Q-Tech Corporation
10150 West Jefferson Blvd. Culver City, CA 90232
Tel (310) 836 - 7900   Fax (310) 836 - 2157

Calculated Failure Rates for QT78/QT88 Crystal Oscillators

I. Background

MTBF (Mean Time Between Failures) rates are usually calculated using MIL-HDBK-217 methods. It requires precise knowledge of the average ambient temperature during operation and storage (not the maximum or minimum storage temperature), the environment, the stress levels and temperature on each sub-component, as well as the maximum rating, type and reliability ratings of these sub-components. Currents, voltages and thermal conductivities have to be measured or estimated for actual operating conditions. Its principal usefulness is in the determination of which component of a circuit is close to over-stress, whether to include redundancy for possible failures, or whether to choose alternate designs or components to reduce overall risk. Although the calculated numbers are not extremely accurate, the calculation is extremely good for finding problem areas.

In calculating MTBF for small electronic hybrids, the times estimated are quite large and have no meaning in the real world. A better understood measure of the reliability is FITs (Failures in Time), which is 10^{+9} hours divided by the MTBF. The most meaningful measure, however, is the Basic Reliability. This requires knowledge of the expected mission time or equipment service life and its duty cycle. The Basic Reliability is essentially a probability of no failures during the expected life of the equipment which contains the component.

II. QT78 and QT88 Crystal Oscillator Data

Circuits for the QT78 and QT88 are currently quite similar with respect to design and construction and the effective thermal conductivities of the packages are similar. Calculations were made to compare MTBF for various quality levels using the assumption of a simple16 MHz oscillator at Vcc of 3.3 V. The environment was assumed to be Ground Benign at 25 C. with a mission life of 10 years. The results are shown in the following table:

CLASS	MTBF	FITs	BASIC REL
Commercial	3,222,000	310.	0.9732
B (Military)	32,220,000	31.0	0.9973
S (Space)	128,886,000	7.76	0.9993

NOTE: The commercial parts may contain materials which can seriously degrade at temperatures above 85 C. It is usually not possible to screen the commercial parts to “remove all failures” and convert them into true military-grade hardware nor is it possible to guarantee that commercial parts which are shown to contain full temperature range materials will continue to be unchanged. Please also note that commercial parts are not constrained by any requirements to notify customers of changes in components or design or source of the components nor are they required to maintain lot traceability of the changes or the components. Testing of commercial parts is usually restricted to measurements only at room temperature.

III. Choices of Environments and Assumptions

Environments may be chosen only from the following selections:

1. **GB:** Ground, Benign (normal laboratory or building).
2. **GF:** Ground, Fixed (warehouse or shed).
3. **GM:** Ground, Mobile (car or truck).
4. **NS:** Naval, Sheltered (inside ship).
5. **NU:** Naval, Unsheltered (exposed to weather on ship).
6. **AIC:** Aircraft, Inhabited, Cargo (inhabited air cargo areas).
7. **AIF:** Aircraft, Inhabited, Fighter (cockpit of high performance plane).
8. **AUC:** Aircraft, Uninhabited, Cargo (uninhabitable, uncontrolled cargo areas).
9. **AUF:** Aircraft, Uninhabited, Fighter (non-cockpit areas).
10. **ARW:** Aircraft, Rotary Winged: (helicopter).
11. **SF:** Space Flight (benign, orbital flight).
12. **MF:** Missile Flight (cruise and air-breathing missiles in flight).
13. **ML:** Missile Launch (manned and unmanned launch and reentry).
14. **CL:** Cannon Launch (entire flight path).

Assumptions made in calculations for crystal oscillators unless otherwise specified:

1. The oscillator is operating in air at approximately 1 atmosphere pressure and the expected ambient temperature without rapid airflow over the case.
2. The oscillator case does not have a radiator attached nor is in intimate thermal contact with a heat-sinking surface.
3. There are no major heat sources in the immediate vicinity of the oscillator which would significantly change thermal radiation or local ambient air temperature.
4. MIL-HDBK-217 does not take ionizing radiation exposure into account when making calculations. If significant exposures to radiation are expected (< 25 R/year), separate specific qualifications of components would be required. This effect upon the overall lifetime is not capable of being evaluated here.

NOTE: It is extremely difficult to predict the temperature of isolated heat-producing objects in a vacuum. If the object is not thermally connected to a temperature-controlled surface, its temperature is controlled by the area and emissivity of its surface as well as the area, emissivity, temperature and geometry of surrounding surfaces. We do not have sufficient information to make this calculation.

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Example of QT78 Reliability Calculations for Missile Launch Conditions

Various QT78 designs have been examined for use at 3.3 volts with frequencies from 3 MHz to 80 MHz. A frequency of 64 MHz (21.3 MHz fundamental) was assumed along with a DC current of 15 mA. The Theta JC for the QT78 case is rated at 20.75 and the Theta CA (case to ambient) for this package is 100 (these packages are usually used without heat-sinking). This produces a power dissipation of 50 mW that causes a case temperature rise of 5 ºC over ambient and a junction temperature rise of 1.05 ºC above case. In performing the attached MIL-HDBK-217F reliability calculations on this part, a mission life of 9 years (78894 hours) for GF (Ground Fixed) storage at 40 ºC, a 1 year mission life (8766 hours) for GF powered field deployment at 50 ºC as well as a one hour ML (Missile Launch) at 70 ºC were used. Calculations of storage (non-operating) life were modified to compensate for deficiencies in some MIL-HDBK models. The results are summarized in the table below.

STATUS	ENV	HRS	ºC	MTBF	FPMH	% REL	FAILURES/1000
Store	GF	78894	40	58,663,058	0.01705	99.8656	1.344
Deploy	GF	8766	50	16,425,433	0.06088	99.9466	0.534
Launch	ML	1	70	5,516,298	0.18128	100.0000	0.0002
TOTAL		87661		46,663,500	0.02143	99.8122	1.878

These numbers are only approximate and may differ up or down by a factor of two (2). The power dissipation that affects the failure rate of the IC is a major function of the crystal frequency and its mode (fundamental or 3^{rd} harmonic). The failure rate of the crystal (the major failure contributor to the oscillator) is independent of temperature in the MIL-HDBK model but is dependent on the frequency of the crystal. There may be zero to three resistors present but their effect is minor. As can be observed in the table above, the launch contribution to the failure rate is minor. Failures occurring during storage and deployment may, in fact, be discovered by routine testing and eliminated or repaired before launch.