MICRO CRYSTAL SWITZERLAND

White Paper

Automotive Qualification of Timing Components - Quartz Crystals and Oscillators per AEC-Q200, and Real-Time Clock Modules per AEC-Q104

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1. Introduction

The automotive sector is undergoing a profound technological evolution, driven by the rapid adoption of autonomous-driving capabilities, electrified powertrains, and increasingly sophisticated advanced driver-assistance systems (ADAS). These emerging architectures place stringent demands on underlying electronic components, which must deliver consistent performance under severe environmental stresses, including wide temperature extremes, mechanical vibration, and elevated levels of electrical and electromagnetic noise.

To support these reliability requirements, the Automotive Electronics Council (AEC) has defined a structured set of qualification standards applicable across semiconductor, passive, optoelectronic, and multichip module technologies. This whitepaper examines how these AEC-Q standards apply specifically to **quartz crystals, oscillators**, and **Real-Time Clock (RTC) Modules**, and outlines the reliability, design, and lifecycle benefits gained by selecting AEC-qualified components for modern automotive platforms.

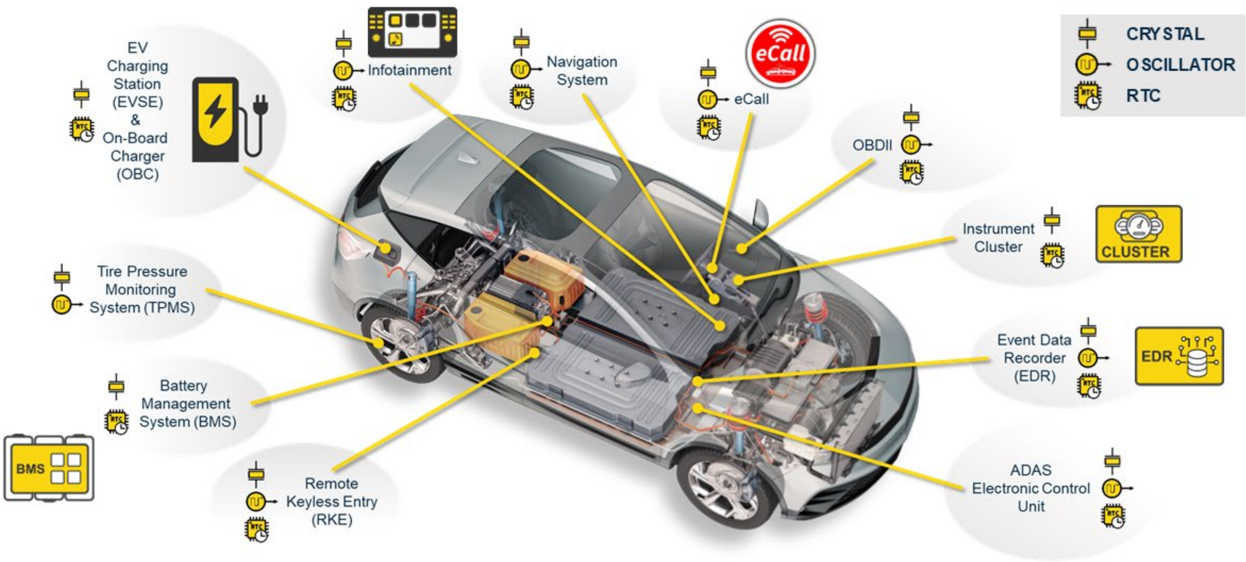


Figure 1: Timing Applications in automotive

2. AEC-Q200 Qualification for Quartz Crystals and Oscillators

2.1. Overview of AEC-Q200

The Automotive Electronics Council (AEC) standards span the full component spectrum: AEC-Q100 for integrated circuits, AEC-Q101 for discrete semiconductors, AEC-Q102 for optoelectronic devices, AEC-Q200 for passive components, and AEC-Q104 for multichip modules (MCMs). Together, they form a unified framework ensuring that components can withstand the thermal, mechanical, and electrical stresses characteristic of automotive applications.

Although more stringent than consumer-grade requirements, AEC qualifications build upon proven JEDEC and MIL-STD test methodologies, augmented with additional criteria tailored to automotive operating conditions.

Within this framework, AEC-Q200 governs the qualification of passive components. It specifies comprehensive environmental, mechanical, and electrical stress tests designed to validate long-term reliability for devices such as resistors, capacitors, inductors, and quartz-based timing components.

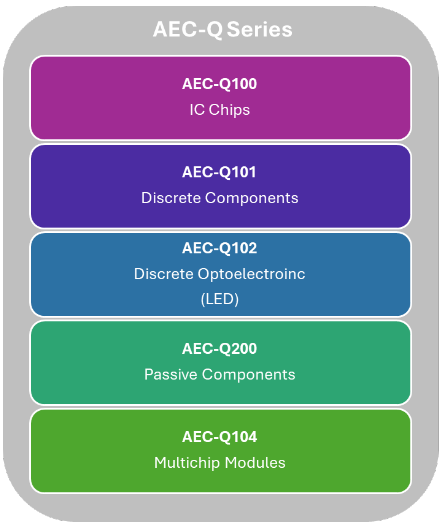


Figure 2: AEC-Q Series Overview

2.2. Oscillators: Extension of AEC-Q200 Qualification

Oscillators integrate a quartz crystal with active circuitry—typically an amplifier and supporting electronics—to generate a stable clock signal. Even though oscillators contain active elements, they are often qualified under AEC-Q200 because their core timing performance is derived from the quartz crystal itself, which behaves as a passive resonator. As a result, the qualification strategy focuses on ensuring that both the resonator and the assembled oscillator module maintain stability and robustness when subjected to the stresses encountered in automotive environments.

To demonstrate compliance, quartz crystals and their oscillator counterparts are exposed to a defined set of environmental, mechanical, humidity, soldering, and electrical stress tests specified in AEC-Q200. These tests validate long-term stability, mechanical resilience, and reliability under harsh conditions such as temperature swings, and vibration.

Table 1: AEC-Q200 Stress Tests

Environmental & Thermal Tests	Requirement
High-Temperature Storage Life (HTSL)	1000 h at the rated high-temperature limit
Temperature Cycling (TC)	Typically −40°C to +85°C/+125°C for 1000 cycles
Thermal Shock (TS)	Abrupt temperature swings per MIL-STD-202 standards

Mechanical Robustness Tests	Requirement
Vibration (VIB)	5 g, 10–2000 Hz, 4 h per axis
Mechanical Shock (MS)	100 g, half-sine pulse, 6 ms, 3× per axis
Board Flex Test (Terminal Bond Strength -BFT)	2 mm PCB deflection
Terminal Strength (Shear Test – TSH)	18 N for 60 s

Solderability & Assembly Tests	Requirement
Solderability (SDR)	>95 % wetting at 257.5 °C, 5 s
Resistance to Soldering Heat (RSH)	High-temperature exposure during reflow simulation

Electrical / Timing-Related Stability Parameters
While not a separate AEC-Q200 test item, electrical parameters such as frequency stability, ESR (Equivalent Series Resistance - the "internal resistance" of the crystal at resonance), motional parameters are measured before and after the defined stress tests. The resulting parameter shifts include the effects of accelerated aging induced by these stresses. Since true aging occurs over long-time scales, it is not directly measured but inferred from these accelerated conditions and supporting reliability models.

These test items form the foundation for the key AEC-Q200 evaluations and qualifications:

- **Thermal Shock** – Confirms the resonator and oscillator assembly can tolerate rapid temperature transitions without shifts in electrical performance.
- **Mechanical Shock and Vibration** – Ensures structural integrity and stable operation in the high-vibration and high-shock environments typical of automotive applications.
- **Frequency Stability** (Pre-/Post-Stress Electrical Verification) – Confirms that the crystal/oscillator maintains frequency tolerance, ESR, and characteristics after exposure to mechanical and thermal stresses.

3. AEC-Q104 Qualification for Real-Time Clock (RTC) Modules

3.1. Overview of AEC-Q104

AEC-Q104 is a relatively recent (2017) addition to the Automotive Electronics Council's qualification framework, created to address the specific reliability challenges associated with MCMs used in automotive systems. These modules combine multiple functional elements—active semiconductor devices and passive components—within a single package that shares a common substrate and internal interconnect structure. Because of this hierarchical assembly approach, the reliability of an **AEC-Q104**-qualified module is not derived solely from tests performed at the module level; instead, it relies in part on the proven robustness of the sub-ICs that compose it. These subcomponents are typically qualified to existing AEC standards such as **AEC-Q100**, **AEC-Q101**, or **AEC-Q200** before being integrated into the final module.

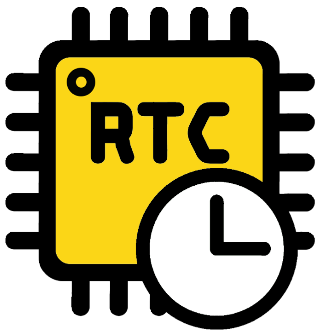
Fundamentally**, AEC-Q104** is a **failure-mechanism-based stress-test qualification** tailored for multichip modules in automotive applications. The standard focuses on identifying and validating the dominant failure mechanisms that emerge when multiple dies and passive elements interact within a shared package environment. This includes stress conditions affecting die-to-die interconnects, substrate-level structures, and the mechanical interfaces that differ significantly from those found in single-chip devices. By concentrating on module-specific risks while assuming baseline robustness from the underlying subcomponents, **AEC-Q104** delivers a streamlined yet targeted reliability framework suited to the increasingly complex module architectures used in modern vehicles.

3.2. What Makes RTC Modules Unique?

Real-Time Clock (RTC) modules provide precise timekeeping functionality, essential for applications like power management, scheduling, and logging in automotive systems. These modules typically integrate:

- A quartz crystal for frequency stability.
- A dedicated IC for clock generation and time management.

This mixed-component nature presents a unique qualification challenge, as RTC modules do not fit neatly into the categories of purely passive (AEC-Q200) or active (AEC-Q100) components.



3.3. Justification for AEC-Q104 Qualification

AEC-Q104 explicitly addresses the requirements of multi-die IC modules, making it the ideal standard for RTC modules. The integration of a quartz crystal and an IC requires qualification methods that ensure both components work reliably together under automotive conditions.

A central element of AEC-Q104 is its emphasis on **Board Level Reliability (BLR)**, the industry's primary methodology for assessing solder-joint integrity once components are mounted onto a printed-circuit board (PCB). As semiconductor content within vehicles continues to expand—driven by electrification, advanced driver-assistance systems, and domain-controller architectures—BLR has become a critical dimension of automotive reliability verification.

Although the current AEC-Q104 BLR requirements encompass only a subset of evaluations—**Temperature Cycle Testing (TCT), Drop Testing, Low-Temperature Storage Life (LTSL), and Start-Up & Temperature Step (STEP) profiling**—the framework nevertheless represents a meaningful advance toward establishing a unified and broadly accepted industry standard for module-level qualification.

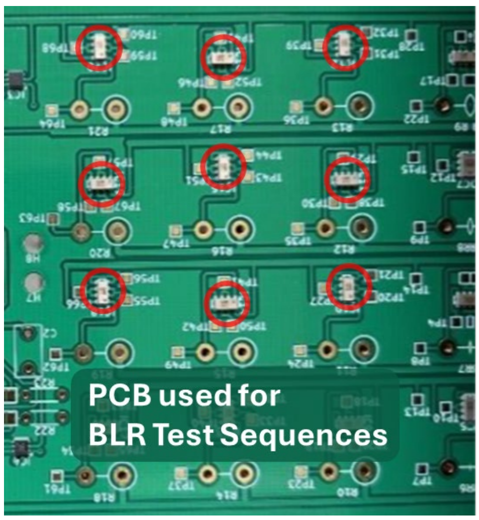


Figure 3: Board Level Reliability Set-up Example for RTC Module

3.4. Qualification Test Method and Key Tests

Qualification of an MCM is achieved by compliance with a combination of applicable AEC standards: the test requirements defined in AEC-Q200 for passive components, the relevant criteria from AEC-Q100 for integrated circuits, and the module-specific evaluations defined in **AEC-Q104**, particularly **Group H (module-level reliability tests)** and **Group E (electrical verification tests).** In practice, the detailed qualification test plan is often defined as a bespoke program, jointly agreed between the component supplier and the automotive customer, to ensure alignment with specific application requirements and risk assessments.

For an automotive RTC module, this approach typically involves integrating an **AEC-Q200-qualified crystal** with an **AEC-Q100-qualified RTC IC** within a single MCM package. The fully assembled module is then validated according to the **AEC-Q104 qualification framework**, ensuring that both component-level robustness and system-level interactions are adequately assessed.

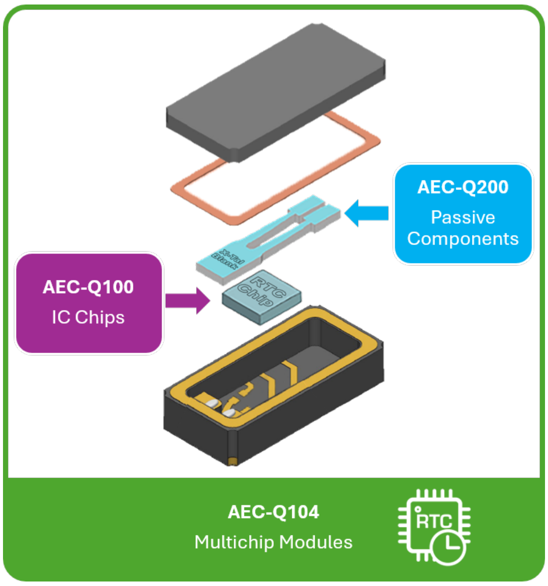


Figure 4: RTC Module Construction

Successful completion of this qualification process enables the generation of a **Q104 Certificate of Design, Construction and Qualification (CDCQ)**. This document provides a comprehensive record of the module design, constituent components, and qualification results, and serves as a key deliverable for **PPAP submission and OEM approval.**

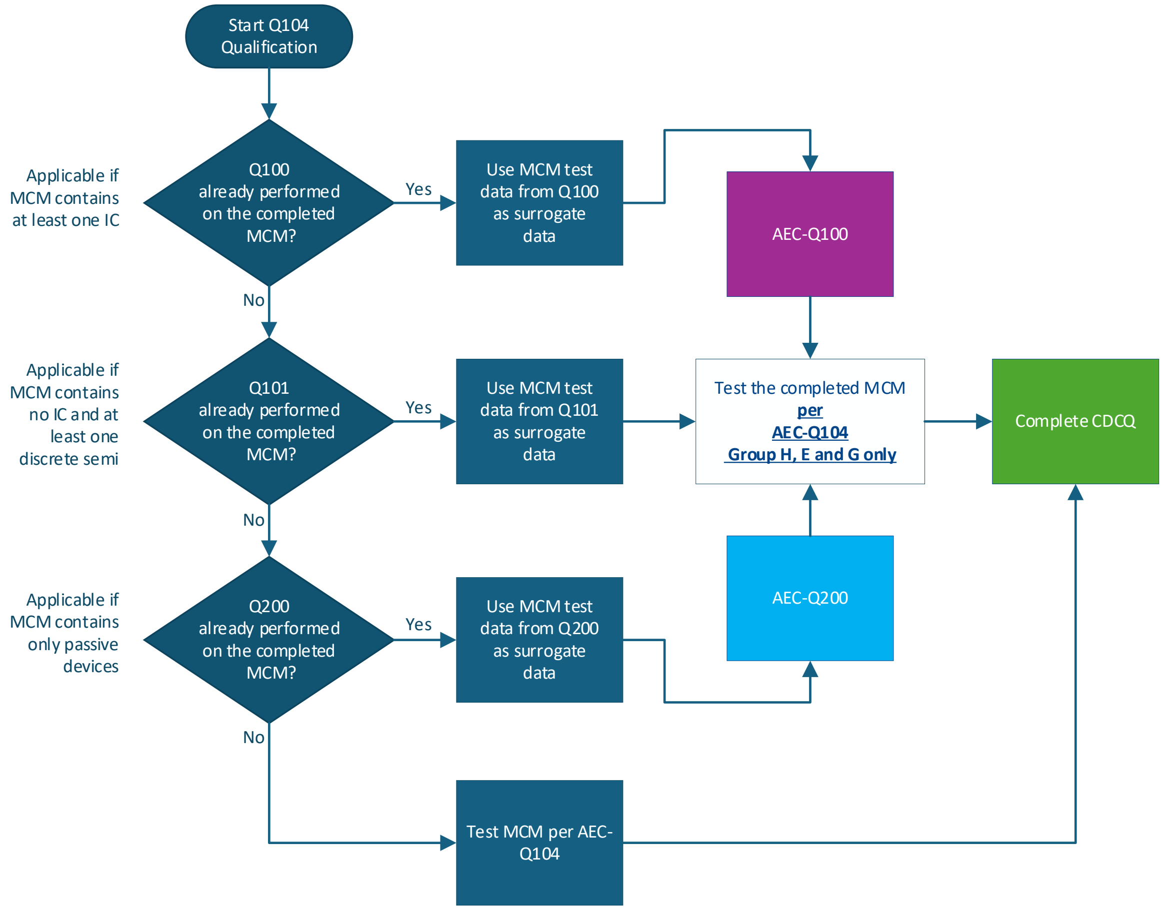


Figure 5: AEC-Q104 Qualification Process Flow

3.4.1. AEC-Q104 Mechanical & Assembly Integrity Tests

3.4.1.1. Board Level Reliability (BLR)

Test Method: IPC-9701B Temperature Cycles: -40 to +105°C
Purpose: Evaluates solder-joint fatigue performance of the assembled module under realistic thermal load conditions.

AEC-Q104 H1

3.4.1.2. Low-Temperature Storage Life (LTSL)

Test Method: JEDEC JESD22-A119 1000 hours at –40 °C
Purpose: Demonstrates module stability under prolonged cold-soak conditions.

AEC-Q104 H2

3.4.1.3. Start-Up & Temp Step (STEP)

Test Method: ISO 16750-4 Power cycling at –40°C to +85°C, Ramp in 10°C increments
Purpose: Ensures reliable Oscillator/IC start-up behavior across extreme temperatures.

AEC-Q104 H3

3.4.1.4. Die Shear (DS)

Test Method: MIL-STD-883 – Method 2019 Measure the force required to shear the die from the substrate.
Purpose: Verify integrity of the die attach inside the module and that it can withstand mechanical and thermo-mechanical stresses encountered during assembly and automotive operation.

AEC-Q104 G7

3.4.2. AEC-Q104 Electrical Robustness Tests

3.4.2.1. Human Body Model (HBM) ESD

Test Method: AEC-Q100-002 Target: No failure at 2 kV HBM
Purpose: Confirms ESD resilience of module-level electrical interfaces

AEC-Q104 E2

3.4.2.2. Charged Device Model (CDM) ESD

Test Method: AEC-Q100-011 Corner pins: 750 V - Other pins: 500 V.
Purpose: Ensures robustness against fast electrostatic discharge events typical during handling, assembly and in-vehicle service.

AEC-Q104 E3

3.4.2.3. Latch-Up

Test Method: AEC-Q100-004 Tested at **maximum ambient operating** temperature
Purpose: Confirms that internal IC and module interconnects do not enter destructive parasitic conduction states, ensures module stability under transient.

AEC-Q104 E4

3.5. Industry Adoption of AEC-Q104

Manufacturers are increasingly qualifying RTC modules under AEC-Q104 to meet the demands of automotive customers.

Figure 6: Infotainment Automotive Applications

This accelerated path to qualification has reinforced OEM and Tier-1 acceptance of AEC-Q104 as the de-facto standard for RTC modules.

As a result, manufacturers increasingly design RTC modules explicitly targeting AEC-Q104 certification in order to:

- Meet OEM qualification requirements for automotive timing components
- Ensure operation in high-temperature ECU environments such as battery systems
- Support low-power architectures, especially in safety-critical or always-on functions
- Provide long-term reliability data to automotive customers
- Facilitate acceptance into Tier-1 automotive supply chains, which demand consistency with AEC-Q standards

This growing adoption underscores the expanding role of MCM-based design within the automotive sector and reflects the industry's continued movement toward higher reliability, integration, and standardization.

3.6. Overview of Temperature Grades

Automotive components are subjected to a wide range of operating environments, from freezing external conditions to elevated temperatures under the hood. To address these challenges, AEC-Q104 specifies temperature grades that define the operational temperature range for electronic components. These grades are essential for categorizing components based on their thermal resilience and application suitability.

Table 2: AEC-Q104 Qualification Grade

Grade	Operating Temperature Range	Application Examples
Grade 0	-40°C to +150°C	Under-the-hood components, engine control units
Grade 1	-40°C to +125°C	Powertrain systems, safety-critical electronics
Grade 2	-40°C to +105°C	Cabin electronics, infotainment systems
Grade 3	-40°C to +85°C	General automotive electronics, interior modules
Grade 4	0°C to +70°C	Non-critical systems, consumer-grade electronics

The choice of temperature grade depends on the location and function of the component within the vehicle. For example, components located near the engine or exhaust system require higher thermal resilience (Grade 0 or Grade 1), while those used in the passenger cabin may only need to meet Grade 2 or 3 requirements.

4. Benefits of Using AEC-Qualified Components

4.1. Enhanced Reliability

Automotive manufacturers increasingly rely on AEC-qualified timing components to meet the stringent performance and longevity requirements of modern vehicles. These components, used across engine control units (ECUs), infotainment modules, advanced driver-assistance systems (ADAS), and other safety-critical electronics, offer proven robustness against the thermal, mechanical, and electrical stresses typical of automotive environments.

4.2. Benefits of AEC Qualification

Compliance with **AEC-Q200** for passive timing devices and **AEC-Q104** for multichip timing modules ensures that quartz crystals, oscillators, and RTC modules satisfy the rigorous environmental, mechanical, and electrical requirements expected in automotive systems. These standardized qualification frameworks validate a component's ability to operate reliably across the full spectrum of stress encountered in the vehicle.

Designers and OEMs benefit from:

- **High reliability under extreme operating conditions**, including wide temperature ranges, vibration, and electrical perturbation.
- **Streamlined component selection**, thanks to standardized testing and uniform performance expectations across suppliers.
- **Reduced risk of failures** in mission-critical automotive applications, supporting improved functional safety and long-term system dependability.

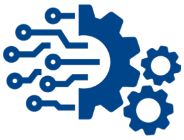
By relying on components that have been qualified through rigorous AEC test regimes, automotive OEMs can strengthen system-level robustness, reduce the likelihood of field failures, and enhance overall vehicle safety. This assurance is particularly valuable in architectures where timing accuracy and stability underpin critical functions such as sensing, control, communication, and power management.

4.3. Simplified Design Process

Incorporating AEC-qualified components into an automotive design significantly reduces development effort. Because these components already meet established industry reliability benchmarks, engineers can avoid extensive supplementary screening, accelerating both component selection and system-level qualification.

4.4. Improved System Performance

AEC-qualified timing devices deliver stable and predictable electrical behavior, which is essential for maintaining synchronization and signal integrity in complex automotive electronics. Their consistent performance contributes to enhanced system efficiency, reduced noise sensitivity, and improved reliability across the full vehicle lifecycle.



5. Why RTCs with Temperature Compensation are Important in Automotive Applications?

Accurate timekeeping is critical in automotive applications, especially for systems requiring precise timing, such as data logging, event recording, and startup or initialization processes, as well as synchronization with external systems. However, maintaining this level of timing accuracy—specifically minimizing time drift and ensuring reliable, low time shift—becomes particularly challenging under the highly variable temperature conditions typical of automotive environments, which can significantly impact the stability and reliability of conventional RTCs.

Standard RTCs are highly sensitive to temperature fluctuations. This is due to the inherent frequency deviation of tuning fork quartz crystals caused by changes in temperature as shown below with typical crystal uncompensated curve.

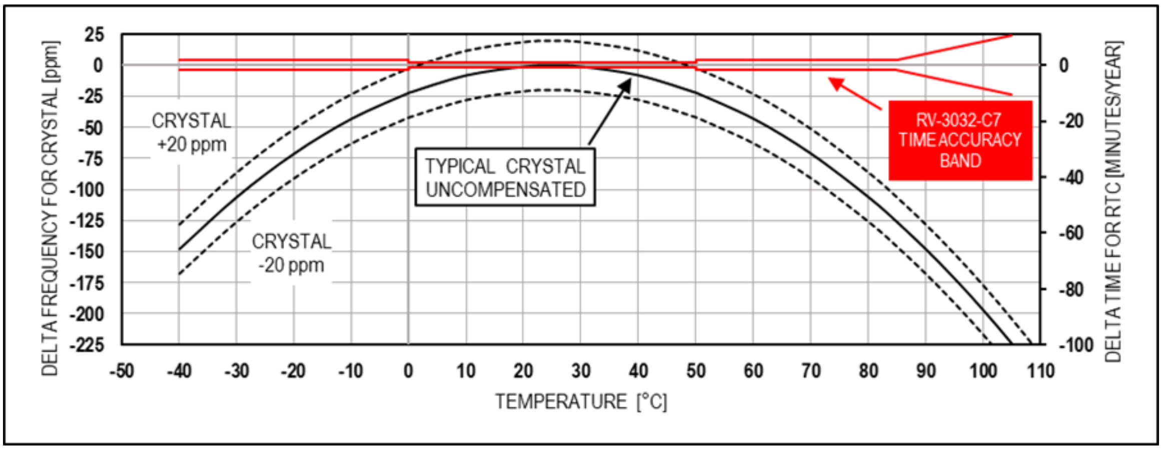


Figure 7: Temperature Effect on Crystal and RV-3032-C7 RTC Module

To address this, the use of temperature-compensated RTCs (DTCXO- Digital Temperature Compensated Oscillator based RTC like the RV-3032-C7 from Micro Crystal) is essential to ensure consistent and accurate timekeeping, even under extreme thermal conditions ranging from freezing cold (-40°C) to extremely high temperatures (+105°C or even +125°C).

5.1. Micro Crystal DTCXO-RTCs for Automotive Applications

Micro Crystal provides a range of high-performance, temperature-compensated RTCs specifically designed for automotive environments and AEC-Q104 qualified. These RTCs ensure accurate timekeeping across a wide temperature range and meet the stringent requirements of automotive-grade applications.

AEC-Q104

Table 3: RTC Modules and AEC-Q104 Qualification Grade

RTC Product	Interface	I_{DD} [nA]	Maximum Time Deviation with Temperature Compensation over -40 / 85°C range	VDD_{min} [V]	VDD_{max} [V]	T_{max} [°C]	AEC-Q104 Qualification Grade
RV-3028-C7	I²C	45	±1.0 ppm at 25°C (no temp. comp.)	1.1	5.5	+85	Grade 3
RV-3032-C7	I²C	160	±2.5 ppm or ± 0.22 sec/day	1.2	5.5	+105	Grade 2
RV-8803-C7	I²C	240	±3 ppm or ± 0.26 sec/day	1.5	5.5	+105	Grade 2
RV-3129-C3	I²C	800	±6 ppm or ± 0.52 sec/day	1.3	5.5	+125	Grade 1
RV-3149-C3	SPI	800	±6 ppm or ± 0.52 sec/day	1.3	5.5	+125	Grade 1

Package [mm]

C3  3.7 x 2.5 x 0.9

C7  3.2 x 1.5 x 0.8

6. Conclusion

The qualification of quartz crystals, oscillators, and RTC modules under AEC-Q200 and AEC-Q104 demonstrates the ongoing importance of meeting established automotive-grade reliability expectations. These standards help ensure that timing components can withstand demanding environmental and electrical conditions, while also supporting consistent system-level integration across a broad range of vehicle architectures.

AEC-Q104 builds on the premise that all subcomponents within a multichip module are already qualified to their respective AEC standards. Its focus on module-level validation—particularly through Board Level Reliability (BLR) testing—addresses the unique challenges posed by today's increasingly complex, multi-die assemblies.

MICRO CRYSTAL OFFERS AEC-Q200-QUALIFIED CRYSTALS, OSCILLATORS AND NOW EXTENDS THIS CAPABILITY TO AEC-Q104-QUALIFIED RTC MODULES

Aligned with these frameworks, Micro Crystal offers AEC-Q200-qualified crystals, oscillators, and RTC modules marked "QA" for automotive use and now extends this capability to AEC-Q104-qualified RTC modules for applications requiring formal module certification. This provides designers with reliable timing solutions that support the safety, performance, and durability targets expected in next-generation automotive systems.

As vehicle electronics continue to evolve, selecting components that comply with AEC standards remains a strategic decision that reduces risk and reinforces long-term system robustness. Micro Crystal's portfolio of low-power, high-performance RTC modules—including temperature-compensated options in compact packages—offers a solid foundation for meeting these requirements. We welcome inquiries and encourage engagement with our engineering teams to identify solutions tailored to your specific application needs.

Additional resources:

For more information about automotive qualified products and Micro Crystal's portfolio of Real-Time Clock modules, please visit:
www.microcrystal.com

About the author:

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Nicolas is Head of Global Marketing at Micro Crystal AG.
He benefits from strong expertise built on his roles and experience in Product Development, Technical Support, Product Management and Technical Sales in sensor business for industrial, consumer and automotive applications.
Nicolas holds an EE degree with specialization in Test & Measure and is fascinated by quantifying the world around us.
He thinks that any sensor measurement is significantly enhanced when combined with an accurate and reliable time reference.

7. Reference documents

Document	Name	Link
AEC Official Documents Page	AEC-Q200 and Q104 available for free download	http://www.aecouncil.com/AECDocuments.html

8. Document version

Date	Version #	Changes
June 29-2026	1.0	Initial version