Quartz Crystal Current Measurement in Crystal Oscillators

APPLICATION NOTES QTAN-108

DEFINITION:

The drive level of a crystal is a measurement of the power dissipation seen by a crystal in the amplifier circuit of the oscillator. The drive level is expressed in milliwats (mW) or microwatts (µW). The maximum power dissipation is generally specified by the type of quartz used and the manufacturer, with typical ratings up to 1mW or 2mW. The drive level of a crystal is defined by the feedback components chosen at both sides of the crystal.

The amplitude of mechanical vibration of the quartz resonator increases proportionally to the applied current. Overdriving the crystal can cause excessive long-term aging, output amplitude and frequency distortion, or worse to the destruction of the resonator.

INDUSTRY STANDARDS:

IEC-60444-6 International, IEC, Measurement of Drive Level Dependence (DLD) of Quartz

MIL-C-40468 Military, Specification, Crystal Unit Quartz (Cancelled since September 2009)

Q-TECH DESIGN METHODOLOGY:

- Goal is to design with lowest drive level to the crystal with enough drive capability to provide energy to start the crystal at very low drive to operating drive levels and to sustain steady-state oscillation in worst-case conditions which included supply voltage variations, power supply ramp rate, operating temperatures, and environmental factors.
- Q-Tech drive levels vary from 50µW to 100µW on fundamental mode and 200µW to 500µW on Overtone mode oscillators.
- Q-Tech uses standard method for Drive Level Dependency (DLD) on crystal measurement and maximum ratio of ESR allowed is 1.3:1.

HOW TO MEASURE DRIVE LEVEL IN OSCILLATORS:

Measure AC current through the crystal with circuit biased at 3.465Vdc using Tektronix AC Current probe amplifier TCP312 and Tekprobe current probe with minimum current sensitivity to 1mA.

SET-UP:

- Insert current probe through the wire connected to the crystal. See figure 1.

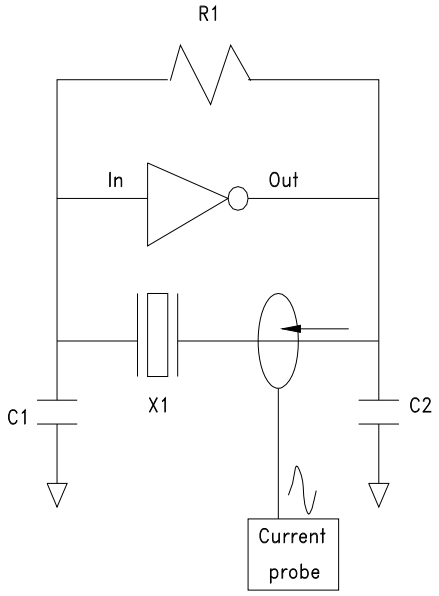

Figure 1

- Measure direct crystal parameters RS, RL, C0
- RL can also be calculated with **$RL = RS * (1 + C0/CL)^2$**
- Read AC current (Ipp) in peak to peak from the oscilloscope
- Calculate RMS current (Irms) with $Irms = Ipp/(2\sqrt{2})$
- Power is calculated using:

$Pcrystal = RL * (Irms)^2$

RESULTS OF A 120MHz 3rd OVERTONE OSCILLATOR:
With C0=1.88pF, CL=20pF, RL=30Ω, F0=120MHz, Vcc=3.465Vdc
Ipp = 0.00918A
Irms = 0.00325A
Pcrystal = 316µW

DERATING:
Crystal current rating: 500mA
Derating factor: 0.5
Actual current: 3.25mA
Stress ratio: 0.0065

RESULTS OF A 48MHz 3rd OVERTONE OSCILLATOR QT625L:
With C0=3pF, CL=20pF, RL=23Ω, F0=48MHz, Vcc=3.63Vdc
Ipp = 0.00112A
Irms = 0.00396A
Pcrystal = 360µW

DERATING:
Crystal current rating: 500mA
Derating factor: 0.5
Actual current: 3.96mA
Stress ratio: 0.0079