BREL INTERNATIONAL COMPONENTS
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CRYSTAL PARAMETERS

Quartz is a piezoelectric material with a property such that mechanical strain is induced by electrical excitation and electrical charge is also induced by mechanical strain conversely.

Quartz crystals, because of their inherently high Q, provide a remarkable improvement in the stability of crystals.

By slicing the raw quartz at various angles with respect to its axis it is possible to obtain a variety of blanks having different vibrating modes and different temperature characteristics.

RESONANT FREQUENCY

The electrical properties of the quartz crystal unit as a function of frequency can be represented by on equivalent circuit diagram(Fig-1)

The oscillating mass of the quartz cyrstal corresponds to the Motional inductance L_1 while the elasticity of the oscillating body is represented by the Motional capacity C_1.

The values of the Motional capacity C_1 are very small compared with the capacities normally used for oscillating circuits in communications engineering and can be calculated for the 'AT' cut as follows:

$C_1(PF)=0.22\times A(m^2)\times F(H_z)/1670$
Where A=area of the electrode
F=resonant Frequency

The C_1 value can be changed for a particular resonant frequency by varying the electrode area. The range of variation of the electrode area depends on the diameter of the quartz element.

The static parallel capacity C_0 is the capacity between the vacuum-deposited metal electrodes and quartz material as a dielectric and we have

$C_0(PF)=40.4\times A(m^2)\times F(Hz)/1670+0.8(PF)$
$L_1(H)=4.22\times 10^4\times(1670)^{31}/[F^3(Hz)/\times A(m^2)]$

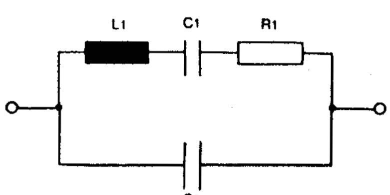

Fig.-2 illustrates the impedance graph for a quartz crystal.

Neglecting losses two resonant frequencies result, namely the series resonant frequency f_s at impedance =0(Fig.-2) and the parallel resonant frequency f_p at impedance=infinity.

$$f_s=\frac{1}{2\pi\sqrt{L_1C_1}} \qquad f_p=\frac{1}{2\pi\sqrt{L_1\frac{C_1\cdot C_0}{C_1+C_0}}}$$

Parallel and series resonant frequencies are linked by the equation:

$$f_p=f_s\sqrt{1+\frac{C_1}{C_0}}$$

The relative frequency interval between the two resonant frequencies:

$$\frac{f_p-f_s}{f}=\frac{1}{2}\cdot\frac{C_1}{C_0}$$

i.e. equal to one half of the ratio of motional to static capacity.

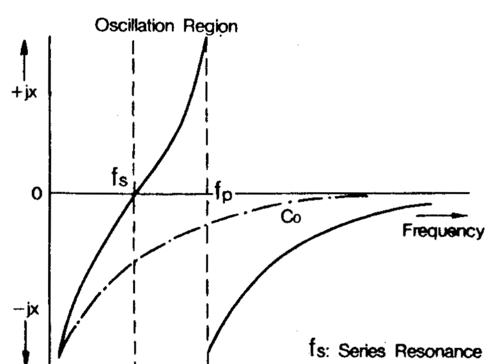

Fig. 2

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TEMPERATURE COEFFICIENT

Temperature coefficient is frequency stability or deviation with temperature change. Temperature coefficient is expressed in parts per millions, change of plus or minus percentage over the operating temperature ranges.

The mode of vibration, the plane of the plate in relation to the axis of the quartz, the dimensions of the plate and the harmonics determine the temperature coefficient.

LOAD CAPACITANCE C_L

The load capacity is the sum of the capacity of the crystal socket or any other parasitic capacitance across the crystal in oscillator.

Load capacitance, C_L is the effective capacitance of the oscillation circuit as viewed from both ends of the crystal units.(shown in Fig.-3)

C_L is the capacitance value comprising the combined capacitance of capacitor, and equivalent capacitance components resulting from the phase lag, Miller's effect, etc, within the semiconductor.

In designing oscillation circuit, proper choice of C_L is very important because the frequency depends on it.

In the electrical equivalent oscillation circuit(Fig.-4), operating frequency, f_0 can be expressed by the following equation.

$$\frac{f_0 - f_s}{f_s} = \frac{1}{2r(1 + C_L/C_0)}$$

Where f_s = series resonance frequency.
$r = C_0/C_1$ (capacitance ratio)

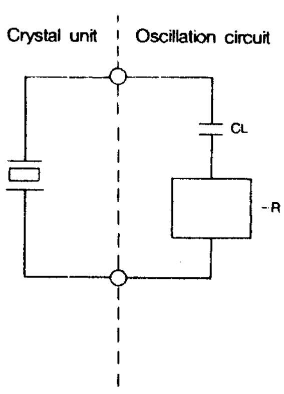

Fig. 3 Equivalent Circuit of a Crystal Oscillator I

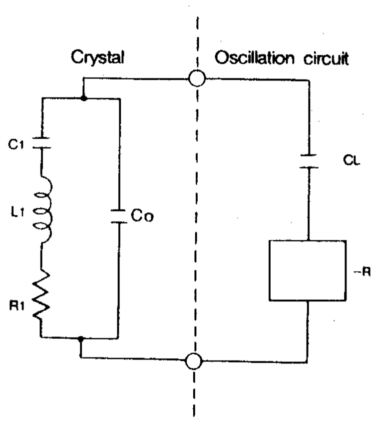

Fig. 4 Equivalent Circuit of a Crystal Oscillator II

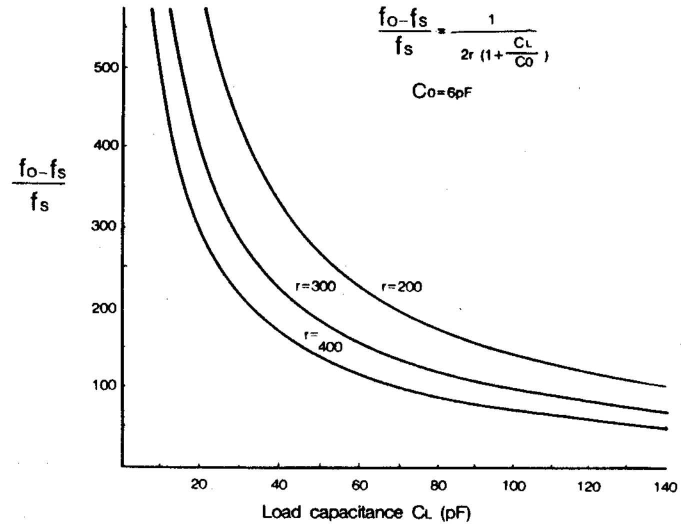

Fig. 5 Load Capacitance Characteristic

Fig.-5 shows an example of the load capacitance characteristic calculated by equation. As can be seen from the figure, the rate of operating frequency change due to change in C_L is high where C_L is small. The rate of operating frequency change due to change in C_L is also high when the capacitance ratio is small.

In most cases the quartz crystal is operated with a load capacity in order to be able to adjust the manufacturing tolerances.

The following applies to the series and parallel connection of C_L:

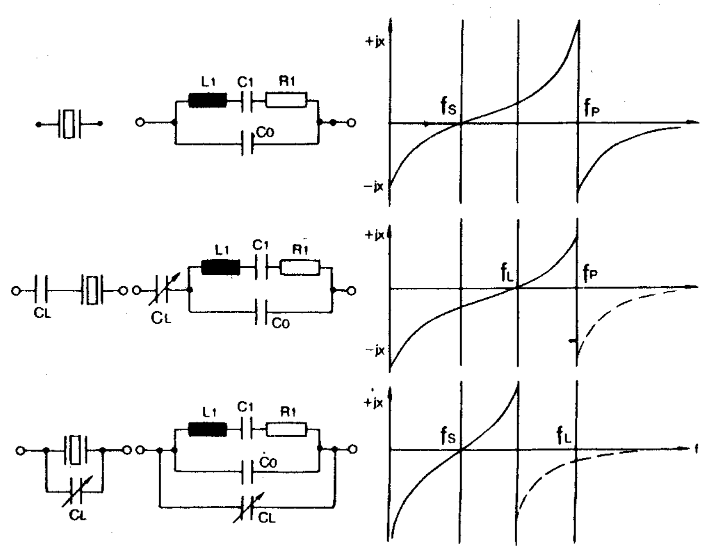

Fig. 6 Influence of the load Capacitance C_L

CRYSTAL PARAMETERS

RESISTANCE AND Q FACTOR

Resistance is the equivalent impedance of the quartz resonator and it determines Q factor of quartz crystal. High crystal Q's are obtained by reducing mechanical and acoustic energy losses which is equivalent to R_1.

The crystal Q is related to the series resonance frequency f_s, the motional inductance L_1, and the equivalent series resistance R_1.

$$Q = \frac{2\pi f_s \cdot L_1}{R_1}$$

A high Q-factor, i.e., low resistance R_1, reduces the influence of external parameters, such as variations in supply voltage, load, temperature, and oscillator components.

SPURIOUS MODES

Spurious modes, which mean unwanted modes, are actually inharmonic modes of vibration of the quartz plate. Since spurious modes are inherent in every crystal resonator, they are suppressed by special design technique.

Typical spurious specifications are 6dB below the desired mode of oscillations but they are more highly suppressed upon customer's request.

DRIVE LEVEL

The drive level normally referenced in milliwatts is the power dissipated in the crystal's equivalent resistance.

Drive level should be the minimum necessary to begin and maintain crystal oscillation, to assure optimum performance and stability.

Excessive drive can result in breakage of the crystal element, excessive frequency drift, and poor aging characteristic.

FREQUENCY TOLERANCE

Frequency tolerance is the amount of frequency deviation(plus or minus) from the desired operating frequency at a specific temperature.

Accuracy requirement for crystal tolerance is expressed in percentage.

AGING

Aging of a quartz crystal is a general term applied to any change in parameters of a crystal unit taking place over a period of time.

In order not to suffer severe aging, the circuit should be designed with drive level kept at absolute minimum.