Clock Features for Power Conscious and Green Applications

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Few topics are hotter than green technology. Some of the most common green applications include energy harvesting, wind and solar power generation, and LED lighting. All of these technologies are either power saving or power generating, and they result in a cleaner, more sustainable global environment. At the component level, there are many exciting developments. For example, microprocessors continue to be designed in increasingly lower-power process technologies and power supplies now achieve >90% efficiency across all load conditions. There are also some lesser-known technology achievements that improve green applications and contribute to power saving. This paper focuses on timing technologies and the clock features that effect power consumption and green applications.

New technologies making an impact

There are many new technologies making an impact in the green tech arena and several of these technologies are based on transitioning to a newer silicon-based approach. For example, one of the most significant power-saving trends to emerge in response to the growing demand for server-storage farms is the adoption of solid-state drives (SSD) as an alternative to the traditional hard-disk drive (HDD). Micro-electro mechanical systems (MEMS) are another example of a new silicon-based technology with break-through benefits for green applications and beyond.

Figure 1: Examples of traditional technologies that are being replaced by improved silicon-based technologies

Quartz crystal timing devices have traditionally been used as a reference clock in electronic systems, but silicon MEMS timing solutions are quickly being adopted because of many advantages this new technology offers. In addition to supply chain benefits such as lower cost and extremely short lead-times, MEMS timing solutions offer performance and feature improvements including higher accuracy, smaller size and lower power consumption.

In regard to power consumption, a reference clock can have features that are optimized for low power including the following.

- Low supply current
- Micro-power standby mode with fast start-up (resume) time
- Low voltage operation, including programmable output to reduce voltage swing

Power consumption, performance and other reference clock tradeoffs

Many microcontrollers (MCUs) specify a quartz crystal (XTAL) for general computing requirements. However, an XTAL does not always meet design requirements. For example, when the clock accuracy (frequency stability) needs to be stable, a clock oscillator (XO) is the best choice. Or if component placement makes it difficult to use an XTAL, an XO with its logic compatible output is the ideal solution. The SiT15xx 32 kHz oscillator family from SiTime is an excellent alternative for XTALs, providing several benefits including improvements in power consumption and size.

When designing a system, the power consumption of all components in the system must be considered. Since the processor is central to any system, it has priority in the power budget and often doesn't leave much power for supporting blocks and other components, including reference clocks. When designing the system clock sources, there are three main reference clock types (XTALs, oscillators and clock generators) to choose from, and two main technologies (quartz and MEMS) as shown in Table 1 below.

Table 1: Types of reference clock sources and their relative features

	32 kHz Clock		Oscillator (XO/TCXO)		Clock Generator (Synthesizer)	
	Quartz XTAL	MEMS (SiT15xx)	Quartz	MEMS	Quartz	MEMS
Power Consumption	Low power: 10 to 100 µA	Lowest power: 750 nA (typ)	Low power options: 1.5 to 5 mA		Limited low power options	
Power Supply	N/A (Comes from SoC/MCU)	1.2 to 4.5V	Limited low voltage	1.8V available	1.8V available	
Interface	Requires SoC/MCU to support XTAL + 2 caps	CMOS-compatible output to SoC/MCU clock/XTAL inputs	CMOS-compatible outputs interface to SoC/MCU clock/XTAL inputs		CMOS-compatible outputs interface to SoC/MCU clock/XTAL inputs	
Layout	Strict layout guidelines	Logic outputs for flexible layout, no proximity issues	Logic outputs for flexible layout, no proximity issues		Logic outputs for flexible layout, no proximity issues	
External Components	Two pulling capacitors (see Fig 2)	No external components needed	No external components needed		Requires external XTAL	No external components needed
Output Options	N/A	CMOS and NanoDrive™	CMOS and differential		CMOS and differential	
Frequency	Limited selection	Programmable from 1Hz to 32 kHz	Limited selection	Any frequency up to 650 MHz	Many frequencies	Any frequency up to 800 MHz
Accuracy	Poor stability: ±160 ppm over industrial temp.	Good stability: ±100 ppm over industrial temp.	Excellent stability: ±0.1 to 50 ppm		Limited stability: ±50 ppm	Good stability: ±20 to 50 ppm
Relative Cost	Low Cost	Low Cost	More expensive than XTAL	Less expensive than quartz	Most expensive	Less expensive than quartz
Suppliers	Multiple, pin compatible	SiTime, pin compatible	Multiple sources, pin compatible		Typically sole source pin-out	

The basic quartz XTAL has low power consumption and is often used for basic clock generation. New MEMS oscillator solutions, such as the SiT15xx 1 Hz to 32 kHz family from SiTime, provide an alternative to XTALs with power consumption that is up to 50% lower than quartz XTALs. These MEMS XOs have several other benefits compared to traditional XTALs including small size (up to 85% reduction in footprint) and better frequency stability, aging, reliability and robustness against shock and vibration.

Replace quartz XTALs with MEMS oscillators to reduce power

Some MEMS oscillators have ultra-low power output that consumes only nanoamps of current. In addition, most MEMS oscillators are designed with a programmable architecture that can enable additional power savings. The SiT15xx oscillator family for example, has the following unique power savings features.

- Lowest power 32 kHz oscillator at 750 nA core supply current (typical)
- Low voltage operation down to 1.2V
- Programmable frequency down to 1 Hz
- NanoDrive™ programmable output to reduce voltage swing

MEMS-based oscillators offer several programmable features that are not available from quartz devices. The basic programmable features include frequency, voltage and stability. For example, the SiT15xx family has a programmable frequency range between 1 Hz and 32.768 kHz in powers of two. Lowering the frequency significantly reduces the output load current (C*V*F). Reducing the output frequency from 32.768 kHz down to 1Hz reduces the load current by more than 99%. Lower frequency oscillators are ideal for applications where a low-frequency reference clock is always running. In contrast quartz XTALs, due to the physical size limitations of the resonator at low frequencies, cannot offer frequencies lower than 32.768 kHz.

Another programmable feature of the SiT15xx family is NanoDrive, a unique programmable output swing (See Figure 2). With NanoDrive, the output swing is programmable from full swing down to 200mV, to match the downstream oscillator input of the SoC/MCU. By optimizing the output stage, significant power savings are realized.

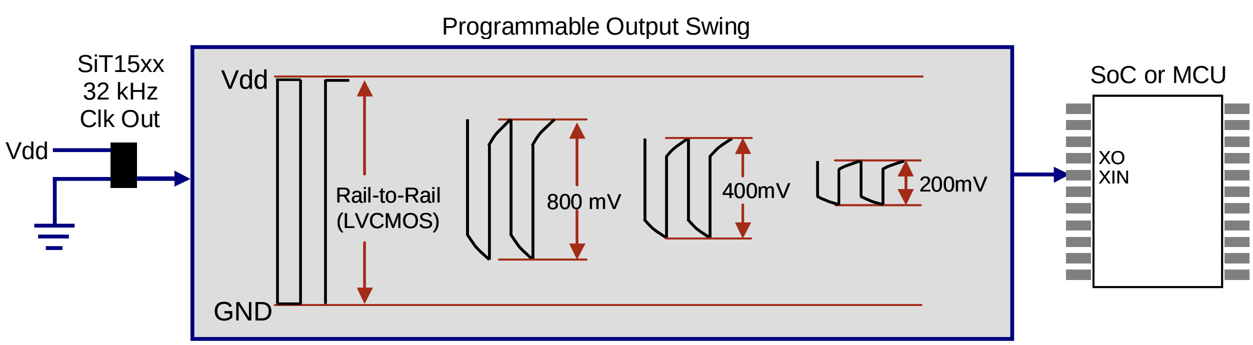


Figure 2: Unique NanoDrive output swing is programmable down to 200 mV to minimize power

Replace quartz XOs with MEMS oscillators to reduce power

For MHz reference clock applications, there are special features available with some oscillators that help to keep power low.

- Low power supply current
- Micro-power standby mode
- Fast resume time
- Low voltage operation down to 1.8V

A typical low-power MHz oscillator consumes less than 5 mA for a single-ended CMOS-compatible oscillator. For example, the low-power SiT1602 and SiT8008 CMOS-compatible oscillators from SiTime have current consumption of 3.4 (typical).

Differential oscillators consume more current due to their output structure. If a differential oscillator is needed but the receiving block has flexibility with the choice of differential logic, LVDS is the lowest power. LVPECL and CML logic consume more power. LVPECL output is limited to 3.3V and 5V power supplies, whereas some LVDS compatible oscillators can accommodate a 2.5V supply.

Standby mode and fast resume time also help to save power. However, basic oscillators do not include power-saving features beyond low-supply current. Traditional oscillators include a Vdd pin and an optional output enable (OE) control pin. The OE function is not a power-saving function. It simply disables the output stage while keeping the oscillator circuitry biased. Therefore, the only way to turn off the oscillator is to add a FET between the Vdd input and the power supply. But some oscillators, such as those from SiTime, include a standby (ST) control pin that reduces supply current to the µA level, and the need for an external FET to gate the Vdd power supply is eliminated. As an example, the supply current of the SiT1602 and SiT8008 oscillators is reduced to 0.6 µA in standby mode.

In addition to basic power consumption, some applications can turn on the clock reference only when the receiving block requires a clock source. One example is an RFIC block. In a system that periodically needs to communicate to another point such as the network or an aggregation point, the RFIC is only turned on during transceiver activity. In this scenario, the clock oscillator turn-on time is very important. An oscillator output is not valid until the oscillator power-up cycle is complete and this typically takes 5 to 10 ms. Specifying oscillators with the short start-up time will help to reduce power consumption. Since the clock source is only valid after start-up, the system is consuming power while waiting for the oscillator to complete its power-up cycle before it can begin its communication process.

Operating an oscillator from a standby (ST) state will save power by starting up approximately 2.5-times faster than conventional Vdd start-up times. Starting from a standby state is called resume time. As an example, the resume time for SiTime oscillators is 4 to 5 ms.

Power supply voltage is another important power consideration. If a 1.8V supply voltage is available, selecting a CMOS compatible oscillator that can operate from 1.8V can save significant power compared to more common 2.5V oscillator options. Reducing the supply voltage from 2.5V to 1.8V can reduce power consumption by 25%.

Low-EMI output options in a pin-compatible footprint

For power conscious portable applications, such as laptop PCs, tablets, e-readers, and WiFi appliances, EMI requirements can often be met by using special clock features. Many designs start with a standard oscillator. As engineering prototypes are built and EMI tests are conducted, the oscillator comes under scrutiny because the clock is a major source of EMI due to its high frequency clock edges. Designers will then focus on the clocks when EMI must be reduced.

With a programmable architecture, MEMS oscillators from SiTime can be easily programmed to reduce EMI by using spread spectrum or by adjusting the output edge rate, all while maintaining the original pinout. Designers can meet low EMI guidelines by adding spread spectrum or selecting a slower output edge rate without any changes to the existing design.

Oscillators provide a smaller footprint and alternative to XTAL layout restrictions

Many green and low-power applications have a small form factor and require components with the smallest footprint possible. An XTAL has very strict layout guidelines and must be placed very close to the SoC or MCU XTAL inputs as shown in Figure 3. Since oscillators have standard CMOS outputs, they are much less sensitive to layout issues and can drive long traces. Therefore, there is much greater flexibility in the layout of an oscillator compared to an XTAL.

Figure 3a: XTAL component placement

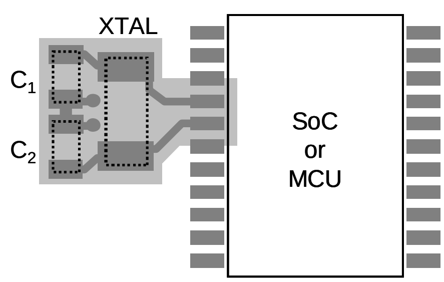
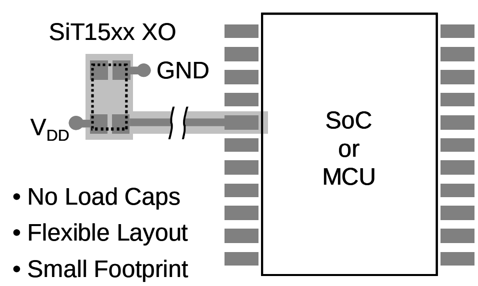


Figure 3b: Silicon MEMS component placement



Oscillators from SiTime enable even smaller footprints with chip-scale packages (CSP) as small as 1.5 x 0.8 mm and package height of only 0.55 mm. If a MEMS oscillator in a 1508 CSP (no capacitors needed) is used to replace a traditional XTAL in a common 2.0 x 1.2 package along with the two required capacitors, the total footprint will be reduced by 80%. Total board area may be further reduced considering the flexibility XOs offer in board design.

MEMS oscillators eliminate frequency restrictions

Quartz crystals and oscillators are restricted to specific available frequencies due to the difficulty in generating new frequencies within the quartz-based manufacturing process. Because SiTime's MEMS oscillators are programmable, any frequency is available from 1 Hz to 650 MHz with up to six decimal places of accuracy. It is important for system architects to be aware of the frequency options and leverage this flexibility early in the design process so the processor can be optimized for the best frequency and load current can be reduced.

Summary

All crystal-based solutions, whether XTAL or oscillator, have inherent limitations that engineers have been forced to accept and work around. However, new MEMS-based reference clocks provide solutions with superior performance and flexibility that addresses the limitations of quartz. SiTime MEMS timing solutions offer the following features.

- Power-saving features such as low voltage operation, fast start-up and resume time, and programmable output swing
- Any frequency available between 1 Hz to 650 MHz
- Low EMI output options including spread spectrum and output edge-rate control

SiTime's MEMS oscillators provide a valuable reference clock solution for low power and green applications.

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