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White Paper

Uprating of Crystal Oscillators

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Uprating of Crystal Oscillators

The crystal oscillator is an integral component for clock creation in digital data transmission circuitry. There tends to be two primary job functions of a crystal oscillator in electronic circuits. The first purpose is to drive the circuit independent of the environment. This is typically the purpose in standard consumer electronics. In this situation, drift and the accuracy of the crystal is not critical as the crystal oscillator is the only reference for all the components within the circuit. The second purpose is to synchronize the oscillator output with an incoming signal, which often requires a voltage controlled crystal oscillator.

1. Functional Parameters (Specified in Datasheet)

An example of the variation in functional parameters that can be provided in manufacturers' datasheets is listed below

Type	SPXO	XO	XO
Nominal frequency	125.000 MHz	125.000000 MHz	125.000 MHz
Frequency stability	± 25 ppm	± 50 ppm	± 50 ppm
Output symmetry	40/60	45/55	40/60
Temperature (Max.)	70°C	70°C	70°C
Temperature (Min.)	0°C	-20°C	-10°C
Tri-state enabled	No	No	No
Harmonic	3rd	N/A	N/A
Output	TTL/CMOS	CMOS	CMOS
Load	15 pF	15 pF	15 pF
Supply Voltage	3.3 V±10%	3.3 V±10%	3.3 V±10%
Supply current	60 mA	40 mA	45 mA
Rise/Fall time	3 ns	3 ns	8 ns
Start-Up Time	N/A	N/A	10 ms

As seen in Figure 1 and Figure 2, the stability of the resonant frequency will vary with temperature. The behavior of this drift will vary depending upon the crystal cut. Since the part manufacturer does not provide this information, it is practically impossible to predict this variation in terms of positive/negative or magnitude based upon the part data sheet. However, if the crystal oscillator is being used as a reference clock, these shifts may be acceptable for the given circuit.

2. Functional Parameters (Not Specified in Datasheet)

If one assumes that crystal oscillators are primarily used as reference clocks, the primary parameter that is temperature dependent, and therefore the rationale for the temperature ratings, is the occurrence of activity dips. An example of this behavior is shown in Figure 3.

Activity dips are not specified in the part manufacturer's data sheet, other than that activity dips can not occur within the given temperature range (if activity dips occur, then the part does not function and this is not a realistic operational temperature range).

The temperature range provided by crystal oscillator manufacturers has a physical basis and tends to be driven by the cut selected and the geometry of the crystal. The behavior of the temperature dependence of the resonant frequency varies with the crystal cut. The most common cuts for crystal oscillators are AT and BT cuts. AT cut crystals are cut at a theta angle of 35 , whereas BT cut crystals at -49 (see Figure 4). As shown in Figure 5, the AT and BT cuts exhibit a thickness-shear mode of vibration (bulk acoustic wave).

There is a very real possibility of activity dips outside this temperature range. However, diligent characterization of the crystal oscillator should provide information as to this occurrence.

3. Electrical Overstress (Robustness)

The primary rating for crystal oscillators is the voltage rating, which tends to drive leakage current. As increasing temperature will increase leakage current, it is possible that on some circuits a change in the voltage rating may be appropriate.

4. Wearout Behavior

The wearout behavior of crystal oscillators primarily consist of drift in the resonant frequency

4.1 Steady State Temperature

Generally, aging of Crystal Oscillators is small compared to the other uncertainties like frequency accuracy and frequency stability (short term variation). Aging will occur mainly during the first year and often is specified to be less than 5ppm during that period. After that time period, the aging effect slows down dramatically and is in the order of 10 ppm to 20ppm over the subsequent ten years. This not expected to be influenced dramatically by temperature.

4.2 Temperature Cycling (Internal Circuitry)

Cycling to "extreme" temperatures can increase the aging rate for the crystal oscillators, leading to a failure of the phase lock and thus the oscillator circuitry.

4.3 Temperature Cycling (Packaging)

Surface mount crystal oscillators are often at risk of solder joint fatigue because of the use of a leadless ceramic chip carrier as the package type. Solder joint modeling or accelerated testing should be performed to ensure sufficient design life given the use environment.

5. Conclusion

The primary concern is the potential presence of activity dips between the rated temperature and the expected field environment. The risk of this failure mode can be minimized through extensive characterization of the approved parts or selection of crystals with extended range designation.

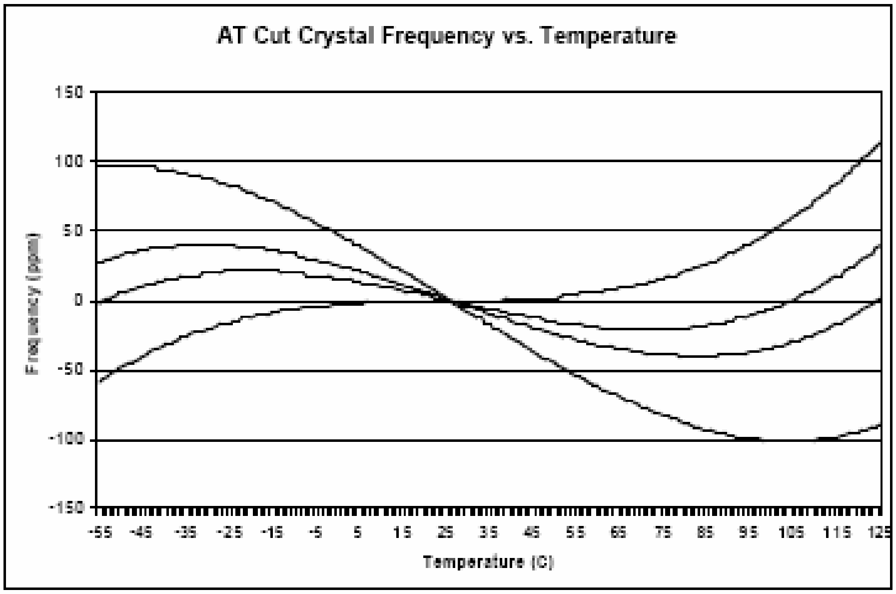

Figure 1: Frequency-temperature curves for the AT-cut crystal at different angle ϕ[1]

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[1] Source: ILSI America

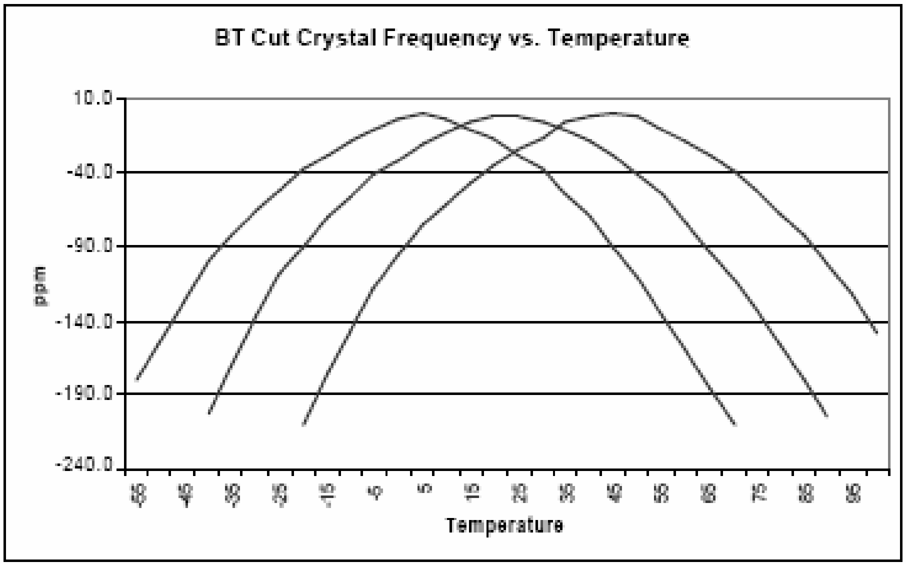

Figure 2: Frequency-temperature curves for the BT-cut crystal at different angle ϕ[2]

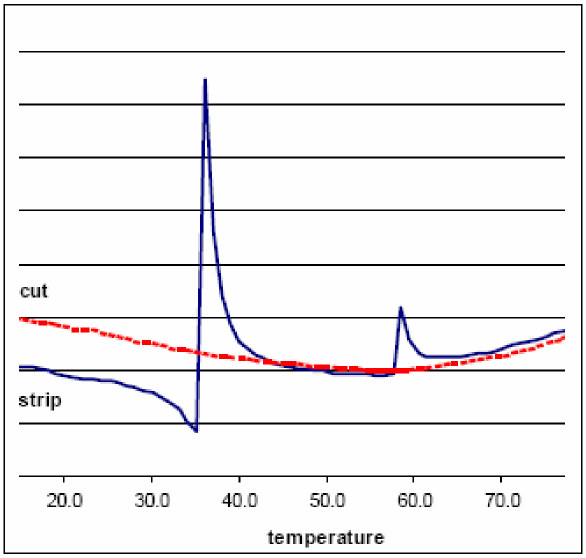

Figure 3: Frequency vs. Temperature variation of AT strips vs AT cuts

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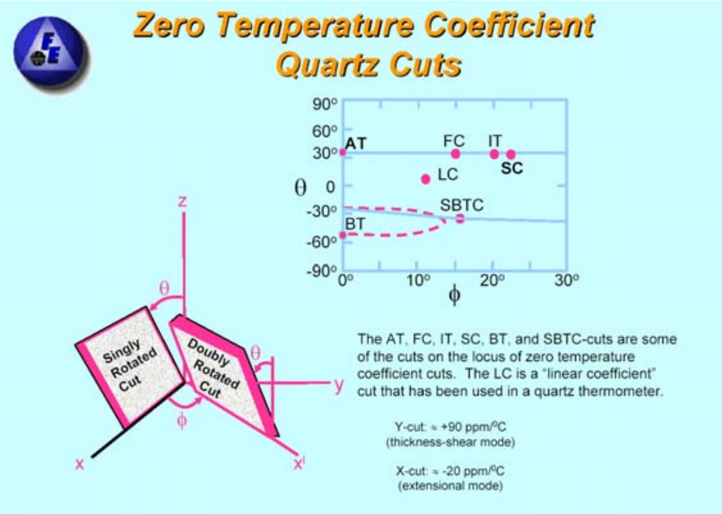
[2] Source: ILSI America



Zero Temperature Coefficient Quartz Cuts

The AT, FC, IT, SC, BT, and SBTC-cuts are some of the cuts on the locus of zero temperature coefficient cuts. The LC is a "linear coefficient" cut that has been used in a quartz thermometer.

Y-cut: ≈ +90 ppm/°C
(thickness-shear mode)

X-cut: ≈ -20 ppm/°C
(extensional mode)

Figure 4: Crystal Cuts for Oscillators[3]

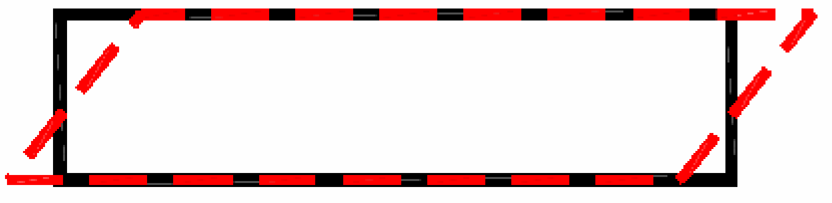


Figure 5: Thickness shear mode of vibration in AT or BT cut crystal[4]

DISCLAIMER

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[3] Source: M. Bloch, Frequency Electronics

[4] Source: Jerry Lichter