbreviations tend to be quite forgiving, with only their electrical parameters, the stability and characteristics of aging degrade when re-managed, low-frequency crystals, especially the flexural mode of them, can break at too high a disk level. The level of drive is defined as the amount of energy scattered in the crystal. Drive levels are about 5 kW for flexible modes up to 100 kHz, 1 kW for fundamental modes at 1-4 MHz, 0.5 kW for 4-20 MHz fundamental modes and 0.5 xW for 20-200 MHz wrap modes. Mhz. disk level can cause problems with the launch of the oscillator. The lower drive level is better for higher stability and lower oscillator energy consumption. Higher levels of drive, in turn, reduce noise exposure by increasing the signal-to-noise ratio. The stability of THE CRYSTALs is reduced by AT and increase in frequency. For more accurate higher frequencies, it is better to use a crystal with a lower fundamental frequency that works with overtones. Aging decreases logarithmically over time, the biggest changes occurring shortly after production. Artificial aging of the crystal by long-term storage at 85-125 degrees Celsius can increase its long-term stability. A poorly designed oscillator circuit can suddenly start to oscillate on the overtone. In 1972, a train in Fremont, California, crashed due to a faulty oscillator. The improper value of the tank capacitor caused the crystal in the control board to be overworked, jumping into the overtone and causing the train to accelerate rather than slow down. The crystal cuts the resonator plate, which can be cut from the crystal source in different ways. The orientation of the incision affects the characteristics of the aging crystal, frequency stability, thermal characteristics and other parameters. These incisions work on a mass acoustic wave (BAW); Surface acoustic wave (SAW) devices are used for higher frequencies. Image of several crystalline incisions (50 Cut Frequency Range Mode Angles Description 0.5-300 MHz haircut thickness (c-mode, slow quasi-haircut) 35 15', 0 ('lt;25 MHz)35'18', 0'(0)('gt;10 MHz) The most common incision, Developed in 1934. The plate contains an x crystal axis and is tilted at 35'·15' from the axis z (optical). Used for oscillators operating in a wider temperature range, ranging from 0.5 to 200 MHz; also used in oven-controlled oscillators. , the 3rd overtone at 30-90 MHz and the 5th overtone at 90-150 MHz; According to another source, they can be made for the fundamental operation of a mode of up to 300 MHz, although this mode is usually used only up to 100 MHz, and according to another source, the upper limit of the fundamental frequency of the AT incision is limited to 40 MHz for small diameter blanks. It can be made either as a regular round disc or as a strip-resonator; The latter allows for a much smaller size. The thickness of the quartz harvest is about (1,661 mm)/(frequency in MHz), this frequency shifts somewhat due to further processing. The third overtone is about 3 times the fundamental frequency; overtones (25 MHz)35'18', MHz)35'18', than the equivalent multiple of fundamental frequency at about 25 kHz per overtone. The crystals designed to work in wrap modes must be specially processed for plane parallelism and surface finish for better performance at this wrapping frequency. SC 0.5-200 MHz 35 '15', 21'54' Special Incision (stress compensated), developed in 1974, is a double turning incision (35'15' and 21'54') for the furnace of stabilized oscillators with low phase noise and good aging characteristics. Less sensitive to mechanical loads. It has a faster warm-up rate, a higher level, better noise in the phase, less sensitivity to spatial orientation against the gravitational vector and less sensitivity to vibrations. Its constant frequency is 1,797 MHz· mm. United modes are worse than that of AT cut, resistance is usually higher; much more care is required to transform between overtones. Works at the same frequencies as the AT cut. The frequency-temperature curve is the third order of the downward parabola with an inflection point at 95 degrees Celsius and a much lower temperature sensitivity than the AT incision. Suitable for OCXOs, such as space and GPS systems. Less accessible than AT cut, harder to produce; improving the parameters in order of magnitude is traded by an order of magnitude more rigid crystalline orientation tolerances. The aging characteristics are 2-3 times better than that of AT cuts. Less sensitive to drive levels. Much less activity of failures. Less sensitive to the geometry of plates. The required oven does not work well at ambient temperature as the frequency drops rapidly at lower temperatures. Has several times lower motion ability than the corresponding incision at, reducing the ability to regulate the crystalline frequency attached to the capacitor; this limits use in conventional TCXO and VCXO devices, as well as in other applications where the crystal frequency must be adjustable. The temperature ratios for the fundamental frequency differ from the third overtone; When the crystal is set to work at both frequencies simultaneously, the resulting impact rate can be used to probe temperature, such as microcomputer-compensated crystal oscillators. Sensitive to electric fields. Sensitive to air damping to get the optimal q it should be packed in a vacuum. The temperature factor for the b-mode is 25 ppm/C, for double mode from 80 to more than 100 ppm/C. Works in the thickness of haircut mode, in b-mode (fast quasi-haircut). It has well-known and repetitive characteristics. It has a constant frequency of 2,536 MHz· mm. Has lower temperature characteristics than at cut. Because of the higher constant, can be used for crystals with higher frequencies than AT cut, cut, to more than 50 MHz. Works in the thick of the haircut. The temperature curve is the third downward parabola with an inflection point of 78 degrees Celsius. Rarely used. It has similar characteristics and properties for the SC cut, more suitable for higher temperatures. FC thickness haircut Special cut, double turning incision with improved characteristics for the furnace stabilized oscillators. Works in the thick of the haircut. The temperature curve is the third order of the downward parabola with an inflection point at 52 degrees Celsius. Rarely used. Used in oscillators controlled by the oven; The furnace can be set for a lower temperature than for AT/IT/SC cuts, by the beginning of the flat part of the temperature-frequency curve (which is also wider than other incisions); When the ambient temperature reaches this area, the furnace shuts down and the crystal works at ambient temperature, while maintaining reasonable accuracy. Thus, this incision combines the energy saving function, allowing a relatively low oven temperature with reasonable stability at higher ambient temperatures. The thickness of the AK straight double-turned incision with better temperature characteristics than at and BT, and with a higher tolerance to crystallographic orientation than the reductions of AT, BT and SC (at a factor of 50 against the standard reduction of AT, according to calculations). Works in thick. CT 300-900 kHz face haircut 38, 0 Frequency temperature curve of the downward parabola. DT 75-800 kHz face haircut 52, 0 Similar to a CT cut. The frequency temperature curve is a downward parabola. The temperature factor is lower than the CT cut; where the frequency range allows, DT is preferred in relation to CT. 75 degrees Celsius is almost zero, due to the cancellation effect between the two modes. E, 5'X 50-250 kHz longitudal has a fairly low temperature ratio, widely used for low-frequency crystalline filters. MT 40-200 kHz longitudal ET 66'30' FT y 57 NT 8-130 kHz width bending (bending) XY, setting forks 3-85 kHz width length flexure Dominant low-frequency crystal, as it is smaller than other low-frequency reductions, cheaper, has low uncleanness and low Co/C1 ratio. The main application is the crystal RTK 32,768 kHz. Its second overtone is about six times the fundamental frequency. Flexibility of 8-130 kHz width is widely used for broadband filters. The temperature factor is linear. J 1-12 kHz length of thick J bend incision is made of two quartz plates glued together, selected for production from phase motion for this electric field. RT Double turned cut. SBTC Double turned cut. TS Double Turn X 30 Double turned cut. LC haircut thickness 11.17 /9.39 Double rotated incision (Linear coefficient) with linear temperature frequency of reaction; can be used as a sensor in crystal thermometers. The temperature factor is 35.4 ppm/C. Single mode with steep frequency-temperature characteristics. The temperature factor is 20 ppm/c. NLSC Temperature is sensitive. The temperature factor is about 14 ppm/C. Single mode with steep frequency-temperature characteristics. The plane plate is perpendicular to the Y crystal axis. It is also called parallel or 30-degree. The temperature factor is about 90 ppm/C. X Used in one of the first crystal oscillators in 1921 W.G. Cady, and as a 50 kHz oscillator in Horton and Marrison's first crystal clock in 1927. The plane plate is perpendicular to the X crystal axis. Also called perpendicular, normal, Curie, zero angle, or ultrasonic. T in the name of the incision denotes a temperature cut, an incision oriented so that the temperature ratios of the lattice are minimal; FC and SC reductions are also offset by temperature. High-frequency incisions are set at the edges, usually on springs; The rigidity of the spring should be optimal, as if it were too stiff, mechanical strokes can be carried over into the crystal and cause it to rupture, and too little stiffness can allow the crystal to collide with the inside of the package when exposed to mechanical shock and break. Strip resonators tend to be at cuts, smaller and therefore less sensitive to mechanical shocks. At the same frequency and overtone, the band has less pull-up, higher stability and a higher temperature factor. Low-frequency incisions are placed on nodes where they are almost stationary; thin wires are attached at such points on each side between the crystal and the wires. The large mass of the crystal, suspended on thin wires, makes the assembly sensitive to mechanical shocks and vibrations. Crystals are usually installed in hermetically sealed glass or metal cases filled with a dry and inert atmosphere, usually vacuum, nitrogen or helium. Plastic dwellings can be used, but it is not airtight and another secondary seal should be built around the crystal. Several resonator configurations are possible, in addition to the classic way of directly attaching leads to a crystal. For example, the BVA (Bo'tier and Vieillissement Am'lior, an improved aging body) developed in 1976; parts that affect vibrations are processed from a single crystal (which reduces mounting stress), and electrodes are deposited not on the resonator itself, but on the most The inside of the two condenser discs are made from adjacent slices of quartz from one bar, forming a three-layer sandwich without voltage between the electrodes and the vibrating element. The gap between the electrodes and the resonator acts as two small series capacitors, making the crystal less sensitive to the chain. The architecture eliminates the effect of surface contacts between electrodes, limitations in installation compounds, and problems associated with the migration of ions from electrodes to the vibrating element grille. The resulting configuration is strong, resistant to shocks and vibrations, resistant to acceleration and ionizing radiation and improved aging characteristics. At cut is usually used, although SC cut options exist as well. BVA resonators are often used in spacecraft applications. In the 1930s and 1950s, people often tuned in to the frequency of crystals using hand-polished. The crystals were grounded with a subtle abrasive suspension, or even toothpaste, to increase their frequency. A slight reduction of 1-2 kHz, when the crystal was above ground, was possible by marking the crystal face with a lead pencil, due to the lowered level. The varator, a diode with a capacity depending on the applied voltage, is often used in voltage-controlled crystalline oscillators, VCXO. Crystal incisions are usually AT or rarely SC, and work in a fundamental mode; the number of available frequency deviations is inversely proportional to the square from the wrap-like number, so the third overtone has only one-ninth of the fundamental mode retraction. SC cuts, while more stable, are significantly less pull. The contour inscriptions and abbreviations on the electric schematic diagrams of the crystals are marked with the letter class Y (Y1, Y2, etc.). Oscillators, whether crystal oscillators or others, are marked with the letter G (G1, G2, etc.). The crystals can also be marked by the X or XTAL scheme, or by a crystal oscillator with XO. Types of crystal oscillators and their abbreviations: ATCXO - Analog temperature controlled crystalline oscillator CDXO - Calibrated double crystalline oscillator DTCXO - Digital temperature compensated by emXO crystal oscillator - Evacuated miniature crystalline aciller GPSDO - Global positioning system disciplined MCXO oscillator OCVCXO - OCVCXO voltage-controlled oven crystal oscillator OCXO - oven-controlled Crystal Oscillator RbXO - Crystal Oscillators Rubidium (RbXO), crystalline oscillator (may be MCXO), synchronized with built-in ruby standard that works only occasionally to save energy TCVCXO - temperature-compensated crystalline voltage oscillator - Temperature-compensated crystalline oscillator TMXO - Tactical miniature crystalline oscillator TSXO - Temperature sensing crystal oscillator, adaptation of TCXO VCTCXO - Tension controlled temperature compensated crystals of VCXO oscillator - Voltage controlled crystal oscillator oscillator also Watch the clock of the watch drift - The clock of the drift of the measurement of crystal oscillators can be used for the measurement of crystal oscillators. The Erhard Kietz crystal filter works on electronic tuning forks and with quartz crystals for precise signal frequencies of Isaac Kogi, inventor of temperature-stable R1 Koga, carved by Pier's oscillator of the quartz crystal microbalance using crystalline oscillators to weigh extremely small quantities. The thickness monitor of the thin film VFO - variable frequency oscillator Links - b Term crystal oscillator refers to the chain, not the resonator: Count, Rudolf F. (1999). Modern Electronics Dictionary, 7th Ed. USA: Newnes. page 162, 163. ISBN 978-0750698665. Amos, S.V.; Roger Amos (2002). Newnes Electronics Dictionary, 4th O.P. USA: Newnes. page 76. ISBN 978-0750656429. Laplante, Philip A. (1999). Comprehensive Dictionary of Electrical Engineering. USA: Springer. ISBN 978-3540648352. Nicholson, Alexander M. Generation and Transmission of Electric Current U.S. Patent 2,212,845 , filed on April 10, 1918, granted August 27, 1940 - Lower, Virgil E. (1981). 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