SiTime
The Smart Timing Choice™

MEMS Oscillators Improve Reliability and System Performance in Motor Control Applications

Reference timing devices such as resonators and oscillators are used in electronic motors control circuits to provide stable reference clocks. These timing devices have historically been based on quartz crystal technology – previously the only viable option. However, in recent years, silicon MEMS (micro-electro mechanical systems) timing devices are replacing quartz-based devices because of their intrinsic robustness against shock and vibration, excellent frequency stability over high temperature, programmable features, very short lead-times and low cost.

MEMS oscillators are more resilient in hostile environments

Electronic motors are used in a wide variety of applications, including equipment used in harsh environments where motors must operate in very high temperatures and high-levels of noise, vibration or shock. For reliable operation, it is important for oscillators to be extremely resilient and operate as expected in the field. Silicon MEMS resonators are inherently more robust than quartz due to their smaller size (mass) and design. Additionally, sophisticated analog design techniques in the oscillator circuitry add to the reliability and performance.

To meet motor control needs, SiTime MEMS oscillators offer the following features.

- High operating temperature up to 125°C
- Excellent frequency stability over the full temperature range – better than quartz TCXOs
- Resistant to vibration – up to 30 times better than typical quartz oscillators
- Resistant to shock – up to 25 times better than quartz oscillators
- Low electromagnetic susceptibility (EMS) – up to 54 times better than quartz oscillators
- Low sensitivity to power supply noise (PSNS) – 3 times better than quartz SAW oscillators

MEMS oscillators are more resistant to shock and vibration

Shock and vibrational forces can degrade performance and cause quartz oscillators to fail. Crystal resonators are cantilevered structures that can be very sensitive, resulting in damage to the resonator, increased phase noise and jitter from vibration, and frequency spikes from shock.

In contrast to quartz, MEMS resonators experience less vibration because they have lower mass which reduces the force applied to the resonator from the vibration-induced acceleration. SiTime MEMS resonators are stiff structures that vibrate in-plane in a bulk mode, a geometry that is inherently vibration-resistant. Additionally, SiTime's resonator structures are self-compensating. When mechanical forces cause the resonator to move in a given direction, a mechanism within the device causes a frequency shift in the opposite direction to cause a cancelling effect and minimize frequency deviation.

To simulate the performance of devices in real-world conditions, SiTime has tested oscillators with similar specifications under various conditions including sinusoidal vibration, random vibration and shock impact using standardized testing methodologies. An excerpt of the sinusoidal vibration and shock impact results follow. To read more about testing methodology and measurement results, refer to SiTime application note AN10032 *Shock and Vibration Performance Comparison of MEMS and Quartz-based Oscillators.*

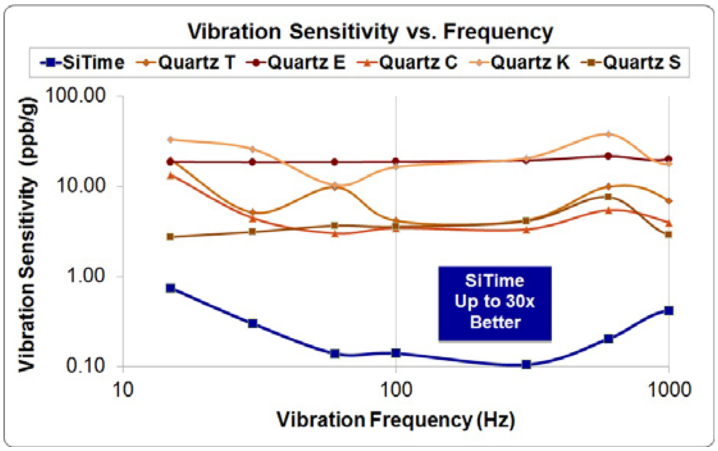

Figure 1: Oscillator sensitivity to sinusoidal vibration

Figure 1 plots noise spurs induced by sinusoidal vibration in terms of ppb/g to demonstrate the low vibration sensitivity of SiTime MEMS oscillators (lower plots/line) at different frequencies compared to quartz-based temperature-compensated oscillators (top and middle plots/lines).

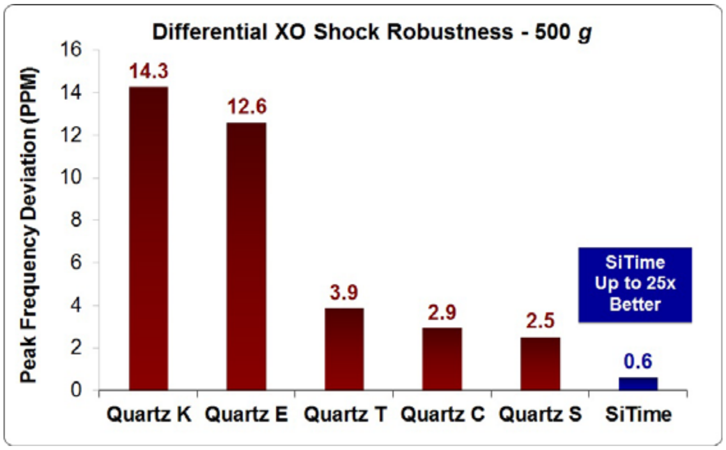

Figure 2: Oscillator sensitivity to 500-g shock

Figure 2 shows the results of mechanical shock testing on different oscillators. Some quartz devices are especially sensitive to shock and exhibit significant frequency deviation. The SiTime device results shown on the far right exhibits frequency deviation of 0.6 ppm and demonstrates that the in-plane geometry and stiffness of the resonator are effective for improving shock resistance.

MEMS oscillators are highly immune to electromagnetic forces and power supply noise

Electromagnetic susceptibility (EMS) is an important consideration in motor control design because EM energy can significantly impact oscillator performance. The switching action of electric motors can be a major source of transient disturbance (electromagnetic pulse). Power supplies and other electronic components can also emit EM energy that creates noise spurs and degrades clock signals.

MEMS oscillators with well-designed analog circuits are more immune to EM noise. The metal cover on quartz oscillator packages does not always provide adequate protection from EM forces or guarantee good EMS performance. EMS performance is more dependent on the intrinsic resonator impedance and coupling mechanism as well as the analog circuit design of the oscillator. Standard-based testing demonstrates that SiTime oscillators outperform other clock devices, as shown in Figure 3.

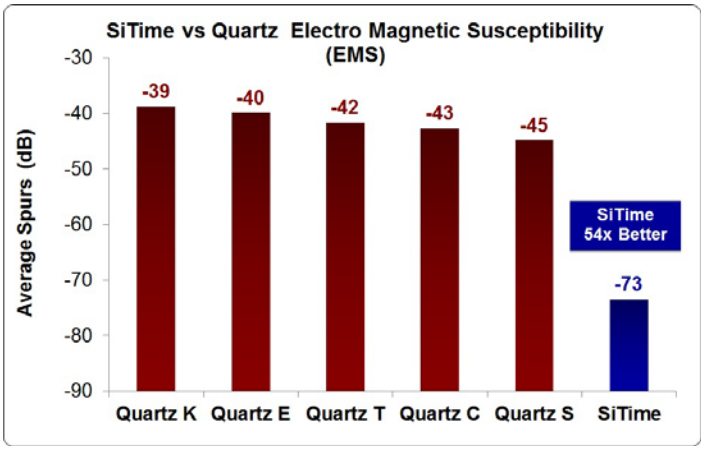

Figure 3: Average EM-induced phase noise spurs on various oscillators

In addition to external EMI, power supplies in the system can be a major source of noise that is detrimental to system performance. Power supply noise is amplified when the power supply is switched on and off. Much of this noise can be filtered out by passive filters and decoupling capacitors. However, some noise remains and board issues such as ground bounce, negatively affects clock jitter. Power supply noise sensitivity (PSNS) is a parameter used in the design of analog circuits and it provides an indication of how robust a circuit is to noise from the power supply. Test results show that SiTime's PSNS is much better than quartz devices, including quartz surface acoustic wave (SAW) oscillators that are designed to meet high frequency, low jitter requirements.

Figure 4 shows integrated phase jitter as a function of power supply switching noise frequency for 50 mV of peak-peak power supply noise, comparing results for a SAW oscillator with a SiTime MEMS oscillator. As the plot indicates, SiTime's MEMS oscillator jitter is lower at nearly all noise frequencies. Unlike typical quartz oscillator companies, SiTime designs the analog circuits for its MEMS oscillators. SiTime devices use advanced analog design techniques including PSNS circuitry to protect the oscillator from power supply-induced jitter.

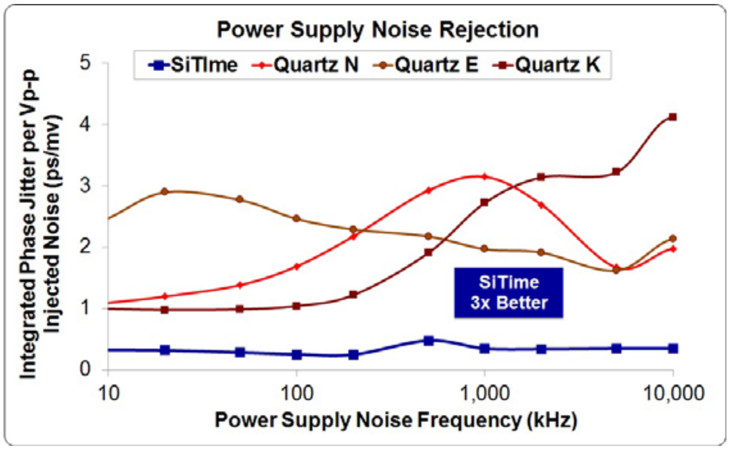

Figure 4: Phase jitter in the presence of 50 mV peak-to-peak power supply noise for SiTime MEMS (lower line) and SAW oscillator (top line) as a function of power supply switching noise frequency

For more details on testing methodology and results of EM-induced phase noise and power supply induced phase jitter, see SiTime application note AN1003 *Electromagnetic Susceptibility Comparison of MEMS and Quartz-based Oscillators.*

MEMS oscillators have a wide temperature range with excellent stability

MEMS oscillators offer reliable operation over a wide temperature range up to 125°C. Unlike quartz oscillator companies, SiTime designs the analog circuitry for its oscillators. The analog circuitry of SiTime oscillators results in excellent frequency stability over temperature.

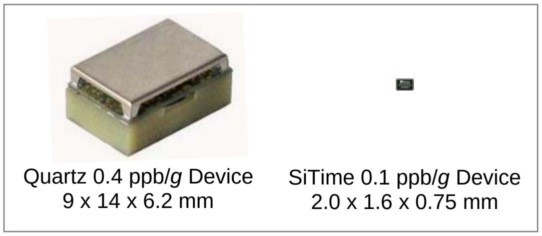

Figure 5: Quartz vs. SiTime low-G sensitivity parts

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 tiny 2016 plastic package. Quartz devices must use large, specialized packaging to achieve low G-sensitivity performance (Figure 5).

MEMS oscillators offer more features to meet application needs

SiTime offers more features and better availability compared to quartz devices. Designers can select from several features as shown in Table 1 below to customize MEMS oscillators and match motor control requirements. For example, a system designer can specify any package combined with any frequency, stability ppm and supply voltage within the wide operating range, and receive the devices within one week. SiTime devices have special features such as programmable drive strength to control rise and fall time. This feature allows designers to change the output edge rate which can reduce EMI issues within the system. SiTime also offers spread-spectrum oscillators with center-spread and down-spread options. With this feature the frequency is modulated to ensure the energy of the clock signal is spread over a larger frequency range to lower peak EMI radiation and further reduce EMI issues.

Table 1: Wide range of configurable features in SiTime Oscillators

Feature	Configuration Options with SiTime Oscillators
Customizable Frequency	Differential XOs: 1 to 625 MHz; Single-ended XOs: 1 to 220 MHz (6 decimals of accuracy)
Frequency Stability	±1.5, ±2.5, ±5, ±10, ±25 or ±50 PPM
Temperature Range	High Temp (-55 to +125°C and -40 to +125°C), Ext. Industrial (-40 to +105°C), Industrial (-40 to +85°C) or Ext. Commercial (-20 to +70°C)
Supply Voltage	1.8V (CMOS), 2.5V, 2.8V or 3.3V (customizable between 2.5 to 3.3V)
Output Signalling Options	Differential XOs: LVPECL or LVDS; Single-ended XOs: CMOS or LVTTL
Special Functions	Spread spectrum capability (SSXO) and digital control (DCXO)
Pull Range	Programmable from ±25 to ±1600 PPM with 0.1% linearity in VCXO/TCXO/DCXO families
Drive Strength	Programmable high (1ns) or low (6ns) drive strength settings
Packages (mm)	2016, 2520, 3225, 5032 or 7050 industry standard plastic packages

MEMS oscillator are programmable

The wide range of SiTime oscillator features can be programmed by system designers in the lab using field programmable oscillators and the Time Machine II™, a low-cost MEMS oscillator programmer from SiTime. The small and durable programmer, which is compatible with all PCs and Microsoft Windows®, can quickly configure oscillators and create instant samples. Since SiTime oscillators are footprint compatible with quartz packages, they can easily replace quartz devices.

Summary

Industrial motor controlled equipment is often subjected to a variety of operating environments from extreme temperatures to high levels of vibration and power supply induced noise. In the presence of these harsh conditions, a reference oscillator must conform to its specifications and not fail due to mechanical or electrical damage. If the oscillator is not resilient, it has the potential to cause catastrophic failure.

Silicon MEMS oscillators are much more robust than quartz crystal oscillators. Test data demonstrate that SiTime's MEMS oscillators outperform quartz-based oscillators when subjected to vibration, mechanical shock and EMI. In addition, SiTime oscillators offer more features and supply chain advantages. The programmability of these oscillators provides design flexibility and fast lead times – a combination that quartz manufacturers cannot provide. SiTime oscillators are therefore an excellent choice for motor control applications.

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