AN14194

MCX A153/2 and A143/2 Product Lifetime Usage Estimates

Rev. 1 — 1 February 2024 | Application note

Document information

Information	Content
Keywords	AN14194, MCX, MCX A, Lifetime, Power-on hours, temperature, PoH
Abstract	This application describes the estimated product Power-on Hours (PoH) for the MCX A153/2 and MCX A143/2 (device) based on the criteria used in the qualification process.

1 Introduction

This document describes the estimated product Power-on Hours (PoH) for the MCX A153/2 and MCX A143/2 (**device**) based on the criteria used in the qualification process.

The product PoH described here are estimates and do not represent a guaranteed lifetime for a product. Contents

This document provides guidance on how to interpret the different device qualification levels in terms of the target operating voltage, the maximum supported junction temperature (T_j), and how these relate to the PoH of the device.

The data presented in this document is provided for convenience. However, it does not represent all potential failing mechanisms and may not accurately represent behavior for all mission profiles or applications. The data is based on a single activation energy and voltage acceleration parameter, using the Arrhenius equation for temperature acceleration and Power Law for voltage acceleration, along with the data collected during High Temperature Operating Life (HTOL), to demonstrate how temperature could impact the PoH of the product.

2 Device qualification level and available PoH

Each qualification level supported (Industrial) defines several Power-on Hours (PoH) available to the device under a given set of conditions such as:

- The target core voltage (Output of internal LDO Core Voltage) for the application (Industrial).
- The junction temperature of the device (T_j).
  - It is important to note that while the device can operate at the maximum T_j listed in its datasheet, operating the device at this temperature for an extended period will reduce its operating PoH.
  - Always ensure that the device is appropriately and thermally managed and the maximum junction temperature is not exceeded.

The junction temperature (T_j) of the device is the temperature of the transistors in the device. It is a different measurement than the case and the ambient temperature. Most applications do not have a constant T_j during operation.

The charts in this document show the relationship between the T_j and Power-on Hours. The percentage of on-time at different temperatures is part of what defines each Mission Profile. When the junction temperature is not constant during the customer application, the Effective Junction Temperature ($T_{j\text{-eff}}$) can be calculated using weighting with the Arrhenius factor (for more about $T_{j\text{-eff}}$, see Section 3).

Note:

Data provided in this document are estimates for PoH based on qualification test data and experience with this product. These estimates must not be viewed as a limit on an individual device lifetime, nor must they be construed as a guarantee by NXP as to the actual lifetime of the device. Sales and warranty terms and conditions still apply.

2.1 Industrial qualification

Figure 1 provides the number of PoH for the use conditions of the Industrial device. The PoH value assumes that the product is powered on and active for 100 % of the time (100 % duty cycle). PoH can be read directly from the curves below to determine the impact of junction temperature at the listed conditions.

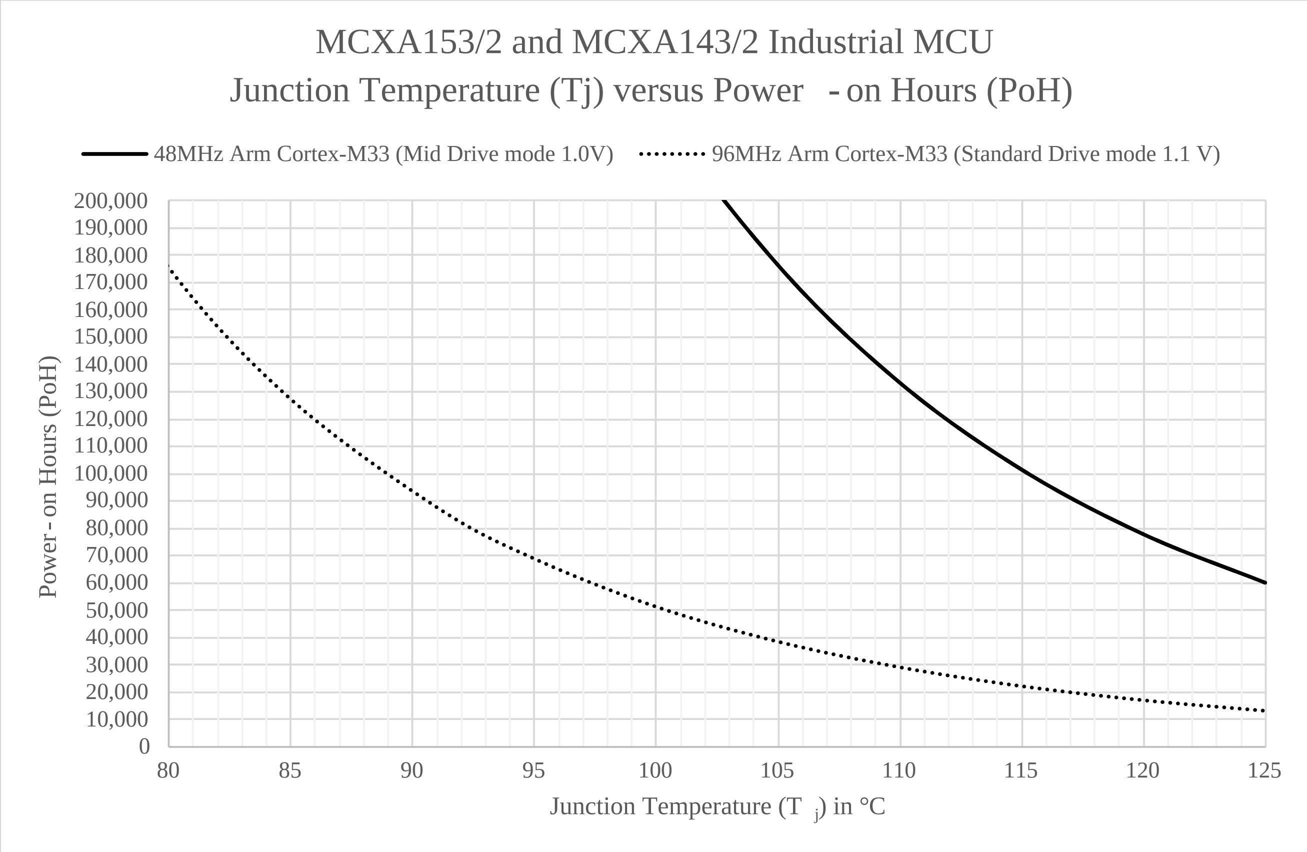

Figure 1. MCX A153/2 and MCX A143/2 Industrial PoH estimates

3 Effective junction temperature

The junction temperature (T_j) of the device is the temperature of the transistors in the device. It is a different measurement than the case and the ambient temperature. Most applications do not have a constant T_j during operation.

The charts in this document show the relationship between the T_j and Power-on Hours. The percentage of on-time at different temperatures is part of what defines each Mission Profile. The Effective Junction Temperature ($T_{j\text{-eff}}$) is the single T_j that represents the mission profile and can be used to extrapolate the PoH in the charts above.

- The $T_{j\text{-eff}}$ depends only on the temperatures during on-time duty cycles of a Mission Profile. Temperatures when the device is powered off do not affect $T_{j\text{-eff}}$.
- $T_{j\text{-eff}}$ is not a simple average of temperatures, as the on-time at higher temperatures consumes more operating life than on-time at lower temperatures.
- When the junction temperature is not constant during the customer application, the $T_{j\text{-eff}}$ can be calculated using weighting with the Arrhenius factor.

3.1 Calculating $T_{j\text{-eff}}$

Assuming that the temperature dependence follows Arrhenius behavior, one can calculate the $T_{j\text{-eff}}$ using the following method:

1. Determine the percentage of time (t_n) that the application is powered on at a small set of discrete temperatures (T_n).
2. Calculate the average failure rate using the Arrhenius method.

$$FR_{AV}=\left[t_1 \cdot e^{\frac{-E_A}{k \cdot T_1}} + t_2 \cdot e^{\frac{-E_A}{k \cdot T_2}} + \ldots + t_n \cdot e^{\frac{-E_A}{k \cdot T_n}}\right] \quad (1)$$

3. The effective temperature can then be calculated.

$$T_{j\text{-}eff} = \frac{-E_A}{k \cdot \ln(FR_{AV})} \quad (2)$$

Here are some notes on the variables and constants used in the formulas above:

- E_A = Activation Energy. A typical value is 0.7 eV and is what is used to generate the charts in this document.
- k = Boltzmann constant. 8.62×10^{-5}
- T_n = The temperatures must be noted in Kelvin. The end result for $T_{j\text{-}eff}$is also be in Kelvin.
- t_n = The percentage of time at a given temperature must be noted in decimal. For instance, 50% is 0.50.

Here is a simple example calculating the $T_{j\text{-}eff}$ of an application that has two different constant values. In this scenario, the T_j of the device is at 100 °C for 50 % of the time, and 50 °C for the other 50 % of time the device is powered on, resulting in an average of 75 °C.

$$FR_{AV}=\left[0.5 \cdot e^{\frac{-0.7}{k \cdot 373.15}} + 0.5 \cdot e^{\frac{-0.7}{k \cdot 323.15}}\right] = 1.83 \times 10^{-10} \quad (3)$$

$$T_{j\text{-}eff} = \frac{-0.7}{k \cdot \ln(FR_{AV})} = 362.18\ K = 89.03℃ \quad (4)$$

In this example, you can see that the $T_{j\text{-}eff}$ of 89 °C is much higher than the average temperature of 75 °C. It shows that higher temperatures have a bigger impact on the life of the device.

4 Conclusion

Selecting the optimal operating performance point and thermal envelope is critical to meet the target application PoH. Trade-offs between the target operating voltage/frequency of the device and the operating junction temperature (Tj) of the device can greatly improve the PoH of the device.

Lowering the operating junction temperature in the application is the most effective means to increase the PoH of the device without affecting the performance of the device. This can be accomplished by increasing the thermal dissipation capacity in the application. In cases where the thermal properties cannot be altered, a lower operating voltage can be used to increase the PoH of the device. Lowering the voltage may result in a lowered performance; the operating frequency may have to be adjusted lower to match the voltage specified in the datasheet.

The data and examples provided in this application are a reference to support the customer in their application development.

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5 Revision history

Table 1 summarizes the revisions to this document.

Table 1. Revision history

Document ID	Release date	Description
AN14194 v.1	01 February 2024	Initial public release

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