AN14180

Estimating Device Lifetime for MCX Nx4x

Rev. 1.0 — 20 January 2024 Application note

Document information

Information	**Content**
Keywords	AN14180, PoH, junction temperature, MCX N, MCX N54x, MCX N94x, max operating temperature, lifetime
Abstract	This document describes the estimated product Power-on Hours (PoH) for the MCX N94X and MCX N54X devices.

1 Introduction

This document describes the estimated product Power-on Hours (PoH) for the MCX N94x and MCX N54x devices, based on the criteria used in the qualification process.

The product PoH described here is an estimate and do not represent a guaranteed lifetime for a product.

This document provides the following:

- Guidance on how to interpret the different device qualification levels in terms of the target operating voltage.
- The maximum supported junction temperature (T_j).
- How the target operating voltage and maximum support T_j 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 cannot accurately represent behavior for all mission profiles or applications. The data is based on a single activation energy and voltage acceleration parameter. The Arrhenius equation is used for temperature acceleration and the power law for voltage acceleration, along with the data collected during High Temperature Operating Life (HTOL), to demonstrate how temperature can impact the PoH of the product.

2 Device qualification level and available PoH

Each qualification level supported (industrial), defines the various PoH available to the device under a given set of conditions, as follows:

- The target core voltage (VDD_CORE) for the application (industrial)
- The T_j of the device:
  - While the device can operate at the maximum T_j listed in its data sheet, operating the device at this temperature for an extended time reduces its operating PoH.
  - Always ensure that the device is thermally managed appropriately and the maximum T_j is not exceeded.

The chart in this document shows the relationship between the T_j and PoH. The percentage of on-time at different temperatures is part of what defines each mission profile. When the T_j 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 information on $T_{j\text{-eff}}$, see Section 3.

Note:

Data provided in this document is an estimate 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, and must not 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 given in Figure 1 to determine the impact of T_j at the listed conditions.

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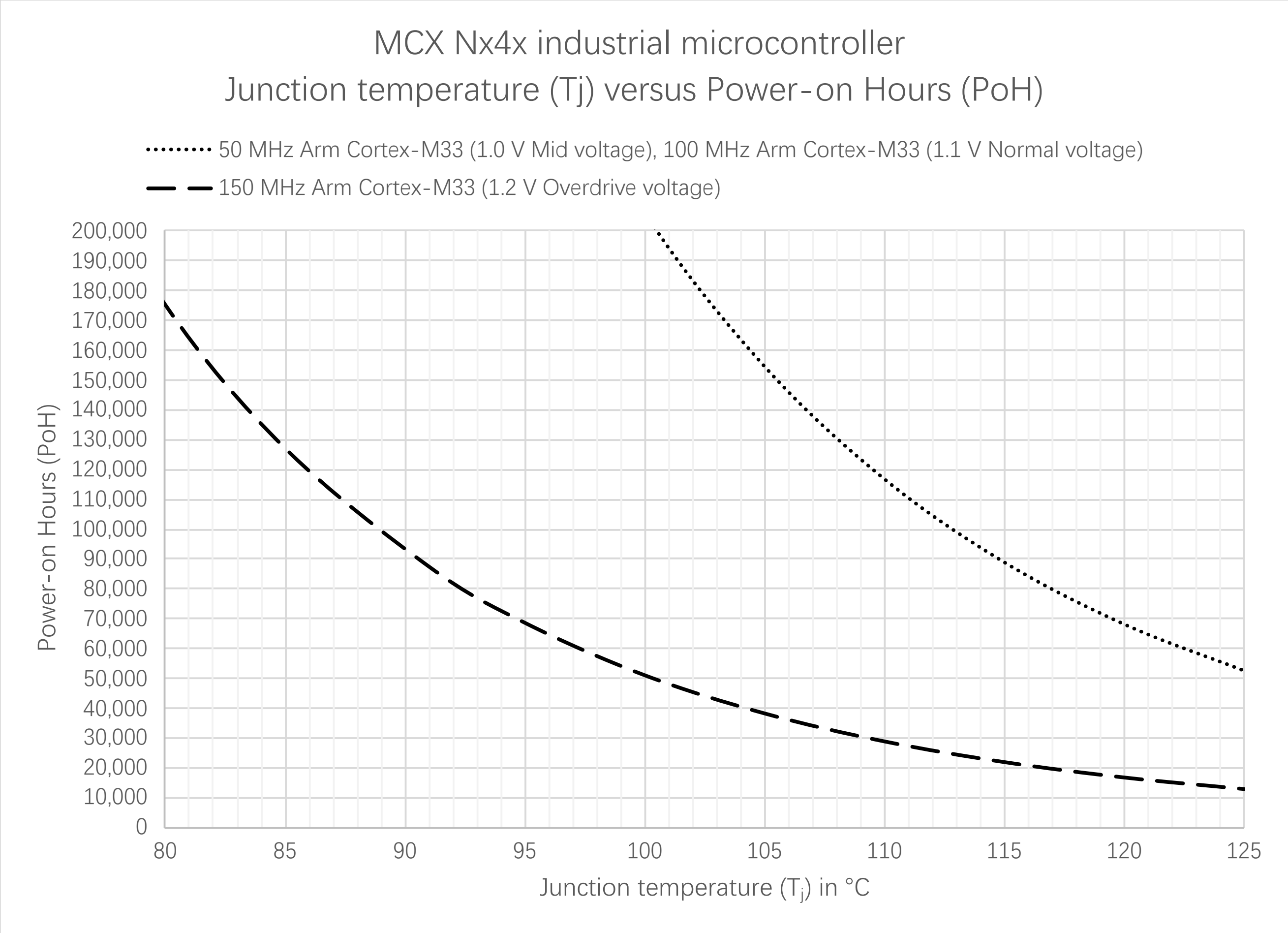

Figure 1. MCX Nx4x industrial PoH estimates

3 Effective junction temperature

The 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 $T_{j\text{-eff}}$ is the single T_j that represents the mission profile and can be used to extrapolate the PoH in the chart given in Figure 1.

- The $T_{j\text{-eff}}$ depends only on the temperatures during the 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 T_j is not constant during the 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:

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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, as given by Equation 1:

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

3. Then, calculate the effective temperature using Equation 2:

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

Where:

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

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

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

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

Equation 3 and Equation 4 show that the $T_{j\text{-eff}}$ with value 89 °C is higher than the average temperature of 75 °C. Therefore, the 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 T_j of the device can greatly improve the PoH of the device.

Lowering the operating T_j 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. For the 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 can result in lower performance; therefore, the operating frequency has to be adjusted lower to match the voltage specified in the data sheet.

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

5 Revision history

Table 1 summarizes the revisions to this document.

Table 1. Revision history

Document ID	Release date	Description
AN14180 v.1.0	20 January 2024	Initial public release

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