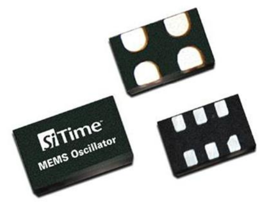
Field Programmable Timing Solutions for Medical Applications

Improve Performance and Reliability with Flexible, Ultra Robust MEMS Oscillators

Reference timing components, such as resonators and oscillators, are used in electronic medical devices to synchronize all signals to a clock source. In a sense, they provide the heart beat of the system. Traditional timing components are based on quartz crystals which are inherently inflexible compared to newer MEMS (micro-electro mechanical systems) timing components. Flexible and feature-rich MEMS-based timing products are rapidly replacing quartz because of the benefits they offer including higher reliability and robustness, smaller size, lower power and lower cost.

Advantages of MEMS-based timing solutions:



- **Flexibility** – programmable architecture, always-in-stock field programmable devices, short production lead-time
- **Feature-rich** – special functions and features such as spread spectrum and programmable drive strength for EMI reduction
- **Robust and reliable** – 20x more reliable, 54x more immune to EMI, up to 30x more robust against vibration and up to 25x more robust against shock
- **Small form factor** – available in a wide range of industry standard packages, including small 2016 packages, that are pin-compatible with quartz for easy drop-in replacement
- **Low power** – low power consumption and other power saving features for portable devices
- **Low cost of ownership** – lower price with silicon cost trajectory, greater long-term savings

The adoption of MEMS timing is increasingly important in the medical industry because of the special requirements (e.g., electromagnetic compatibility) and the diversity of electronic medical devices. These applications, ranging from diagnostic and monitoring instrumentation to therapeutic equipment, tend to be highly specific and often complex, and they demand flexible robust solutions.

Field programmable architecture

As evidenced through the growing use of FPGAs in medical applications, customization and field programmability are critical to meeting the design needs of the diverse medical electronics industry. In addition to meeting specific design requirements, programmable solutions accelerate all phases of the design and test cycle. Programmable timing components offer similar benefits. In contrast to quartz oscillators, which are available only in select frequencies, voltages and stability specifications, MEMS-based oscillators are designed with a programmable architecture that enables any combination of these specifications.

MEMS oscillators are comprised of a MEMS resonator die packaged together with an analog oscillator IC. There different types of MEMS resonators for different application needs as shown on the left side of Figure 1. MEMS resonators are connected to the MEMS-specific circuit blocks on the analog IC and are driven through electrostatic excitation.

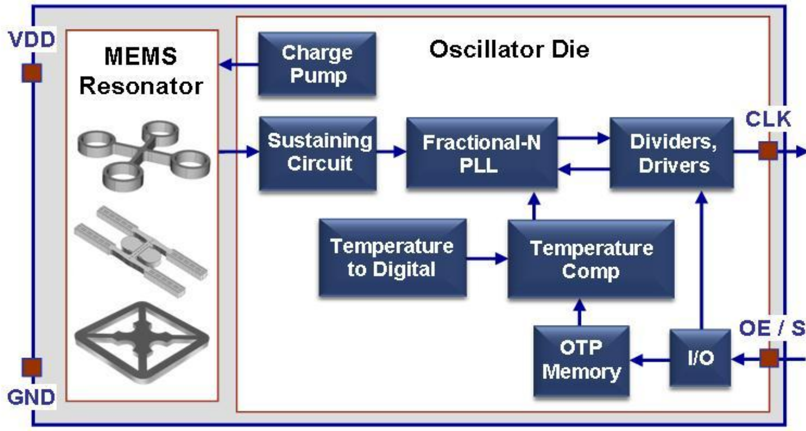


Figure 1: Programmable architecture of SiTime's MEMS-based oscillators

The output frequency is configured and generated through use of a fractional-N PPL (phase locked loop) that is located on the analog oscillator die. Frequency ranges from 1 Hz to 650 MHz with 6 decimals of accuracy. Output drivers enable configurable drive strength. On-chip one time programmable (OTP) memory is used to store the programmed parameters.

Field programmable timing solutions

Field programmable (FP) oscillators, such as those available from SiTime, allow for fast prototyping and real-time customization of features. FP oscillators are available in a wide range of industry standard package sizes and can be configured to exact specifications using a MEMS oscillator programmer. See tables below for available options (partial list).

Field Programmable Oscillators

Product Family	Package Size (mm x mm)	Frequency Range (MHz)	Freq. Stability (ppm)	Temp. Range (ºC)	Voltage (V)
SiT8008 Low power single-ended XO	2.0x1.6, 2.5x2.0, 3.2x2.5, 5.0x3.2, 7.0x5.0	1 to 110	±20, ±25, ±50	-40 to +85, -20 to +70	1.8, 2.5 to 3.3
SiT8208/9 Ultra performance single-ended XO	2.5x2.0, 3.2x2.5, 5.0x3.2, 7.0x5.0	1 to 200			
SiT9121 High performance differential XO	5.0x3.2, 7.0x5.0	1 to 220			2.5 to 3.3

Field Programmable Voltage-Controlled Oscillators (VCXO)

With programmable pull range from ±25 to ±1600 ppm and <1% pull-range linearity

Product Family	Package Size (mm x mm)	Frequency Range (MHz)	Freq. Stability (PPM)	Temp. Range (ºC)	Voltage (V)
SiT3808/9 High performance single-ended VCXOs	2.5x2.0, 3.2x2.5, 5.0x3.2, 7.0x5.0	1 to 220	±25, ±50	-40 to +85, -20 to +70	1.8, 2.5 to 3.3
SiT3821/2 High performance differential VCXOs	5.0x3.2, 7.0x5.0	1 to 625			2.5 to 3.3

Field Programmable Spread Spectrum Oscillators (SSXO)

With center spread range from ±0.25% to ±2% and down spread range from -0.5% to -4%

Product Family	Package Size (mm x mm)	Frequency Range (MHz)	Freq. Stability (PPM)	Temp. Range (ºC)	Voltage (V)
SiT9001/3 Spread spectrum single-ended XO	2.5x2.0, 3.2x2.5, 5.0x3.2, 7.0x5.0	1 to 110	±50, ±100	-40 to +85, -20 to +70	1.8, 2.5, 3.3
SiT9002 Spread spectrum differential XO	5.0x3.2, 7.0x5.0	1 to 220			

Through use of the programmer and FP devices, designers can instantly program any frequency, stability and supply voltage within the operating range of the device. The output drive strength can also be configured. In addition, pull range can be programmed from ±25 to ±1600 ppm in VCXO devices. With customized frequencies and features, these programmable solutions can optimize system design while also significantly reducing design and development time.

MEMS oscillator programmer

The Time Machine II™ is a low-cost MEMS oscillator programmer from SiTime. The small and durable programmer is very portable for use in the lab or at the designer's desk. The programmer, which is compatible with all PCs and Microsoft Windows®, connects to the PC through a USB cable that also powers it.

To program devices, FP oscillators are inserted into a socket card. The desired configuration is specified by either entering a part number or using the built-in part number generator (see Figure 2). Next, the user clicks *Program* and the part is programmed in less than five seconds.

The programmer kit is housed in a DVD-sized carrying case and includes a base programmer, socket cards, sample packs containing FP oscillators, software and all accessories required to program devices.

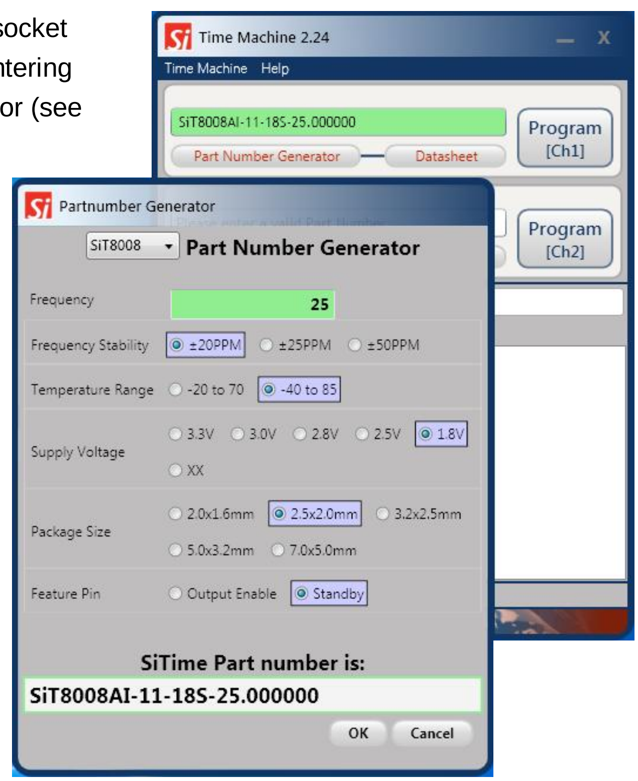


Figure 2: Time Machine II interface and part number generator enable quick and easy programming of multiple specifications

Programmable drive strength reduces electromagnetic problems

Electromagnetic compatibility (EMC) is a major concern in medical electronics since electromagnetic interference (EMI) can cause medical devices to malfunction with serious consequences. Compliance with EMC standards such as IEC 60601-1-2 is mandatory in most of the world. This standard focuses mainly on EMI immunity to external EMI but it also addresses EM emission from within the equipment. Both types of EM issues (emissions and immunity) can be reduced with the use of MEMS oscillators.

Clocks are a major source (emitter) of continuous EMI noise. The frequency spectrum of square-wave clocks consists of a fundamental tone as well as a collection of higher harmonics. Shielding and filtering are common techniques used to minimize the effects of EMI, but this consumes board space, adds cost and complexity, and with some medical equipment it may not be possible to protect the entire system. Reducing the level of energy emanating from the clock is an effective technique for reducing interference. This can be achieved by using SiTime's spread spectrum oscillators or by using the programmable drive strength feature available with all SiTime oscillators.

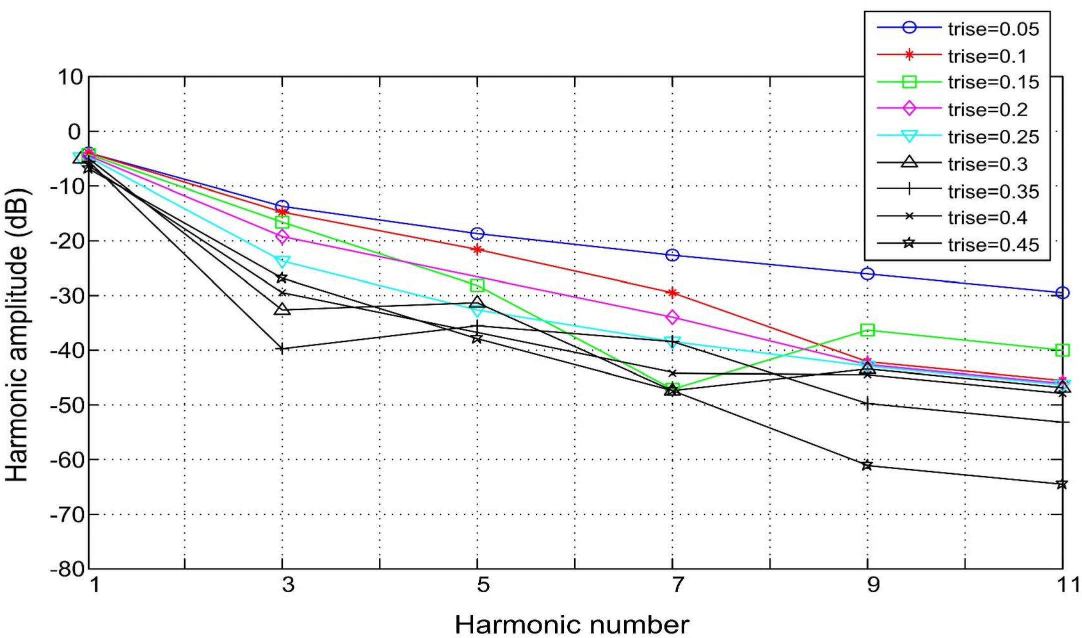


Figure 3: Harmonic EMI reduction as a function of slower rise/fall time

Programmable drive strength provides a simple method for optimizing the clock rise/fall time for specific applications, including the ability to improve system radiated EMI by slowing down the rise/fall time. Figure 3 shows the harmonic power reduction as the rise/fall times are increased (slowed down). The rise/fall times are expressed as a ratio of the clock period. For the ratio of 0.05, the signal is very close to a square wave. For the ratio of 0.45, the rise/fall times are very close to near-triangular waveform. These results, for example, show that the 11th clock harmonic can be reduced by 35 dB if the rise/fall edge is increased from 5% of the period to 45% of the period.

SiTime's spread-spectrum oscillators (see table on page 3) are another option for reducing EMI. These oscillators have configurable spread options with center spread percentages (modulation limits) of ±0.25%, ±0.5%, ±1.0% or ±2.0% and down spread percentages of -0.5%, -1.0%, -2.0% or -4.0%. By modulating the clock's frequency slowly over time, the peak spectral energy in both the fundamental and harmonic frequencies is reduced.

SiTime's oscillators use industry standard packaging that is footprint compatible to quartz oscillators. As drop-in replacements for quartz products, SiTime oscillators can easily be used if EMC problems arise late in the design cycle. They can help pass environmental tests without any board changes or use of additional expensive components. For more information, see the *SiTime Oscillator Rise and Fall Time Selection* Application Note [1] and *SiTime Spread Spectrum Clock Oscillator* Application Note [2]. http://www.sitime.com/support/application-notes

Robust and reliable timing solutions

As medical technologies advance and the diversity of applications grows, the environments in which medical devices are used become more varied. Whether in a clinical environment with an increase in electronic equipment and wireless communications, or in the field with the growing use of portable and home healthcare equipment, medical devices must be reliable and able to withstand a wide range of operating conditions. The higher reliability and robustness of MEMS oscillators lends an important advantage over quartz products. SiTime's MEMS timing devices have silicon-level reliability, better robustness against mechanical shock and vibration, and better immunity to EMI.

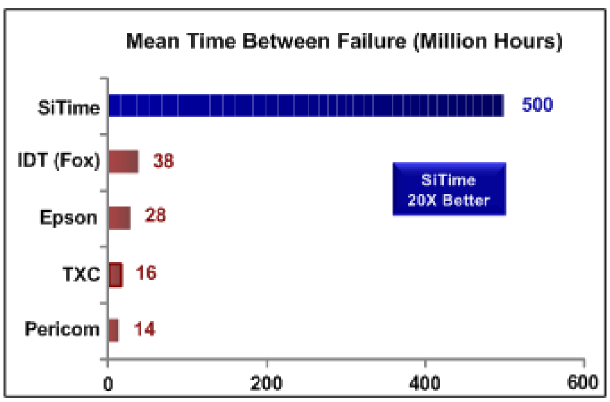


Figure 4: Reliability Comparison [3]

Silicon is inherently more reliable than quartz as shown in Figure 4. SiTime's MEMS resonators are vacuum-sealed using an advanced Epi-Seal™ process that eliminates foreign particles and improves reliability.

SiTime oscillators are highly immune to EMI and power supply noise, and therefore, they are well suited for medical devices that operate near other equipment, power supplies or other sources of electro-magnetic energy. As shown in Figure 5, SiTime oscillators exhibit the best (lowest) EMS (electromagnetic susceptibility). This is due to the unique oscillator design and MEMS resonator structure. The differential architecture and on-chip regulators also make SiTime oscillators more resilient against noise on the power supply as shown in Figure 6. 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.

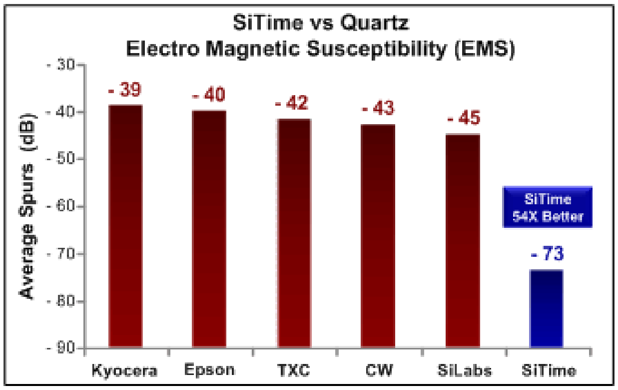


Figure 5: Electro Magnetic Susceptibility [4]

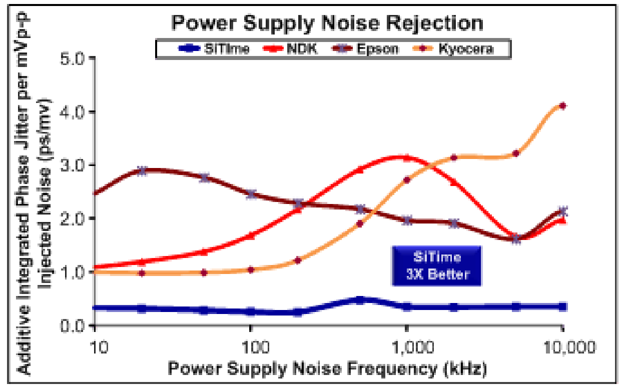


Figure 6: Power Supply Noise Rejection [5]

SiTime's MEMS resonator designs are inherently robust against shock and vibration. The very small mass and structural design of the resonators make them extremely immune to external forces such as mechanical acceleration. Figure 7 shows the ppb/*g* performance of various oscillators and Figure 8 shows frequency deviation when subjected to 500-*g* shock. A SiTime oscillator (SiT9120) demonstrates the best performance in both shock and vibration tests as compared to SAW and 3rd overtone quartz-based oscillators.

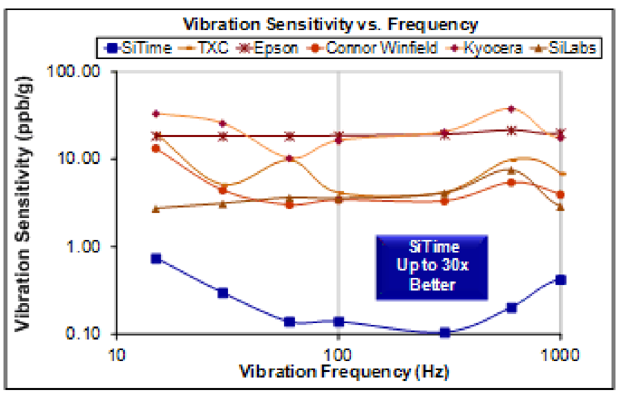


Figure 7: Vibration Robustness [6]

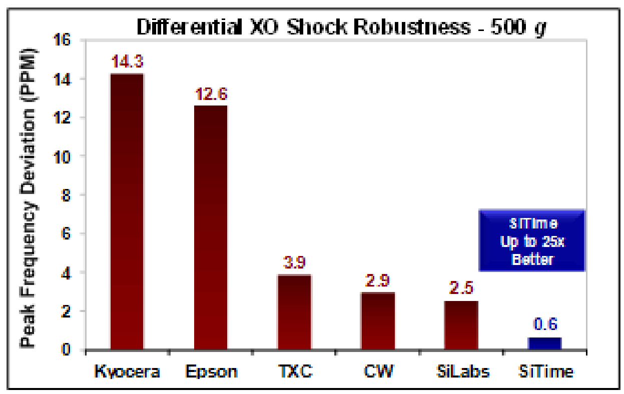


Figure 8: Shock Robustness [7]

Conclusion

Trends in healthcare industry have created a demand for a wide range of affordable and reliable medical devices that improve the diagnosis and treatment of patients. Medical device designers and manufacturers require flexible and robust, feature-rich components to meet today's design challenges. Field programmable MEMS oscillators from SiTime are the ideal choice for medical designs—they offer higher reliability, better resilience against shock, vibration and EMI, smaller size, lower power and lower cost. Samples are immediately available in any specification with the Time Machine II programmer and production volumes have very short lead-times. As a drop-in replacement for quartz oscillators, SiTime's MEMS oscillators are rapidly replacing legacy quartz.

Notes and References

[1] SiTime Oscillator Rise and Fall Time Selection Application Note
http://www.sitime.com/support2/documents/AN10022-rise-and-fall-time-rev1.1.pdf

[2] SiTime Spread Spectrum Clock Oscillator Application Note
http://www.sitime.com/support2/documents/AN10005-Spread-Spectrum-Oscillators.pdf

[3] Data Source: Reliability documents of named companies

[4] 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:

- 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

[5] 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

[6] Devices used in this test: same devices listed in Note 4

[7] 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 4

Additional data on test methodology and results is available upon request to qualified customers.
Please contact productsupport@sitime.com

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