Crystal terms and application notes

SERIES RESONANCE

When a crystal is operating at series resonance (Fs), it looks resistive in the circuit. Thus, impedance at Fs is near zero. In a well designed series resonant circuit, correlation is not a problem and load capacitance does not have to be specified. See Fig. 3.

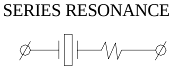


Figure 3

PARALLEL RESONANCE

When a crystal is operating at parallel resonance (Fs<Fr<Fa), it looks inductive in the circuit. Thus, function of a load capacitance is very important in selecting the stable point of oscillation. As well as reactance changes, the frequency changes correspondingly, thus changing the pullability of the crystal. The difference in frequency between the Fs and Fa depends on the Co/C$_l$ ratio of the crystal unit, and the inductance L$_l$. In parallel circuit design, load capacitance CL shall be specified. (Fig. 4)

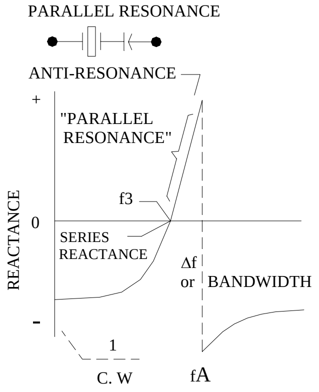
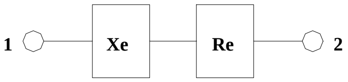


Figure 4

The crystal equivalent circuit can be simplified as a series resistance Re with a reactance Xe. (Fig. 5)



Ze = Re + jXe

Figure 5

NEGATIVE RESISTANCE "-R"

Negative resistance is an important parameter to consider when designing an oscillator. Figure 1 shows an equivalent circuit for an oscillator. "-R' represents the negative resistance; To maintain stable oscillation at a constant frequency,

The oscillator must have enough negative resistance I-RI > 10 Re) to compensate for the resistance (loss) of the resonator.

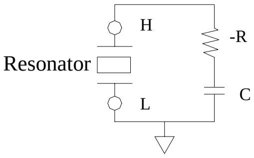


Fig. 6. Negative Resistance in an oscillator circuit

CHANGE OF LOAD CAPACITANCE AND PULLABILITY

When a crystal is operating at parallel resonance (Fs<Fr<Fa),it looks inductive in the circuit. As the reactance changes, the frequency changes correspondingly, thus changing the pullability of the crystal. The difference in frequency between the Fs and Fa depends on the Co/C$_l$ ratio of the crystal unit. The frequency changes by A F, i.e., F$_L$-F$_O$

$$\frac{\Delta F}{F_0} = \frac{1}{2\frac{C_0}{C_1}(1\times\frac{C_L}{C_0})}$$

The same crystal with frequency at third-overtone mode will have much less pulling because its motional capacitance C$_l$' is
approximately 1/9 of C$_l$ at fundamental.

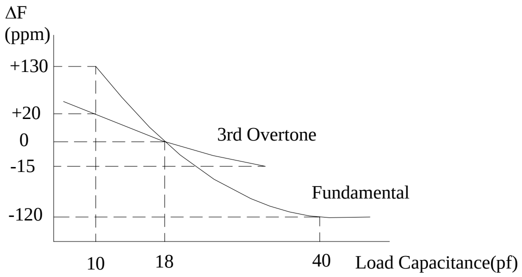


Fig. 7 Change of load capacitance and pullability

Frequency pullability of a fundamental 20 MHz crystal vs. its 3rd overtone crystal. The oscillating mass of the quartz crystal corresponds to the motional inductance L$_l$ while the elasticity of the oscillating body is represented by the motional capacitance C$_l$.

C$_l$ (pF) = 0.22 x A(m2) x F(Hz) / l 670
Where A = area of the electrode
F = resonant Frequency

CHANGE OF LOAD CAPACITANCE AND PULLABILITY

When a crystal is operating at parallel resonance (Fs < Fr < Fa), it looks inductive in the circuit. As the reactance changes, the frequency changes correspondingly, thus changing the pullability of the crystal. The difference in frequency between the Fs and Fa depends on the C0 / Cl ratio of the crystal unit. The frequency changes by A F, i.e., F$_L$ - F$_O$

$$\frac{\Delta F}{F_0} = \frac{1}{2\frac{C_0}{C_1}(1\times\frac{C_L}{C_0})}$$