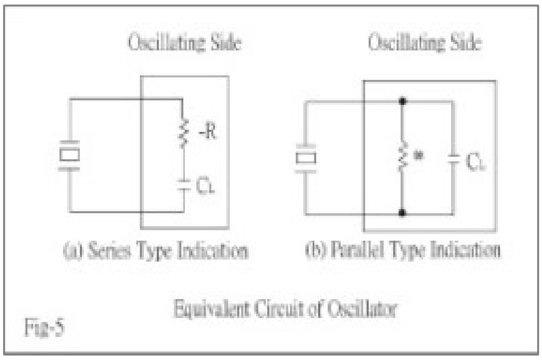
• Oscillation Frequency and Load Capacitance

In an oscillation circuit in which a quartz resonator works as inductive impedance, the equivalent circuit is can be indicated by the combination of an inductance series with a resistance, as shown in Fig-5 . Fig-5 (a) expresses the oscillation circuit with a series circuitry, while (b) expresses a parallel circuitry.



Here the capacitance CL is an effective capacitance when the oscillating side is viewed from the ends of the quartz resonator, usually called a load capacitance, and - R and - ρ are negative resistances of the oscillating side.
In this type of oscillation circuit, the quartz resonator works as a series circuitry of an inductive reactance Xe and a resistance Re, as shown in Fig.6 and its oscillation frequency is expressed by:

$$Xe = \frac{1}{2 * f * C_L}$$

The conditions for oscillation to start is $|Re| < |-R|$ in the case of (a), and $|Rp| > |-\rho|$ in the case of (b), where Re is the series resonant resistance (equivalent series resistance) of the series circuitry of a quartz resonator and capacitance CL, and Rp is the parallel resonant resistance (equivalent parallel resistance) of the parallel circuitry of quartz resonator and capacitance CL.

In order to have certain oscillation while increase of the equivalent resistance at a low excited level of the quartz resonator is taken into consideration, the negative resistance (- R) of the circuit must be good deal larger compared with Re.

Thus the oscillation frequency is decided by the electrical equivalent constant of the quartz resonator and the load capacitance of the oscillating side regardless of configuration of the oscillation circuit (operating temp. and driving level to be specified separately), so that the load capacitance of the oscillation circuit must be defined clearly at the time of manufacture or use. The equivalent circuit of the quartz resonator and a series connected load capacitance CL is expressed as in Fig-7, and constants at this time are as following:

$$L_1' = L_1\left(1+\frac{C_0}{C_L}\right)^2 \qquad R_1' = R_1\left(1+\frac{C_0}{C_L}\right)^2$$

The oscillation frequency at this time is increased by Δf, and we have:

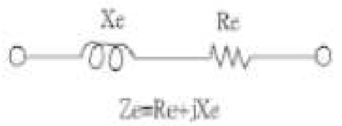
$$C_1' = \frac{C_1 C_L^2}{(Co+C_1+C_L)(Co+C_L)} \qquad C_0 = \frac{C_0 C_L}{C_0+C_L}$$

where Δf is the difference from the frequency fo in series resonance. Re-arrangement of this equation will yield the following equation:

$$\frac{\triangle f}{f_0} = \frac{C_1}{2(C_0+C_L)}$$

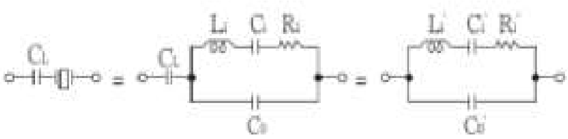
Where C_0/C_1 is called the capacitance ratio, The capacitance ratio serves as a reference for knowing the size of the amount of change in the oscillation frequency due to alteration of the load capacitance.

$$\frac{\triangle f}{f_0} = \frac{1}{2r}\cdot\frac{1}{1+\frac{C_L}{C_n}} \qquad r = \frac{C_0}{C_1}$$



Impedance Representation of a Quartz Resonator

Fig-6



Equivalent Circuit of a Quartz Crystal with Load Capacitance

Fig-7

Fig-8 shows the load capacitance vs. frequency change ratio characteristic of a fundamental AT cut resonator and a 3rd overtone resonator.
It is required. as shown by the Fig-8 to use a fundamental resonator and select a small load capacitance in order to obtain the amount of change over a wide frequency range through changing of the load capacitance.

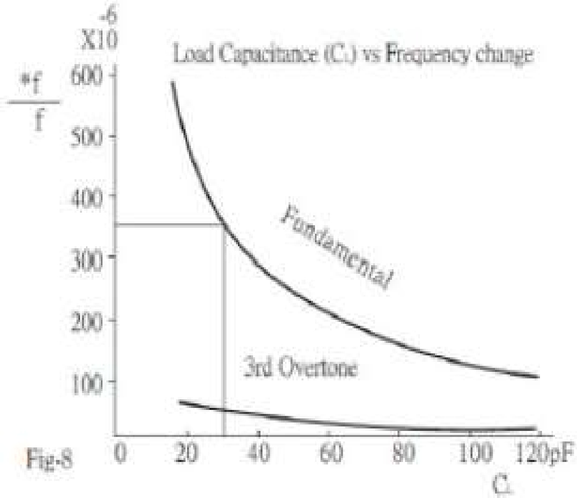


Fig-8