# IPOSIM Lifetime Estimation service

## User Manual

## About this document

### Scope and purpose

The objective of this document is to provide a detailed explanation about how to use IPOSIM Lifetime Estimation service.

### Introduction

Estimating lifetime of power modules considering real mission profiles, is important at an early stage of the power electronics system design, especially, but not only, in applications with long-life requirements, such as for example traction and wind in the industrial arena [1]. In order to do that, complex simulations need to be performed, very often stressing the used tools and the methodology to their limits, due to very long, highly variable profiles, creating big amounts of data to be handled. Such is the case for example with solar and wind power converters. Understanding the impact, that real usage profiles are expected to have, is crucial, on one side for reliability improvement, and on the other, for driving cost reduction of power electronics systems [2].

This document describes the steps to execute Lifetime Estimation (LTE) in IPOSIM; in addition, it provides a guidance on the result graphs delivered in the Lifetime calculation report.

## Table of contents

# 1 Lifetime Estimation Methodology

Lifetime Estimation (LTE) service is based on a unique algorithm improved throughout the years, incorporating our experience from supporting customers as well as the extensive knowledge of Infineon power modules characterization.

The implemented algorithm is based on the methodology described in [3], and a simplified flow scheme is depicted in the Figure 1. Different load profiles with varying thermal conditions, can lead into diverse levels of thermal stress in applications using the same type of power devices. Therefore, the first step is the selection of the power device and the implementation of the load profile.

Once the input data is defined, the algorithm calculates the power losses under the specified operation conditions. This information is relevant in order to estimate the power electronics system efficiency, and most important, this is the input for the thermal calculation.

The power losses are dissipated as heat from the chip to the ambient. Depending on the thermal model of the power device and the heatsink configuration, the junction temperature, the case and heatsink temperature behavior can be accurately calculated.

There is a distinction between two types of cycling capability, the junction temperature which is related to the power cycling (PC), and the solder joint and case temperature which are related to the thermal cycling (TC). It is important to point out that TC is not calculated for certain types of power modules, e.g. baseplate-less modules, or when the heatsink temperature is fixed.

For complex and varying temperature profile, the rainflow-counting algorithm is used in the analysis of fatigue life. It reduces the spectrum of varying stresses into a set of cycle numbers. With these results and using the cycling diagrams it is possible to obtain the lifetime estimation.

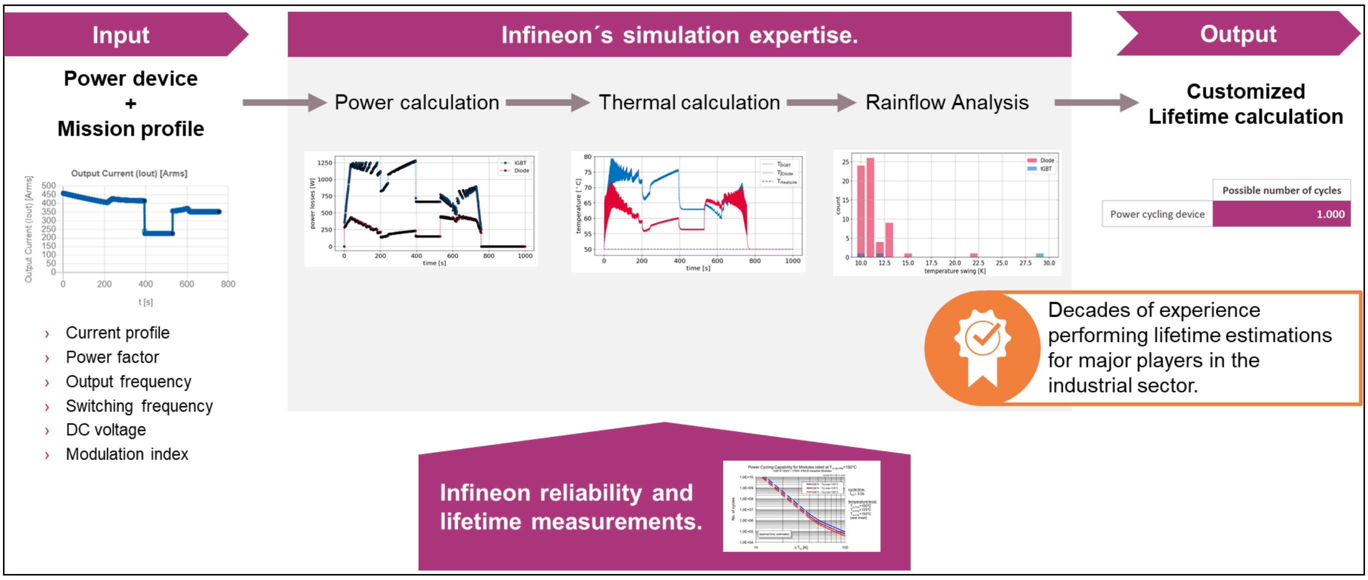



**Figure 1 Flow scheme of the lifetime estimation algorithm.**

# 2 Lifetime Estimation Simulation Settings

## 2.1 Evaluation case design

The LTE service can be found on the IPOSIM platform, and the process starts with the topology and the device selection as can be seen in the Figure 2. The results will be calculated for the individual devices forming the topology, and it is possible to select up to five devices for the same simulation run.

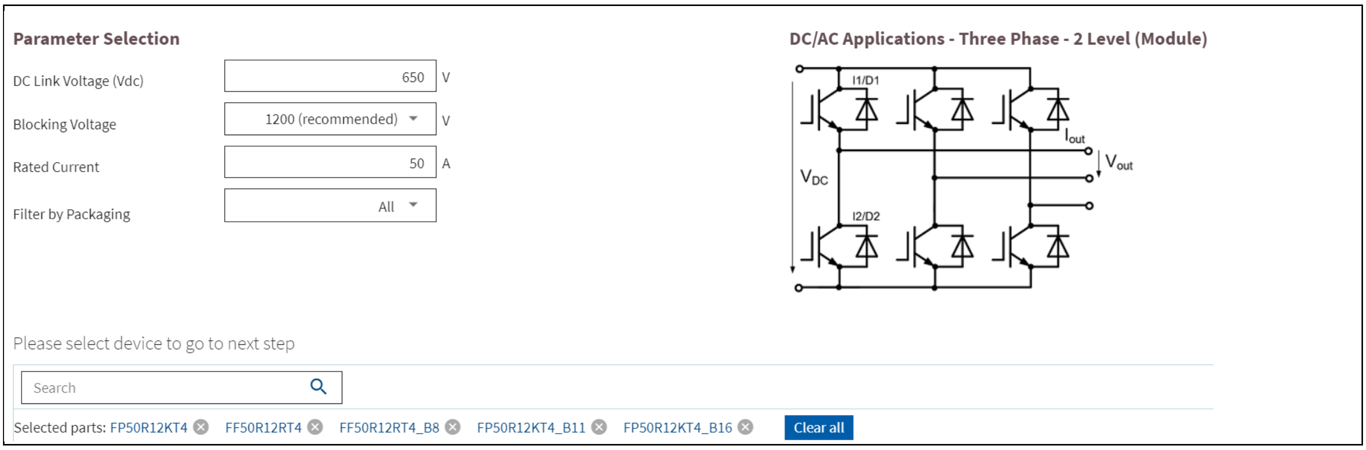



**Figure 2 Topology and device selection.**

### 2.1.1 Application data

After selecting the simulation type “Lifetime Estimation”, the users can set-up the different parameters based on their system design.

**Circuit and control**

- Modulation algorithm: The most used modulation strategies are available for the simulation.
- Load type: It is possible to select between lagging (inductive), or leading (capacitive) load.

**Cooling condition**

- Predefined heatsink: An example heatsink design is provided, depending on the cooling method (forced air or water).
- User defined heatsink: Users can provide information about the thermal description (foster model) of their own heatsink characterization.
- Fixed heatsink: The heatsink is be considered as a fixed temperature source.

It is important noticing that the heatsink values must be provided per single power device, so that IPOSIM calculates power losses and temperature per single switch.

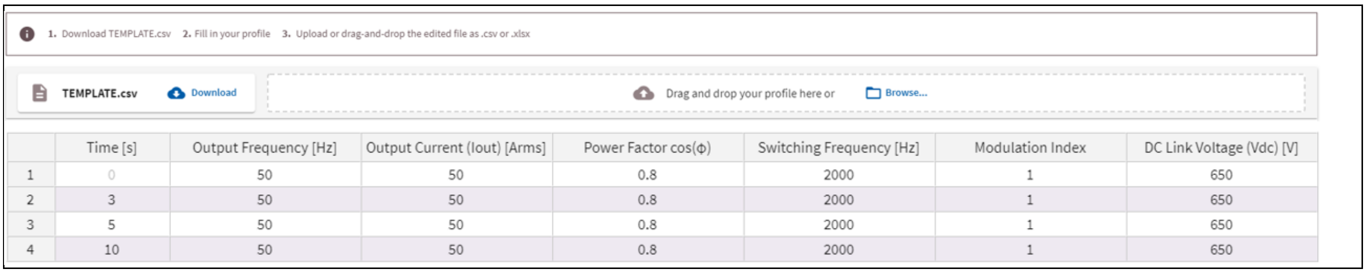
**Advanced parameters**

The power losses calculation is dependent on the gate resistor; hence the user can modify these parameters:

- RGon: Turn-on gate resistor.
- RGoff: Turn-off gate resistor.

## 2.1.2 Load cycle profile

It is possible to set-up the mission profile by uploading a csv file, or filling up the table depicted in the Figure 3.




| | Time [s] | Output Frequency [Hz] | Output Current (Iout) [Arms] | Power Factor cos(ϕ) | Switching Frequency [Hz] | Modulation Index | DC Link Voltage (Vdc) [V] |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 50 | 50 | 0.8 | 2000 | 1 | 650 |
| 2 | 3 | 50 | 50 | 0.8 | 2000 | 1 | 650 |
| 3 | 5 | 50 | 50 | 0.8 | 2000 | 1 | 650 |
| 4 | 10 | 50 | 50 | 0.8 | 2000 | 1 | 650 |

**Figure 3 Load cycle profile set-up table.**

The design of the load profile can be automatic modified by using the configuration options depicted on the Figure 4.

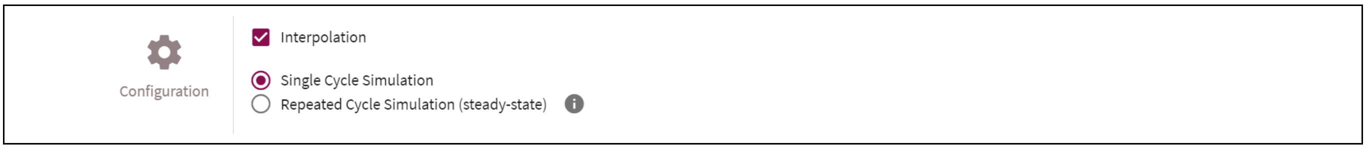



**Figure 4 Load profile configuration.**

The available options are:

- Interpolation: When this option is activated, the algorithm interpolates the operation points between two-time steps. On the other hand, when the option is deactivated, the operation points change instantaneously at the same time step. The effect of this configuration is shown in the Figure 5.

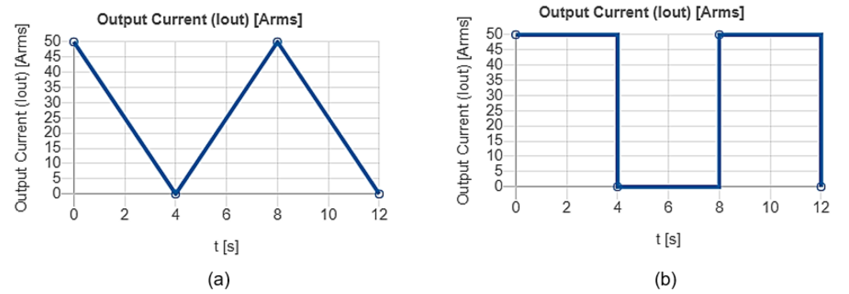



**Figure 5 Interpolation option: (a) Activated. (b) Deactivated.**

- Single cycle simulation: The simulation will be performed for only one cycle, and the temperature results will be displayed starting from the defined reference temperature.
- Repeated cycle simulation: The load cycle repeats until it reaches a system thermal equilibrium. E.g. The heatsink will be heated-up if the duration of the load cycle is lower than the heatsink time constant.

## 2.2 Running Lifetime Estimation

Lastly, a summary of the parameters defined for the simulation are displayed. The user can review the content and add a comment to identify the simulation before clicking on the Confirm/Run button.

### 2.2.1 Report generation

After confirming the simulation parameters, user will be notified that the process has successfully started as depicted on the Figure 6.

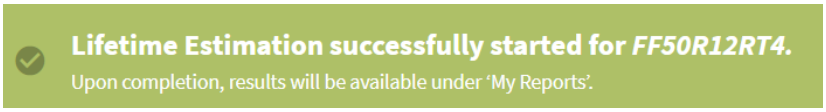



**Figure 6 Simulation start message.**

Under the button "My Reports" the user can find the LTE simulations that have been executed. Once the simulation is completed the report will be available for download. An approximation of the time required to complete the simulation, is displayed on the State column as shown in Figure 7.

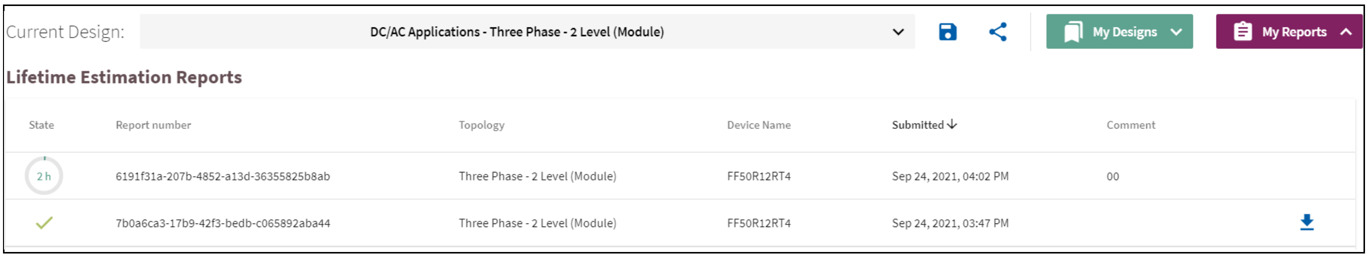



**Figure 7 Lifetime Estimation reports.**

# 3 Lifetime Calculation Report

The simulation process concludes with the automatic generation of a PDF report. This file depicts the main input parameters, the target mission profile and the most relevant results. The Figure 8 shows an example of a typical simulation summary. The desired device is highlighted and some relevant information and results are included as well.

**Summary**

| | |
|---|---|
| Lifetime calculation for: | **FZ750R65KE3** |
| Topology: | DC/AC Three Phase - 2 Level |
| Load cycle duration: | 00:16:39 [h:min:s] |
| Analysis mode: | Single cycle simulation |
| Cooling: | Liquid cooling |
| Max. junction temperature: | 102.1 °C (IGBT) |
| Estimated lifetime: | 38 possible cycles |
| Lifetime limititation : | IGBT - Power cycling |

**Figure 8 Example of a simulation summary.**

## 3.1 Converter simulation results

The first depicted results, as shown in the Figure 9, are the converter output power and the power losses calculation. With this information it is already possible to have a rough estimate of conversion efficiency.

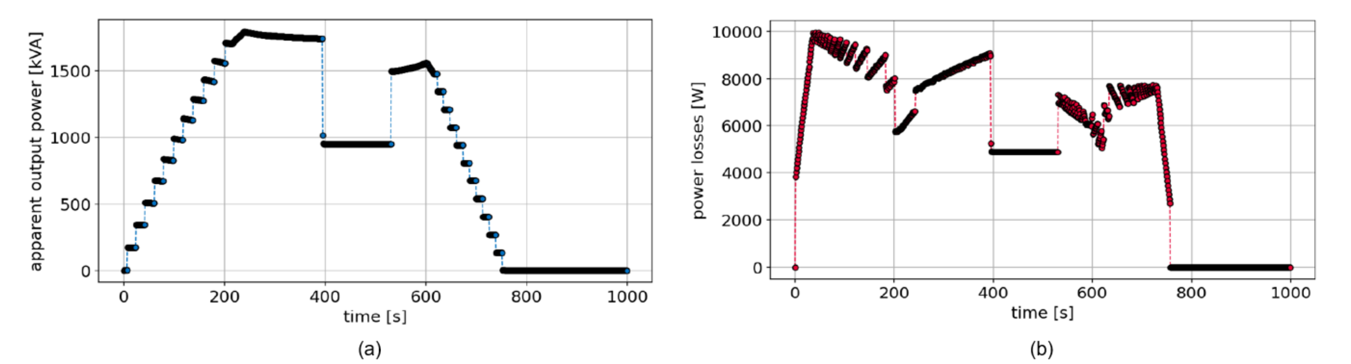



**Figure 9 Converter simulation results. (a) Output power. (b) Power losses.**

## 3.2 Device simulation results

The Figure 10 depicts the simulated results per device, either IGBT/Diode or SiCMOSFET, depending on the device selection. In addition, the figure shows the maximum device case temperature and this is plotted only in case of thermal cycling calculation.

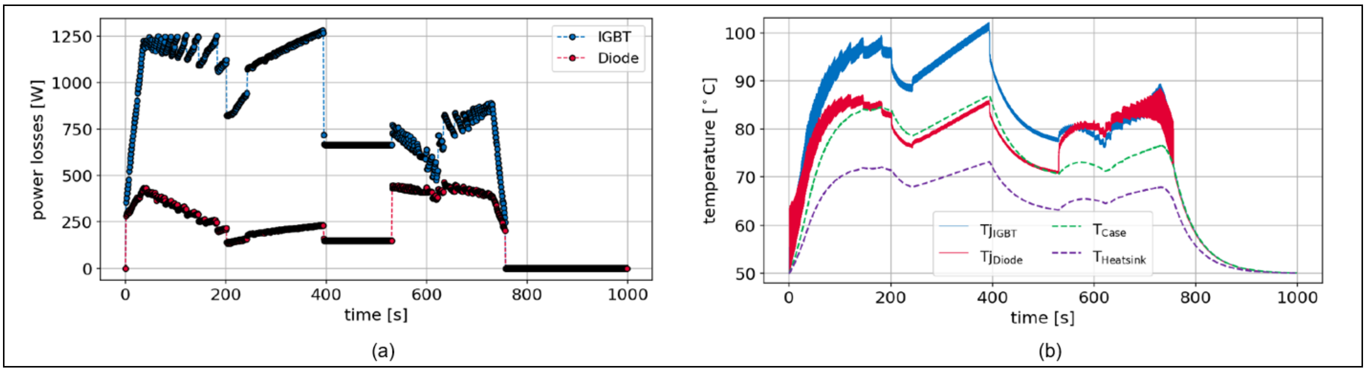



**Figure 10 Device simulation results. (a) Power losses. (b) Temperature.**

## 3.3 Lifetime calculation results

To determine the expected lifetime of an application, the temperature cycles must be counted. In order to check the power cycling, the junction temperature is considered. On the other hand, the case temperature is used to check the thermal cycling [3].

The rainflow algorithm is one of the most popular counting method used in the analysis of fatigue data. It reduces the spectrum of varying stress into a set of cycle numbers. This algorithm is specially used for load cycles with a complex, varying temperature profile [4].

The Figure 11 shows the power cycling results. The output counting is depicted in the figure (a), where the histogram shows the number of counts per temperature swing. Moreover, the consumption of lifetime is also calculated and the results are shown in the figure (b). It is possible noticing that the higher temperature swings consume more lifetime than the lower ones. In addition, the minimum temperature swing is fixed at 10 K, so that the characterization of the cycling curves is limited to this minimum value.

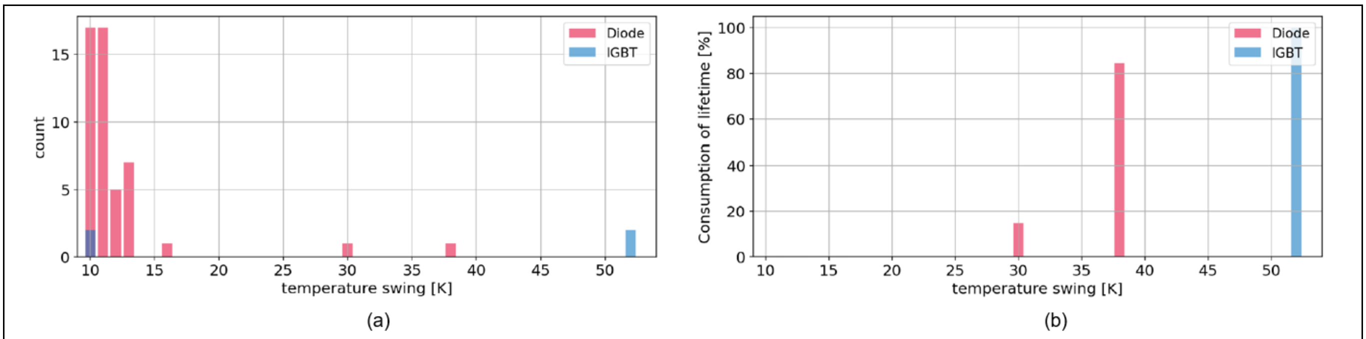



**Figure 11 Power cycling results. (a) Temperature swing count. (b) Lifetime consumption.**

As was mentioned before, the thermal cycling is calculated based on the case temperature. However, thermal cycling could be omitted in some of the following cases:

- Selection of modules with not available thermal cycling curve.
- Selection of baseplate-less modules.
- Selection of fixed heatsink temperature as cooling condition.

The Figure 12 shows the thermal cycling results. The output counting is depicted in the figure (a), where the histogram shows the number of counts per temperature swing. Moreover, the consumption of lifetime is also calculated and the results are shown in the figure (b).

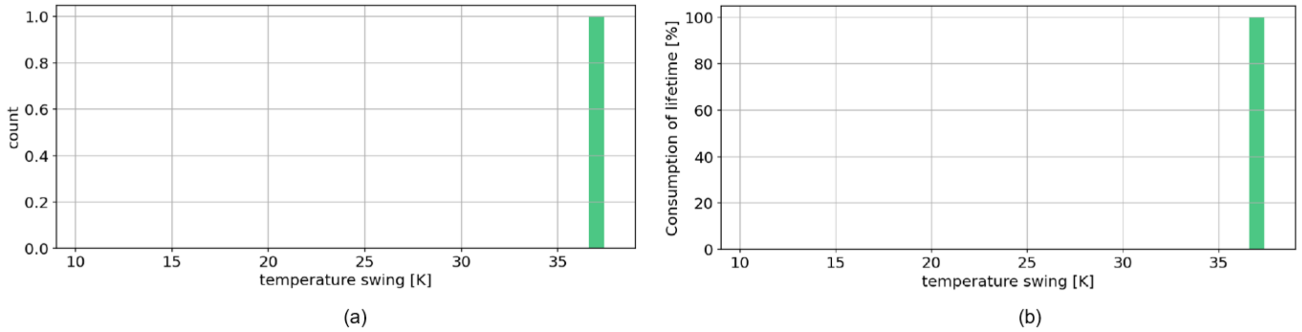



**Figure 12 Thermal cycling results. (a) Temperature swing count. (b) Lifetime consumption.**

Finally, a brief summary is depicted on the report as shown in the Figure 13. The possible number of cycles is highlighted as well as the lifetime limitation. It is basically the lowest value between power cycling and thermal cycling results.

| | Power cycling IGBT | Power cycling Diode | Thermal cycling |
|---|---|---|---|
| Possible number of cycles | **38** | **$4.552\times10^{6}$** | **$9.676\times10^{5}$** |

Total lifetime: **38 cycles**
Lifetime limitation: **IGBT - Power cycling**

**Figure 13 Lifetime calculation summary.**

## 3.4 Calculation status messages

Besides the results, the first page of the report includes messages about the simulation status as shown in Figure 14. It helps the user to verify if the simulation process ran normally, or if there were some issues during the simulation steps.

**Summary**

| | |
|---|---|
| Lifetime calculation for: | **FF600R12ME4** |
| Topology: | DC/AC Three Phase - 2 Level |
| Load cycle duration: | 00:01:00 [h:min:s] |
| Analysis mode: | Single cycle simulation |
| Cooling: | Fixed heatsink temperature |
| Max. junction temperature: | 124.3 ℃ (IGBT) |
| Estimated lifetime: | $1.607\times10^{6}$ possible cycles |
| Lifetime limititation : | IGBT - Power cycling |

**User comments**

test

**Calculation status message**

Calculation finished normally

**Figure 14 Calculation status message.**

The possible messages are:

- Calculation finished normally: This message informs the user, that all simulation steps were successfully completed.

- Maximum device temperature is above allowable device temperature: This message informs the user, that the device temperature exceeded the maximum allowable limit. The thermal simulation concludes and the result is depicted on the report. However, lifetime calculation is skipped.
- Maximum device temperature is 25 K above allowable device temperature: This message informs the user, that the device temperature exceeded 25 K more to the maximum allowable limit. The thermal simulation stops and the report depicts the thermal result until the moment when the temperature reached this maximum value. In this case the lifetime calculation is skipped.
- Simulation aborted: This message informs the user, that the thermal simulation was stopped.
- Skipping rainflow: This message informs the user, that the lifetime calculation was not performed.

*Note: The information given in the lifetime calculation report is the result of Infineon's reliability measurements and the methodology used by Infineon to estimate the lifetime of power devices. Such information is given as a hint for the implementation of the relevant Infineon products only. The lifetime estimations shall be verified by Infineon's customers before implementation of the relevant Infineon products, as actual operating conditions and environmental factors differ from Infineon's assumptions. Therefore, Infineon is not responsible for the correctness of any calculations that are based on this lifetime estimation. Please note that the technical specifications of Infineon's products are conclusively stated in the applicable Infineon data sheets. Please contact your sales partner of Infineon products for further information.*

# 4 Frequent Asked Questions

## 4.1 What if the load profile used for my design has parameters that are not included in the IPOSIM csv template? What do I have to do?

Answer: The CSV template offered in IPOSIM is standard for all lifetime simulations. In this case you would need to adjust manually your load profile information to the exact format of the csv template.

All parameters available in IPOSIM should be filled out in the right way. After uploading your CSV file into IPOSIM, the tool will highlight those parameters that do not comply with the platform requirements.

## 4.2 What if the parameters range I need are not available in IPOSIM (e.g. gate resistor)?

Answer: Please use the range available. IPOSIM displays the parameters range based on components characterization.

## 4.3 Does IPOSIM have a limitation on the length of the load profile?

Answer: The limit on the length depends on the inserted parameters of the load profile. IPOSIM has been optimized for both short and long profiles; in case that limits are exceeded IPOSIM will display a message when uploading the load profile like the one shown in Figure 15.

| | Time [s] | Output Frequency [Hz] | Output Current (Iout) [Arms] |
|---|---|---|---|
| 1 | 0 | 0.1 | 50 |
| 2 | 3 | 0.1 | 50 |
| 3 | 5 | 0.1 | 50 |
| 4 | 100000000000000 | 100 | 50 |

Duration limit exceeded. For the given profile the duration t is limited to xxx s.

**Figure 15 Duration limit message.**

## 4.4 Does IPOSIM have a limitation on the number of points for the load profile?

Answer: There is no limitation on the number of points. However, the longer the number of points in the profile the longer the simulation will take. Please review section 2.2.1 in this user manual.

## 4.5 I was running a LTE simulation but got this error message "Running Lifetime Estimation failed for the following devices: XXXXXX". What should I do now?

Answer: Please try to run your LTE simulation later, if it does not work please contact support.

# 5 Contact Support

Visit www.infineon.com/support where you can find FAQs section. Filter the search by entering the word "IPOSIM" in the search bar, or contact our support team.

## References

[1] K. Mainka, M. Thoben and O. Schilling, "Lifetime calculation for power modules, application and theory of models and counting methods," Proceedings of the 2011 14th European Conference on Power Electronics and Applications, 2011, pp. 1-8.

[2] K. Ma, M. Liserre, F. Blaabjerg and T. Kerekes, "Thermal Loading and Lifetime Estimation for Power Device Considering Mission Profiles in Wind Power Converter," in IEEE Transactions on Power Electronics, vol. 30, no. 2, pp. 590-602, Feb. 2015, doi: 10.1109/TPEL.2014.2312335.

[3] Infineon Technologies AG. AppNoteNumber AN2019-05: PC and TC diagrams V1.0. www.infineon.com

[4] L. R. GopiReddy, L. M. Tolbert, B. Ozpineci and J. O. P. Pinto, "Rainflow Algorithm-Based Lifetime Estimation of Power Semiconductors in Utility Applications," in IEEE Transactions on Industry Applications, vol. 51, no. 4, pp. 3368-3375, July-Aug. 2015, doi: 10.1109/TIA.2015.2407055.

## Glossary

**LTE**
*Lifetime Estimation simulation in IPOSIM (LTE)*

**RGon**
*Turn-on gate resistor (RGon)*

**RGoff**
*Turn-off gate resistor (RGon)*

## Revision history

| Document version | Date | Description of changes |
|---|---|---|
| 1.00 | 2021-11-19 | First release |
| | | |
| | | |

**Trademarks**
All referenced product or service names and trademarks are the property of their respective owners.

**Edition 2021-11-19**

**Published by**

**Infineon Technologies AG**

**81726 Munich, Germany**



**Do you have a question about this document?**

**Email: erratum@infineon.com**

**Document reference**