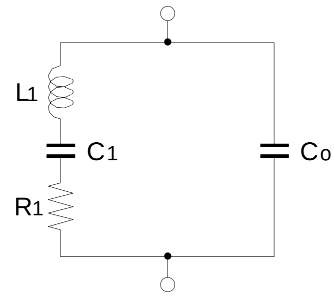
Hy-Q International

PRODUCT INFORMATION

CRYSTAL THEORY

The Equivalent Circuit

L_1 – Dynamic or Motional Inductance (mH)
C_1 – Dynamic or Motional Capacitance (fF)
R_1 – Equivalent Series Resistance (ohms)
C_o – Parallel or Static Capacitance (pF)



Note 1:- L_1, C_1 and R_1 are not true electrical components. They are apparent values of inductance, Capacitance and Resistance which serve to model mechanical / piezoelectric performance of the vibrating crystal in the region of resonance.
2 In all cases the units shown in brackets are those normally used for AT-cut Crystals.
3 It is necessary to use consistent units in the equations, i.e Farads, Henries etc.

Circuit Equations - Basic Crystals

Series Resonant Frequency

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

Parallel Resonant Frequency

$$f_p = \frac{1}{2\pi\sqrt{L_1 C}}$$

where

$$C = \frac{C_1 \times C_o}{C_1 + C_o}$$

Note:- In practice, an allowance usually has to be made for 'strays'.

Quality Factor

$$Q = \frac{2\pi f_s L_1}{R_1} = \frac{1}{2\pi f_s C_1 R_1}$$

Capacitance Ratio

$$R = \frac{C_o}{C_1}$$

Figure of Merit

$$M = \frac{Q}{r} = \frac{1}{2\pi f_s C_o R_1}$$

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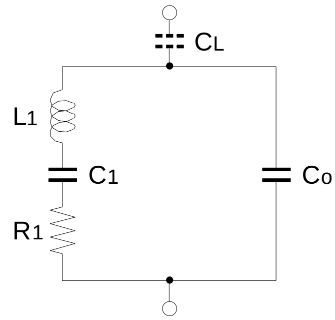
CRYSTAL THEORY (continued)

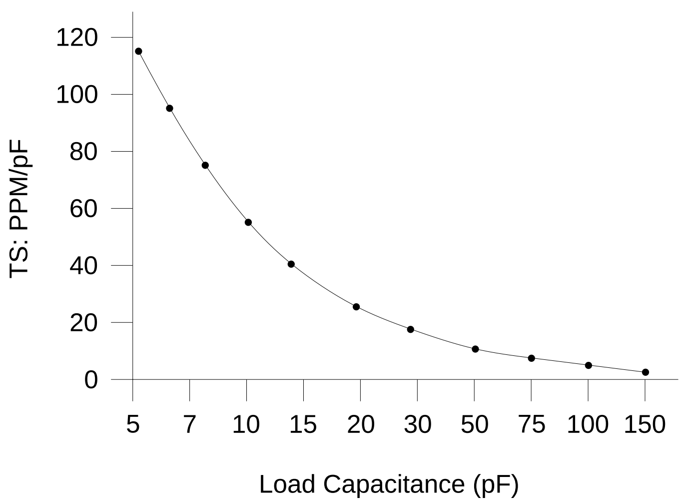
Circuit Equations - with external load



Frequency Deviation - Series to load $$D = \frac{C_1 \times 10^6}{2(C_O + C_L)} \text{ ppm}$$

Note
1. Series Capacitance (C_L) increases the frequency.
2. The effect of a trimmer may be readily assessed by calculating D and D' for C_L and C_L' and subtracting.
3. Units are correct for C_1, C_0, and C_L in Farads.

Trim Sensitivity $$TS = \frac{C_1 \times 10^{-6}}{2\{C_O + C_L\}^2} \text{ (ppm/pF)}$$



The above graph shows the effect of external load capacitance on the trim sensitivity of a representative 20 MHz fundamental mode crystal. Notice the large frequency shift with small load changes when fundamental mode crystals are operated at low load capacitances.
Overtone mode crystals are generally less affected by external loads. A rough approximation is to reduce the fundamental mode trim sensitivity by a factor of the overtone mode squared.

Apparent Series Resistance (with C_L) $$R_e = R_1 = \left(1 + \frac{C_O}{C_L}\right)^2$$

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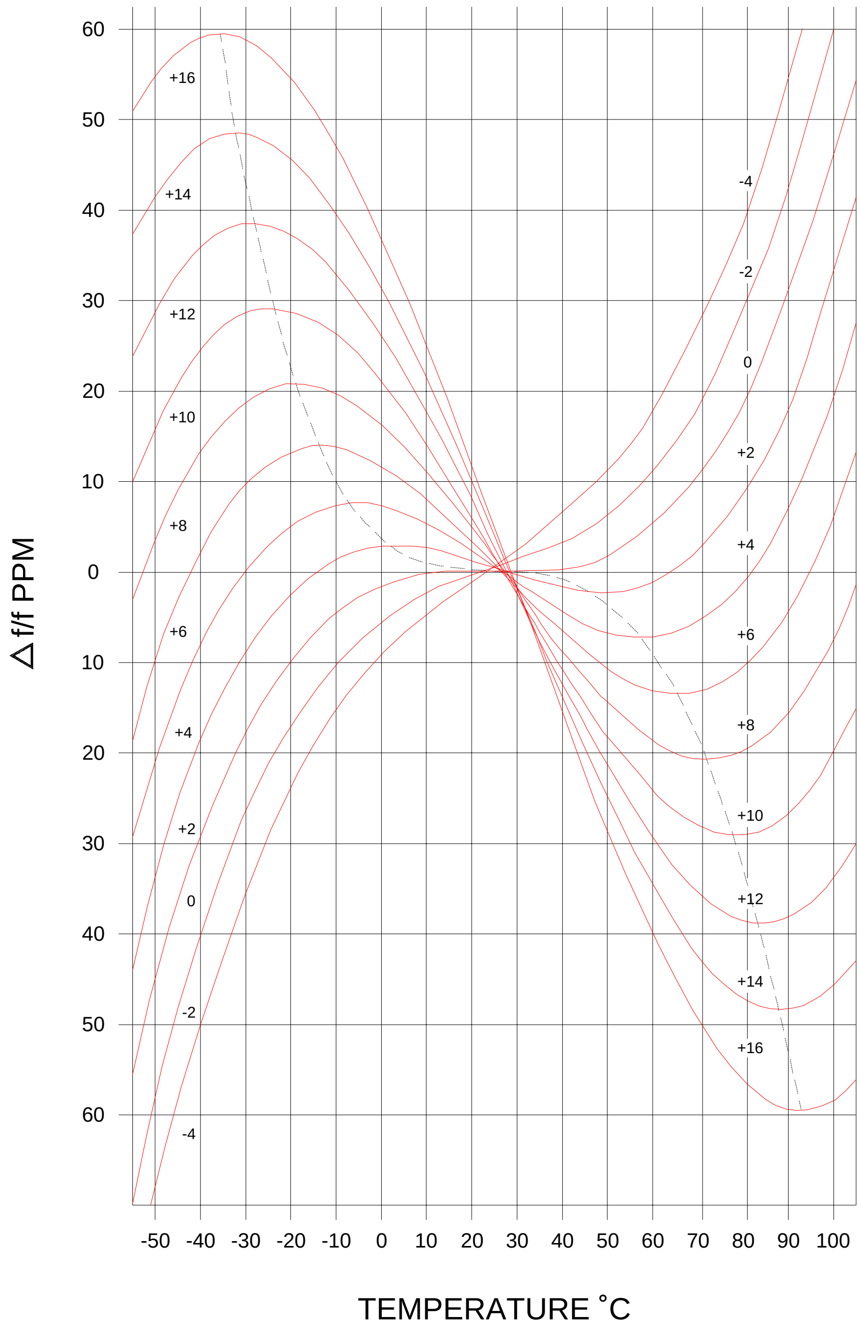
NORMALISED AT-CUT FREQUENCY TEMPERATURE CURVES



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