Mean Time Between Failure (MTBF) of Crystal Oscillators

APPLICATION NOTES QTAN-101

Reliability is defined as the probability that a device will function to its specification for a specific period of time.

The Bathtub curve

The "bathtub curve" describes the hypothetical failure rate of a device versus time. The first period is called Infant Mortality period. The next period is the flat portion of the graph. It is called the normal life. The third period begins at the point where the slope begins to increase and extends to the end of the graph.

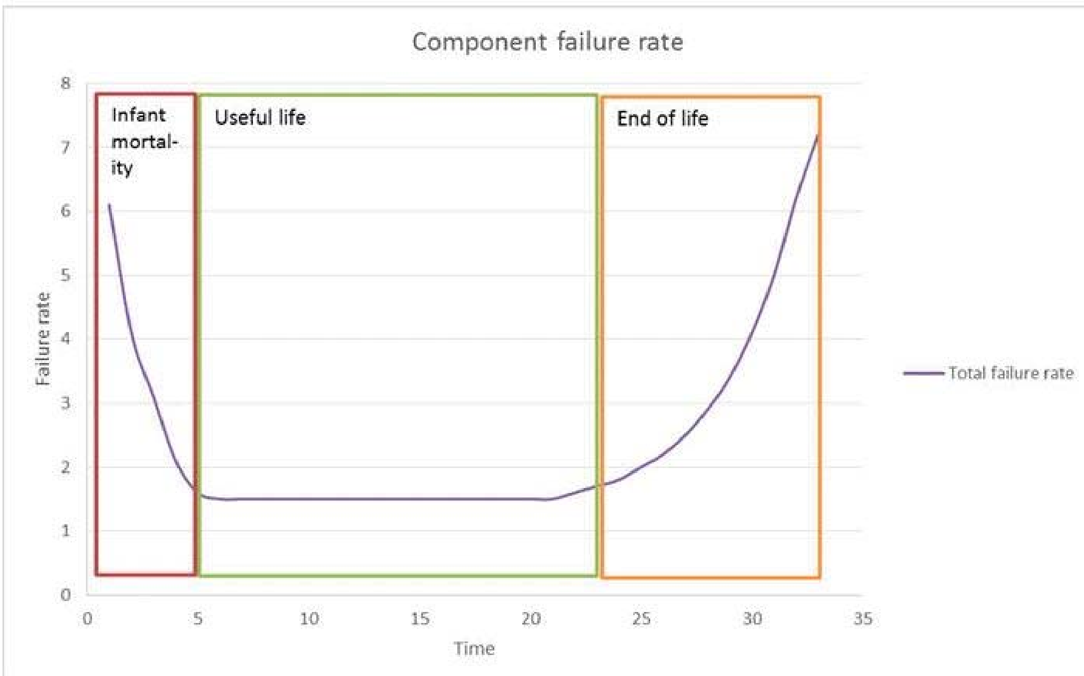

Figure 1 Reliability Bathtub curve

The failure rate calculated from MIL-HDBK-217 applies to the Useful Life period as the product matures, and the weaker units weakened and started to fail as a relatively constant and low failure rate. The useful life period is the most common time frame for making reliability predictions.

Accelerated Life Testing

Accelerated Life testing employs high stress methods to seek shortening the life of a product or quickening the degradation of the product's performance. Various stress tests in oscillators included extended Burn-in time, i.e. Life test at +125°C or higher for a minimum of 1,000 hours under bias. Some other tests included heat, humidity, temperature, vibration, and load.

Reliability Predictions Methods

Prediction methods are based on components data based on a variety of sources:

- Life test data
- MIL-HDBK-217

Reliability Prediction Illustration

Reliability Prediction of a Q-Tech Space qualified QT122L11S-32.895MHz using both Life test data and calculation with MIL-HDBK-217 is shown below:

Design technology:
The QT128L11S design employed an ASIC FACT 1.3µ technology ACMOS logic, Radiation Tolerant to 100kRad(Si) with approximate thermal activation energy 0.4eV and a swept quartz at 32.895MHz Fundamental mode mounted on a three (3) point mount.

Absolute Maximum ratings of the die:

- Absolute Maximum power dissipation: 500mW
- Absolute Maximum junction temperature: +175°C
- Absolute Maximum supply voltage: +7Vdc

Operating conditions:

- Maximum current drawn: 15mA max. at +3.63V
- Theta JC = 30°C/W
- Theta JA = 130°C/W
- Maximum temperature rise: 1.6°C

MTBF PER MIL-HBK-217:

MTBF calculation is based on MIL-HBK-217 with Space Flight Environment (SF) at ambient +65°C, CL=90%, using a 32.895MHz crystal, Fundamental mode at 3.3Vdc±10% supply, 16-FP package with seal perimeter of 1.8 inches.

Bill of Materials:

- Package, 16-FP 0.500" x 0.375" (1.75in seal perimeter)	Qty: 1
- Microcircuit, ACMOS, digital	Qty: 1
- Interconnections Au-Au	Qty : 22
- Ceramic, multilayer capacitor, Class S, 25V	Qty: 1
- Quartz crystal, swept, 2mW	Qty: 1
- Resistor	Qty: 1
- Interconnect jumpers	Qty: 2
- Substrate	Qty: 1

Hybrid Failure Rate = Σλp (1+0.2 πe) πf πq πl

πe =0.5; πf =1; πq=0.25; πl=1

[(1x0.000011) + (1x0.0045) + (1x0.0000079) + (1x0.0084) + (22x0.0013) + (1x0.015)] (1+0.2 x0.5) (1.0x0.25x1.0) = 0.016 Failure/10^6 hours

Hybrid QT128L11S Failure Rate = 0.016 Failure/114 years

FIT = 16

MTBF PER ACTUAL LIFE TEST:

For the same design at 5Vdc and +3.3Vdc third overtone, Q-Tech has collected over 100,000 device hours during Life test at +125°C with no failure. Using a chi-square distribution at 60% confidence level, we predict the failure rate as follows:
Number of parts tested: 100+
Part number tested: MCMs with 3rd Overtone designs
Supply voltage: **+3.3Vdc and +5Vdc**
Load: 15pF//10kohms
Number of failures: **0**
Test temperature: **+125°C**
Number of hours: **100,000+**
Device hours = **100,000 dev hrs**
Acceleration Factor (AF) = $e^{(Ea/k)*(1/T1-1/T2)}$

Where Ea=0.4eV; k=8.62E-5 eV/K;T1=298K; T2=398K
AF = 50

$$\textbf{MTBF} = \frac{\textbf{(Device hours x AF x 2)}}{\textbf{Chi Square}}$$

(with Chi square =1.833 for Zero failures at 60% Upper Confidence Level)
MTBF = **5,455,537 hours**
Failure Rate = 1/MTTF = **183.3E-9**

FITS= Failure Rate x 1E9 = 183