ST PowerStudio dynamic electro-thermal simulation software for power devices

Introduction

ST PowerStudio is a dynamic electrothermal simulation software dedicated to ST power devices.

The software provides a comprehensive power and thermal analysis which allows the user to predict the device performance, shorten the solution design and save time and resources. Furthermore, the tool helps to select the proper device that fits the application mission profile.

Based on a very precise built-in electrical and thermal model and on an iterative calculation, taking into account self-heating effects, ST PowerStudio provides a highly accurate estimation of the power loss as well as the junction and case temperatures.

The software can simulate the mission profile with static load (single set of input conditions) or dynamic load, by changing the input conditions over time and performing a very long simulation profile.

The software allows the simulation of several thermal setup input conditions, such us:

- Devices without heatsink, by estimating the case and junction temperatures
- Fixed case temperature (with heatsink), by estimating the junction temperature and the heatsink R_{th}
- Fixed heatsink thermal resistance, by estimating the case and junction temperatures
- Fixed heatsink thermal impedance, by estimating the case and junction temperatures and considering the thermal inertia of the system

Simulation results are displayed in tables and dedicated scope views, in function of the time, the current load and the switching frequency. An output report is generated, which summarizes all information and results to allow easy archiving.

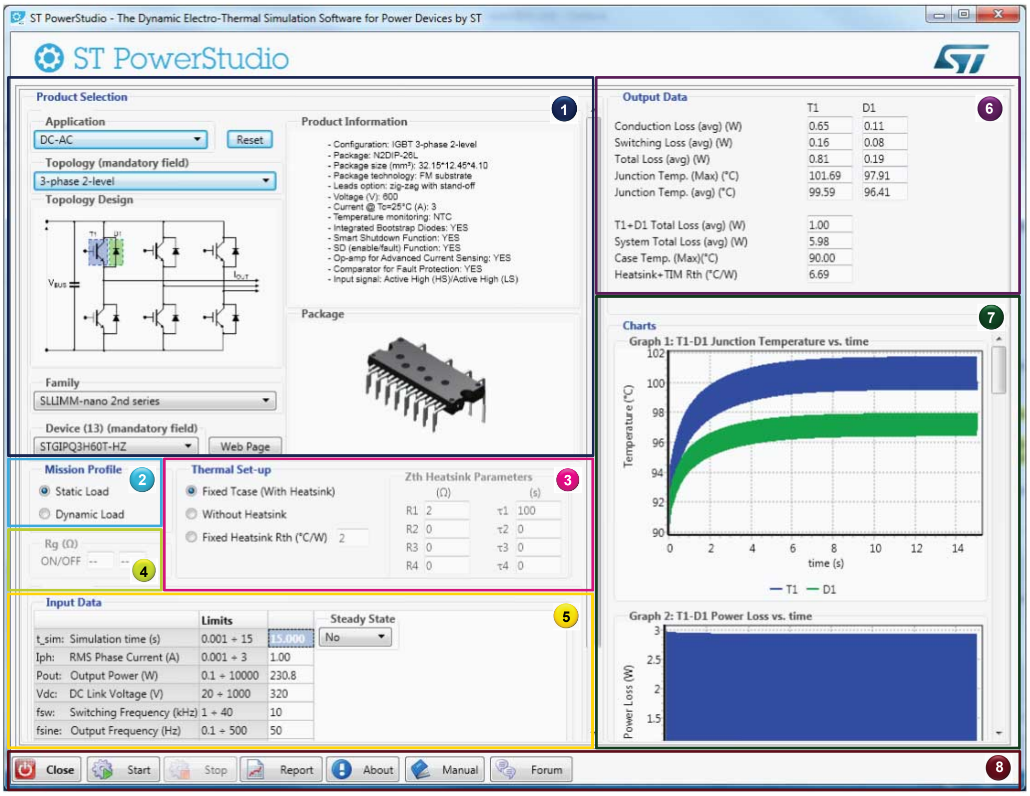
ST PowerStudio currently enables the 3-phase 2-level topology with a sinusoidal PWM technique and supports a large selection of power devices (SLLIMM™-nano, SLLIMM-nano 2nd series, SLLIMM, SLLIMM 2nd series and ACEPAK™) and facilitates the connectivity with st.com for dedicated documentations and resources. An on-line forum provides additional support to ST PowerStudio users. Access to the forum is available at https://community.st.com/community/st-powerstudio .

1 Overview

The user interface of the ST PowerStudio includes eight sections, as listed below and shown in Figure 1. User interface.

1. Product selection: this section allows to select the device to be simulated and specify the application and the topology. It includes a list of the main characteristics of the device and the package configuration.
2. Mission profile: this section allows to select static or dynamic load, in order to match any real working conditions of the application.
3. Thermal setup: this section enables the thermal conditions of the simulation. The simulation can be carried out with or without heatsink.
4. Gate driving: this section allows to set the gate resistance values for the devices that have a driving network not internally fixed.
5. Input data: this table allows to set up the electrical and thermal input parameters of the application and the simulation time.
6. Output data: these fields show the simulation results: power loss of the device, case and junction temperatures and thermal resistance of the heatsink.
7. Charts: this section shows two main chart groups: the first one shows the real time junction and case temperature of the IGBT/MOSFET and freewheeling diode; the second one shows the average power loss as a function of phase current and switching frequency (for more details, refer to Section 2 User interface description).
8. Command buttons: this area includes the main command buttons used to handle the simulation and get support.

Figure 1. User interface



GADG231120171130SA

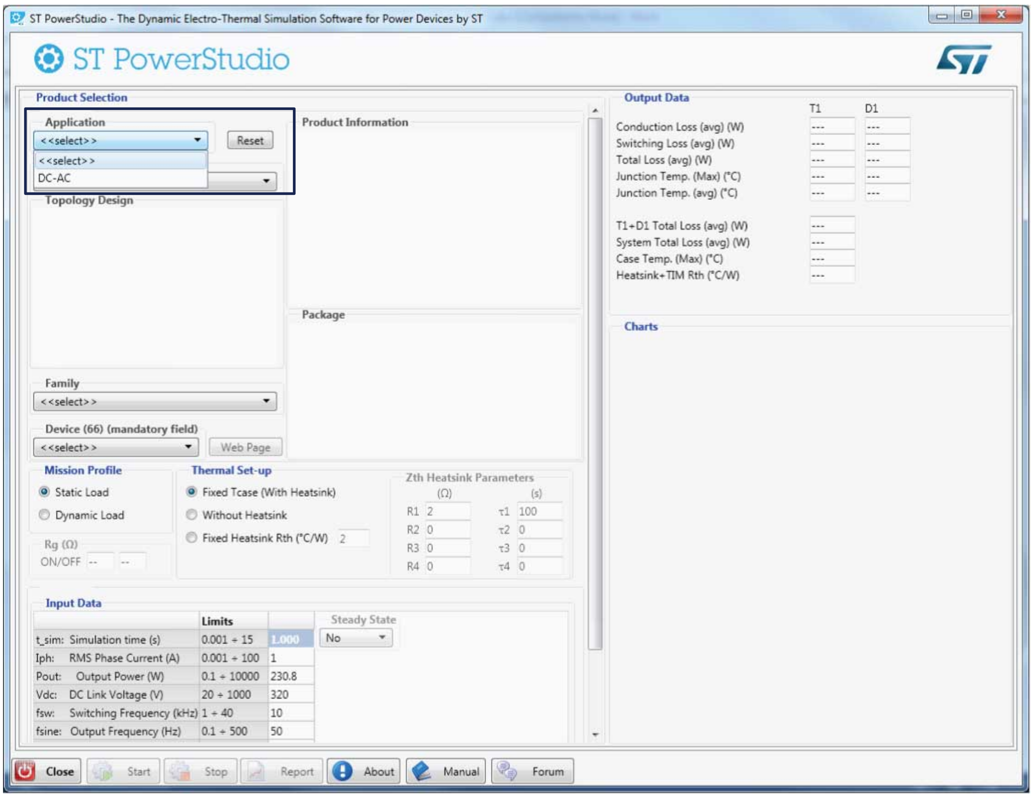
2 User interface description

2.1 Product selection

The product selection section allows to choose the device based on the application and the topology. It includes four menus, linked to each other with a filter:

- The application drop-down menu is used to select the application to be simulated (Figure 2. Application selection).

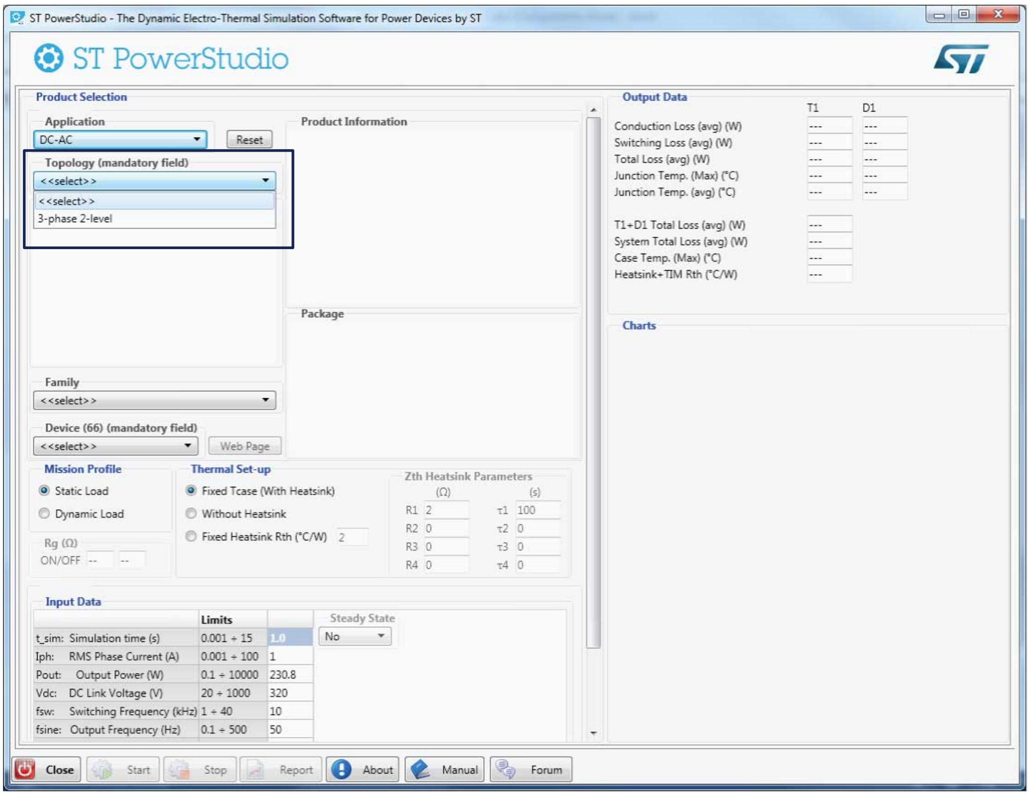
Figure 2. Application selection



GADG231120171147SA

- The topology drop-down menu lists the topologies to be chosen for the simulation (Figure 3. Topology selection). Once the topology has been selected, the circuit configuration appears in the topology design field (Figure 4. Family selection).

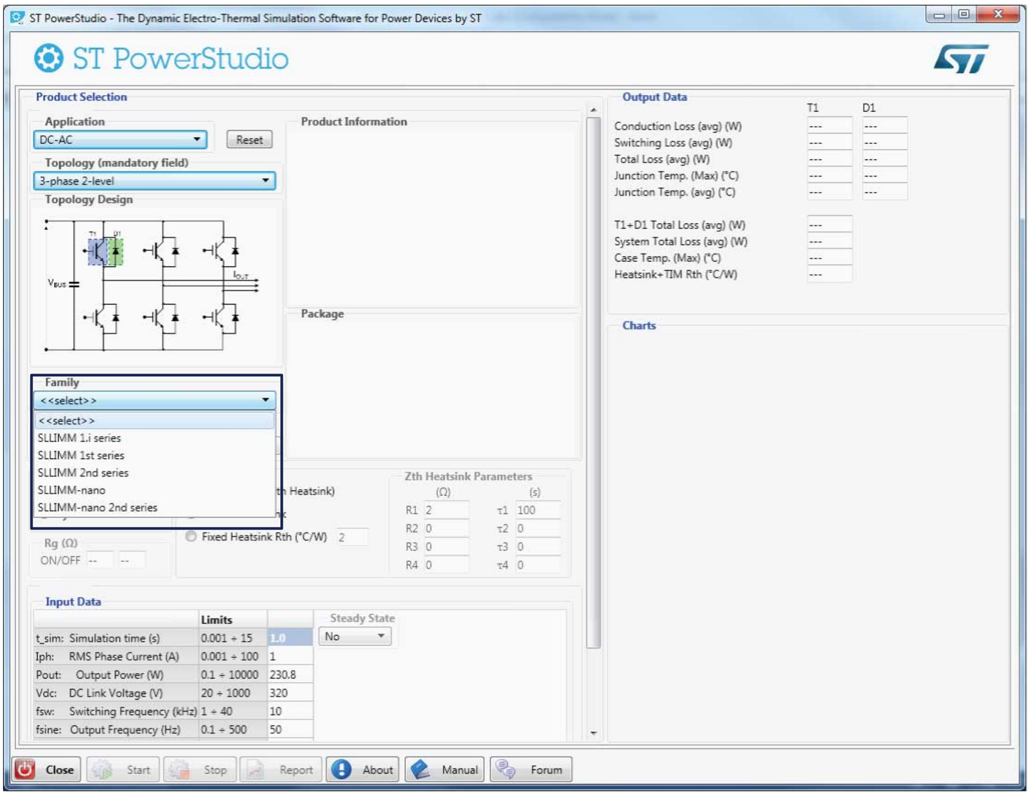
Figure 3. Topology selection



GADG231120171220SA

- The family drop-down menu lists the ST product families (Figure 4. Family selection).

Figure 4. **Family selection**



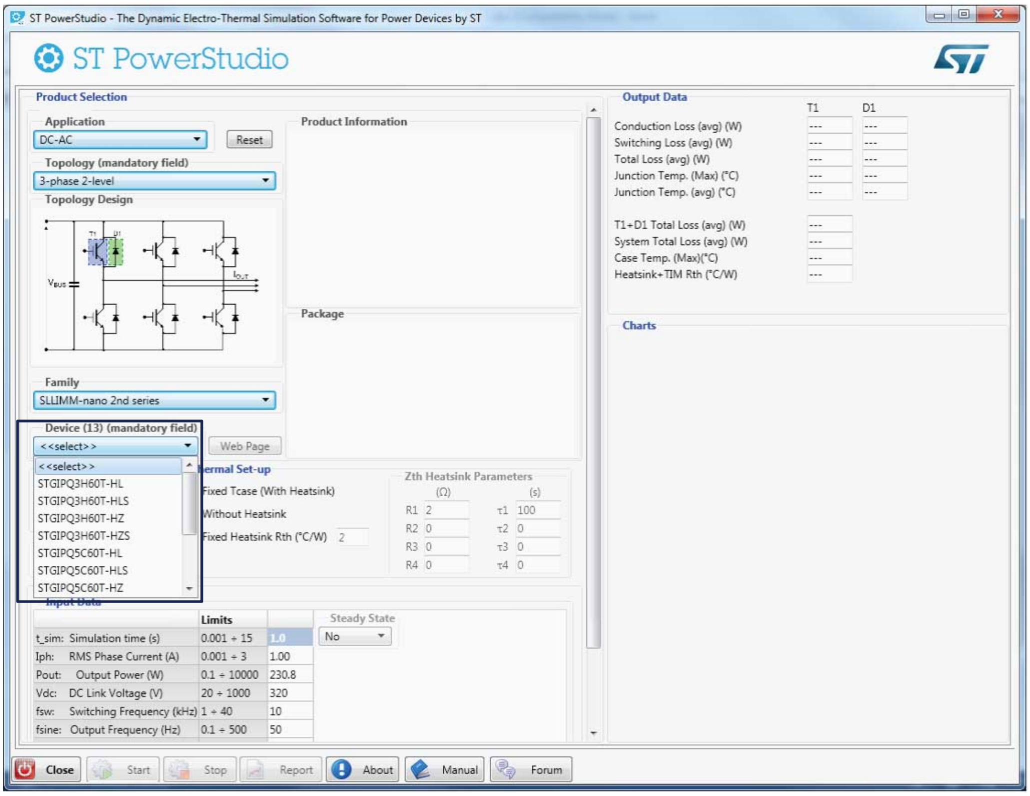
GADG231120171222SA

- The device menu (Figure 5. Device selection) is the final step of the device selection as it allows to select the part number among the products filtered from the previous menus.

  Once the device has been selected, an information list containing the main product data appears in the Product Information field. This information includes also the package configuration, and it is useful for the first selection of the device which better fits the application requirements.

  To access the device web page, click on the web page button.

Figure 5. Device selection

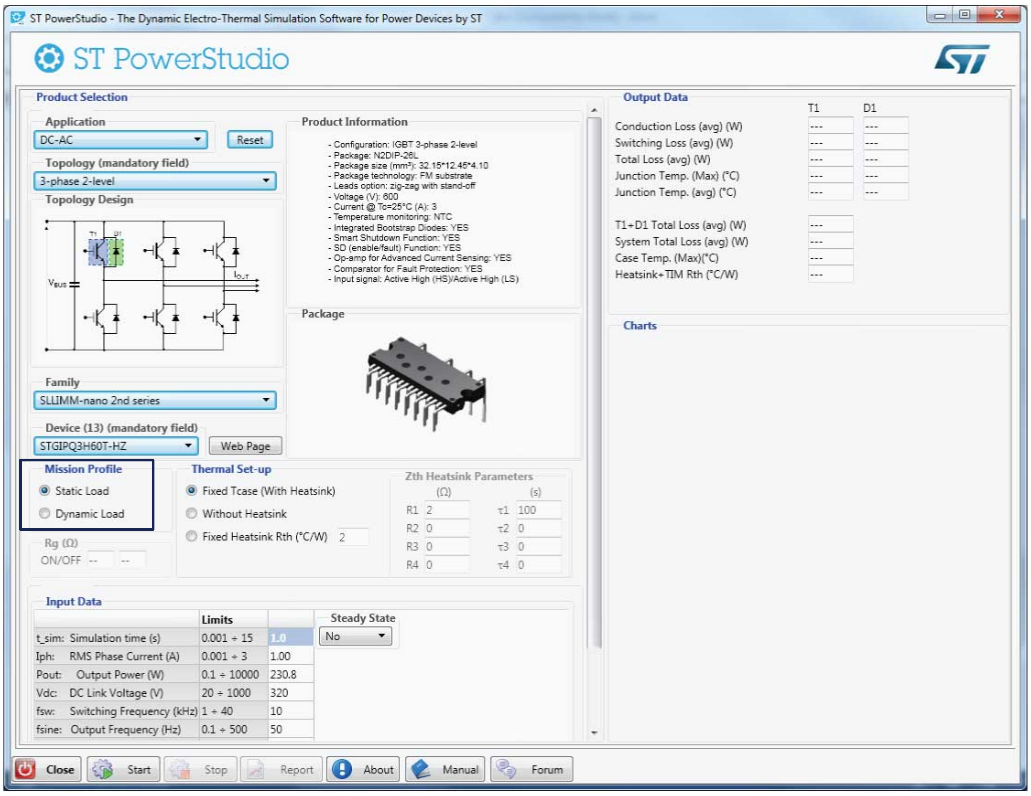


GADG231120171225SA

2.2 Mission profile

ST PowerStudio can simulate both static and dynamic load configurations, to match any real mission profile of the application. The user can select the simulation type in the mission profile field (Figure 6. Mission profile selection). Static load provides a single set of input conditions and shows the instantaneous behavior for the power loss and junction temperature estimation. The dynamic load enables up to ten sets of input conditions, changing independently all input parameters over the time. This setup allows a long application mission profile simulation in a very short computation time, without effecting the accuracy.

Figure 6. Mission profile selection



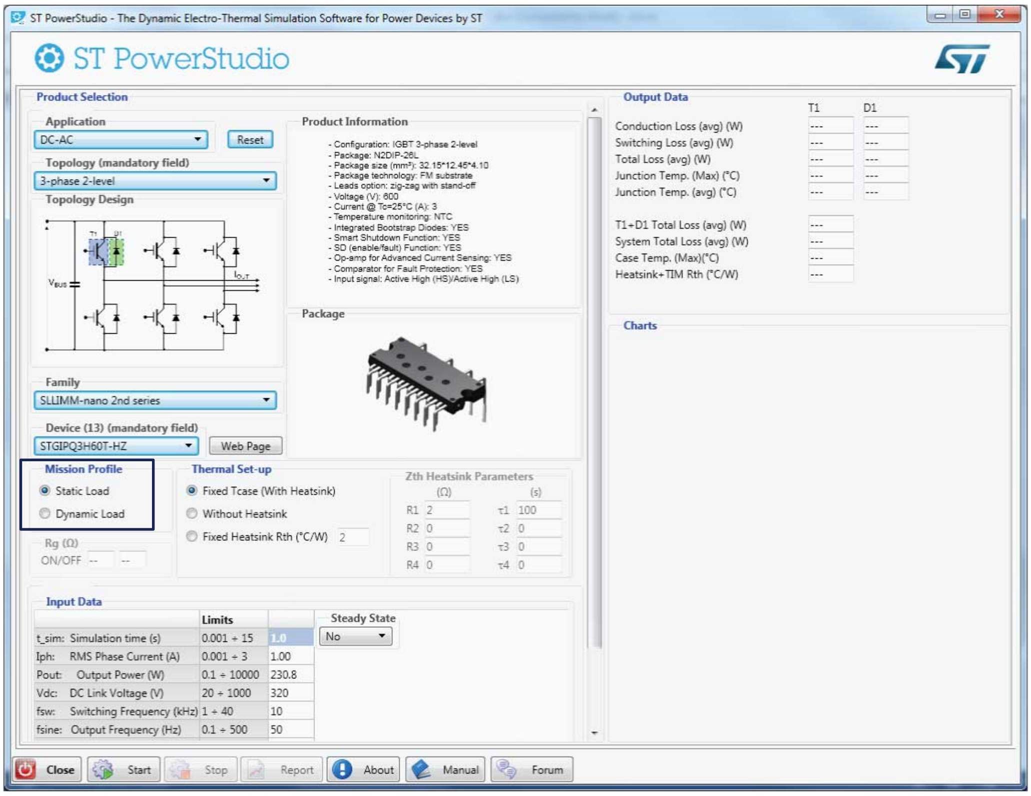
GADG231120171236SA

2.3 Thermal setup

In the thermal setup section the user can select four different options (Figure 7. Thermal setup selection).

- Fixed T_{case} (with heatsink) / fixed $T_{heatsink}$: the device is supposed to be used with a heatsink and the case temperature or heatsink temperature is fixed by the user. Using the dynamic mission profile, the T_{case} can be fixed, step by step, at different values (see input data section).
- Without heatsink: the device can be used without heatsink and, therefore, case temperature is estimated by the simulation. This option is allowed only for SLLIMM-nano product families.
- Fixed heatsink R_{th}: the heatsink thermal resistance is defined by the user. According to this heatsink R_{th} value and the estimated power loss, ST PowerStudio will calculate the case temperature as well.
- Z_{th} heatsink: the heatsink thermal impedance is defined by the user. The thermal behavior of the heatsink is simulated by a Foster model, set by up to four R and t parameters inserted by the user. According to this heatsink Z_{th} model and the estimated power loss, ST PowerStudio will calculate the time-dependent case temperature as well.

Figure 7. Thermal setup selection

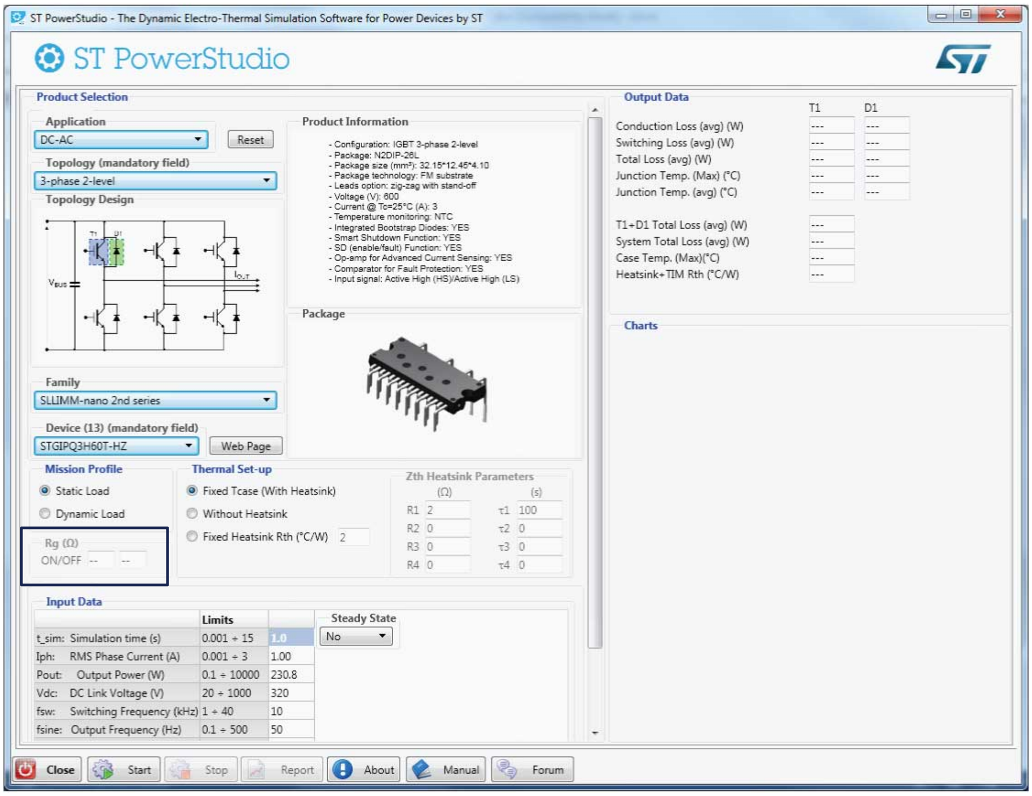


GADG231120171242SA

2.4 Gate driving

The gate driving section (see figure below) allows to set the gate resistors values, split for ON and OFF. This field is available only for the devices designed to be driven by an external network (SLLIMM devices do not require any external gate resistor thus the fields will be displayed as a dash).

Figure 8. **Gate driving section**



GADG231120171307SA

2.5 Input data

The input data section (Figure 9. Input data section for static load simulation) includes the input simulation parameters, as listed below and shown in Figure 10. 3-phase sinusoidal PWM parameters. The table also shows the validity data range for each parameter.

- Simulation time (t_sim): this is the time window for the event under simulation. For static load simulations, t_sim can be set in steady state; the t_sim field will be automatically filled with the time sufficient to reach the steady state for the device junction temperature, starting from the T_{case}.
- RMS phase current (Iph): this is the RMS value of phase current (3-phase 2-level topology).
- Output power (Pout): this is the output power of the 3-phase 2-level topology. This value can be entered by the user or can be automatically calculated using the other input parameters, according to equation 1 below:

$$P_{out} = \frac{3\sqrt{2}}{4} I_{ph} \cdot MI \cdot PF \cdot V_{dc} \tag{1}$$

- DC link voltage (V_{dc}): this is the DC bus voltage.
- Switching frequency (f_{sw}): this is the switching frequency of the device.
- Output frequency (f_{sine}): this is the electrical frequency on the load, given by equation 2 below:

$$f_{Sine} = \frac{rpm \cdot (2p)}{60} \tag{2}$$

where rpm is the number of revolutions per minute of the rotor and 2p is the number of pole pairs.

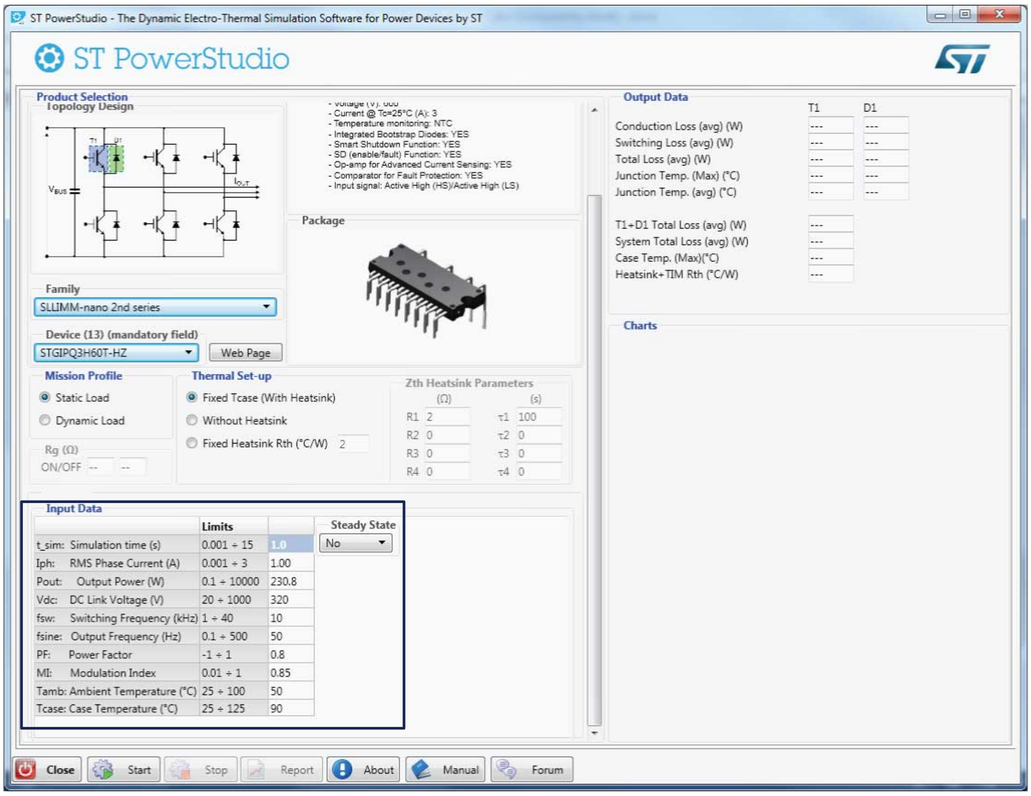
- Power factor (PF): this is the cosine of the phase angle between phase voltage V_A and phase current I_{ph} (or the *cos φ*).

- Modulation index (MI): this is the modulation index of the 3-phase sinusoidal PWM, given by equation 3 below:

$$MI = \frac{V_{m,\ Sine}}{V_{m,tri}} \quad (3)$$

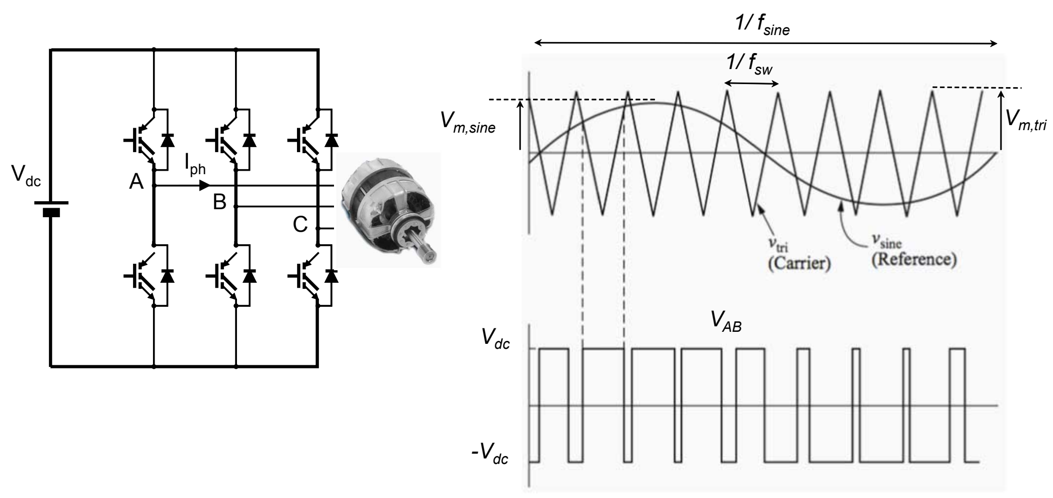
- Ambient temperature (T_{amb}): this is the local ambient temperature measured close to the application.
- Case temperature (T_{case}) / heatsink (T_{hs}): it is the temperature on the case or on the heatsink and it can be fixed by the user, if the thermal set-up is in fixed T_{case} (with heatsink) / fixed $T_{heatsink}$ configuration, or it represents the hottest case point as result of the simulation, in any other thermal set-up configuration.

Figure 9. Input data section for static load simulation



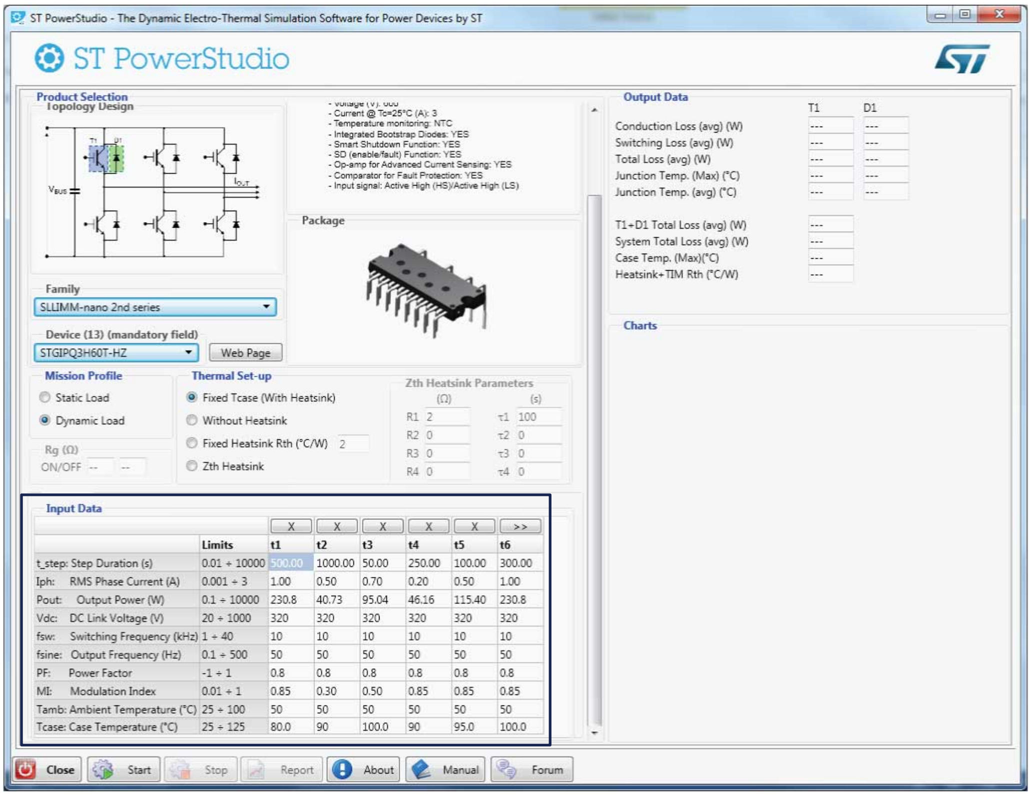
GADG231120171326SA

Figure 10. **3-phase sinusoidal PWM parameters**



If the mission profile menu is set on dynamic load, the input data section allows to enter the following parameters for each mission profile step (Figure 9. Input data section for static load simulation).

Figure 11. **Input data section for dynamic load simulation**



GADG231120171347SA

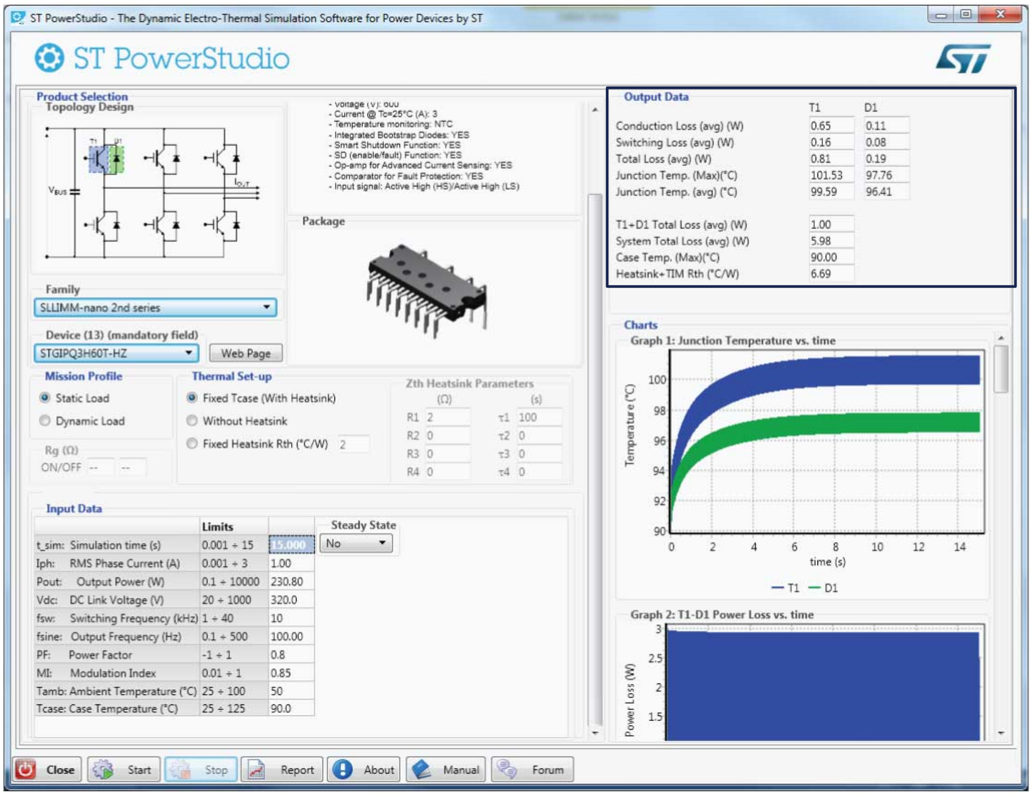
2.6 Output data

The output data section (see Figure 12. Output data section for static load simulation) includes a set of simulation results, as listed below, according to the circuit configuration selected in the topology design field:

- Conduction loss (T1): this is the IGBT/MOSFET conduction power loss (average on the simulation time, t_sim).
- Conduction loss (D1): this is the freewheeling diode conduction power loss (average on the simulation time, t_sim).
- Switching loss (T1): this is the IGBT/MOSFET switching power loss (average on the simulation time, t_sim).
- Switching loss (D1): this is the freewheeling diode reverse recovery power loss (average on the simulation time, t_sim).
- Total loss (T1): this is the IGBT/MOSFET total power loss, conduction plus switching (average on the simulation time, t_sim).
- Total loss (D1): this is the freewheeling diode total power loss, conduction plus reverse recovery (average on the simulation time, t_sim).
- Junction temp. (T1, Max): this is the IGBT/MOSFET maximum junction temperature during the simulation time under analysis.
- Junction temp. (D1, Max): this is the freewheeling diode maximum junction temperature during the simulation time under analysis
- Junction temp. (T1, avg): this is the IGBT/MOSFET junction temperature (average on the simulation time, t_sim)
- Junction temp. (D1, avg): this is the freewheeling diode junction temperature (average on the simulation time, t_sim)

- T1+D1 total loss: this is the total switch power loss IGBT/MOSFET plus freewheeling diode (average on the simulation time, t_sim).
- System total loss: this is the total inverter power loss 6x IGBT/MOSFET plus 6x freewheeling diode (average on the simulation time, t_sim).
- Case temp. (max) / heatsink temp. (max): it is the maximum case or heatsink temperature during the simulation time under analysis.
- Heatsink+TIM R_{th} / heatsink R_{th}: it is the thermal resistance of the heatsink system (including the thermal interface material, when mentioned) required to match the input conditions.

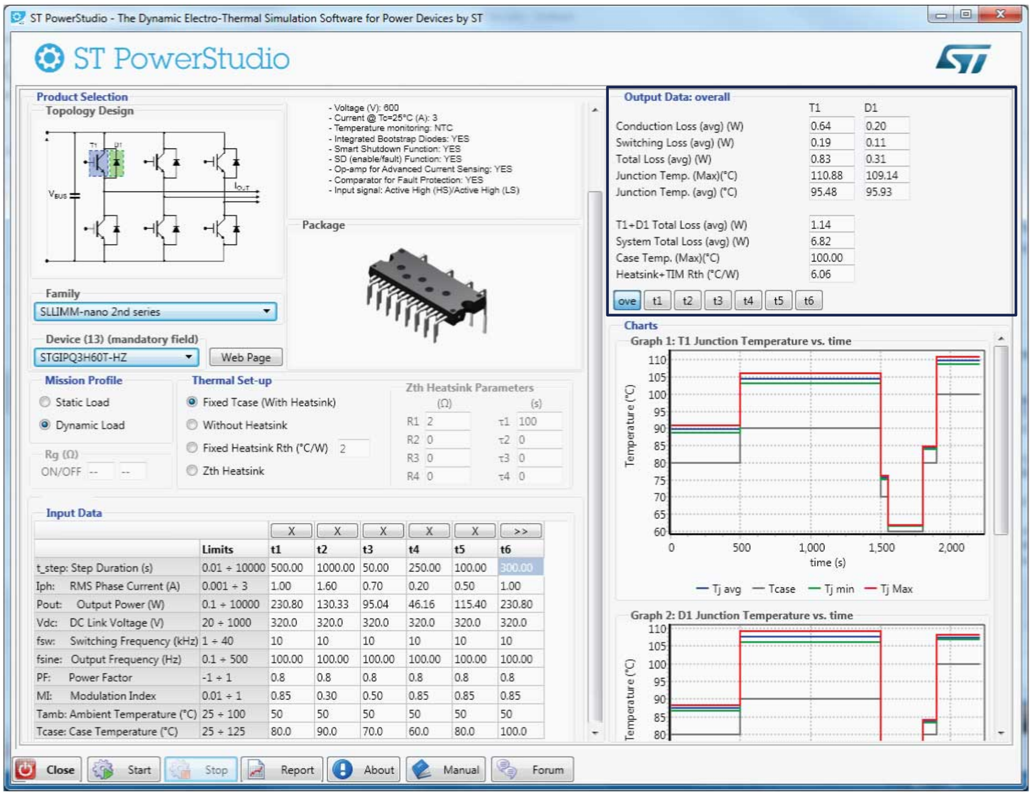
Figure 12. Output data section for static load simulation



GADG231120171350SA

For dynamic load simulations, the output data section (see Figure 13. Output data section for dynamic load simulation) consists of n+1 tabs, where n is the number of mission profile steps. The output results, related to each step, can be shown clicking the t_1 ,…,t_n buttons, whereas the ove tab shows the overall output results, calculated considering all the steps.

Figure 13. Output data section for dynamic load simulation



GADG231120171354SA

2.7 Charts

The output charts section includes a set of charts which show the real-time behavior for temperatures and power loss, and some additional charts describing power loss as a function of phase current or switching frequency. The output charts for static load simulations (see Figure 14. Output charts for static load simulations) are described below:

- *Graph 1: T1-D1 junction temperature vs time*

The real time junction temperatures for both IGBT/MOSFET and freewheeling diode are shown.

- *Graph 2: T1-D1 power loss vs time*

The real time total power loss for both IGBT/MOSFET and freewheeling diode is shown.

- *Graph 3: T1 power loss vs current RMS*

The average power loss for the IGBT/MOSFET as a function of RMS current is shown. The power loss is split into two components: conduction and switching, and the total power loss is also displayed. The curves are calculated using the input data set by the user. The grey vertical line shows the RMS phase current in the input data.

- *Graph 4: T1 power loss vs switching frequency*

The average power loss for the IGBT/MOSFET as a function of switching frequency is shown. The power loss is split into two components: conduction and switching, and the total power loss is also displayed. The curves are calculated using the input data set by the user. The grey vertical line shows the switching frequency in the input data.

- *Graph 5: D1 power loss vs current RMS*

The average power loss for the freewheeling diode as a function of RMS current is shown. The power loss is split into two components: conduction and switching, and the total power loss is also displayed. The curves are calculated using the input data set by the user. The grey vertical line shows the RMS phase current in the input data.

- *Graph 6: D1 power loss vs switching frequency*

The average power loss for the freewheeling diode as a function of switching frequency is shown. The power loss is split into two components: conduction and switching, and the total power loss is also displayed. The curves are calculated using the input data set by the user. The grey vertical line shows the switching frequency in the input data.

- *Graph 7: inverter power loss vs current RMS*

The average total power loss for the inverter as a function of RMS current is shown. The curve is calculated using the input data set by the user. The grey vertical line shows the RMS phase current in the input data.

- *Graph 8: inverter power loss vs switching frequency*

The average total power loss for the inverter as a function of switching frequency is shown. The curve is calculated using the input data set by the user. The grey vertical line shows the switching frequency in the input data.

- *Graph 9: power loss distribution vs current RMS*

The percentage of conduction and switching of both the IGBT/MOSFET and the freewheeling diode as a function of RMS current is shown. The curves are calculated using the input data set by the user. The grey vertical line shows the RMS phase current in the input data

- *Graph 10: power loss distribution vs switching frequency*

The percentage of conduction and switching for both IGBT/MOSFET and freewheeling diode as a function of switching frequency is shown. The curves are calculated using the input data set by the user. The grey vertical line shows the RMS phase current in the input data.

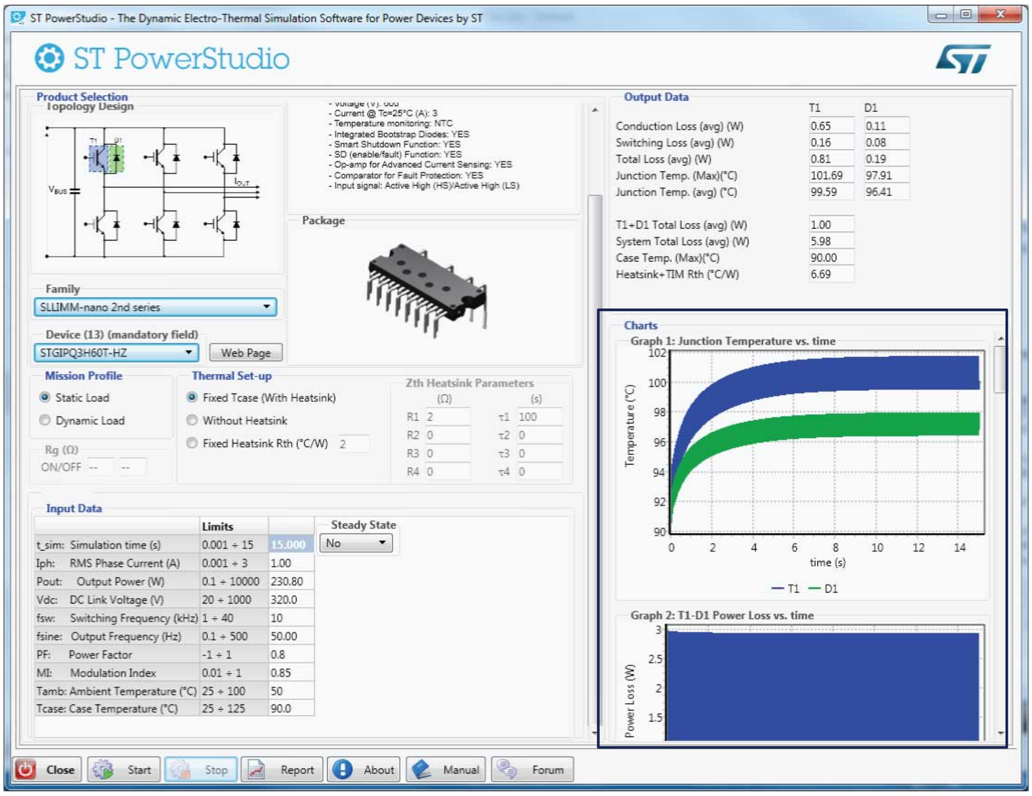
- *Graph 11: maximum allowable case temperature vs current RMS*

This graph shows the temperature which must not be exceeded on the case temperature of the device in order to keep the junction temperature within the absolute maximum ratings as a function of the RMS current. The curve is calculated using the input data set by the user. The grey vertical line shows the RMS phase current in the input data.

- *Graph 12: maximum allowable case temperature vs switching frequency*

This graph shows the temperature which must not be exceeded on the case temperature of the device in order to keep the junction temperature within the absolute maximum ratings as a function of switching frequency. The curve is calculated using the input data set by the user. The grey vertical line shows the switching current in the input data.

Figure 14. **Output charts for static load simulations**



GADG241120170826SA

The output charts for dynamic load simulations (see Figure 15. Output charts for dynamic load simulations) are described below:

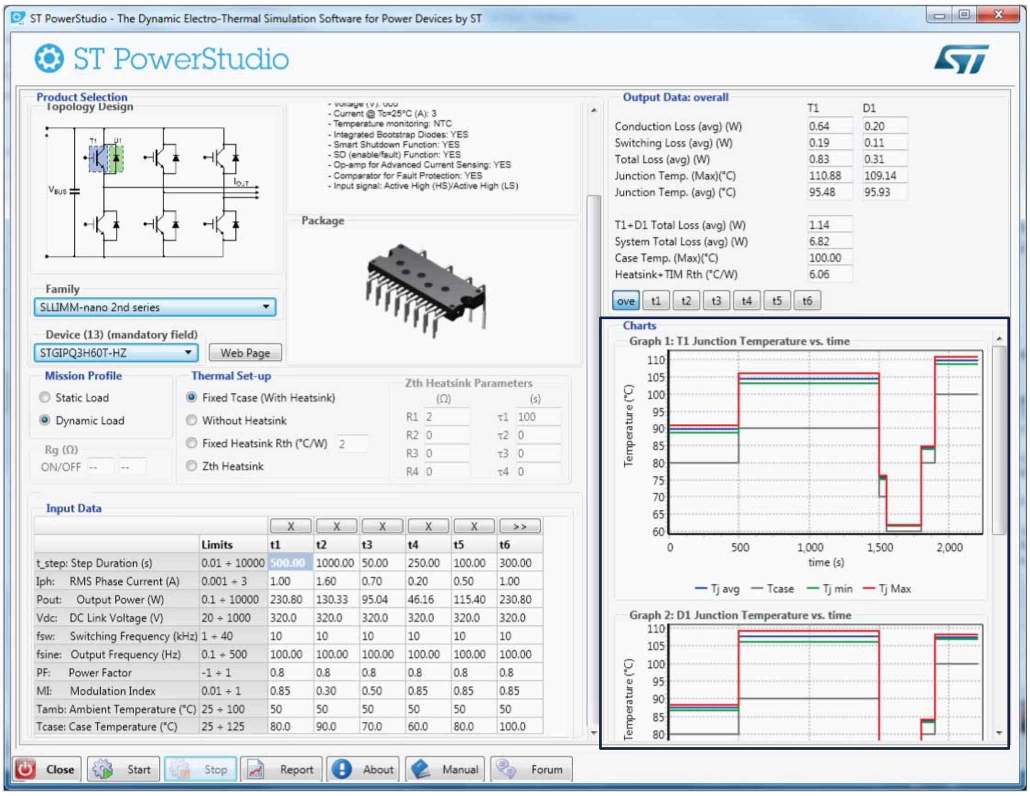
- *Graph 1: junction temperature vs time*

The case and junction temperatures for the IGBT/MOSFET are shown. The junction temperature is split into three curves: average, minimum and maximum T_j. The device case temperature (grey line) is displayed if the thermal setup is set in fixed T_{case} (with heatsink), while this temperature is calculated for simulations without heatsink or when the heatsink is defined by the user (by R_{th} of Z_{th} insertion).

- *Graph 2: T1-D1 power loss (avg) vs time*

The average power loss for both the IGBT/MOSFET and the freewheeling diode is shown.

Figure 15. **Output charts for dynamic load simulations**



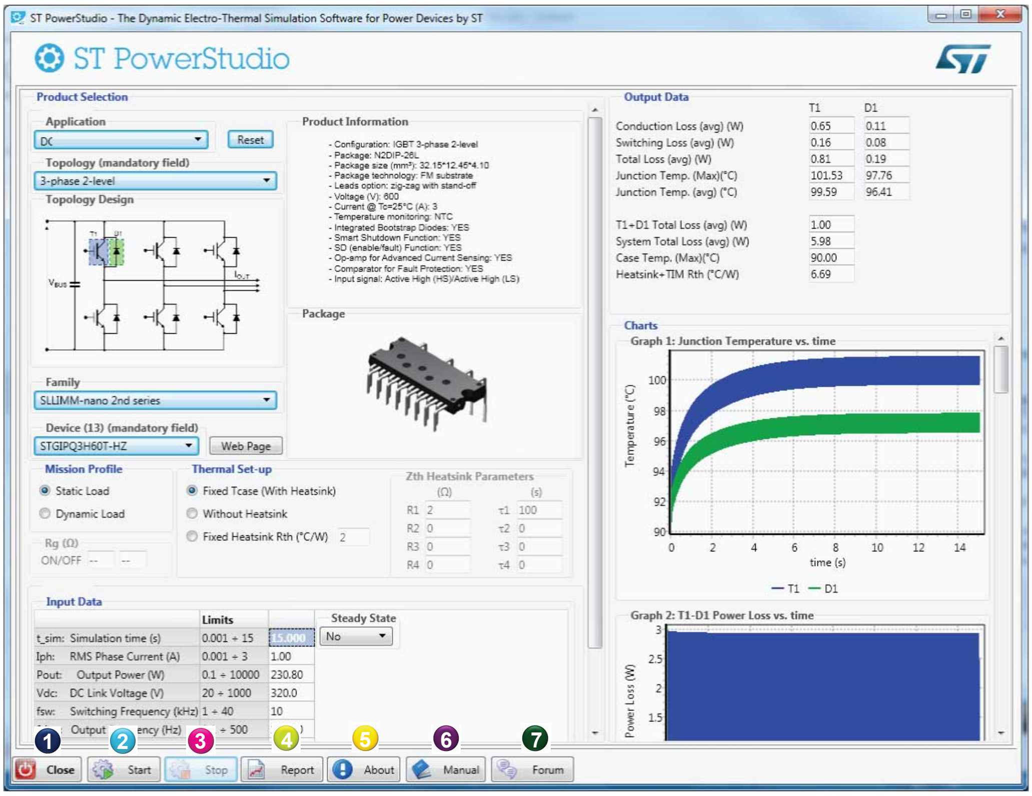
GADG241120170829SA

2.8 Command buttons

Figure 16. Command buttons shows the main ST PowerStudio command buttons, which are briefly described below:

1. Close: this allows to close the ST PowerStudio.
2. Start: once the user clicks the start button, the simulation begins.
3. Stop: clicking the stop button, the simulation can be ended at any time. Once the simulation stops, the computation is reset.
4. Report: this is enabled at the end of the simulation in order to open the report section.
5. About: this opens the About windows, which displays a brief description of the ST PowerStudio and provides links to its web page, the license agreement and the ST web page.
6. Manual: this opens the user manual.
7. Forum: this opens the forum page, available at https://community.st.com/community/st-powerstudio.

Figure 16. Command buttons



GADG241120170831SA

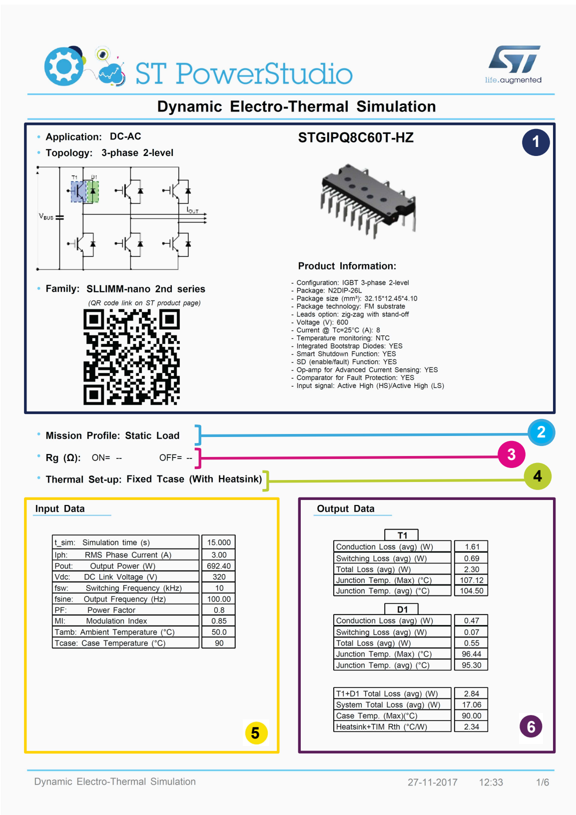
3 Simulation report

ST PowerStudio allows to summarize the simulation results within a simulation report, clicking the *Report* button (see Figure 1. User interface, in particular section 8 of the same picture), available at the end of the simulation.

The simulation report includes seven sections, as listed below and shown in Figure 17. Simulation report, page 1 and Figure 18. Simulation report, page 2:

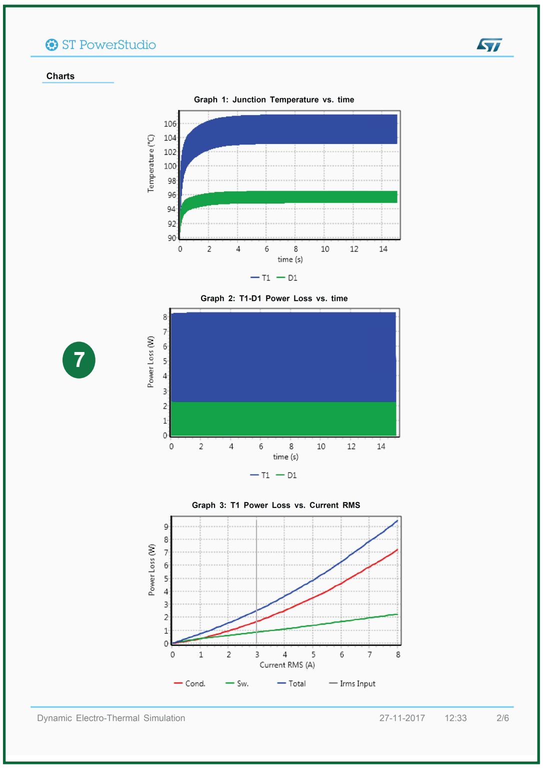
1. Product description: this section shows the product part number with its main electrical specifications and the package picture. The application and topology under simulation are also shown. The product description is completed by the QR code of the ST product page link.
2. Mission profile: the simulation type is specified (static or dynamic load).
3. Gate driving: the gate resistors values of the gate driving network, split for ON and OFF, are shown in this section. This information is reported only if the gate driving network of the device has been defined by the user.
4. Thermal setup: shows the thermal setup chosen for the simulation.
5. Input data: the simulation input data table is displayed in this section.
6. Output data: the simulation results table is displayed in this section. For dynamic load simulations the table includes the data for all the mission profile steps.
7. Charts: this section includes all output charts

Figure 17. Simulation report, page 1



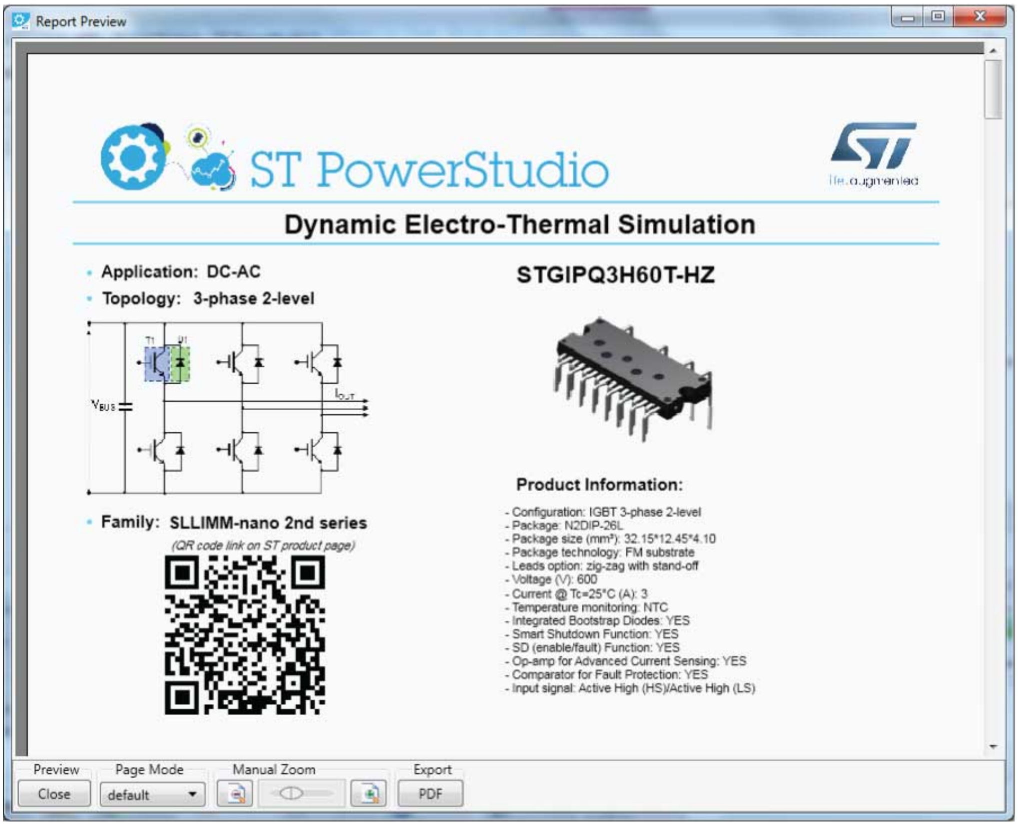
GADG011220170957SA

Figure 18. **Simulation report, page 2**



Once created, the report can be exported in .pdf format (see Figure 19. Report window) by clicking the PDF button, and it can be then saved or printed.

Figure 19. Report window



GADG241120171210SA

4 Electrical and thermal modelling

Power semiconductors generate power loss during their functioning, which is dissipated in form of heat increasing the junction temperature. Power semiconductors are also thermally limited, thus a good thermal design is a key point for a reliable system. It is therefore essential that the thermal design determines in an accurate way the maximum junction temperature from the device power dissipation.

ST PowerStudio allows to estimate the power loss and to determine accurately the junction temperature of power semiconductors, thanks to a very precise built-in modeling of each device's electrical and thermal parameters, and thanks to a sophisticated and iterative calculation which considers the self-heating effects.

4.1 Electrical and thermal models

The major sources of power loss are given by the conduction loss and the switching loss. The conduction loss (P_{cond}) is the on-state loss during the conduction phase, and it depends on the on-state voltage drop on the transistor ($V_{CE(sat)}$ for IGBT and $V_{DS(on)}$ for MOSFET) or the forward drop V_f across the diode.

The switching loss (Psw) is the dynamic loss encountered during commutation. In the transistor, switching losses mainly occur during turn-on and turn-off transients, while in the diode these losses are mainly due to reverse recovery.

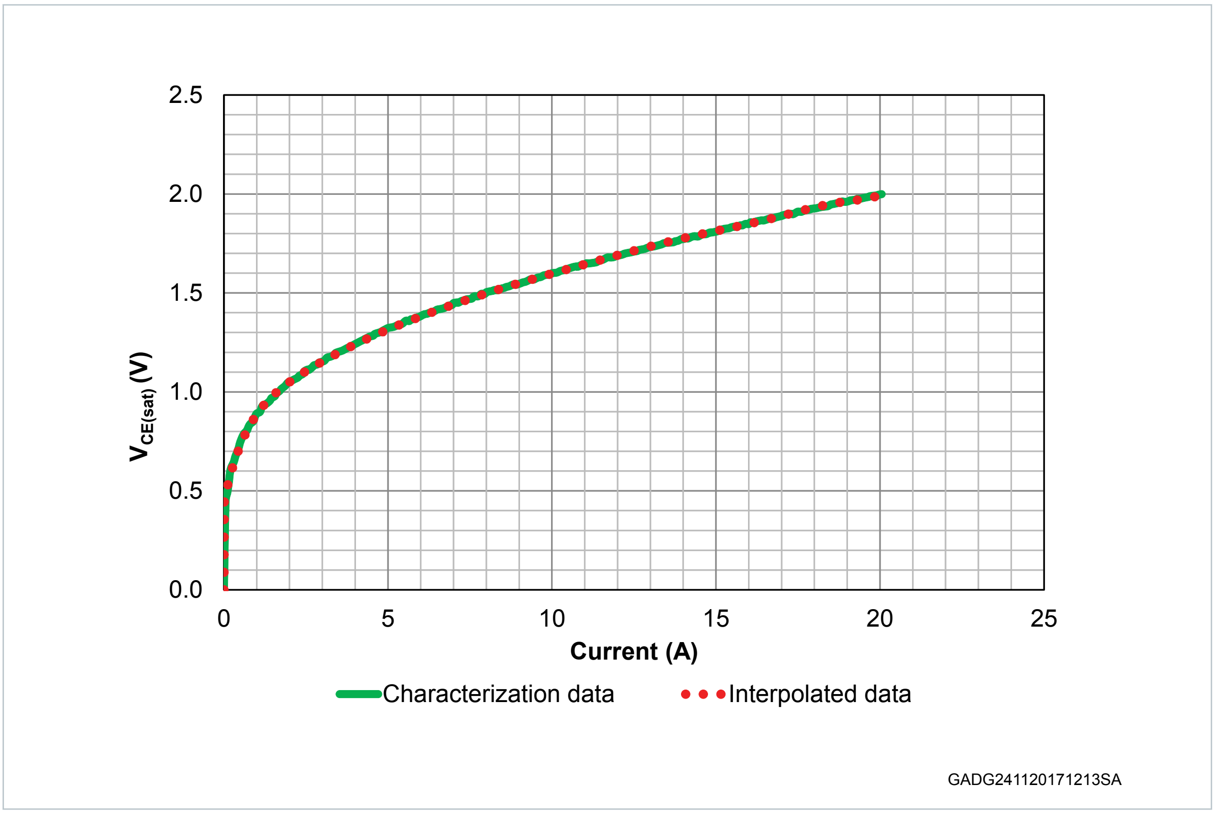
Voltage drop for transistors, as well as forward drop for diodes, can be represented as a function of current and junction temperature, while switching energy as a function of current, voltage, junction temperature and driving network (gate resistors).

All these electrical parameters ($V_{CE(sat)}$/$V_{DS(on)}$, V_f, E_{on}, E_{off}, E_{rr}) result from characterization data on a typical inductive load (for dynamic measurements) and are then approximated with empirical models. To achieve the highest accuracy in the power loss estimation, ST PowerStudio is based on the nth degree Lagrange interpolating polynomial, where n is the most accurate for the finest fitting in each of the aforementioned parameters, as follows:

$$p_n(x) = a_0x^n + a_1x^{n-1} + \cdots a_{n-1}x + a_n \qquad i = 0,1,\cdots,n \tag{4}$$

Figure 20. Example of $V_{CE(sat)}$ fitting curve shows an example of interpolated data (dotted line) compared with the characterization data (solid line).

Figure 20. **Example of $V_{CE(sat)}$ fitting curve**

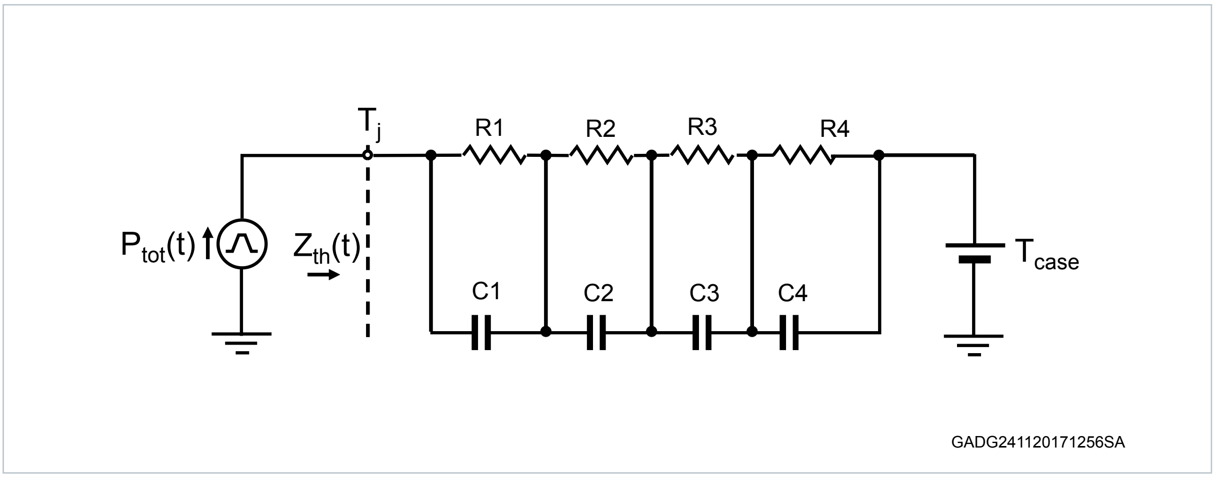


The junction temperature is a key element that impacts each one of these parameters and is well considered in this simulation tool as linear interpolation between two known points.

In addition to the average junction temperature, the temperature ripple of the semiconductor must be calculated since the temperature fluctuations stress the power semiconductor.

The temperature model of a semiconductor can be represented by an electrical equivalent RC network using a thermo-electrical analogy. The number of RC sections increases the model details. Finally, the transient thermal impedance $Z_{th}(t)$ is represented with a fourth order model, based on the Foster network, as shown in Figure 21. Foster RC equivalent circuit.

Figure 21. **Foster RC equivalent circuit**



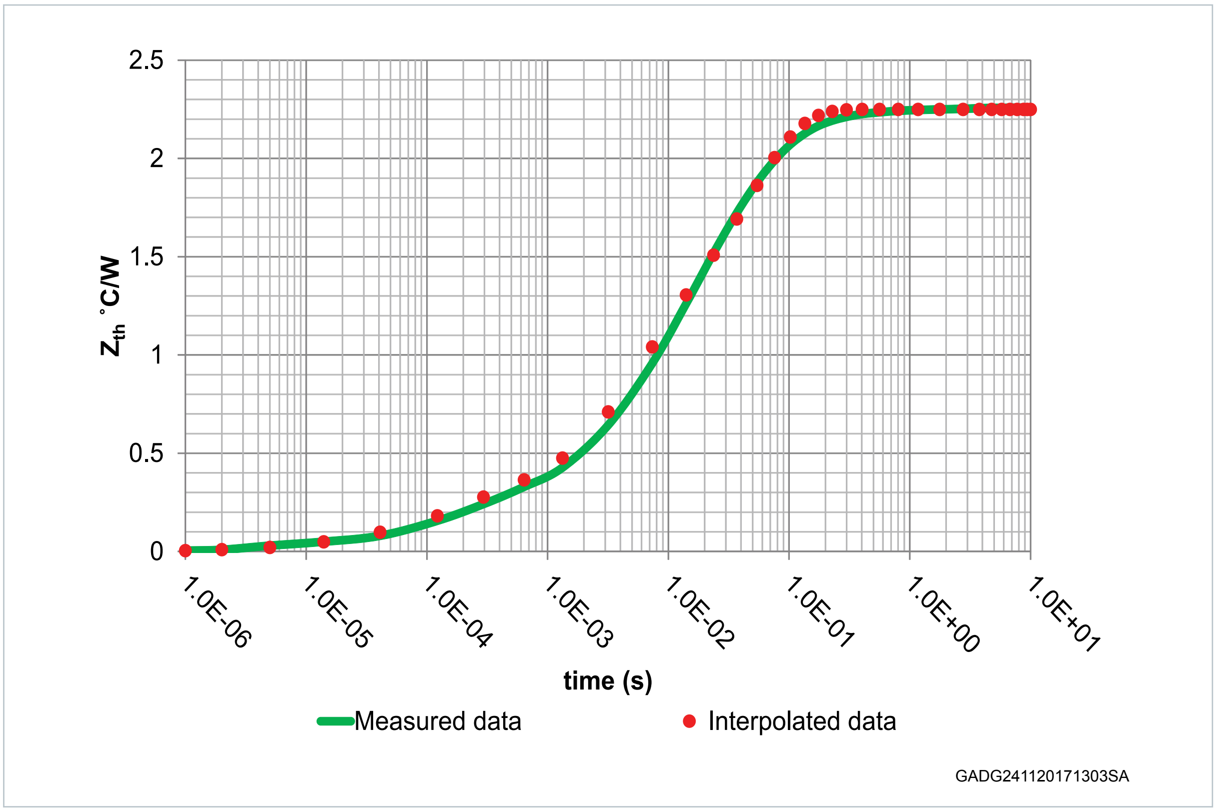
The input to the thermal model is the power loss in the semiconductor. Furthermore, the $Z_{th(j-c)}$ (or $Z_{th(j-h)}$ for ACEPACK products) can be analytically represented by using the equation below:

$$Z_{th(j-c)}(t) = \sum_{i=1}^{n} R_i\left(1 - e^{-t/\tau_i}\right) \quad (5)$$

where R is the resistor value shown in the Foster network and t is the time constant value (R*C).

Figure 22. Transient thermal impedance fitting curve shows the fitting curve using the analytic equation (dotted line) and the measured data (solid line).

Figure 22. Transient thermal impedance fitting curve



5 Power loss and junction temperature calculation

ST PowerStudio is based on a sophisticated calculation flow which benefits of a fine discretization of output current. This results in a more accurate estimation of the power loss and junction temperature as a function of time.

According to the application, the topology and the modulation technique type (3-phase sinusoidal PWM is used in the current version) and considering the electrical and thermal models mentioned above, the time-dependent power loss is calculated as follows for each single discretization step:

Step 1: transistor conduction loss

for Power MOSFET:

$$P_{cond(Tr)}\left(i, T_j\right) = i \cdot V_{DS(on)}\left(i, T_j\right) \cdot \delta \tag{6}$$

for Power IGBT:

$$P_{cond(Tr)}\left(i, T_j\right) = i \cdot V_{CE(sat)}\left(i, T_j\right) \cdot \delta \tag{7}$$

Step 2: transistor switching loss

$$P_{sw(Tr)}\left(i, V, R_g, T_j, V_{DC}\right) = \left[E_{on}\left(i, V, R_{g(on)}, T_j, V_{DC}\right) + E_{off}\left(i, V, R_{g(off)}, T_j, V_{DC}\right)\right] \cdot f_{sw} \tag{8}$$

Step 3: diode conduction loss

$$P_{con(Di)}\left(i, T_j\right) = i \cdot V_f\left(i, T_j\right) \cdot \left(1 - \delta\right) \tag{9}$$

Step 4: diode switching loss

$$P_{sw(Di)}\left(i, V, R_g, T_j, V_{DC}\right) = E_{rec}\left(i, V, R_{g(on)}, T_j, V_{DC}\right) \cdot f_{sw} \tag{10}$$

ST PowerStudio is based on a self-heating strategy that allows to estimate the power loss in real time, which is dynamically influenced by junction temperature itself.

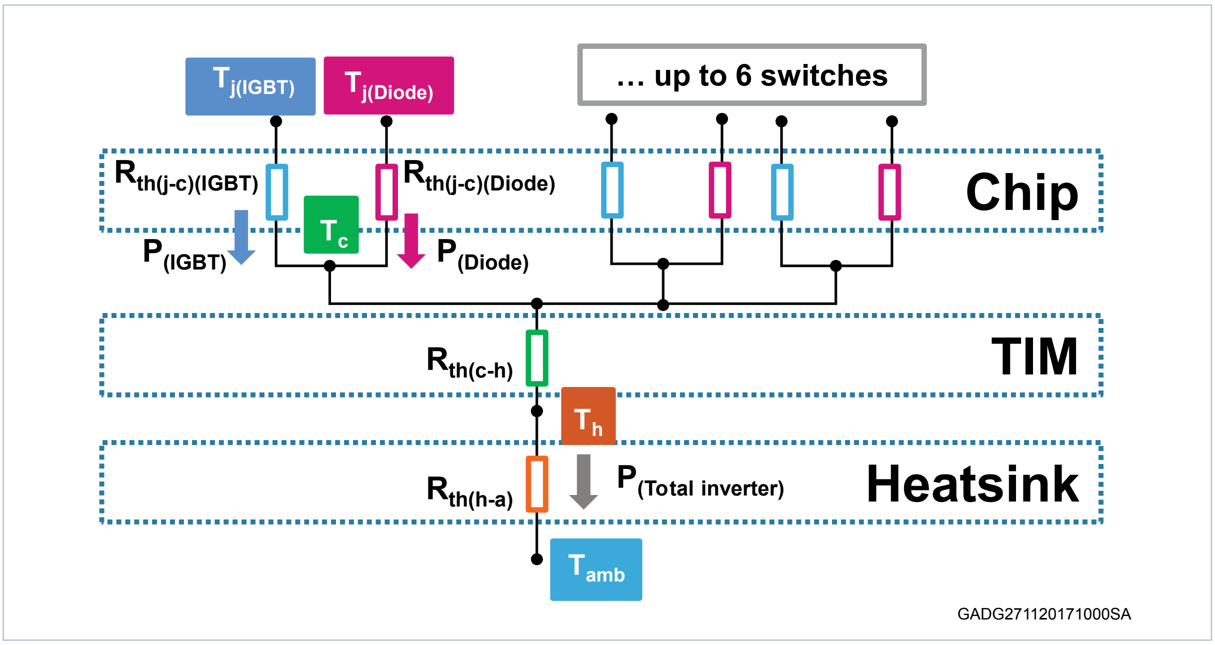
The time-dependent junction temperature is estimated for all power chips using the transient thermal impedance, as shown in the equation below, and is calculated based on the general thermal diagram shown in Figure 23. General thermal diagram.

$$T_j\left(t\right) = Z_{th(j-c)}\left(t\right) \cdot \left[P_{cond}(t) + P_{sw}(t)\right] + T_{case} \tag{11}$$

or

$$T_j\left(t\right) = Z_{th(j-h)}\left(t\right) \cdot \left[P_{cond}(t) + P_{sw}(t)\right] + T_{\text{heatsink}} \tag{12}$$

Figure 23. General thermal diagram



The computation method is shown in Figure 24. Computation flow chart, which highlights the self-heating effect on the power loss estimation and, therefore, on the junction temperature. This loop is iterated, step-by-step, till the end of the simulation.

Figure 24. Computation flow chart

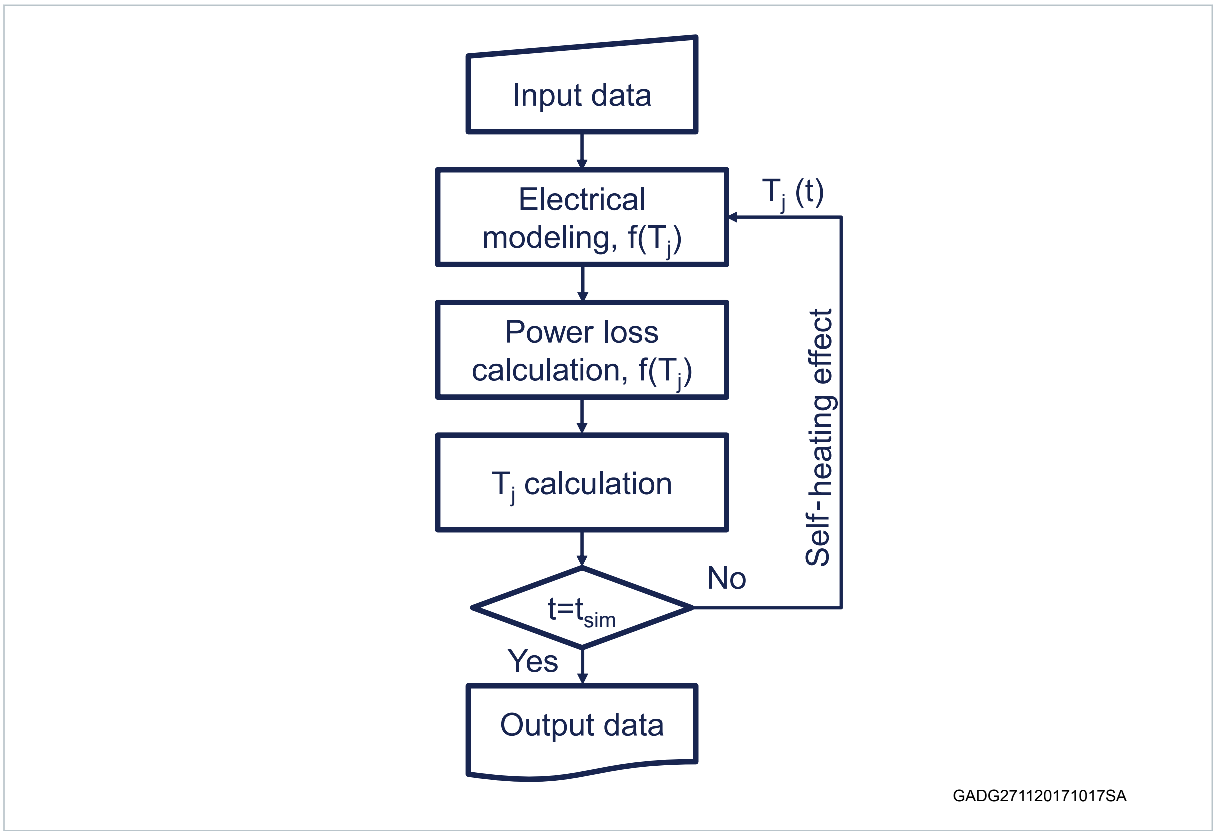
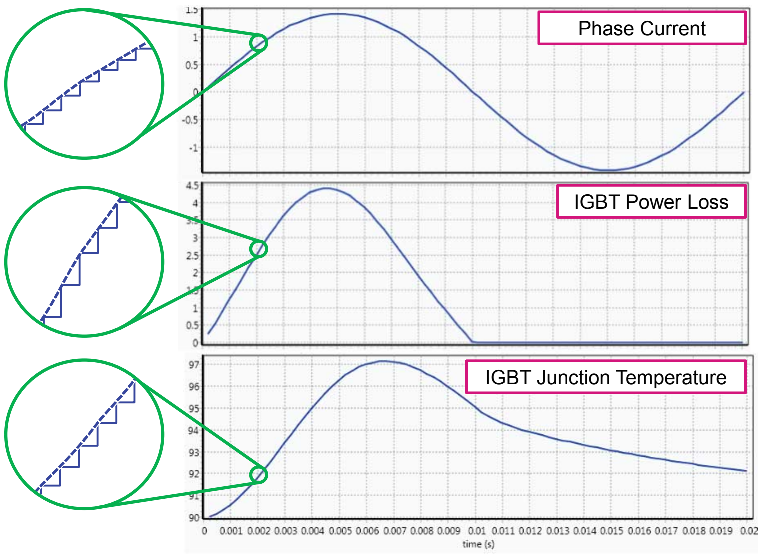


Figure 25. Discretization process shows some details of the discretization process applied on the output current and, thus, on the power loss and junction temperature used in the simulation.

In inverter applications, each IGBT or MOSFET, as well as each diode, conducts for half of the cycle-time of the sinusoidal output. Power loss appears for one half-period, while the IGBT/MOSFET or diode in the opposite inverter position is not active. Therefore, the junction temperature oscillates with the output frequency.

Thanks to the discretization process, the time-dependent power loss in the device follows the sinusoidal shape of the output current. Consequently, the time-dependent junction temperature follows closely the power loss variation as well, allowing a more precise estimation of the ripple and peak junction temperature.

Figure 25. Discretization process



Note that:

In MOSFET-based devices the power loss and the junction temperature ripple take in account also the body diode in both half-periods.

A Appendix Limited license agreement for ST materials evaluation

Important-read carefully: This limited license agreement (“LLA) for ST materials is made between you on behalf of yourself, and on behalf of any entity by which you are employed or engaged (collectively referred to in this LLA as "you" or “licensee”) and STMicroelectronics international NV, a company incorporated under the laws of the Netherlands acting for the purpose of this LLA through its Swiss branch located at 39, Chemin du Champ des Filles, 1228 Plan-les-Ouates, Geneva, Switzerland (hereinafter “ST”). Affiliates shall mean any corporation, partnership, or other entity that, directly or indirectly, owns, is owned by, or is under common ownership with ST, for so long as such ownership exists. For the purposes of the foregoing, "own", "owned," or "ownership" shall mean ownership of more than fifty percent (50%) of the stock or other equity interests entitled to vote for the election of directors or an equivalent governing body.

The ST materials licensed under this LLA shall mean the software and/or any hardware material which accompany or are otherwise made available by ST and/or its Affiliates upon agreeing to this LLA, including any associated media, documentation (collectively the “licensed materials”). Documentation shall include any comments, annotations, instructions, manuals, and other materials, whether in printed or electronic form, including without limitation installation manuals, user’s guides, and programmer guides, related to any software and/or any hardware material made available under this LLA. The licensed materials include any software updates, hardware products and supplements that ST and/or its affiliates may provide you or make available to you after the date you obtain the licensed materials to the extent that such items are not accompanied by a separate license agreement or other terms of use.

The licensed materials are licensed to you on the condition that you accept all the terms and conditions of this LLA. By clicking on the "I accept" button or by installing, copying, downloading, accessing or otherwise using the licensed materials, you agree to be bound by the terms of this LLA. If you do not agree with any condition of this LLA, do not install, access or use the licensed materials

1. **Limited license** -

   Subject to the terms and conditions of this LLA and applicable open source terms (as defined hereafter) and during the term of this LLA, ST hereby grants you under intellectual property rights owned by ST and its affiliates or under which ST and its affiliates has the right to grant a license, a worldwide, non-exclusive, non-transferable, royalty-free, license, without the right to sub-license, to use internally the licensed materials solely and exclusively with ST chipsets or ST integrated circuits (collectively “ST chipsets”) for the sole purpose of performing evaluation, simulation, testing and development of software/hardware applications and performing non-commercial demonstration of such licensee’s software/hardware applications with ST chipsets (“limited license purpose”).

   To the extent the licensed materials are made available to you in source code and subject to the terms and conditions of this LLA, ST hereby grants you under intellectual property rights owned by ST and its affiliates or under which ST and its Affiliates has the right to grant a license, during the term of this LLA, a worldwide, non-exclusive, royalty-free, non-transferable license, without the right to sublicense, to use, reproduce and modify the source code form of the licensed materials and compile such modified source code into new object code, for the limited license purpose only.

   Subject to the terms and conditions of this LLA, ST hereby grants you under intellectual property rights owned by ST and its Affiliates or under which ST and its affiliates has the right to grant a license, a worldwide, non-exclusive, non-transferable, royalty-free, license without the right to sub-license, to use internally and make a reasonable number of copies of the documentation provided by ST under this LLA, solely to support the limited license purpose.

   Subject to all limitations described herein, you are authorized to have third party contractors exercise for you and on your behalf the license rights as set forth above.

   You are fully responsible vis-à-vis ST for any act or omission of your contractors and any breach by your contractors shall be deemed a breach by you hereunder.

   You acknowledge that the licensed materials have not been specifically designed to meet your individual requirements and that you have all information necessary to evaluate whether the licensed materials meet your requirements or not, and will be suitable for your intended use or application. Therefore the licensed materials shall be deemed accepted upon delivery to Licensee. You shall use, at your own risk, the licensed materials and any development that is obtained from such use. You acknowledge that ST and its affiliates cannot in any way be held responsible for the consequences resulting from use of the licensed materials and any development made following such use of the licensed materials.

   You acknowledge you are receiving the licensed materials under a limited license and not as a purchaser of the licensed materials.

2. **Restrictions** -

Unless otherwise expressly stipulated under article 1, you shall not, and shall not permit any third party to: (i) copy, reproduce or duplicate the licensed materials; (ii) translate, modify, adapt, decompile, disassemble or reverse engineer and make derivative works of (any portion of) the licensed materials; (iii) rent, disclose, publish, sell, assign, lease, lend, sublicense, market, transfer, distribute or otherwise provide third parties access to (any portion of) the licensed materials for any purpose; (iv) attempt to derive the source code, algorithmic nature or structure of any object code portions of the licensed materials; (v) use the licensed materials to create any product that competes with the licensed materials or ST chipsets; (vi) remove or circumvent any protection or other restrictive technology mechanism of the licensed materials or ST chipsets; (vii) disclose the results of the licensed materials' performance to any third party; or (viii) otherwise use any portion of the licensed materials in any manner not expressly authorized by this LLA.

Other than the limited expressed license granted to you under article 1 herein, no other rights or licenses are granted, or implied by estoppel or otherwise, under any intellectual property rights of ST and/or its Affiliates or any intellectual property of a third-party residing in the licensed materials or in any other confidential information furnished by ST and its affiliates, including (i) for the combination of such licensed materials or other confidential information with one or more other items (including items acquired from ST and/or its affiliates) even if such items have no substantial use other than as part of such combination (ii) with respect to any trademark, trade or brand name, domain name, corporate name of ST and/or affiliates, or any other name or mark, or contraction abbreviation or simulation thereof, (iii) under any intellectual property rights covering any standard set by a standard setting body and any de facto standards.

You may not use the licensed materials for commercial purposes nor sell, or otherwise transfer it for value. Commercial purposes include the use of the licensed materials as a standalone product or in a product, to be distributed, marketed or otherwise offered for sale or for rent ultimately. For avoidance of doubt, nothing shall prevent the Licensee from distributing any of Licensee's software/hardware applications, provided that such licensee's software/hardware applications do not contain any licensed material or part thereof and/or result in whole or in part from use of the licensed materials hereunder.

You shall limit access and use of the licensed materials to you and those individuals who may be employed by you who have a need to access the licensed materials for the limited license purpose and provided that you shall ensure that such individuals shall comply with the provisions of this LLA, and except as expressly permitted under article 1 or as otherwise expressly agreed in writing by ST, you shall not allow any third-party to use the licensed materials. You shall be liable towards ST for any damages due to a failure by such third-party(ies) to comply with the provisions of this LLA.

ST and its affiliates have no obligation to provide you with maintenance, technical support or updates for the licensed materials.

3. **Ownership, copyrights and trademarks** -

The licensed materials are and will remain the exclusive property of ST and/or its affiliates or its licensors, whether or not specifically recognized or perfected under the laws of the country where the licensed materials are used. You will not take any action that jeopardizes ST and its affiliates or its licensors' proprietary rights or acquire any rights in the licensed materials, except the limited rights specified in article 1.

All right, title and interest in and to the licensed materials, are owned or licensed by ST or its affiliates or licensors. You shall ensure that all notices, including but not limited to all copyright and trademark notices of ST or its affiliates or licensors are reproduced in any copy of the whole or any part of the licensed materials. You shall not remove, modify or alter any ST or its affiliates' or licensors' copyright or trademark notice from any part of the licensed materials.

4. **Confidentiality** -

Confidential information shall include all information provided with the licensed materials which (a) is designated as "confidential", "proprietary" or with a similar legend, (b) is by its own nature of a type which would reasonably be considered confidential and/or (c) is source code ("confidential information"). You may only use the confidential Information for the limited license purpose and shall protect the confidentiality of the confidential information provided by ST and its affiliates under this LLA by using the same degree of care, but not less than a reasonable degree of care, to prevent its unauthorized use, dissemination, or publication as you use to protect your own confidential information of like nature.

You shall be liable towards ST for any damages incurred due to a failure by any employee having access to the licensed materials and/or the confidential information to comply with the provisions in this LLA. You shall immediately notify ST of any unauthorized use or disclosure of, or of any unauthorised access to, or of any theft or loss of the licensed materials or confidential information or part thereof, which comes to your notice.

The confidentiality obligations shall not apply to confidential Information, which can be shown by documentary evidence: (i) entered the public domain through no fault of the licensee; or, (ii) was known to the licensee prior to receipt from ST and its affiliates; or, (iii) was disclosed to the licensee by a third party having the right to disclose; or, (iv) was independently developed by the licensee without use of the licensed materials or confidential information, the onus of proof of independence being on the licensee.

These confidentiality obligations shall survive any termination or expiration of the LLA for whatever cause.

5. **Disclaimer of warranty** -

   You acknowledge that the licensed materials and any and all parts thereof are provided “as is”. ST and its affiliates make no representations or warranties with respect to the licensed materials and or parts thereof whether express, implied, or statutory, including but not limited to, implied warranties of merchantability and fitness for a particular purpose. Specifically, without limiting the generality of the foregoing, st and its affiliates make no representation or warranty that (I) the use of the licensed materials and or parts thereof will be uninterrupted or error free, and or (II) any use of the licensed materials and or parts thereof, whether integrated into other equipment or not, are free from infringement of any third party intellectual property rights. It shall be your sole responsibility to make such determination as is necessary with respect to the acquisition of licenses under patents and other intellectual property rights of third parties. consequently, ST and its affiliates disclaim any liability in case any such use infringes any third party’s intellectual property rights. Furthermore ST and its affiliates hereby disclaim any warranty and liability whatsoever for any development created by or for you or your customers. You acknowledge that you have relied on no warranties other than the express warranties in this LLA and that no warranties are made by ST or its affiliates or granted by law whenever it is permitted by law.

6. **Open source** -

   Some portion of the licensed materials might contain open source software subject to open source terms (as defined below) applicable for each such portion, as further specified in the licensed materials. Such open source software is supplied to you under the applicable open source terms and is not subject to the terms of this LLA to the extent the terms of this LLA are in conflict with such applicable open source terms.

   Except for open source software, you have no rights under this LLA to, and may not under any circumstances use the licensed materials or any parts thereof such that they become subject to any open source terms. These actions include but are not limited to combining the licensed materials by means of incorporation or linking or otherwise.

   For the purpose of this LLA, “open source terms” shall mean any open source license which requires as part of distribution of software that the source code of such software is distributed therewith, or any other open source license that complies with the open source definition specified at www.opensource.org and any other comparable open source license such as for example GNU general public license (GPL), Eclipse public license (EPL), Apache software license, BSD license and MIT license. “Open source software” shall mean any software that is licensed or distributed under open source terms as specified in the licensed materials.

7. **Compliance** -

   You agree not to use the licensed materials in violation of any law, statute, ordinance or other regulation or any obligation by which you are bound. You agree to comply with all applicable laws and regulations regarding the use of the licensed materials. Specifically but without limiting the generality of the foregoing, you acknowledge that the licensed materials are subject to export controls restrictions and you agree to comply with the European export regulations and US similar regulations, and to obtain any necessary export license or other documentation prior to exportation or re-exportation of the Licensed Materials.

   Some licensed materials may (i) require licenses from third parties claiming intellectual property rights covering use or implementation of the licensed materials or (ii) be based on industry recognized standards or software programs published by industry recognized standards bodies and certain third parties may claim to own intellectual property rights that cover implementation or use of those standards. You agree that you will obtain any necessary licenses from such third parties prior to execution of the license rights granted by ST to you herein.

8. **Disclaimer of damages** -

   In no event shall ST and its affiliates be liable to the licensee and its customers for any indirect, incidental, punitive, special or consequential damages, lost profits or lost savings, loss of bargain or opportunity, professional fees or expenses, business interruption, lost revenues or sales, damage to product or equipment or to facilities, costs of substitute product, facilities or services, rework charges, costs associated with down time, loss of goodwill, loss of data or for any damages costs or expenses associated with warranty or intellectual property infringement claims, whether foreseeable or unforeseeable and whether or not such damages are based on warranty, contract or any other legal theory, arising out of or in connection with this lla – even if licensee has been advised, or is aware, of the possibility of such damages. ST and its affiliates aggregate and cumulative liability towards licensee under this lla shall not exceed 100 USD (one hundred USD). The limitations set forth above in this article 8 shall only apply to the maximum extent permitted by applicable law.

9. **Term and termination** -

   This LLA shall be valid for an initial period of one year from acceptance by you of this LLA, thereafter, it shall automatically renew for an unlimited period of time until terminated by either ST or licensee upon one (1) month prior written notice to the other. Notwithstanding the foregoing, licensee may terminate this LLA at any time by destroying all licensed materials, documentation and other confidential information or by returning those to ST. ST may terminate this LLA at any time if (i) you fail to comply with the terms and conditions of this LLA, or (ii) you file litigation against ST or its affiliates, (iii) ST or its affiliates receive notice of any claim, suit or proceeding that alleges that the licensed materials or your use of the licensed materials infringes any third-party intellectual property rights or (iv) to the extent permitted by laws, a voluntary or involuntary petition in bankruptcy or winding up is filed against licensee, any proceedings in insolvency or bankruptcy are instituted against licensee, a trustee or receiver is appointed over licensee, or any assignment is made for the benefit of creditors of licensee. Upon termination, you shall delete, destroy, or return to ST all licensed materials in your possession and you shall stop using the licensed materials for any purpose whatsoever. The rights and obligations under articles from 2 to 11 will survive the termination or expiration of this LLA.

10. **Miscellaneous** -

    If a court or agency of competent jurisdiction holds any term of this LLA invalid, illegal, or unenforceable for any reason, the remainder of this LLA shall be valid and enforceable and you and ST shall discuss in good faith a substitute, valid, enforceable provision which most nearly effects the parties intent in entering into this LLA.

    The failure by ST to enforce any provisions of this LLA or to exercise any right in respect thereto shall not be construed as constituting a waiver of its rights thereof.

    No agency, joint venture, partnership or other business organization shall be created or be construed as being created by reason of this LLA. You will not have the right or authority to, and shall not, assume or create any obligation of any nature whatsoever on behalf of ST and its affiliates or bind ST and its affiliates in any respect whatsoever. You and ST are independent parties. Nothing in this LLA shall be construed as making you an employee, agent or legal representative of ST.

    This LLA contains the entire and sole agreement between you and ST on the subject matter of this LLA, and supersedes all representations, undertakings and agreements previously made between you and ST and/or its affiliates and shall prevail over the terms and conditions set forth in any document from you with respect to the subject matter of this LLA. Any amendment to this LLA shall be agreed in writing and be duly signed by you and ST or signed or agreed solely by you on the format proposed by ST and shall make reference to this LLA.

11. **Applicable law** -

    This LLA is governed by the laws of Switzerland, without regard to its conflict of law rules. All disputes or questions arising out of or in connection with this LLA shall be finally settled by the competent courts of Geneva, Switzerland. Notwithstanding the aforesaid, nothing in this LLA shall prevent ST from seeking any interim or final injunctive or equitable relief by a court of competent jurisdiction.

Revision history

Table 1. **Document revision history**

Date	Revision	Changes
21-Dec-2017	1	Initial release
01-Mar-2018	2	ACEPACK packages included in the document. Document updated accordingly, minor text changes.

Contents