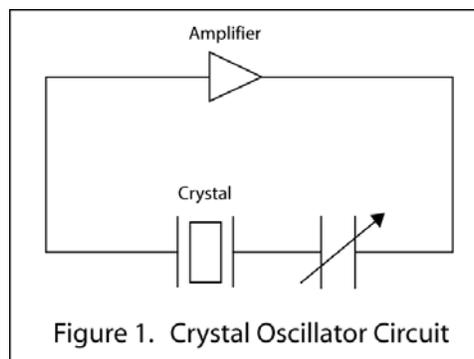


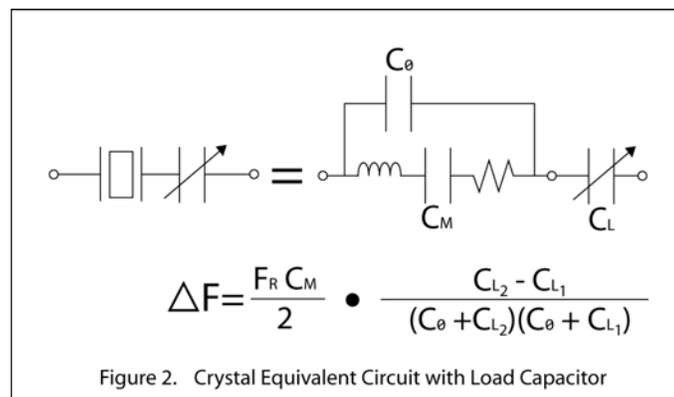
CRYSTAL FREQUENCY PULLABILITY (delta F)

by
Robert Kinsman
Tellurian Technologies, Inc.

The ability to adjust the resonance frequency of a crystal is required in most oscillator applications. This can be accomplished by connecting a variable capacitor in series with the crystal as shown in Figure 1.



The variable capacitor may be mechanical (trimmer capacitor) or electronic (varactor). In clock oscillators, frequency adjustment is needed to compensate for the manufacturing tolerance of the crystal, i.e. to set the oscillator on the exact specified operating frequency. In a VCXO, the frequency is pulled over a specified frequency range by an applied voltage. A critical factor, particularly in the VCXO application, is the frequency deviation that can be obtained. The crystal pullability is a function of the load capacitor and the electrical equivalent circuit of the crystal. The pullability is often defined as the crystal “delta F” and can be calculated using a rather complicated formula as seen in Figure 2.



In Figure 2, the crystal equivalent circuit plus a load capacitor is shown with the formula for calculating delta F. From the formula it can be seen that the crystal delta F is a direct function of the C_M and is also affected by the C_0 . For a typical 10 MHz crystal equivalent circuit values would be $C_M = 15$ fF and $C_0 = 4.0$ pF. For a nominal 20 pF capacitive load the delta F is equal to 130 Hz/pF or equivalently, 13 ppm/pF. In higher frequency oscillators it is desirable to use 3rd overtone crystals for cost reasons. However, the delta F for a 3rd overtone crystal is much lower than for the fundamental mode crystal at the same frequency because the overtone crystal has a much lower C_M value. This can be illustrated by calculating the delta F for a 40 MHz fundamental and 3rd overtone crystal:



**Tellurian[®]
Technologies, Inc.**

1801 Hicks Rd. Suite A Rolling Meadows, IL 60008
PH: 847-934-4141 FAX: 847-934-4175
www.telluriantech.com

40 MHz Fundamental crystal; $C_M = 13$ fF, $C_0 = 4.5$ pF,

For a nominal 20 pF load capacitor, $\Delta F = 433$ Hz/pF or 10.8 ppm/pF

40 MHz 3rd overtone crystal, $C_M = 0.9$ fF, $C_0 = 3.5$ pF

For a nominal 20 pF load capacitor, $\Delta F = 32.6$ Hz/pF or 0.815 ppm/pF

In summary, the crystal pullability or ΔF is a critical characteristic for oscillator crystals particularly in VCXO applications. For higher frequency oscillators fundamental mode crystals are often required in order to achieve a reasonable frequency deviation.