AN14244

i.MX 8ULP Processor Estimated Power-on Hours

Rev. 1 — 8 March 2024 **Application note**

Document information

Information	Content
Keywords	AN14244, i.MX 8ULP, power-on hours, PoH, effective junction temperature
Abstract	This document describes the estimated power-on hours (PoH) for the i.MX 8ULP applications processor (*device*) based on the criteria used in the qualification process.

1 Introduction

This document describes the estimated power-on hours (PoH) for the i.MX 8ULP applications processor (*device*) based on the criteria used in the qualification process. The device PoH described here are estimates and do not represent a guaranteed lifetime for a device.

This document is intended to provide guidance on how to interpret different device qualification levels in terms of the following factors:

- The target operating voltage
- The maximum supported junction temperature (T_j)

The document also describes how these factors relate to the PoH of the device.

The data presented in this document is provided for your convenience. It does not represent all potential failing mechanisms. Also, it may not accurately represent the behavior for all mission profiles or applications. The data demonstrates how temperature can impact the PoH of the device, and it is based on:

- The activation energy using the Arrhenius equation for temperature acceleration
- The voltage acceleration parameter using the power-law for voltage acceleration
- The data collected during high-temperature operating life (HTOL)

2 Device qualification levels and available PoH

The i.MX 8ULP processor supports the following qualification levels:

- Industrial qualification
- Commercial qualification

Each qualification level defines the power-on hours (PoH) available to the device under a given set of conditions, such as:

- Target core voltage (VDD_SOC) for the application
- Junction temperature of the device (T_j)

Note: *While the device (SoC) can operate at the maximum T_j listed in its data sheet, operating the device at this temperature for an extended period reduces its operating PoH.*

Note: *Always ensure that the device is thermally managed and the maximum junction temperature is not exceeded.*

Note: *For the device voltage and temperature limits, refer to the respective device data sheet available on nxp.com.*

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 PoH. The percentage of on-time at different temperatures is part of what defines each mission profile.

If the junction temperature is not constant during an application, you can calculate the effective junction temperature ($T_{j\text{-eff}}$) using weighting with the Arrhenius factor. For more details, see Section 3.

Note: *The data provided in this document are estimates for the PoH, based on the qualification test data and experience with this device. These estimates must not be viewed as a limit on an individual device lifetime. Also, they must not be construed as a guarantee by NXP to the actual lifetime of the device. Sales and warranty terms and conditions still apply.*

2.1 Industrial qualification

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

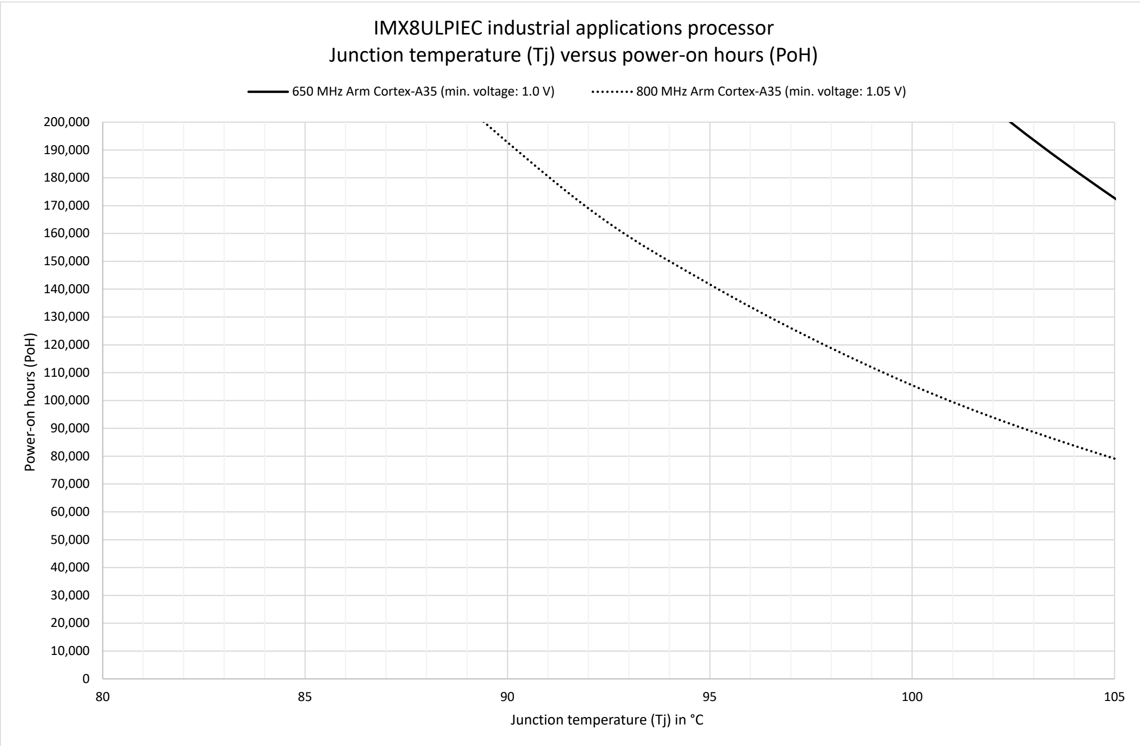

Figure 1. i.MX 8ULP industrial PoH estimates

2.2 Commercial qualification

Figure 2 provides the number of PoH for the use conditions of the commercial device. The PoH can be read directly from the curves shown in Figure 2 to determine the impact of junction temperature at the listed conditions.

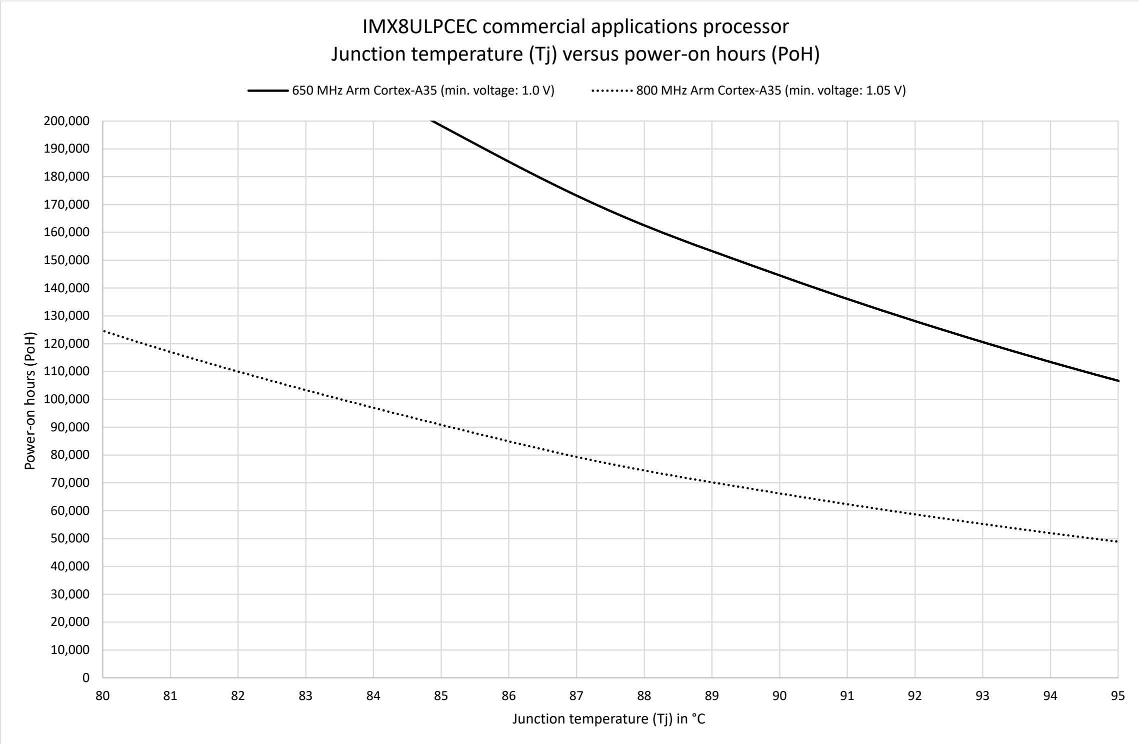

Figure 2. i.MX 8ULP commercial PoH estimates

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 PoH. 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. It can be used to extrapolate the PoH in the charts shown in Figure 1 and Figure 2:

- $T_{j\text{-eff}}$ 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.
- If the junction temperature is not constant during an application, you can calculate $T_{j\text{-eff}}$ using weighting with the Arrhenius factor.

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

Assuming that the temperature dependence follows Arrhenius behavior, you 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:

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

3. Then, calculate the effective temperature:

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

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

- E_A: Activation energy. A typical value for E_A is 0.7 eV, which is used to generate the charts in this document.
- k: Boltzmann constant. Its value is 8.62 x 10^{-5}.
- T_n: Temperature in Kelvin. The resulting $T_{j\text{-}eff}$ must also be in Kelvin.
- t_n: The percentage of time at a given temperature. t_n must be noted in decimal, for example, 50% becomes 0.50.

The following is a simple example explaining how to calculate $T_{j\text{-}eff}$ of an application that has two constant temperature values for a given period.

Assume that the T_j of the device is at:

- 100 °C for 50% of the time
- 50 °C for the other 50% of the time the device is powered on

In this case, the average temperature is 75 °C.

Now, using Equation 1, the average failure rate can be calculated as follows:

$$FR_{AV}=\left[0.5\cdot e^{\left(\frac{-0.7}{k\cdot 373.15}\right)}+0.5\cdot e^{\left(\frac{-0.7}{k\cdot 323.15}\right)}\right]=1.83\times10^{-10} \tag{3}$$

Then, using Equation 2, the effective temperature can be calculated as follows:

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

You can notice that $T_{j\text{-}eff}$ of 89 °C is higher than the average temperature of 75 °C. It indicates 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 crucial to meet the target application power-on hours (PoH). Trade-offs between the target operating voltage/frequency of the device and the operating junction temperature (T_j) of the device can greatly improve the PoH of the device.

Lowering the operating junction temperature during an application (without impacting device performance) is the most effective way to increase the PoH of a device. It can be achieved by increasing the thermal dissipation capacity in the application. For optimal thermal management, refer to the device hardware developer's guide.

In cases where the thermal properties cannot be altered, a lower operating voltage can be used to increase the PoH of the device. However, lowering the voltage reduces device performance. To match the voltage specified in the data sheet, you may need to reduce the operating frequency.

You can use the data and examples provided in this application note as a reference during your application development. For additional recommendations on power optimization, refer to power optimization related application notes available on nxp.com.

5 Revision history

Table 1 summarizes the revisions to this document.

Table 1. Revision history

Document ID	Release date	Description
AN14244 v.1	8 March 2024	Initial public release

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