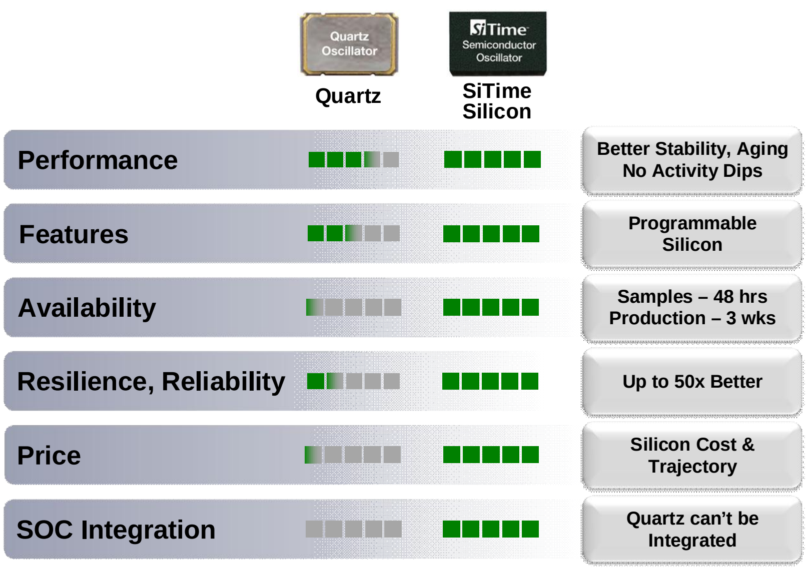
Enhance Performance and Reliability of Industrial Equipment with High-temperature, Ultra Robust MEMS Oscillators

Reference timing components (such as resonators and oscillators) are used in industrial systems to synchronize signals to the clock source. For several decades, reference timing components were based on quartz crystal technology—previously the only viable option that offered high stability and performance. However, over the past half-decade, MEMS (micro-electro mechanical systems) resonators and oscillators are revolutionizing the electronics industry by offering a feature-rich, cost-effective alternative to quartz crystal technology.

MEMS-based oscillators are fabricated in silicon, using standard semiconductor manufacturing practices. Silicon MEMS oscillators have new features and superior reliability, both which are particularly important for industrial applications, offering unique benefits as compared to quartz crystal technology.



Silicon MEMS Oscillators Offer More Features and Higher Performance

Unlike quartz oscillator companies, SiTime designs the analog circuitry for its silicon MEMS oscillators. This core competency allows SiTime to offer better performance and more features with much greater reliability compared to quartz devices. For example, SiTime's high-temperature, ultra-robust oscillators operate over the widest temperature range (-55 to +125°C) while consuming half the power of quartz oscillators. These oscillators are twice as stable, 20 times more reliable, up to 25 times more robust against shock and up to 30 times more robust against vibration compared to quartz oscillators.

SiTime oscillators are designed with a programmable architecture that allows designers to select from a wide range of specifications including any frequency within the operating range with six decimal places of accuracy. SiTime's devices operate at 1.8V or any voltage between 2.5 and 3.3V, irrespective of package size or frequency. Quartz oscillators, on the other hand, typically limit the frequency or the package size for low voltage operation. Designers can order samples and get devices within one week, or they can use a MEMS oscillator programmer in their lab to create instant samples with any frequency, stability or voltage. It is impossible for quartz products to offer this kind of flexibility.

This table shows a variety of features that are available with SiTime's MEMS oscillators.

Feature	Configuration Options with SiTime Oscillators
Customizable Frequency	kHz Clocks: 1 to 32768 kHz; MHz Clocks: 1 to 625 MHz (6 decimals of accuracy)
Frequency Stability	±0.5, ±1, ±1.5, ±2.5, ±5, ±10, ±25 or ±50 PPM
Temperature Range	-55 to +125°C, -40 to +125°C, -40 to +105°C, -40 to +85°C or -20 to +70°C
Supply Voltage	MHz LVCMOS: 1.8 to 3.3V; Differential: 2.5 to 3.3V; kHz: 1.2 to 4.5V
Output Signalling Type	Single-ended: LVCMOS or NanoDrive™; Differential: LVPECL, LVDS, HCSL or CML
Special Functions	Spread Spectrum (SSXO), Digitally Controlled (DCXO) or Serially Configured (SCXO)
Pull Range	Programmable from ±25 to ±1600 PPM in VCXO and DCXO families
Drive Strength	Programmable edge rate from 1ns to 6 ns for better EMI or driving multiple loads
Packages	MHz XOs: 2016, 2520, 3225, 5032 or 7050 industry-standard plastic packages MHz Clock Generators: SOT23-5 leaded packages for high board level reliability kHz XOs: 2012 DFN and 1508 chip-scale packages for ultra small applications

Silicon Level Reliability

Silicon is inherently more reliable than quartz, a factor that is critical in many industrial applications. Unlike quarts suppliers, SiTime has in-house MEMS and analog CMOS expertise that allows SiTime to develop more reliable products. SiTime's MEMS resonators are vacuum-sealed using an advanced Epi-Seal™ process that eliminates foreign particles and improves reliability and long-term aging (Figures 1 and 2).

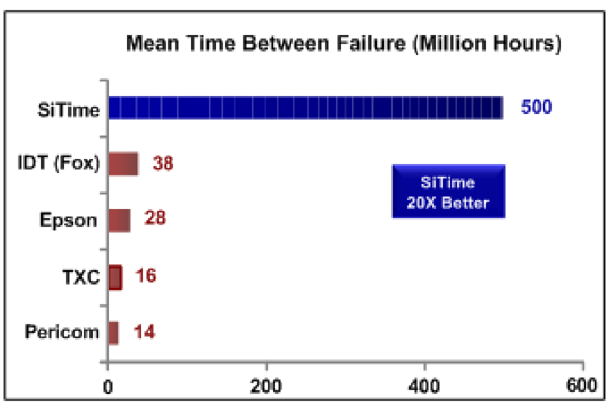


Figure 1: Reliability Comparison [1]

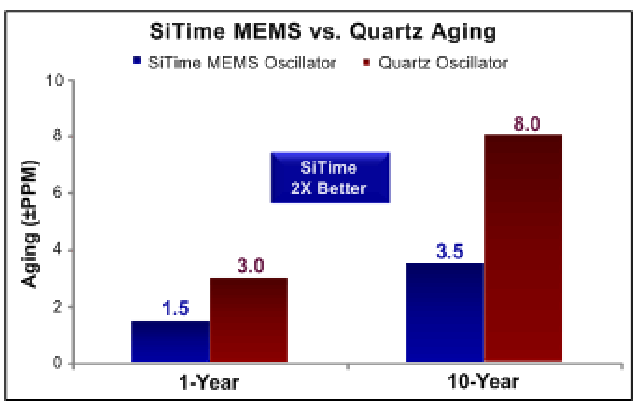


Figure 2: Aging Comparison [2]

Silicon MEMS Oscillators are More Robust than Quartz Oscillators

Industrial equipment is typically subject to higher levels of mechanical shock and vibration as well as electromagnetic sources. While operating in these harsh environments, an oscillator must conform to its specifications. If the oscillator is not reliable, it has the potential to cause catastrophic failure.

The MEMS technology that is used to build SiTime's oscillators is also used to build life-saving automotive components such as air-bag sensors and gyroscopes used in stability and traction control. Using advanced MEMS technology, SiTime has developed a proprietary resonator design that is inherently robust against shock and vibration. The very small mass and structural design of SiTime resonators make them extremely immune to external forces such as mechanical acceleration. The MEMS resonator, with a mass that is 1000 to 3000 times smaller than quartz resonators, operates like a very stiff spring. Using a single-point, center-anchored MEMS resonator, SiTime devices are specifically designed to eliminate stress error sources.

Quartz 0.4 ppb/*g* Device
9.0 x 14.0 x 6.2 mm

SiTime 0.1 ppb/*g* Device
2.0 x 1.6 x 0.75 mm

Figure 3: Quartz vs. SiTime low-G sensitivity parts

G-sensitivity, expressed in ppb/*g*, represents the change in frequency caused by an acceleration force. SiTime's high-temp oscillators deliver 0.1ppb/*g* performance in a small 2016 plastic package. Quartz devices must use large, specialized packaging to achieve low G-sensitivity performance (See Figure 3). SiTime MHz oscillators are packaged in standard plastic QFN packages that are footprint compatible with quartz devices. These packages are RoHS compliant, lead-free and are moisture sensitivity level 1 (MSL-1) rated for indefinite storage life. For industrial applications that require higher board-level solder joint reliability, SiTime offers leaded SOT23-5 packages.

SiTime devices are housed in standard plastic packaging and are highly resistant to shock and vibration. The test results below show performance under shock and vibration of a SiTime oscillator compared to SAW and 3rd overtone quartz-based oscillators. Figure 4 shows the ppb/*g* performance of various 156.25 MHz oscillators; Figure 5 shows frequency deviation when subjected to 500-*g* shock [3], [4].

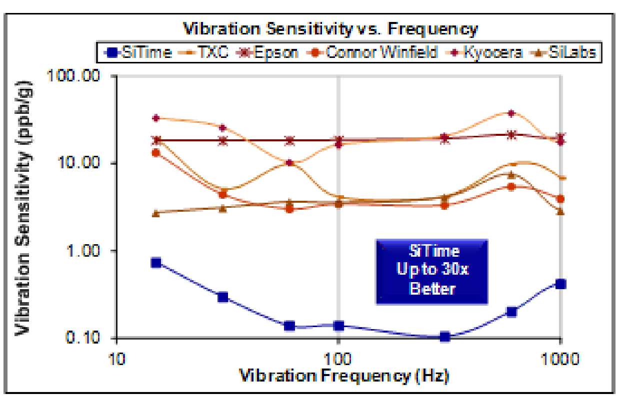


Figure 4: Vibration Robustness [3]

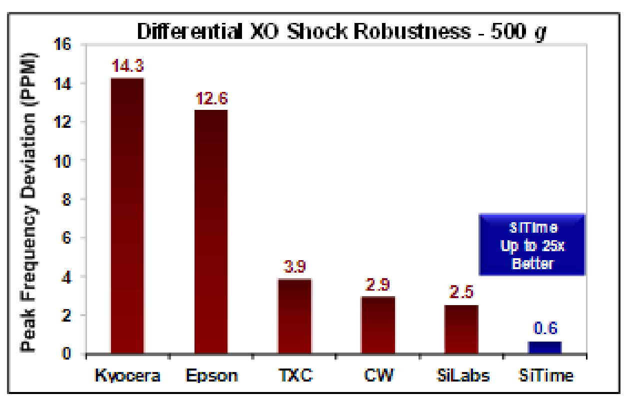


Figure 5: Shock Robustness [4]

Silicon MEMS Oscillators Demonstrate the Best Electromagnetic Performance

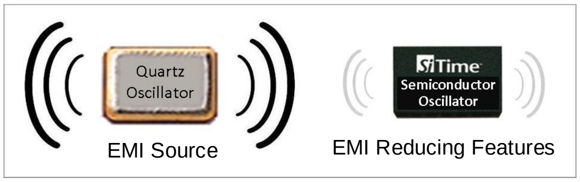


Figure 6: EM field produced by clock

SiTime oscillators improve system performance by managing EMI emitted from the clock as well as electromagnetic (EM) forces produced by external sources. As a potential source of EMI, SiTime devices have features that greatly reduce the EM energy that originates at the clock. This is especially important because industrial and medical equipment typically operate in an environment near other equipment where one device can adversely affect the operation of another. To reduce EMI issues, SiTime offers programmable high and low drive strength with SoftEdge™ rise/fall time control. SiTime also offers spread-spectrum oscillators with both center-spread and down-spread options. This feature allows the frequency to be modulated to spread the energy of the clock signal over a larger frequency range and reduce peak EMI radiation. Because SiTime oscillators are a drop-in replacement for quartz oscillators, they can be used to pass EMI tests without board changes or the use of expensive components or shielding. For more information, see the *SiTime Oscillator Rise and Fall Time Selection* Application Note [5] and *SiTime Spread Spectrum Clock Oscillator* Application Note [6].

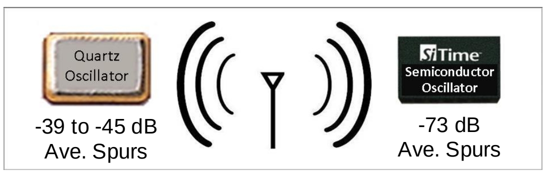


Figure 7: EM field produced by external sources

The second condition in which SiTime oscillators improve system performance is under EM fields radiated from external sources. SiTime oscillators exhibit better (lower) EMS (electromagnetic susceptibility), as shown in Figure 8. This EMS performance is due to the unique design of SiTime's oscillator IC and MEMS resonator. SiTime oscillators are also more resilient against noise on the power supply as shown in Figure 9 due to the oscillator architecture which includes on-chip regulators. The extremely small size of SiTime resonators minimizes antenna pick-up effects compared to larger quartz resonators. In addition, SiTime's MEMS resonators are electrostatically driven and are therefore inherently immune to EMI as compared to quartz devices which are driven piezoelectrically.

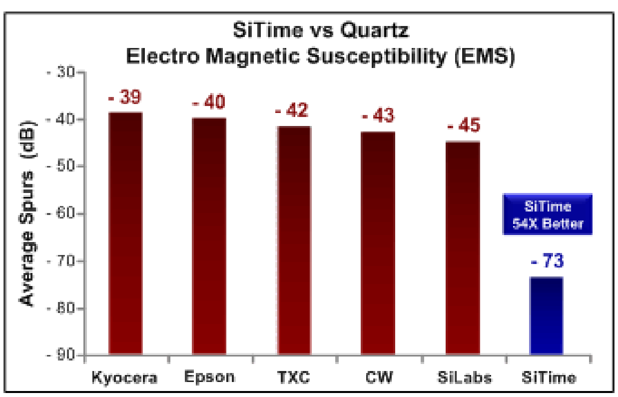


Figure 8: Electro Magnetic Susceptibility [7]

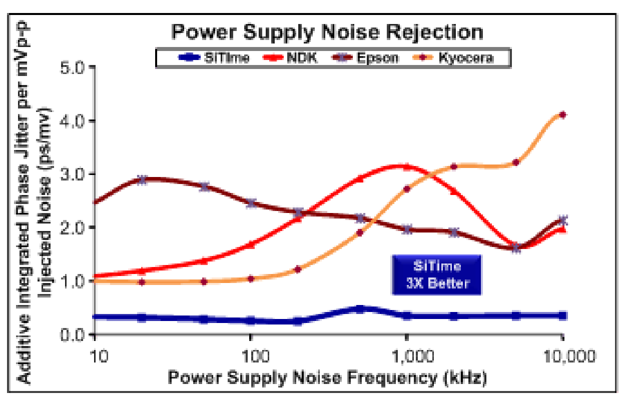


Figure 9: Power Supply Noise Rejection [8]

Conclusion

SiTime's MEMS oscillators have the capability to withstand high amounts of vibration, shock and external electromagnetic forces, while continuing to perform reliably and within specifications. The ultra-high reliability combined with the vast features and flexibility of SiTime oscillators make them the ideal choice for industrial applications.

Notes and References

[1] Data Source: Reliability documents of named companies; http://www.sitime.com/support2/documents/AN10025-SiTime-Reliability-Calculations.pdf

[2] Data source: SiTime and quartz oscillator devices datasheets: http://www.sitime.com/products/products-overview-mems-oscillators

[3] Devices used in vibration test:

- SiTime, SiT9120AC-1D2-33E156.250000 - MEMS based - 156.25 MHz
- Epson, EG-2102CA 156.2500M-PHPAL3 - SAW based - 156.25 MHz
- TXC, BB-156.250MBE-T - 3rd Overtone quartz based - 156.25 MHz
- Kyocera, KC7050T156.250P30E00 - SAW based - 156.25 MHz
- Connor Winfield (CW), P123-156.25M - 3rd overtone quartz based - 156.25 MHz
- SiLabs, Si590AB-BDG - 3rd overtone quartz based - 156.25 MHz

http://www.sitime.com/support2/documents/AN10032-Shock-Vibration-Comparison-MEMS-and-Quartz-Oscillators.pdf

[4] Test conditions for shock test:

- MIL-STD-883F Method 2002
- Condition A: half sine wave shock pulse, 500-g, 1ms
- Continuous frequency measurement in 100 µs gate time for 10 seconds

Devices used in this test: same devices listed in Note 3.

http://www.sitime.com/support2/documents/AN10032-Shock-Vibration-Comparison-MEMS-and-Quartz-Oscillators.pdf

[5] SiTime Oscillator Rise and Fall Time Selection Application Note

http://www.sitime.com/support2/documents/AN10022-rise-and-fall-time-rev1.1.pdf

[6] SiTime Spread Spectrum Clock Oscillator Application Note

http://www.sitime.com/support2/documents/AN10005-Spread-Spectrum-Oscillators.pdf

[7] Test conditions for electromagnetic susceptibility (EMS):

- According to IEC EN61000-4.3 (Electromagnetic compatibility standard)
- Field strength: 3V/m
- Radiated signal modulation: AM 1 kHz at 80% depth
- Carrier frequency scan: 80 MHz – 1 GHz in 1% steps
- Antenna polarization: Vertical
- DUT position: Center aligned to antenna

Devices used in this test: same devices listed in Note 3.

http://www.sitime.com/support2/documents/AN10031-EMS-Comparison-MEMS-and-Quartz-Oscillators.pdf

[8] 50 mV pk-pk sinusoidal voltage.

Devices used in this test:

- SiTime, SiT8208AI-33-33E-25.000000, MEMS based - 25 MHz
- NDK, NZ2523SB-25.6M - quartz based - 25.6 MHz
- Kyocera, KC2016B25M0C1GE00 - quartz based - 25 MHz
- Epson, SG-310SCF-25M0-MB3 - quartz based - 25 MHz

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