SiTime
The Smart Timing Choice™

How to Improve Tablet PCs and Other Portable Devices with MEMS Timing Technology

The tremendous success of tablets and smart phones such as the iPAD, iPHONE and Android-based devices presents both challenges and opportunities for the growing number of portable device makers. This market is highly competitive, and to capture the attention of consumers and grow market share, portable device makers must push the envelope with constant innovation. Designers and manufacturers are under extreme pressure to be first-to-market with a differentiated product. As they are improving product design and aesthetics, they are under additional pressure to lower costs. The competitiveness of this market poses a number of significant challenges to designers and supply chain managers alike:

- The quest for thinner and smaller form factors requires components that can continue to be reduced in size.
- The success of feature-rich portable devices is dependent on components that can deliver the performance and feature set required to keep up with user demand.
- Portable devices must contain reliable and robust components that can sustain operation through changes in temperature as well as the shock and vibration conditions experienced by hand-held products.
- Portable product life cycles are becoming shorter and time-to-market of new designs is critical to ensure the success of the device; therefore, components need to be flexible to accommodate design changes and issues.
- The demand for such devices is highly seasonal and faces constant fluctuation; therefore, component availability is critical to minimize the risk of shortages and reduce inventory overhead while meeting the shifting demand of the market place.

An Introduction to All-Silicon MEMS Oscillators

Oscillators, resonators and clock generators are used as a clock or timing reference source. These devices provide important frequency control and can be thought of as the heart of the system. A typical electronic system uses three to five timing devices, and that number is growing as system complexity increases

Until recently, the timing market has been primarily dominated by quartz crystal-based devices. However, many portable device manufacturers have increasingly adopted MEMS-based timing devices to address the challenges of this rapidly changing market. A MEMS oscillator is one of several types of MEMS timing devices – including resonators, oscillators, and clock generators – that can be used as a clock or reference source.

The transition from quartz-based devices has been accelerated by supply chain issues along with the intrinsic technological limitations of quartz. Quartz devices have reached the limits of performance improvement and cost reduction. Consequently, they can no longer meet the demands of system vendors.

A typical MEMS oscillator is an all-silicon device, comprising a MEMS resonator die stacked on top of a high-performance analog CMOS oscillator IC, as shown in Figure 1.

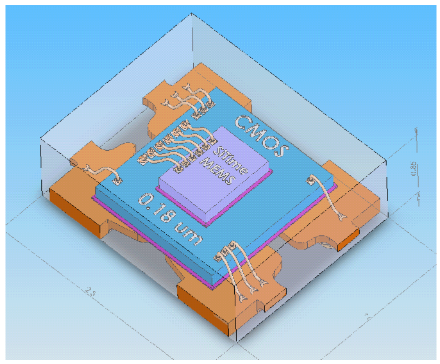

Figure 1: A Typical Silicon MEMS Oscillator Contains a MEMS Resonator Die Stacked on an Analog CMOS Oscillator IC

The two stacked die are together molded into a single Quad Flat No-lead (QFN) plastic package. Contact shapes match the position of a standard quartz oscillator package. The MEMS oscillators can thus be 100% pin compatible with quartz devices and soldered on boards designed for quartz parts without the need for modifying or redesigning the PCB.

In contrast to quartz oscillators, which are available in only selected frequencies, voltages and stability specifications, MEMS oscillators are based on a highly programmable platform that enables any combination of these specifications. This programmability allows MEMS oscillators to be customized to the portable device manufacturer's exact specifications. System designers can choose the optimal oscillator specifications for optimal system performance without having to sacrifice lead times, and while improving quality and reliability.

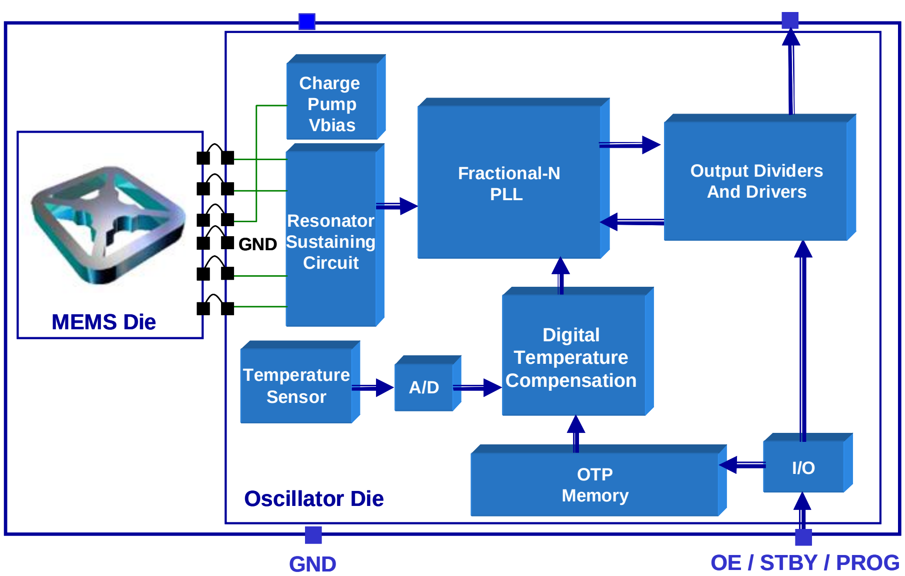

Figure 2: MEMS Oscillator Block Diagram

By leveraging the massive semiconductor manufacturing and packaging infrastructure, MEMS timing device suppliers have continued to rapidly innovate. MEMS devices now support the performance, features and reliability required for leading-edge feature-rich devices, such as:

- <1ps integrated RMS (root mean square) phase jitter that meets the requirements of applications such as 3G wireless,
- ±0.1 PPM in frequency stability over commercial temperature range (0 to 70°C),
- Low power consumption (2.5 μA in standby, 3.5 mA in active mode),
- Outstanding silicon reliability of 500 Million hours MTBF (10 times better than quartz),
- 50,000 *g* shock and 70 *g* vibration resistance (10 times better than quartz),
- Customizable frequencies of up to 800 MHz with six decimal places of accuracy to support any wireless/communications protocol.

MEMS timing devices now cover almost the entire range of oscillator product types, including single ended oscillators with LVCMOS-compatible output, differential oscillators, low-power oscillators, voltage-controlled oscillators (VCXO), voltage-controlled temperature-compensated oscillators (VCTCXO), and spread-spectrum oscillators.

This broad MEMS timing product portfolio enables MEMS timing suppliers to serve as the one-stop-shop for all timing needs for portable device developers and manufacturers. As an example, a typical tablet design, depending on the choice of the applications processor and other functions it supports, can contain several low-voltage, single-ended oscillators with LVCMOS-compatible output. These functions can be supported by SiT8003 low-power and SiT8208 low-jitter oscillators from SiTime.

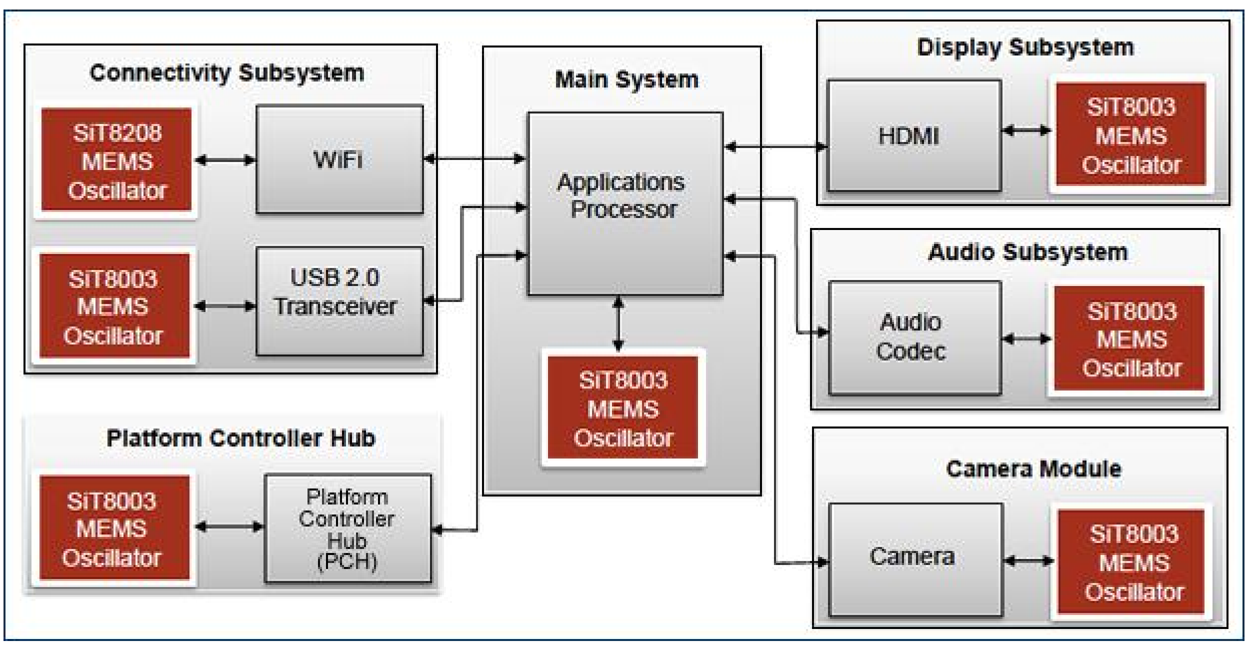

Figure 3: MEMS Oscillators in Tablet PC Designs

MEMS Oscillator Solutions for Tablet PCs

Application	SiTime Oscillator	Key Features*
Application Processor	SiT8003AC-12-18S-26.00000	26 MHz, ±25 PPM, 1.8V, 2.5 μA standby current, 2.5 x 2.0 mm package
WiFi	SiT8208AC-21-25S-40.000000	40 MHz, ±20 PPM, 2.5V, 3.2 x 2.5 mm package
USB 2.0	SiT8003AC-12-18S-26.00000	26 MHz, ±25 PPM, 1.8V, 2.5 μA standby current, 2.5 x 2.0 mm package
Platform Controller Hub	SiT8003AC-13-33S-14.31800	14.318 MHz, ±50 PPM, 3.3V, 2.5 μA standby current, 2.5 x 2.0 mm package
HDMI	SiT8003AC-13-33S-22.57920	22.5792 MHz, ±50 PPM, 3.3V, 2.5 μA standby current, 2.5 x 2.0 mm package
Audio Codec	SiT8003AC-13-33S-24.57600	24.576 MHz, ±50 PPM, 3.3V, 2.5 μA standby current, 2.5 x 2.0 mm package
Camera Module	SiT8003AC-13-33S-27.00000	27 MHz, ±50 PPM, 3.3V, 2.5 μA standby current, 2.5 x 2.0 mm package

*SiT8003 products also offer the following options for customization

- Any frequency between 1 and 110 MHz with 5 decimal places of accuracy
- Operation at 1.8V, 2.5V, 2.8V or 3.3V, configurable.
- 2520, 3225, 5032 and 7050 packages
- Configurable Rise and Fall times (Drive Strength) for EMI reduction
- Configurable Output Load Control

Configurable Feature Sets of MEMS Oscillators Ensure the Fastest Time-to-Market

Because MEMS oscillators are typically programmable, system designers can quickly customize oscillator specifications to their exact needs and resolve design issues to get products to market quickly. Eliminating in-system EMI issues with the configurable control of the MEMS oscillator's rise/fall times is an example of the benefits of programmability.

A portable device such as a tablet typically comprises a wireless subsystem and a few other analog and digital subsystems. Often, when the PCB is not laid out optimally for EMI compliance, the harmonics that are produced by the oscillator devices in the digital subsystem can be a major source of undesirable EMI and cause significant functional issues for the RF transmitter and receiver in the wireless subsystem. This degradation in RF performance can lead to reduced data throughput over the wireless link and, in the worst case, will lead to complete loss of wireless connectivity.

Traditionally, designers can eliminate clock EMI by either redesigning the system board or by adding metal shielding, both of which can be expensive and lead to product launch delays. By using a programmable MEMS oscillator, designers can potentially resolve the EMI issue completely by simply adjusting the clock's rise and fall times.

Tablets typically use single-ended oscillators. EMI energy for such devices is usually concentrated at the clock frequency and its harmonics. Reducing rise/fall times for single-ended clock signals is an effective method for reducing EMI harmonics without increasing power consumption or adding more components such as expensive shielding devices.

Figure 4 shows the clock waveform for three different rise and fall times. Figure 5 shows the amplitude of clock harmonics as a function of rise/fall time (rise and fall times are assumed to be the same). All the rise times are selected to maintain the peak-to-peak clock signal at its maximum value.

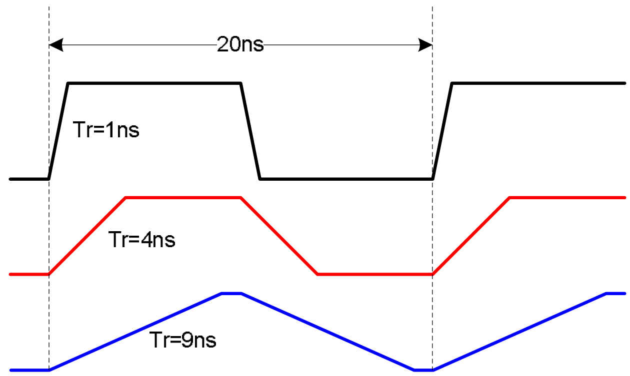

Figure 4: 50MHz Clock Waveform for Three Different Rise and Fall Times

As figure 5 shows, most harmonics can be reduced by >20 dB while maintaining peak-to-peak clock swing. This harmonic reduction as a result of rise/fall time adjustment can eliminate EMI interference with the wireless subsystem in portable devices.

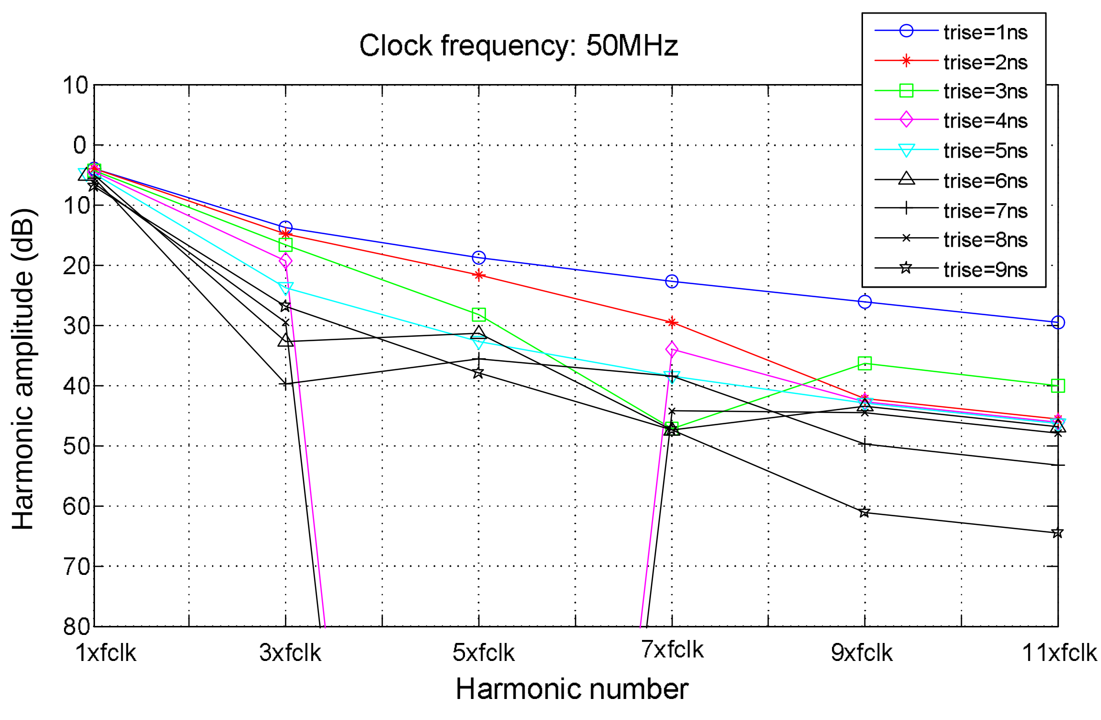

Figure 5: The Harmonic Amplitude of Clock Signals Decreases as the Rise/Fall Time Slows Down

In contrast, quartz oscillators cannot be programmed to provide slower rise/fall times. This lack of flexibility in fixed frequency quartz devices is intrinsic to the technical limitations imposed by quartz and requires design engineers to find other more expensive and time-consuming solutions for EMI issues.

Thinner, More Esthetic Portable Devices

The trend towards super-thin feature-rich portable devices such as tablets and smart phones requires component vendors to continue reducing the size and height of their components.

The reduction of height represents a particularly difficult challenge to quartz oscillator suppliers, as a certain amount of quartz thickness is required for the quartz device to oscillate at a specific frequency. Typically, the lower the frequency, the thicker the quartz must be cut. Yet many device makers use low frequency devices for the lowest possible cost timing components.

Typical Thicknesses of Different Oscillators

Quartz Oscillator	Typical MEMS Oscillator	SiTime SiT8003XT
1.4 mm	0.75 mm	0.25 mm

MEMS oscillators are typically twice as thin as legacy quartz oscillators. However, they can be made even thinner by placing the MEMS resonator alongside the high-performance analog CMOS oscillator IC instead of stacking them on top of each other. In this way, oscillators as thin as 0.25 mm in height have been achieved (see Figure 6).

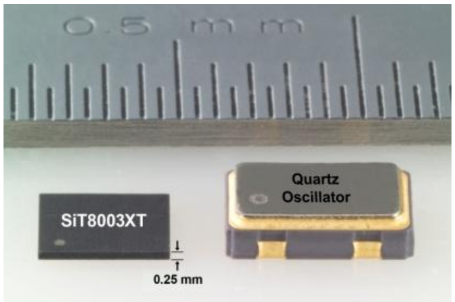

Figure 6: A Super-Thin, 0.25 mm MEMS Oscillator Compared to a Quartz Oscillator

This extremely thin device removes the height constraint on clocking devices and enables the realization of a variety of super-thin end products such as wireless dongles and RF payment cards that can be used as add-on cards for portable devices

Shortest Lead Times, Better Inventory Management

While designers are mostly focused on the performance and the feature sets of components, supply chain managers are more concerned with the availability of components that can directly impact the revenue and the cost of their products.

Demand for portable devices can fluctuate to reflect shifting consumer preferences as well as macro-economic conditions. Supply chain managers must ensure a sufficient component inventory to meet potential demand spikes. However they must also minimize the cost of inventory overhead that can directly impact company profitability.

This dilemma can be illustrated by examining the sourcing of legacy quartz oscillators, typically produced in only a few standard frequencies and sold under only a few standard part numbers. These characteristics limit quartz oscillator suppliers to stocking only inventories of standard devices and using a "build-to-order" model for devices with non-standard configurations. Because quartz suppliers use a captive downstream supply chain containing only a few makers of the key components required for oscillators, quartz oscillator lead times can be greatly affected by the availability of key materials. Consequently, quartz oscillator suppliers typically provide 6- to 8-week lead times for standard parts and stretch the lead time to 8 to 16 weeks for non-standard items when the channel contains no existing inventories.

These long lead times pose significant challenges to portable electronics manufacturers facing ongoing demand fluctuation. This can create either a shortage of quartz timing components or large inventories of unusable quartz oscillators. Both situations impact revenue and increase overall costs. Proper planning of inventory levels to minimize inventory overhead, reduce cost and maintain the ability to service demand spikes represents an ongoing struggle for many supply chain managers in the tablet business.

In contrast, MEMS oscillators leverage a semiconductor supply chain and production flow, illustrated in figure 7, which can significantly reduce timing device lead times. In this flow, MEMS oscillator suppliers can shorten production cycle time by placing a significant inventory in "die banks" with additional inventory in the form of blank parts. Because these devices can be programmed at the final stage to any combination of specifications, there is lower risk of dead inventory. Suppliers can adjust their production plans based on actual customer purchase orders, and reduce lead times down to 2 weeks or less, irrespective of frequency, voltage, stability and package specifications.

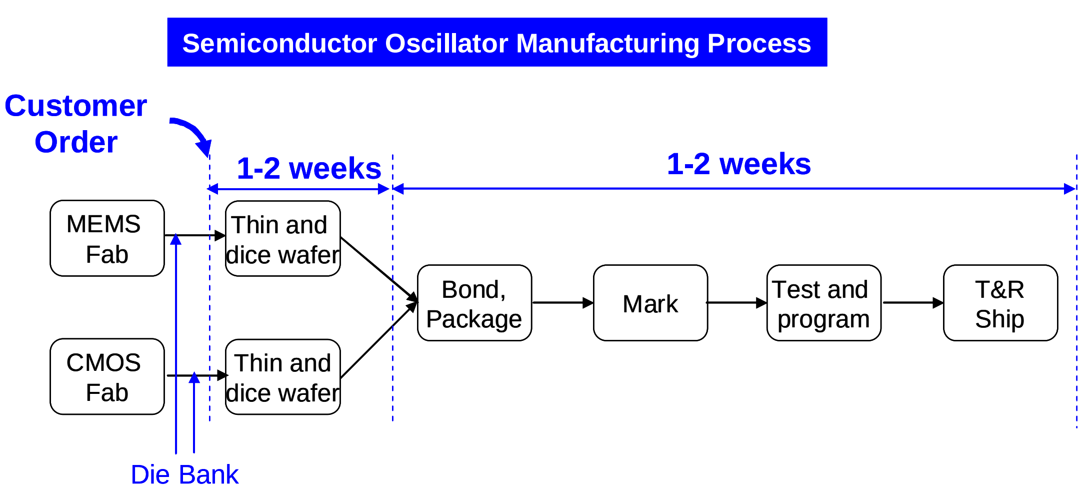

Figure 7: Silicon MEMS Oscillator Production Flow

MEMS Oscillators as a Risk Diversification Strategy Against Supply Disruption

In addition to shorter lead times and simplified supply chain management, MEMS oscillators also represent a significant risk diversification strategy in the context of a vulnerable global supply chain.

The quartz oscillator industry is characterized by a highly captive downstream supplier base. The two key components required to build an oscillator are the package substrate and the oscillator IC, both of which are dominated by two to three players with production facilities in Japan. This high concentration in the small number of suppliers and their locations represents significant risk to the continuity of supply. MEMS oscillators, in contrast, feature a semiconductor-centric supply chain that is completely different from the quartz supply. The dies for MEMS resonators and companion analog CMOS ICs are typically manufactured in standard IC fabs, and the oscillators' standard plastic IC packages are available from multiple sources. MEMS oscillator suppliers also outsource assembly and test to multiple subcontractors with production facilities in different parts of the world.

This diversity in supplier base and their production locations enables MEMS oscillator suppliers to better ensure continuity in delivering production-quality materials to their customers. For portable device makers, adopting MEMS oscillators can serve as a risk mitigation measure against potential shortages.

Conclusion

In a quickly evolving market, portable product design and manufactures require new solutions and technologies that enable rapid innovation.

MEMS oscillators give portable and mobile device makers several benefits compared to quartz oscillators. They provide shorter lead times and better inventory management, continuous availability to meet fluctuating demand and flexible, programmable feature sets for shorter time-to-market in new designs.

In addition to supply chain advantages, there are a number of design benefits that MEMS oscillators offer including the following.

- Smaller and thinner design enabled by oscillator footprints of 2.5 x 2.0 mm and package heights a little as 0.25 mm
- Resistance to shock and vibration with 50,000 G shock resistance, 70 G vibration resistance and 500 million hour MTBF reliability
- Longer battery life with low power oscillators
- Elimination of EMI and interference issues between different subsystems with programmable rise/fall time that minimize clock harmonics

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