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APPLICATION NOTE 5589

INDUSTRY TURNS TO MEMS FOR ACCURATE REAL-TIME CLOCKS

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Abstract: Real-time clocks (RTCs) continue to evolve, keeping pace with changes in their use and application by becoming smaller and more accurate. A major driver behind this evolution and adaptation is a new resonator technology—microelectromechanical systems (MEMS). This application note explores advancements in timekeeping accuracy, and examines the trends, concepts, and characteristics of more accurate real-time clocks.

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Introduction

Many argue that there is no better to way to improve industrial control and automation than with more accurate timekeeping. The issues, and benefits, are not just with time-of-day information. Highly accurate timekeeping will enhance complex control systems in many ways, starting with the simple scheduling of tasks and maintenance. More importantly, accurate timekeeping with real-time clocks (RTCs) allows an industrial system to operate more autonomously, helping to ensure that systems meet operational goals, focus on predetermined outcomes, and thereby minimize costs. RTCs must, of course, provide all this information with the highest accuracy possible.

Accurate Timing—The Need Is Timeless

However sophisticated an application may be today, good old-fashioned timing still matters greatly. Timing can even be critically important in some circumstances. That is why we see a steady demand for even more accurate RTCs. Timekeeping accuracy can directly impact financial activities, provide time-of-day forensics that may influence legal or criminal cases, affect record keeping in a myriad range of industries and applications, or simply improve quality of service.

Why is accuracy so important? The most important answer is not always obvious. Highly accurate RTCs will allow system designers to implement semi-autonomous system control without requiring all related system resources to be networked to time. Imagine lighting control systems where lights need to be turned on or off at specific times of the day throughout a busy industrial complex. Accurate timekeeping with programmable RTCs is an easy solution because these clocks eliminate the need to connect each lighting fixture to a single network timing resource. The RTCs simplify the complexity of wiring network resources throughout a building; they can replace complex wireless networks that typically require initial customization to ensure proper operation and connectivity, and then long-term maintenance for sustained operation.

While the need for accurate timing is actually straightforward, the design challenges to meet these demands are not. The best RTCs now typically provide highly accurate solutions (< 0.5s/day) that work over wide operating temperature ranges (-40°C to +85°C), in low power, at cost-effective prices, and in small packages. And today, it is microelectromechanical systems (MEMS) technology that enables the smallest, most accurate, rugged clocks.

The Evolution of Highly Accurate RTCs

The industry's first 32.768kHz temperature-compensated crystal oscillator (TCXO) was introduced in 1999 and it provided timekeeping accuracy of ±2 minutes per year over the -20°C to +70°C range. By 2005, with the combination of innovative packaging technology and improved temperature-sensor capability, an extremely accurate I^2C-integrated RTC/TCXO/crystal was introduced, the DS3231S. Considered the industry's most accurate RTC at the time, the DS3231S incorporated a 32kHz tuning fork crystal into a highly reliable 16-pin, 300-mil SO package. This highly integrated RTC provided a frequency accuracy of less than ±3.5ppm over the -40°C to +85°C temperature range, accuracy that is equivalent to less than ±0.3ss/day. It set a new standard for clock accuracy.

Just four years ago, only two corporations offered RTCs with accuracy at > 0.5s/day. Applications were demanding smaller packages with lower cost, higher accuracy standards, and substantially more ruggedness. The culmination of that design work was a new generation of RTCs based on MEMS technology. Introduced in 2010, the DS3231M integrated a TCXO with a MEMS resonator and provided accuracy of ±5ppm. That changed the entire composition of how accurate timekeeping is evaluated.

Beyond the issue of accuracy, today's RTCs include independent time-of-day alarms; user-configurable memory for storage of system information; accurate temperature sensing to advise on thermal environmental conditions; the ability to timestamp critical system events; and simple time-of-day information. At least six corporations manufacture accurate RTCs. Potentially any industrial control or automation operation can use some form of accurate timekeeping.

The MEMS Evolution

MEMS have challenged the conventional limitations of crystal-based designs. Because of its size, MEMS technology enables significant space savings when compared to cylindrical crystals. A single MEMS resonator occupies 47 times less area and 182 times less volume than a cylindrical crystal. Consequently, the approximate area of an RTC drops by more than half. This dramatic reduction in size is possible because of the transition from the standard barrel, cylindrical crystal to the small ceramic 32.768kHz crystal and the extremely small size of a Maxim MEMS resonator.

Aging is negligible (< 1ppm lifetime) in MEMS resonators. Crystal-based clocks have typical aging characteristics of ±1ppm per year. Shock and vibration characteristics are significantly more robust in MEMS resonators. Demonstrable performance with mechanical shock (up to 2900g; 5 shocks × 6 axes, JESD22-B104C Condition H) and vibration (with variable frequency of 20g; 20/2000Hz, JESD22-B103B Condition 1) has been recorded for MEMS resonators.* This rugged performance comes with no

discernible frequency perturbations greater than ±1ppm. Lastly, overall accuracy for MEMS-based RTCs is specified with lifetime accuracy and stability figures of < ±5ppm.

The Future of Clocks Is MEMS

Longer term, clocks will need to reduce size and cost even further and to boost accuracy yet higher. It will be MEMS technology that enables these improvements for RTCs in larger segments of the industrial, automotive, smart grid, and medical markets.

*Performance data is available to qualified customers from SiTime at www.sitime.com/.

Related Parts		
DS3231	Extremely Accurate I²C-Integrated RTC/TCXO/Crystal	Free Samples
DS3231M	±5ppm, I^2C Real-Time Clock	Free Samples
DS3232	Extremely Accurate I²C RTC with Integrated Crystal and SRAM	Free Samples
DS3232M	±5ppm, I²C Real-Time Clock with SRAM	Free Samples
DS3234	Extremely Accurate SPI Bus RTC with Integrated Crystal and SRAM	Free Samples
DS32KHZ	32.768kHz Temperature-Compensated Crystal Oscillator	Free Samples

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