MICRO CRYSTAL SWITZERLAND

Technical Note

Real-Time Clock Module selection made easy

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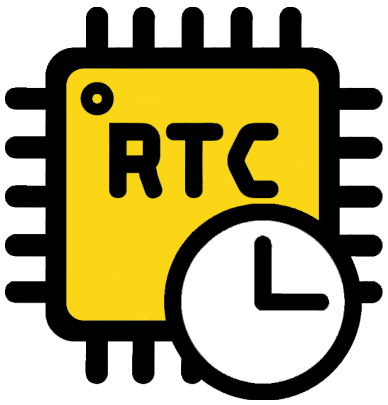
Frequently Asked Questions and Guidelines



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A COMPANY OF THE SWATCH GROUP

Headquarters: Micro Crystal AG, Mühlestrasse 14, CH-2540 Grenchen, Switzerland

Tel. +41 32 655 82 82

Internet www.microcrystal.com

Email sales@microcrystal.com

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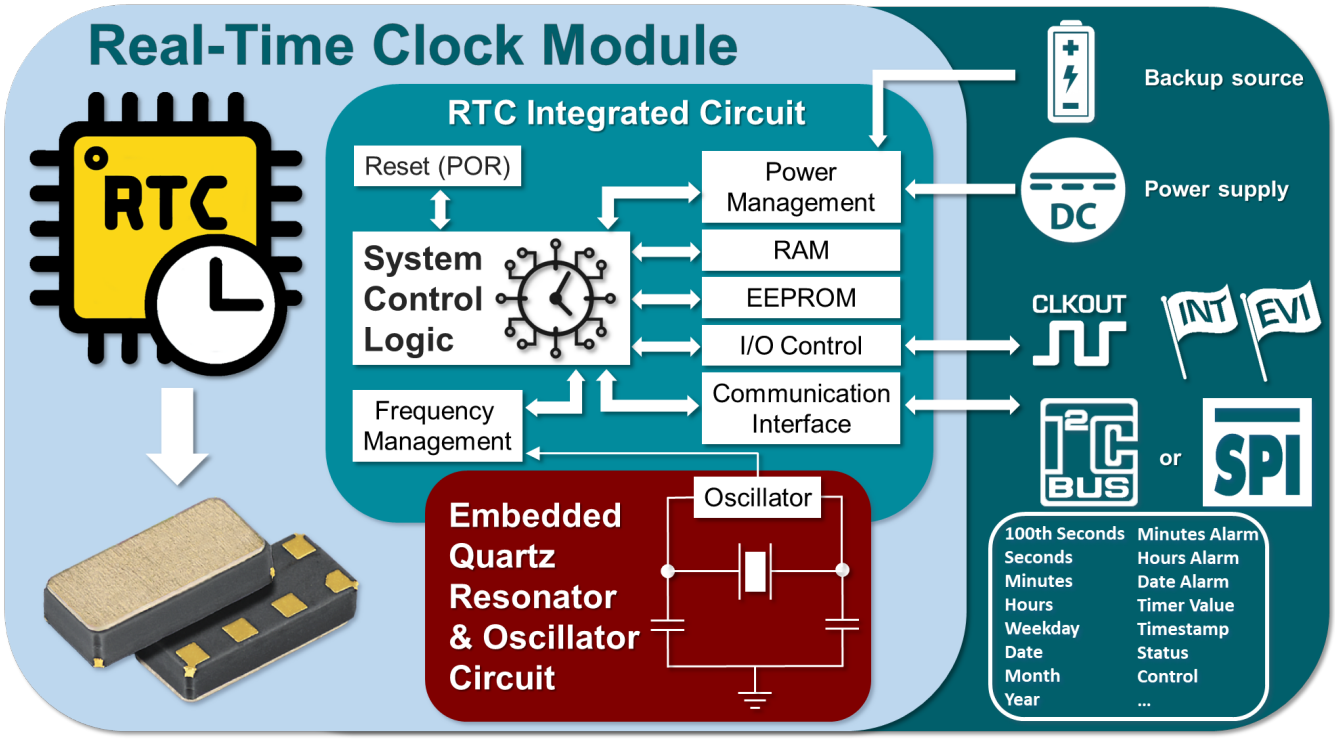
1. Introduction

At Micro Crystal, our portfolio encompasses Quartz Crystals, Oscillators, OCXOs, and Real-Time Clock (RTC) Modules for the world's leading manufacturers of IoT, wearables, consumer products, GPS modules, automotive electronics, healthcare, medical and medical implantable products.

As a recognized industry leader and innovator of extreme-low power, highly accurate, ultra small Real-Time Clock solutions, Micro Crystal stay in close cooperation with customers worldwide from early design-in activities through mass production.

2. Our proposition

With a range of options that enrich microcontroller-based hardware, the Real-Time Clock Modules developed by Micro Crystal are helping electronic engineers address ever more complex challenges of designs where increased performance and added features are built into smaller and smaller form factor while minimizing power consumption.



By assembling the Quartz Crystal and the Real-Time Clock integrated circuit within a single RTC package, Micro Crystal's RTCs allow to minimize the footprint. It does not require any oscillator adjustment during OEM's design phase, minimizing integration constraints thus lowering development cost and time to market. The factory calibration process and the hermetic package ensure high accuracy and stability over lifetime thus high reliability of these devices.

The RTC's assortment includes RTC modules with I²C or SPI interface and extra functions such as alarms, timers, timestamps, clock output control, external event interrupt (for example for tamper detection), power management or even accurate temperature monitoring.

To simplify the selection process of your RTC module, most of the key questions and features are discussed here and some guidelines are proposed.

3. Frequently Asked Questions

3.1. What is RTC?

A real-time clock (RTC) is a digital clock; its main function is to keep accurate track of the time even when the main power supply is turned off, or the device placed in low power mode.

RTC is composed of an oscillator coupled with a controller system. The controller and oscillator circuitries are combined in a specific IC that is linked to an external or embedded 32.768 kHz quartz crystal resonator. All RTCs from Micro Crystal are with embedded quartz and designated as "RTC Modules". These devices are engineered to provide better performances than discrete components, simplify integration in new designs and accelerate time to market.

The registers are stored in RAM and updated periodically during RTC module operation. RTC design generally contains as well a long-life battery, or other backup source, to allow it to keep track of the time even when there is no power applied avoiding to the user the need to set the time and date every time the device supply is turned on.

RTCs are used in a variety of applications where they play a critical role in keeping an updated track of the current time while providing alarms, timer and interrupt functions and helping reducing power consumption.

3.2. Why using an RTC?

With today's access to the Internet or GPS, one could consider that once connected, a device can get the accurate time. For the devices having permanent internet connection, the lack of an RTC could be justified. This benefit comes however, at the expense of high power consumption and can be acceptable only for devices connected to the main.

Battery operated devices cannot afford to continuously enable the wireless transceiver because that will drain the battery very quickly. Those devices need however somehow a continuous operation in order to keep track of time. Engineers thought then to have intermittent activity to prolong the battery life. The use of an RTC function allows the designer to power down the microcontroller when no task is required, resulting in significant power savings.

When microcontrollers with integrated RTCs go into a deep sleep or low-power mode, the clock and the circuitry needs to keep running in order to provide accurate time-keeping and alarm functions. Microcontroller power consumption, with only the internal RTC function active, is however far above (> 1000 nA) the one of an external RTC. Ultra-low quiescent current achieved by today's RTC modules (45 nA typ. for RV-3028-C7 in time keeping mode – with no bus communication) allows a significantly extended battery life.

The RTC module solve then the problem of having the always staying on device drawing the lowest power when no other task is required. Even if RTCs were never considered as key components in systems, the always on timekeeping function is a must-have and RTC choice is conditioning today's design of personal electronics, medical devices, or industrial products where power savings and backup timekeeping are at premium.

3.3. What interface is used to communicate with the RTC?

There are two options available:

I²C - is a simple, bidirectional two-wire synchronous serial bus. Fast mode devices can receive and transmit up to 400kbit/s. It requires external pull-up device for both lines.

SPI - is similar to I²C with a different form of serial-communications protocol operating at full-duplex and requires 3 or 4 lines. It operates at faster data transmission rates than I²C (up to 7Mbits) and is used where speed is important.

***Selection Criterion**:*
I²C is the standard. It is fast enough for RTC timing data transmission and minimize number of lines. It requires extra pull-up resistors thus affecting PCBA surface used. Where data transmission speed is important use SPI.
Current is flowing through pull-up resistors during the I²C clock and data transitions, resulting in a higher current consumption in the I²C case than in the SPI case, at the same communication frequency condition.

3.4. What level of accuracy is achieved?

One of the main datasheet's specification for an RTC is its clock accuracy based on oscillator stability. Expressed in parts per million (±X ppm), it means the variation of ±X oscillations per million of oscillations and is directly linked to gain or loss of seconds per day, minutes per year.

Designs with RTC chip combined with an external crystal resonator will cumulate the errors generated by:

• Quartz Crystal	±20 ppm
• External Capacitors	±7 ppm
• Board tracks	±2 ppm
• RTC IC	±8 ppm
Total (typical example):	**±37 ppm**

As the frequency reference used in RTCs is usually based on a 32.768 kHz tuning fork crystal resonator, the time deviation is directly and mainly linked to this part of the oscillator. Moreover, due to its negative temperature coefficient with a parabolic frequency deviation, a change in quartz frequency of up to 150 ppm across the entire industrial operating temperature, ranging from -40°C to +85°C, can result.

At a constant 25°C operation, an RTC oscillator with ±20 ppm accuracy (stability) can lead to more than ±10 minutes error per year as calculated here below:

$$\underbrace{\frac{\pm 20\ [\text{ppm}]}{10^6} \times \frac{365\ [\text{days}] \times 24\ [\text{hours}] \times 60[\text{minutes}]}{1\ [\text{year}]}}_{\pm\ \text{minutes deviation per a year}} \times \underbrace{1\ [\text{year}]}_{\text{over a year}} = \pm 10.5\ [\text{minutes}]$$

All Micro Crystal's RTC modules are adjusted in frequency at ambient temperature during production in order to achieve an overall typical accuracy of ±20 ppm.

For high accuracy RTC modules, this value drops to ±3 ppm or even ±1 ppm. A high time accuracy is required for application where timing measurement is used for billing; like in utility metering, point of sale terminals, or security related equipment and systems. Such products are easily found in parametric search tool as they are labelled with below symbol:

***Selection Criterion**:*
Some applications require high timekeeping accuracy over a wide temperature range. This is for example important when a sensor is installed or is mainly operated outdoor. In this case, it is recommended to choose an RTC with temperature-compensation capability.
With such feature, an accuracy of ±3 ppm (± 0.26 sec/day) is achievable over the full industrial temperature range.

3.5. What is the current consumption of an RTC?

This key selection criteria is based on the timekeeping current consumption which allows to define the battery lifetime of the global solution once the main supply voltage source is disconnected. It is defined in specific operating conditions, typically at 3V and 25°C.

Unlike MEMS based RTC which need significantly more energy (>2'000 nA) to divide the high base frequency of MEMS resonator, low frequency crystal based RTCs from Micro Crystal can achieve extreme low level of current consumption (45 nA), even the ones with temperature compensation (160 nA). Crystal based RTC hardware that consumes less current is preferable to its power-hungry counterpart. Such products are easily found in parametric search tool as they are labelled with below symbol:

In optimized timekeeping mode, the RTC need to be configured as to minimize its power consumption. The clock output should be disabled and communication stopped. In this mode, the RTC module can however behave as watchdog with low power budget and wake-up the system on demand (alarm, timer, event interrupt).

Out of this low power timekeeping mode, an RTC will see its current consumption vary according to its features and configuration settings (operation of power management circuit, oscillator output enabled,…). Current consumption is also affected by the interface type. Current flowing through pull-up resistor during open drained I^2C communication.

3.6. What can be used as backup source?

In many design, a specific and dedicated power source is available for the RTC in order to keep accurate track of time as long as possible without interruption and need for setting the time again. Some devices are equipped with an automatic switch able to detect low level of main supply voltage and performing a battery switchover.

As it is the case for the selection of the optimum RTC module for your application, the power budget will drive the choice of the backup source type. The main supply shortage duration or the global battery lifetime requirements will define the power capacity required.

The most common backup source are MLCC (Multilayer Ceramic Capacitor), Supercap (very high value capacitor with value of tenth a farad or more), primary (disposable) and secondary (rechargeable) battery.

***Selection Criterion**:*
The use cases have to be deeply assessed in order to take into account all parameters linked to backup source limitations like cost, size, behaviour with temperature, auto-discharge, charging cycles, shelf life, polarization, reflow process compliance, recycling (eco-friendly),…

The backup source's profile of discharge at low current and covering the wide voltage range featured by Micro Crystal's RTC, is a key optimization selection factor to prolong timekeeping autonomy. The potential to use the charge pump feature included in some modules to extend the charge is also worth considering.

3.7. What type of alarm is available?

Alarms are based on timing settings (from second to years) but the interrupts can be generated by many sources see 3.10 for details.
It is important to mention that the interrupt output is also active when RTC is operated with backup source (VBACKUP Power state).

3.8. Do these RTC modules need to be calibrated?

No user calibration is required with those modules because Micro Crystal calibrates the devices during manufacturing process using highly accurate timing reference units.
Temperature sensors included in DTCXO (Digitally Temperature Compensated Crystal Oscillator) devices are also calibrated over the whole operating range.

Because the devices are calibrated, all errors involved in timing and measuring and digitizing the temperature value are included in the sensor's accuracy specifications.

3.9. What is the stability of these devices?

The stability is linked to the performance of the oscillator operated in the RTC module. Its behaviour may be subjected to changes linked to the environment or caused by the time (aging).

In the self-contained solutions proposed by Micro Crystal, integrating the crystal resonator and the RTC circuit, the protection against pressure change, humidity or external chemical contamination is ensured through a perfect sealing of the ceramic package under vacuum.

The effect of temperature is compensated in DTCXO (Digitally Temperature Compensated Crystal Oscillator) based RTC module by removing pulses so as to skip count if crystal is running faster or adding clock pulses if crystal is running slower.

The quartz frequency will slightly vary with time as aging is modifying material properties of quartz and capacitors used in the oscillator circuit. The aging is specified within ±3 ppm (corresponding to a variation over the year of ±1.6 minute) during the first year and significantly reduced during following years.

This aging effect of the oscillator frequency can be corrected through an “offset” register adjustment feature.

3.10. What are the features included in an RTC module?

The functions integrated nowadays within RTC modules allow to supervise system behaviour through power management, temperature monitoring, alarming on time elapsed or on external event while having host microprocessor in idle mode. It doesn't take care of Daylight Savings Time (because it changes from place to place).

The table on the right lists all functions available.

***Selection Criterion**:*
Caution, some features are in all RTC modules when some others are only present in some products.

The wide operating voltage range, low power consumption, high accuracy and compact form factor allow to implement easily any Micro Crystal’s RTC modules in a new hardware. The selection criterion will then be based on other sophisticated features like timers resolution, clock output frequency or the need for event timestamp.

The full definition of your application requirements will guide you towards the right choice avoiding overdesign.

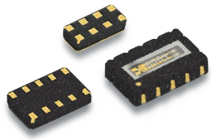
Function	Comments
Year	With automatic leap year calculation
Month	
Date	
Weekday	
Hours	12 or 24 hours modes
Minutes	
Seconds	
100th of seconds	Reading only feature, for more precise timing data
UNIX time counter (32 bits)	It is the number of seconds that have elapsed since the Unix epoch, minus leap seconds; the Unix epoch is 00:00:00 UTC on 1 January 1970 (an arbitrary date);
Alarms	from second to years defined by user settings
Timers	Up to 2 timers with programmable duration according to clock settings (from 244 µs to 4095 minutes)
Interrupts	Several sources of interrupt: • Periodic time update • Periodic countdown for timers • Alarm (from second to years defined by user) • External event (damper detection) • Temperature window crossing (high/low) • Voltage low detection • Automatic switchover • Power on reset
Programmable Clock Output	Selectable frequency from Hz to MHz on enabled/disabled single CMOS output for peripheral devices
Timestamp	Record timing occurrence of external or internal event, generate an interrupt. It can be the timing of first or last occurrence, number of occurrences is also counted.
Temperature	For temperature compensated modules with reading in 8-bit or 12-bit options
User RAM	0 to 256 bytes depending of RTC type (on top of RTC functional RAM)
User EEPROM	0 to 43 bytes depending of RTC type (on top of configuration EEPROM)
Offset adjustment	Oscillator frequency adjustment (aging compensation) Temperature offset adjustment
Programmable Password	Safety against inadvertent overwriting Time, Control and Configuration registers protection
Power On Reset (POR)	RAM registers initialized to their reset values and refresh of the RAM mirror values by the ones in the Configuration EEPROM.
Battery Switchover	Detection of main supply low voltage and switch to backup source
Trickle Charger	Backup source charge management
Charge Pump	Allows charging of backup source at higher voltage to extend lifetime during power down

Use the parametric search tool to have an overview of features present in each product.

3.11. What are the different types of packaging?

The RTC modules are available in various sizes.

Type	Dimensions [mm]
C2	5.0 x 3.2 x 1.2
C3	3.7 x 2.5 x 0.9
C7	3.2 x 1.5 x 0.8



As most battery-operated devices have to be very small for portability or easy installation, the RTC modules are now also assembled in small size DFN (Dual Flat No Leads) package with **3.2 x 1.5 x 0.8 mm** (C7 type) with metal lid. Such products are easily found in parametric search tool as they are labelled with below symbol:

3.12. What are the best practices for layout?

The RTC module does not need to be located close to MCU as it is the case when using a bare quartz device and capacitors. This offers flexibility for the designer to place the RTC device on the board. For RTC with ambient temperature measurement feature follow the rules used for temperature sensor application.

As the RTC's oscillator operation is guaranteed by design and calibrated in production before sealing in a high- reliable hermetic package, there is no need for protection against environmental contamination with conformal coating.

3.13. What are the qualification of these products?

The products are RoHS/Lead-Free/REACH compliant and AEC-Q200 qualified, which facilitates new design-in. Medical graded parts are dedicated for specific use in Class III implantable medical devices.

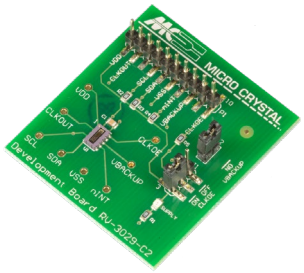
100% of the parts are adjusted in frequency and the accuracy is verified before shipping ensuring high quality level.

Micro Crystal is ISO 9001 (Quality), ISO 14001 (Environmental) and IATF 16949 (Automotive) certified.

You can access "Certificates" for more details.

3.14. Are evaluation board and samples available?

For customer evaluation, Micro Crystal offers a pack of 5 RTC samples and a dedicated evaluation board containing a soldered RTC module. The board can be connected to an interface dongle (I^2C/SPI compatible) for communication with a PC.



3.15. What other resources are available?

For your selection, it is possible to use the RTC product page where the key functions are listed. Use the parametric search tool to quickly find the right device that fits your specifications. You will have also access to a downloadable Excel file (RTC modules parametric table) to perform your selection off-line.

Micro Crystal provides Linux drivers and Windows GUI on request.

The PCB symbol, footprint and 3D models are also available on product pages in order to facilitate the design work.

Various Whitepapers are also available detailing the various aspects of use cases and applications.

3.16. Other Questions/Feedback

We believe that "Great Questions" lead to "Great Designs", so do not hesitate to contact us with the next "What/Why/How…?"

Micro Crystal values feedback on our RTC modules. Please send feedback to Micro Crystal via:

marketing@microcrystal.com

If you're looking to learn more about how Micro Crystal has the solution for you, talk to us and our team of experts:

tech-support@microcrystal.com

4. Reference documents

Document	Name	Link
Certificates for RTCs	Certificate of Compliance Environment	Download
Parametric Table	RTC Modules Parametric Table	Download

5. Document version

Date	Version #	Changes
February-22-2021	1.0	Initial version - NMO