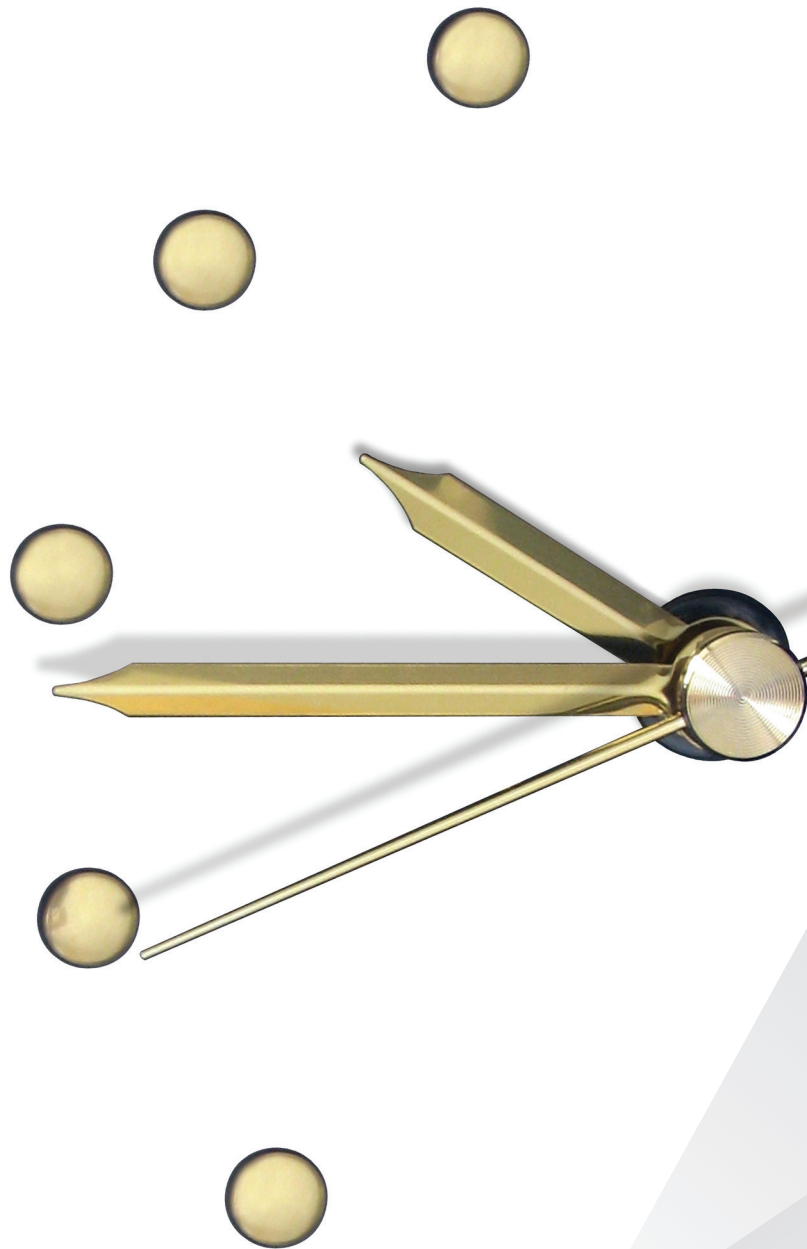


1<sup>st</sup> Edition

# ACCURATE MEMS REAL-TIME CLOCKS

*Product Guide*



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# Introduction

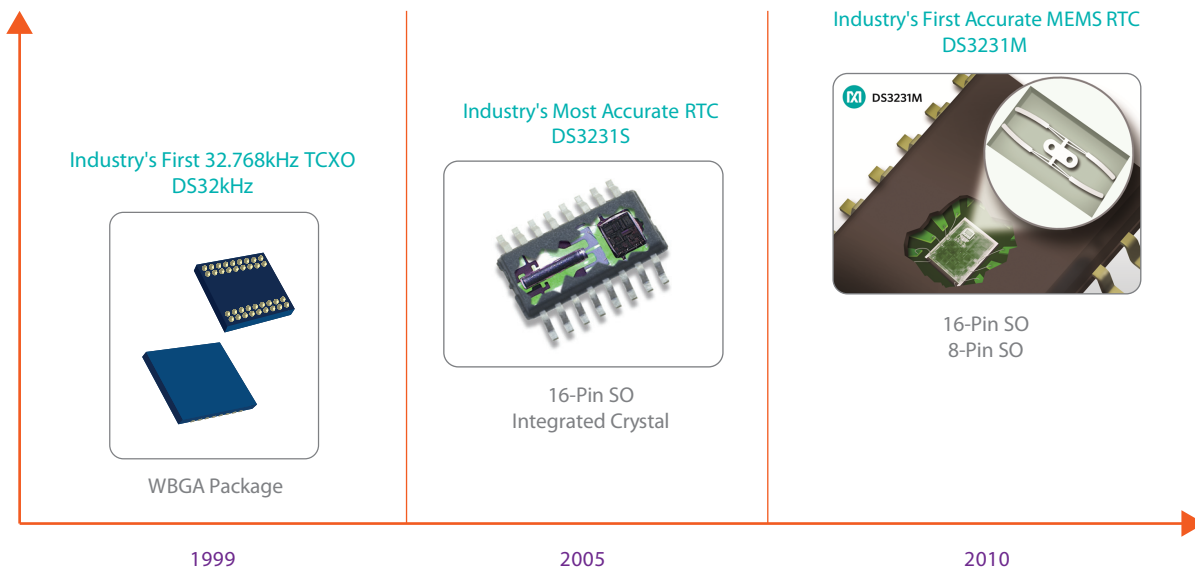
## Advancing Timekeeping Accuracy

In 1999, Maxim Integrated introduced the **DS32kHz**, a 32.768kHz temperature-compensated crystal oscillator (TCXO), which was the industry's first accurate timekeeping product for real-time clock (RTC) applications. The product boasted an accuracy of  $\pm 7.5\text{ppm}$  across the entire  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  industrial temperature range.

By 2005, with the combination of innovative packaging technology and improved temperature sensor capability, we introduced what would be considered the industry's most accurate RTC, the **DS3231S**, an extremely accurate I<sup>2</sup>C-integrated RTC/TCXO/crystal. The DS3231S featured a highly reliable and innovative package that incorporated a 32kHz tuning fork crystal into a standard 16-pin, 300-mil SO. This highly integrated device further enhanced timekeeping accuracy by providing a frequency accuracy of less than  $\pm 3.5\text{ppm}$  over the  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  temperature range. This accuracy is equivalent to less than  $\pm 0.3$  seconds/day.

In 2009, Maxim Integrated embarked on a goal to create a quantum leap in technology advancement by developing an RTC that would exceed the performance of the DS3231S, but provide it in a smaller package with lower cost, higher accuracy standards, and substantially more ruggedness. The culmination of this work is a product family based on microelectromechanical systems (MEMS) technology.

The **DS3231M**  $\pm 5\text{ppm}$ , I<sup>2</sup>C RTC was first introduced in 2010 with all the capability outlined in the company's development goals. The device has a timekeeping accuracy of  $\pm 5\text{ppm}$  over all conditions including temperature, voltage, and aging. The design is extremely rugged, has achieved automotive AEC-Q100 certification, and can sustain extreme levels of mechanical shock and variable frequency vibration. Because of the extremely small size of the MEMS resonator, the device is packaged in a small 8-pin, 150-mil SO—something unattainable with tuning fork crystals.



# Accurate MEMS RTCs at a Glance

## Industry's Single Most Integrated Solutions for Accurate Timekeeping

Maxim Integrated embarked on a goal to create a quantum leap in technology advancement by developing an RTC that would exceed performance in a smaller package, with lower cost, higher accuracy standards, and be substantially more rugged for use in power meters, video surveillance, and automotive, industrial, and medical applications. The culmination of this work is a product family based on the MEMS technology: the DS3231M and [DS3232M](#).

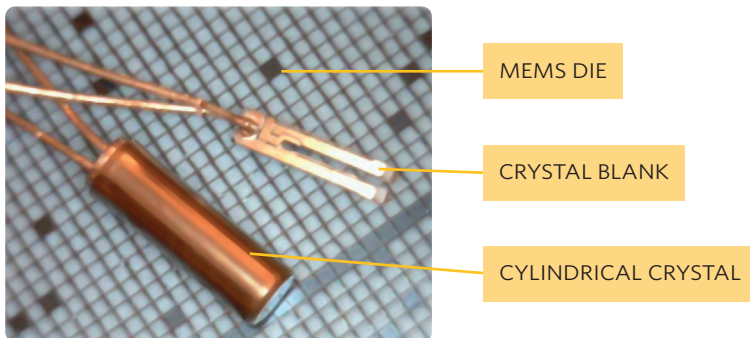
### DS3231M

The DS3231M is the first temperature-compensated RTC with an internal MEMS resonator to reduce crystal mechanical failure. Designed to be footprint and functionally compatible to the popular DS3231S, the DS3231M replicates the 16-pin, 300-mil SO for users looking for a less-expensive solution but want the same functionality, firmware, and board layout found with the DS3231S. The DS3231M integrates several important system features—resonator, RTC, TXCO, digital temperature sensor, and automatic power switching—to support battery-backed applications in one device.

### DS3232M

The DS3232M is an RTC that adds memory in the smallest package with 236 bytes of battery-backed user memory. The DS3232M is a MEMS-equivalent to the popular [DS3232S](#) crystal-based RTC. Major space-saving gains are made with this miniature MEMS resonator in the 8-pin, 150-mil package versus the 20-pin, 300-mil SO of the DS3232S.

## From Crystals to MEMS



MEMS DIE

CRYSTAL BLANK

CYLINDRICAL CRYSTAL

MEMS technology, because of its size, 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. This size differential allows for smaller packaging options, provides significantly enhanced ruggedness in high vibration and shock environments, and demonstrates little to no aging ( $< \pm 1\text{ppm}$  total) over the life of the device.

### Simpler Assembly

- Standard IC plastic packaging
- Wire-bonding vs. welding
- Ultrasonic cleaning
- Facilitates large-scale assembly operations

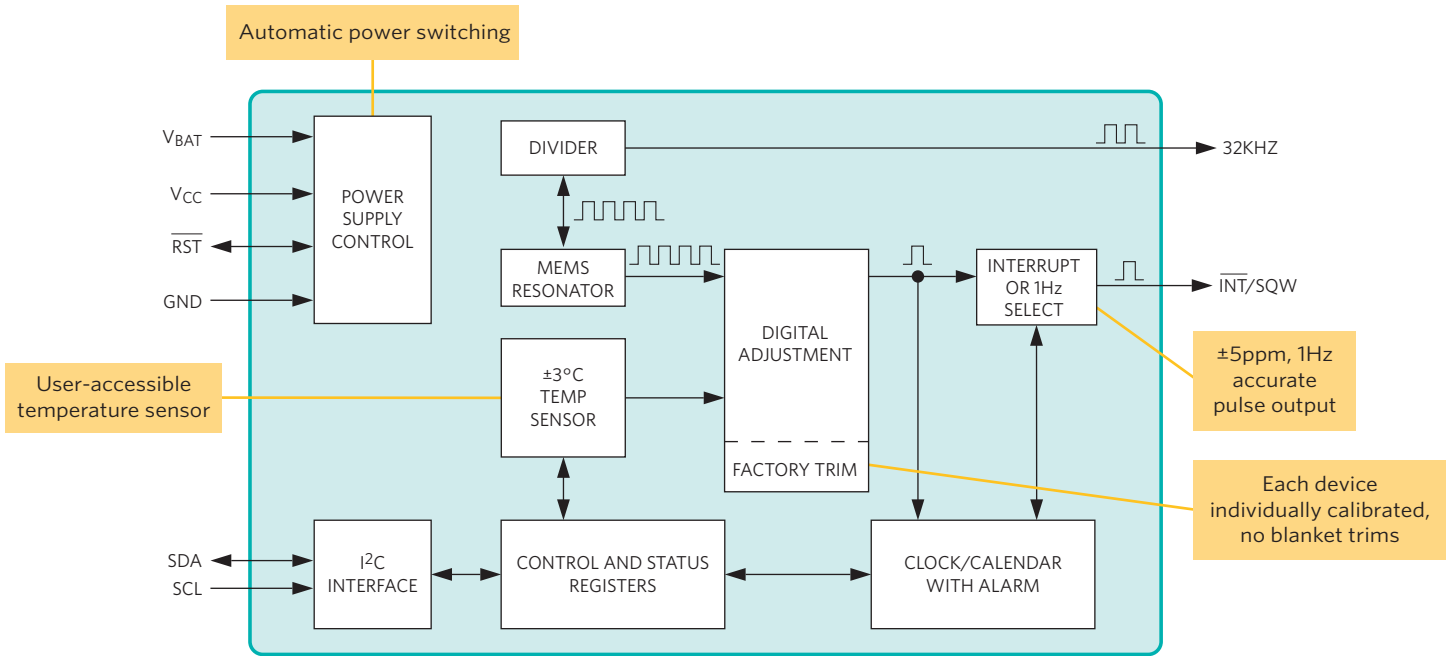
### Smaller Packaging

- 8-pin (150 mil) vs. 16-pin (300 mil)
- Chip-scale packaging (CSP) possible

### Lower Cost

- No special/custom crystals required
- Lower cost MEMS resonator
- Lower cost packaging

### DS3231M Block Diagram



### Benefits

- Precise timekeeping accuracy ( $\pm 5\text{ppm}$ ) without user calibration
- Low power consumption ( $< 3.5\mu\text{A}$ ) supports battery-powered applications
- Completely self-contained power-switching circuitry saves board space
- Fully contained digital temperature sensor saves additional system component cost

### MEMS Real-Time Clocks

Part Number	Package	User Memory (Bytes)	Temp Range (°C)	AEC-Q100
DS3231M+	16-SO (300 mils)	—	-40 to +85	—
DS3231MZ+	8-SO (150 mils)	—	-40 to +85	—
DS3231MZ/V+	8-SO (150 mils)	—	-40 to +85	✓
DS3232MZ+	8-SO (150 mils)	236	-40 to +85	—
DS3232MZ/V+	8-SO (150 mils)	236	-40 to +85	✓

+Denotes a lead(Pb)-free/RoHS-compliant package.  
 /V denotes an AEC-Q100-qualified part.

# Benefits of MEMS Technology in RTC Applications

## Environmental and Manufacturing Ruggedness

Maxim Integrated’s MEMS-based RTC products have proven, demonstrable performance advantages based on environmental criteria and observation. In reflow operations that replicate customer attachment, MEMS devices demonstrate frequency shifts of less than  $\pm 1\text{ppm}$  (**Figures 1a** and **1b**). Crystal-based products that face the same regimen of reflow temperature exposure demonstrate shifts as high as  $\pm 5\text{ppm}$ . One of the most important criteria for establishing how well a device operates is its frequency performance prior to attachment to a motherboard compared to its performance after this attachment process. The attachment process can have temperature excursions as high as  $+260^\circ\text{C}$  for several seconds and be above  $+200^\circ\text{C}$  for several 10s of seconds. Dependable frequency performance over the life of the device is the most important criteria for choosing accurate timekeeping products. Maxim Integrated MEMS RTCs guarantee  $\pm 5\text{ppm}$  frequency accuracy and stability regardless of voltage, time (aging), or temperature.

Additionally, MEMS-based RTCs have demonstrable shock and vibration performance and have passed AEC-Q100 qualification, making them one of the most rugged, dependable, and accurate solutions in the industry.

### Benefits

- Higher manufacturing temperature processes ( $+260^\circ\text{C}$  reflows,  $< 1\text{ppm}$  frequency shifts, fully RoHS)
- Significantly higher shock and vibration capability ( $> 50g$ )
- Wide operational temperature environments ( $-40^\circ\text{C}$  to  $+85^\circ\text{C}$ )

## 1Hz FREQUENCY ERROR TESTED WITH MULTIPLE DS3231M DEVICES

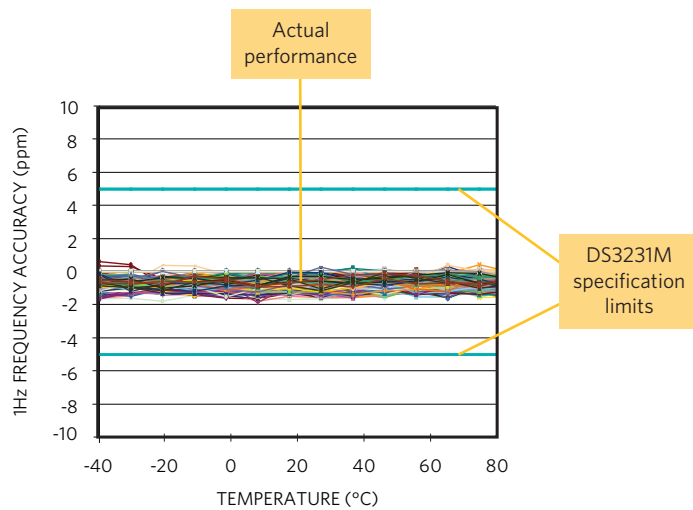


Figure 1a. DS3231M Pre-reflow

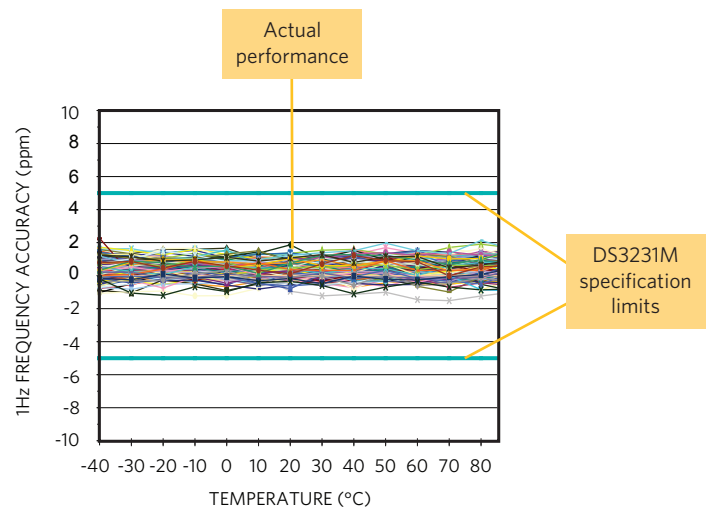


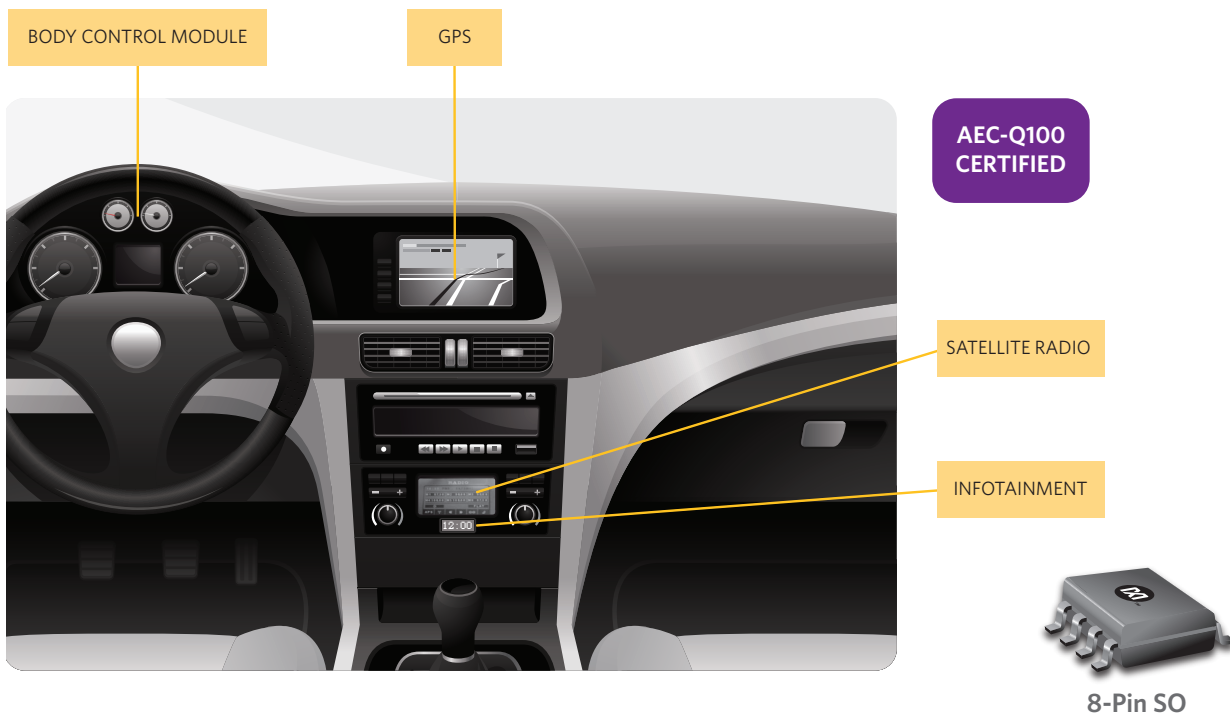
Figure 1b. DS3231M Post-reflow

# Automotive

## Automotive Embraces Ruggedness of MEMS Accurate RTC Products

Automotive environments are demanding and require component technologies that can withstand harsh environments. Maxim Integrated's MEMS RTC products are tough enough to withstand even the most rugged needs.

The MEMS resonator includes wider operating margins for temperature, greater shock and vibration capability than crystals, more precise frequency accuracy and stability, and less aging over the lifetime of the product.



### Reliability

- Crystal-less design for tough or harsh environments

### Size and Ruggedness

- Extremely durable, small 8-pin SO packages can withstand mechanical shock and vibrations
  - Up to 2900g: 5 shocks x 6 axes, JESD22-B104C Condition-H
  - Variable frequency of 20g: 20/2000Hz, JESD22-B103B Condition-1

### Automotive Certified

- DS3231MZ/V+ and DS3232MZ/V+ AEC-Q100 certified

### High Operating Temperature Ranges

- -40°C to +85°C (DS3231MZ/V+ and DS3232MZ/V+)

### High Accuracy

- < ±5ppm (under all conditions)

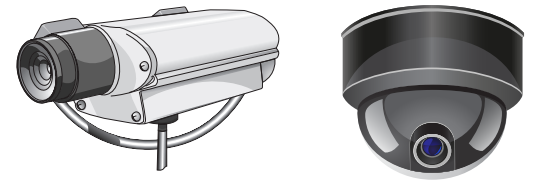
# Video Security and Surveillance

## Security and Surveillance Systems Benefit from Accurate Timestamping and Small Size of RTC Products

Accurate timestamping of event data is an important aspect of video security and surveillance systems. MEMS-based RTCs further enhance this by providing timekeeping accuracy far exceeding the most robust crystal designs. Besides less aging, Maxim Integrated’s MEMS-accurate RTC products support accuracy and stability standards of much less than  $\pm 5\text{ppm}$  lifetime over voltage, temperature, and time. This translates to less than  $\pm 0.432$  seconds/day, much better than  $\pm 3$  minutes/year. A smaller product package size (8-pin SO) provides users with small footprint solutions to accommodate space-constrained designs. Power consumption of  $< 3.5\mu\text{A}$  make the devices suitable for battery-backed applications.



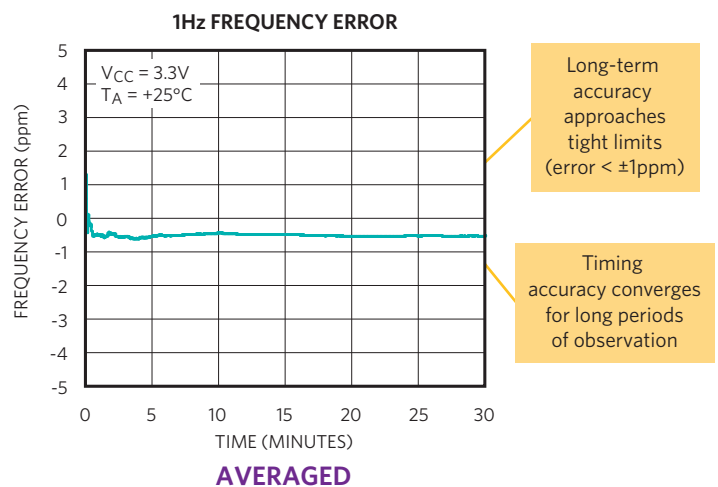
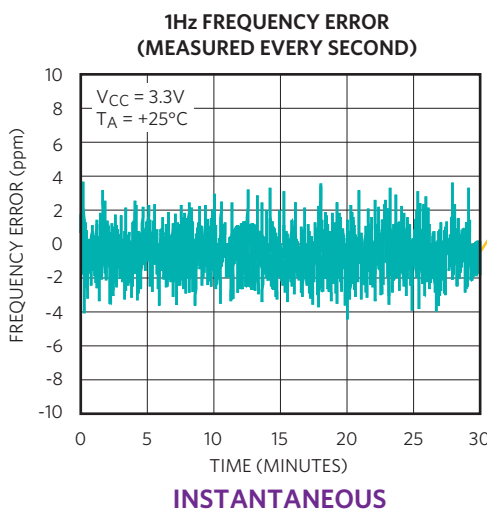
Simulated Image



### Benefits

- Extreme accuracy:  $< \pm 0.432$  seconds/day
- 8-pin SO supports space-constrained designs
- Suitable for battery-backed applications  $< 3.5\mu\text{A}$
- Automatic power switching between supplies

## INSTANTANEOUS vs. LONG-TERM ACCURACY OVER LONG PERIODS OF OBSERVATION (REAL-LIFE RESULTS)





# Industrial and Medical

## MEMS RTCs Meet Critical Factors for Industrial and Medical Applications in Ruggedness, Size, and Temperature

Industrial and medical markets have expanded their acceptance of MEMS-accurate RTCs based on the newly introduced 8-pin, 150-mil SO package, the inherent ruggedness of the MEMS design, and the status and success of the standard device's AEC-Q100 automotive qualification. Long-term accuracy ( $< \pm 5\text{ppm}$ ) of the MEMS RTC contributes to its acceptance in these applications, where demand for highly reliable and accurate timekeeping/time-stamping of event data is extremely critical.

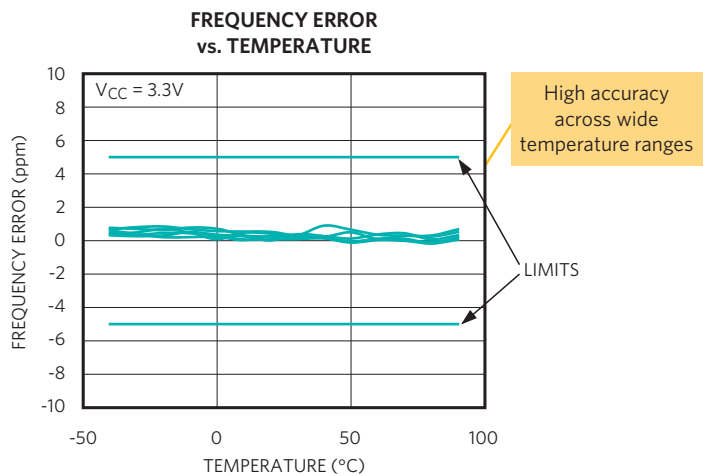
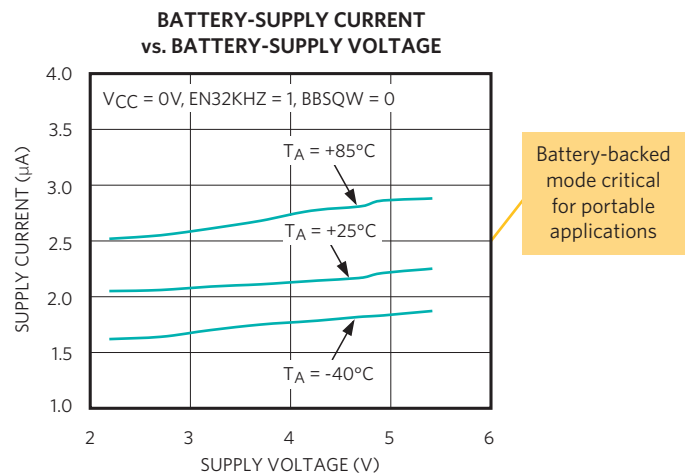
Temperature performance is extremely important for industrial applications. The standard device provides a wide ( $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ ) operating temperature range by keeping accurate time across this band of temperatures. Low operating currents ( $< 3.5\mu\text{A}$ ) and the 2.3V to 5.5V wide-operating voltage range aid critical portable medical applications that are battery powered. Heavy machinery, blood glucose meters, and environmental system controls benefit from the high accuracy, low power consumption, device ruggedness, and small package size.



Blood Glucose Monitor

### Applications

- Patient Monitoring
- Heavy Machinery
- Portable Medical Devices
- Environmental Systems



# Power Meters

## MEMS RTCs Deliver Pinpoint Precision for Metering

Maxim Integrated is a premier supplier of electronic component technology designed for smart grid and metering applications. Accurate timekeeping is an essential part of smart power meter design. Applications such as multirate billing drive the need to use accurate timekeeping products like the DS3231M+ and DS3231MZ+. Temperature variations cause frequency drift in crystal-based RTCs. Frequency drift causes timekeeping errors sometimes approaching  $\pm 30$  minutes/year in standard RTCs. This attribute negatively affects billing accuracy and resolution. Additionally, high-humidity environments adversely affect timekeeping accuracy when over-molded crystals are not used. Maxim Integrated's MEMS-based RTCs eliminate these environmental concerns and provide timekeeping accuracy over the entire industrial  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  temperature range and operate in high-humidity environments without accuracy issues.

### *Newport Smart Meter Reference Platform*

The Newport Smart Meter reference platform is a smart meter reference design featuring all its premier technologies. Explore the capability of this technology and accelerate your time to market with proven solutions. This includes products in energy measurement (metrology), robust G3-PLC™ communications, and integrated security. Pluggable NAN and HAN communication modules, form-factor design, and complete system software make the Newport Smart Meter reference platform the ultimate development tool.

### *Power and Timing*

In addition to metrology, communication, and security, the Newport Smart Meter reference platform offers enhanced timing accuracy with the DS3231M MEMS-based RTC. Power for both the metrology and communications boards is regulated by the [MAX17498](#) flyback controller.

### *Metrology and Security*

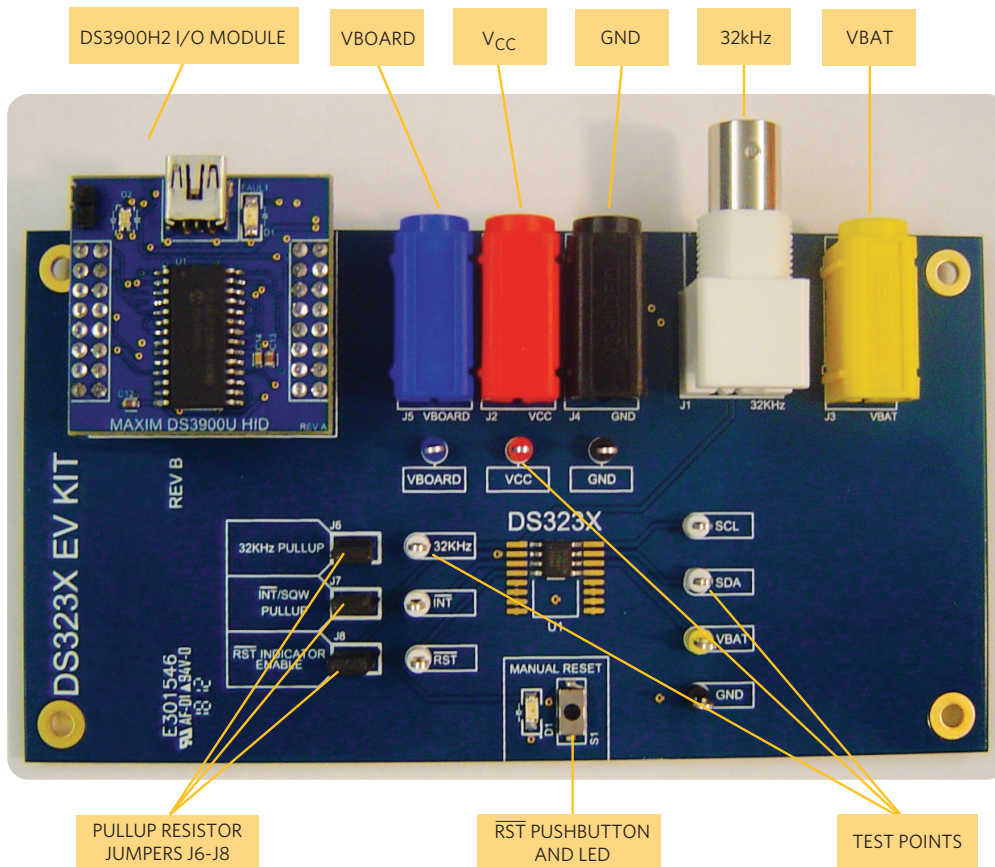
The [71M6541](#) sits at the heart of the system and measures electricity to 0.1% accuracy across a dynamic range of 2000:1 in all four quadrants. An ARM® core hosts system software to ensure compatibility with existing development software, while the [MAXQ1050](#) provides multilayered secure authentication to thwart the most determined security threats.

### *Communications*

The [MAX2991](#) and [MAX2992](#) communicate to and from points in the grid through the power line. They support speeds up to 300kbps, following the G3-PLC specification. Adaptive tone mapping, a robust mode, and programmable tone matching make communications quick and reliable in high-noise scenarios, and compatible with older PLC solutions. An isolated RS-485 communications interface ([MAX13256](#) and [MAX13412E](#)) is also provided for any serial communications needs.



# Evaluate MEMS RTC Technology with DS323x Reference and Development Kits



**EV kit includes:**

- Demonstration board
- USB I/O module (DS3900H2)
- CD containing the application program and instructions

The DS323x evaluation kits (EV kits) are fully assembled and tested circuit boards with an accompanying application program that demonstrate the operation of the DS3231M and DS3232M RTCs. Maxim Integrated’s accurate MEMS RTCs constantly monitor operating temperature and periodically adjust the internal oscillator frequency to maintain highly accurate timing information.

The EV kits allow devices to be operated in all possible power-supply configurations. The application program provides easy access to device register settings, while observing various device functions for timekeeping. The EV kits also allow users to connect their I<sup>2</sup>C master to the sample component for operational verification and/or code development. The EV kits are Windows®-compatible (Windows XP® or later version, requires USB port and USB cable).

## MEMS Real-Time Clock Evaluation Kits

Part Number	Description
DS3231MEVKIT#	16-Pin Package EV Kit for the DS3231M+
DS3231MZEVKIT#	8-Pin Package EV Kit for the DS3231MZ+
DS3232MEVKIT#	8-Pin Package EV Kit for the DS3232MZ+

+Denotes a lead(Pb)-free/RoHS-compliant package.  
#Denotes RoHS-compliant.

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