Reliability Calculations for SiTime Oscillators

1 Introduction

Semiconductor components are expected to perform reliably over the lifetime of the product. Choosing devices with the highest reliability ratings limits the likelihood of faulty components causing product failure in the field. SiTime provides oscillators that meet this goal, with zero field failures over 100 million units (as of May 1, 2012).

Zero field failures is impressive, but engineers want assurance that parts have been adequately tested for reliability. The key metric for gauging reliability of semiconductor components is Mean Time Between Failure, or MTBF. The higher the MTBF, the longer the expected lifetime of the device and therefore the more reliable the device. This application note describes the testing process and calculations of predicted MTBF for SiTime MEMS oscillators.

2 Accelerated testing

The predicted MTBF for semiconductor components is the inverse of the Failures In Time (FIT) rate, which is the number of failures statistically expected after one billion operating hours. It is obviously not realistic to test devices for one billion hours, so the common approach is to conduct accelerated testing at elevated temperature and voltage (burn-in) for a shorter number of hours and extrapolate.

SiTime conducts burn-in testing in a chamber set to an industry standard temperature of 125°C. However, due to heat dissipation when the part is powered up, there is typically a five degree rise in junction temperature during stress testing and during operation. This is factored into the values shown in table 1. The acceleration factor due to temperature, A_{FT}, follows an Arrhenius relationship and is calculated in reference to standard operating temperature using equation 1.

$$A_{FT} = e^{\left(\frac{E_a}{k}\right)*\left(\frac{1}{T_s}-\frac{1}{T_0}\right)} \quad (1)$$

Table 1. Parameter values for acceleration factor due to temperature

Parameter	Description	Value
E_a	Activation energy	0.7 eV
k	Boltzmann's constant	$8.63x10^{-5}$
T_o	Operating temperature	30°C or 303K
T_s	Temperature under stress	130°C or 403K

Nominal operating voltage for the tested SiTime oscillators is 3.3 volts. Stress testing is conducted at a power supply voltage to 3.6 volts, or about 10 percent above nominal voltage. The acceleration factor due to voltage, A_{FV}, is calculated using equation 2, with the parameters as specified in table 2.

$$A_{FV} = e^{\frac{(V_S - V_O)}{\gamma t_{ox}}} \quad (2)$$

Table 2. Parameter values for acceleration factor due to voltage

Parameter	Description	Value
γ	Gamma, voltage exponent factor for gate oxide	3.88
t_{ox}	Gate oxide thickness	32 Å
V_o	Operating voltage	3.3 V
V_s	Voltage under stress	3.6 V

3 Results for SiTime Oscillators

SiTime has stress tested thousands of oscillators for a cumulative test time of 2,090,352 device hours with no failures. Using statistical methods it is possible to predict the number of failures

after one billion hours with a certain degree of confidence, using equation 3, where n is the number of device hours of burn-in testing.

$$FIT_0 = \frac{\chi^2 \times 10^9}{2 \times n} \quad (3)$$

For a 90 percent confidence level of zero fails, the χ^2 statistic has a value of 4.6. Plugging into equation 3 results in a FIT_0 rate of 1101.5. It is now necessary to correct for accelerated test conditions using the acceleration factors from equations 1 and 2. The adjusted final FIT rate is given by equation 4.

$$FIT = \frac{FIT_0}{A_{FT} \times A_{FV}} \quad (4)$$

Using the values in tables 1 and 2 to calculate the acceleration factors and the FIT_0 value above, the final FIT for SiTime oscillators is:

$$FIT = 1.38 \quad (5)$$

The MTBF is the inverse of the FIT rate, expressed in billions of hours. For the FIT rate calculated above, MTBF is about 722 million hours or over 82,000 years. Rounding up to a more conservative estimate of 2 FIT, SiTime states a MTBF of 500 million hours. This greatly exceeds reported MTBF for competing semiconductor-based and quartz-based oscillators, as shown in figure 1.

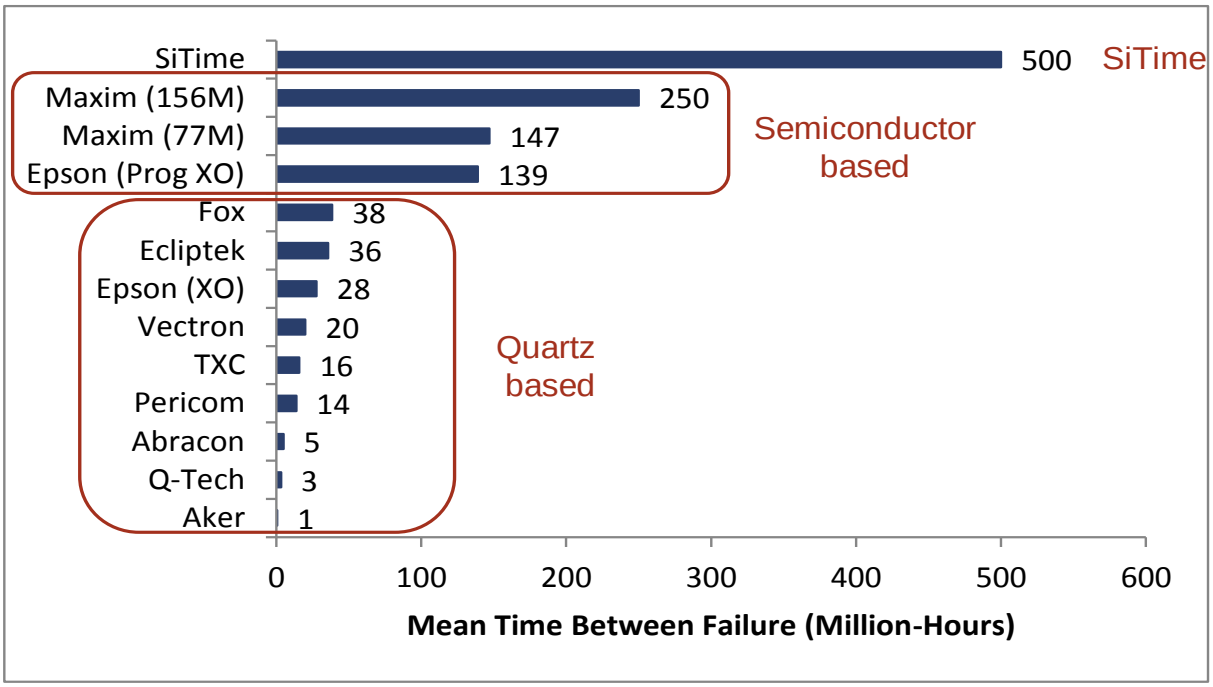

Figure 1. Reliability of quartz- and semiconductor-based oscillators in terms of MTBF

The data in figure 1 show that semiconductor-based oscillators as a class are more reliable than quartz oscillators by a factor of at least ten. Comparing SiTime to other semiconductor-based oscillators, they still greatly outperform the competition.

4 Conclusions

SiTime reliability testing demonstrates a FIT rate of less than 2, corresponding to MTBF of over 500 million hours. This is a factor of two better than the nearest MEMS competitor and 13 to 40 times better than MTBF of quartz oscillators, making SiTime MEMS oscillators the most reliable oscillators on the market.

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