2016

Schottky&FERD eTool User Manual

Rev 2

Contents

List of symbols and abbreviations

V_{RRM}	:	Maximum Repetitive peak reverse voltage
$I_{F(av)}$	:	Average Forward Current
V_F	:	Forward Voltage
I_F	:	Forward Current
I_R	:	Reverse current or leakage current
V_R	:	Reverse Voltage
T_j	:	Junction Temperature
P/N	:	Part Number
PSR	:	Power Schottky Rectifier
FER	:	Field Effect Rectifier
FWD	:	Forward
REV	:	Reverse
App	:	Application

1 Introduction

The application ***Schottky&FERD eTool*** is a digital tool developed to help designing with Power Schottky and Field Effect Rectifiers in a dynamic way, complementing diodes datasheets.
The purpose of this tool is to provide our customers a quick and simple way to access the typical performance of the diodes.
Of course, for all cases, the datasheet compliance is the only reference and valid document. And it is customers' liability to validate the ST diodes function and performance in his application designs.

Schottky&FERD eTool offers the following possibilities:

1. Search for a diode by its Commercial Part Number
2. Do a cross-search
3. Sort diodes by:
    a. Voltage Rating (V_{RRM})
    b. Current Rating ($I_{F(av)}$)
    c. Package
    d. Assembling type (single diode, double diodes, common cathode, separate diodes)
    e. Diode technology:
        - Schottky Barrier
        - Field Effect Rectifier
    f. Number of diodes per package
    g. Grade:
        - Automotive
        - Non-automotive
4. To plot static typical and maximum electrical characteristics: (V_F, I_F) and (V_R, I_R)
5. To calculate forward and reverse power losses with current and voltage waveform function of junction temperature.
6. To estimate diodes performance:
    a. By comparing V_F or I_R at a given bias level and T_j.
    b. By comparing power losses for a given application waveform.

2 Features description

2.1 Features location

Figure 1 shows the dashboard of *Schottky&FERD eTool*. Most of the important features can be accessed from the main page, as described in the following paragraph. See below a description of each item identified by a number:

1) Mode: diodes selection or power losses calculation
2) Indicator of number of diodes available in the tool
3) Indicator of number of diodes satisfying filters criteria
4) Number of diodes selected
5) Language selection: English or simplified Chinese
6) Information: user manual, guides
7) Select all diodes
8) Unselect all selected diodes
9) Search by diode part number
10) Filter by current rating ($I_{F(av)}$)
11) Filter by voltage rating (V_{RRM})
12) Filter by diodes features:
    a. Type (technology)
    b. Topology
    c. Number of diodes per package
    d. Package type
    e. Grade
13) Cross reference search
14) Area where available diodes are listed
15) Selection list + summary table
16) Buttons to access to:
    a. Extended electrical characteristics table
    b. Forward characteristics chart
    c. Reverse characteristics chart

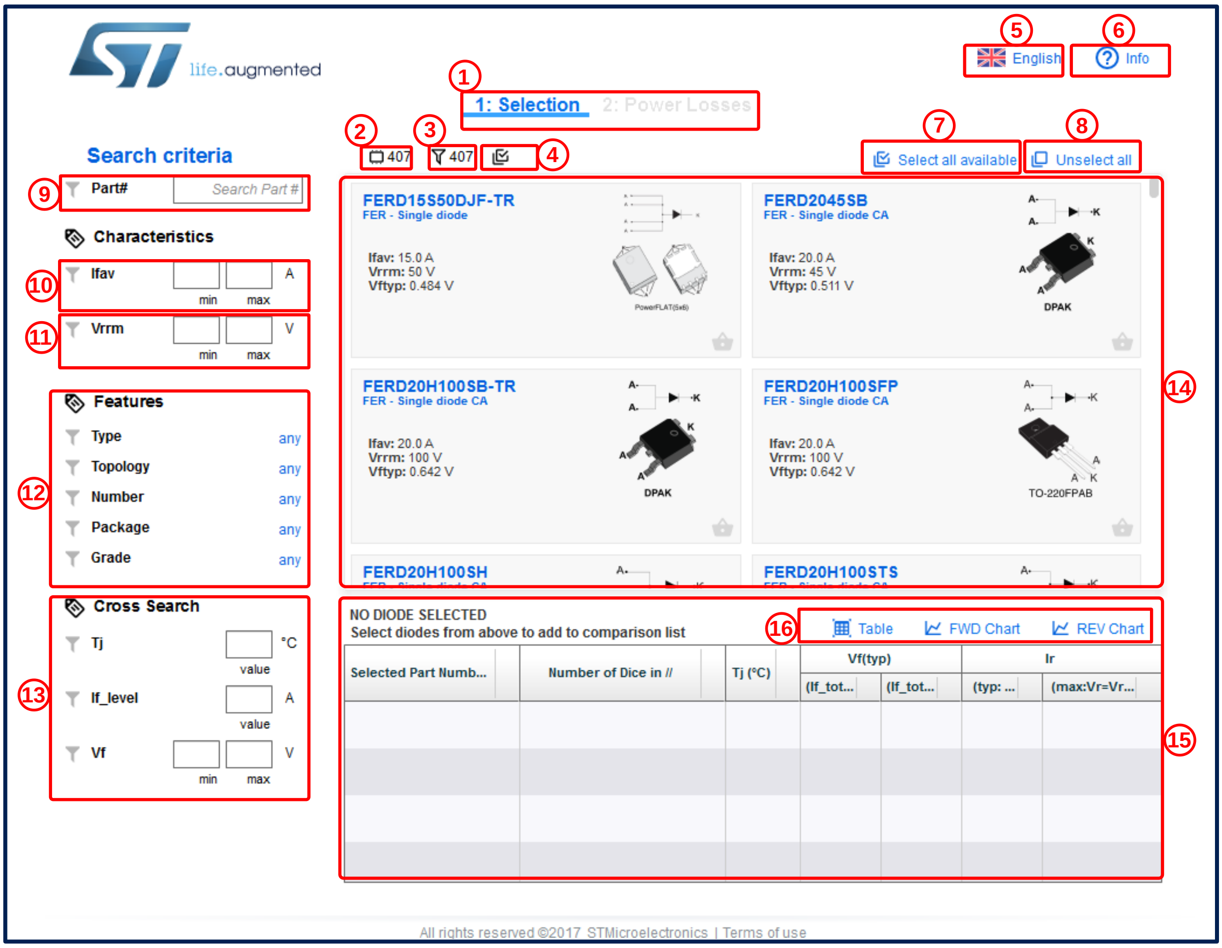


Figure 1: Dashboard

2.2 Language

Default language of Schottky&FERD eTool is English.

Simplified Chinese is proposed as second language. Click on flag locate on top right change the language: English 中国

2.3 Filter and search functionality

2.3.1 Search by P/N

To search for a Part Number, write the P/N reference in the search field. In the example of Figure 2, the P/N 'FERD20M60ST' is wanted. When 'FERD20M60ST' is entered in search field only the P/N corresponding to the label appears in diodes list.

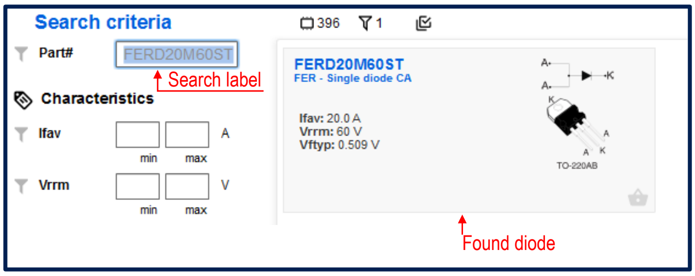


Figure 2: Search by diode P/N

2.3.2 Filter by current rating

Filter by current rating is located in section 6 of Figure 1. This filter allows to search for diodes within a certain current rating range. Figure 3 gives an illustration.

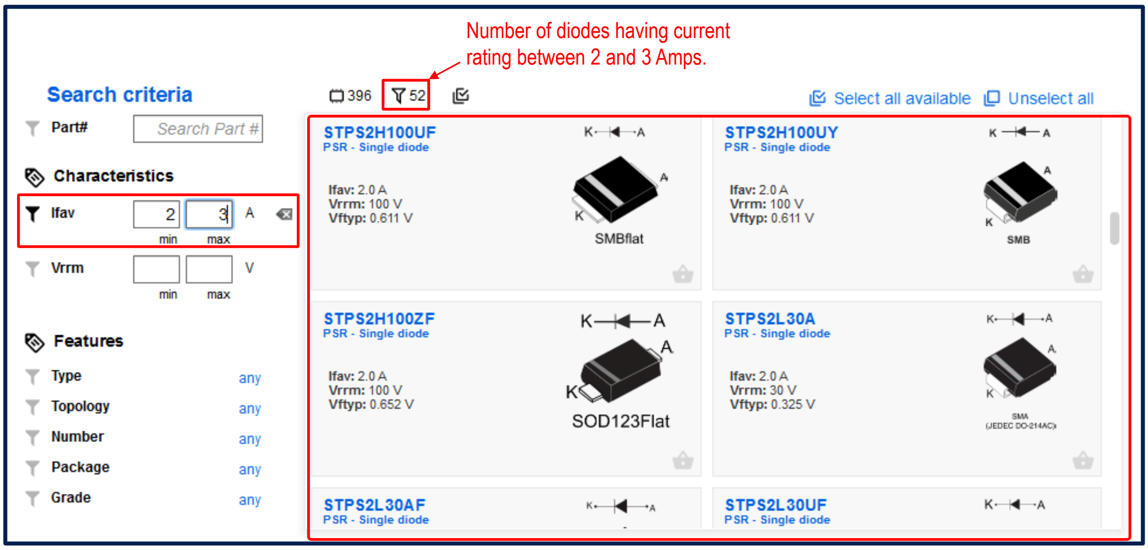


Figure 3: Filter by current rating example

2.3.3 Filter by Voltage Rating

Same functionality as current rating filter. To enter the voltage range in section 8 of Figure 1.

2.3.4 Filter by diode features

2.3.4.1 Diode type

Three choices are available (see Figure 4):

1. any
2. Field Effect
3. Schottky Barrier

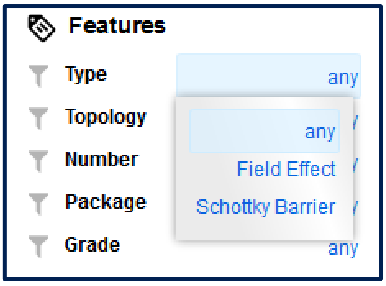


Figure 4: Diodes type (technology) filter

2.3.4.2 Topology

Filter by assembling type: single diode, double common cathode diode, etc.

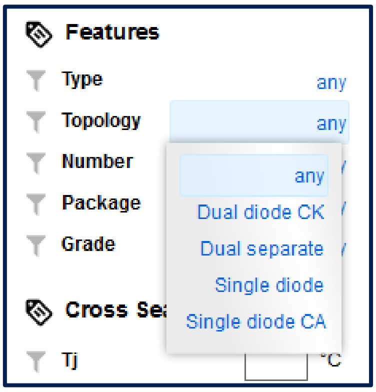


Figure 5: Filter by topology

2.3.4.3 Number of diodes per package

Filter by number of diodes in the package.

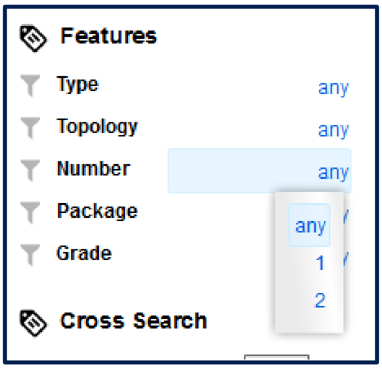


Figure 6: Filter by number of diodes inside the package

2.3.4.4 Package type

Filter by package type (Figure 7)

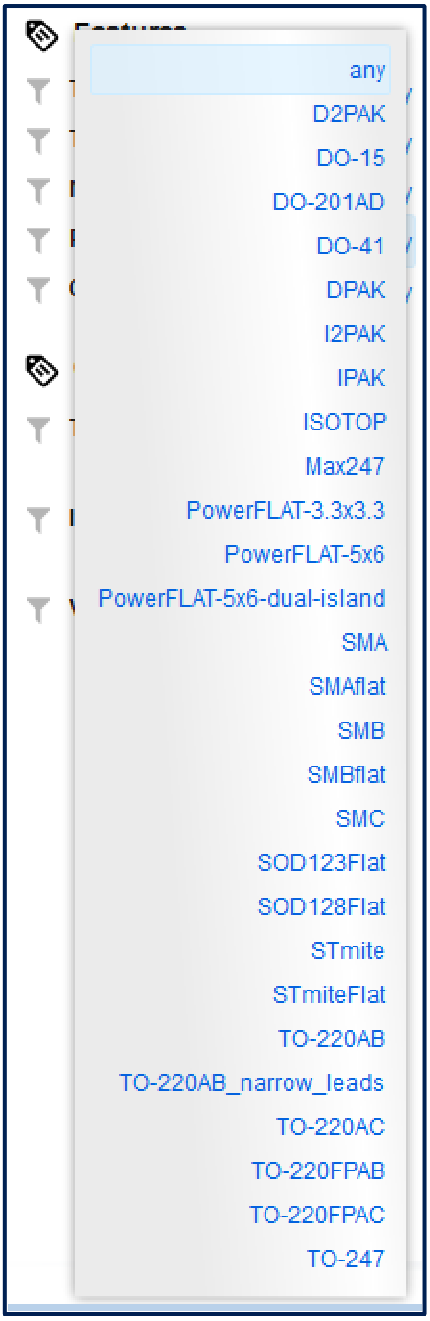


Figure 7: Filter by package

2.3.4.5 Grade

Filter by grade: Automotive grade products, and non-automotive (general purpose devices), Figure 8.

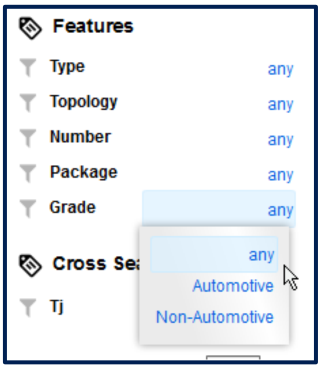


Figure 8: Filter by number product grade

2.3.5 Cross-search

This option allows to make cross-search. It is possible to search for a diode that has a typical V_F performance within a user-defined interval, for a given I_F level, T_j and voltage rating.

Example:
Let's say we want a 100V diode that has $V_{F(typ)} \leq 0.5\ V$ at $10A$ and $125°C$. Figure 9 illustrates this cross-search.
Note that all previous filters (voltage rating, type, grades, etc…) can be combined with cross-search.

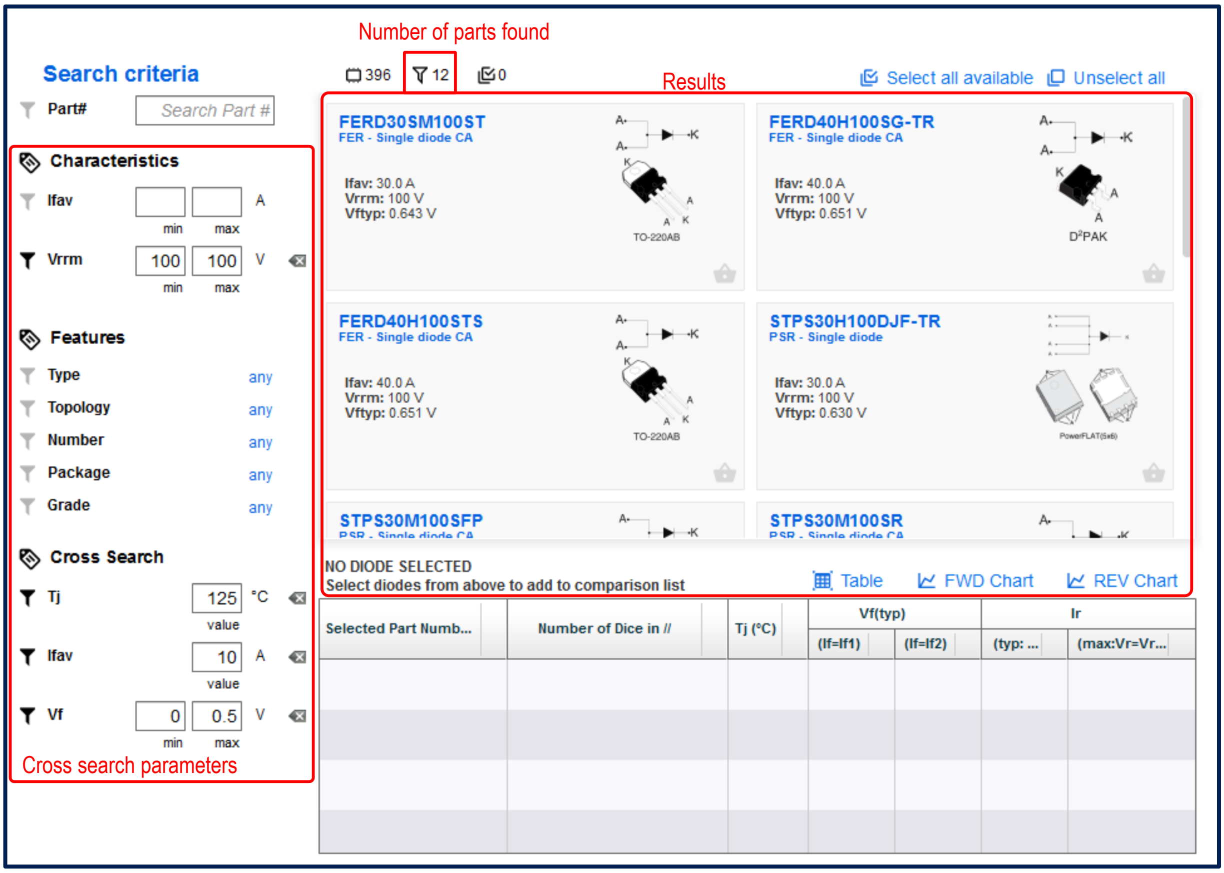


Figure 9: Cross-search for a $100\ V$ diode having $V_F(10A,\ 125°C) \leq 0.5\ V$

2.4 Access datasheet and product page on ST website

The button 'Datasheet' gives a redirection to datasheet of the P/N to ST website (Figure 10). The button 'Product Folder' links to product page on ST website.

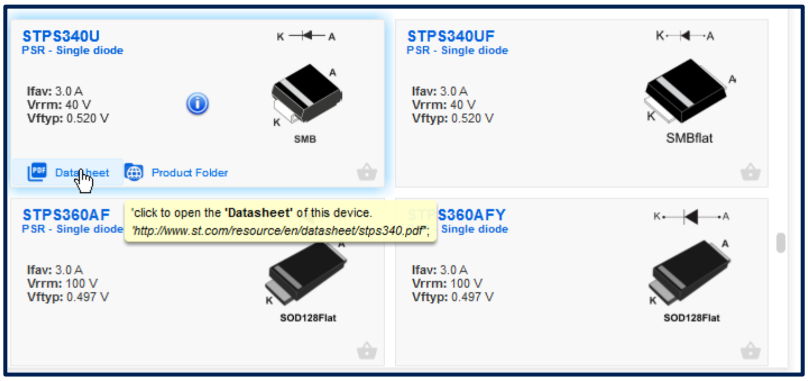


Figure 10: Link to datasheet and diode page on ST website

2.5 Exploring diode characteristics

Select a P/N by clicking in the grey basket icon like in Figure 11. Once the diode is selected the basket icon becomes blue, the selected diode appears in selection (see Figure 12). Electrical characteristics (forward and reverse) of selected diodes can be explored. Two methods are proposed:

1. A numerical vale table (detail in next section)
2. Forward and reverse characteristics chart.

By default, for a selected P/N, characteristics of only one diode (or die) are showed (like in datasheet), even if the package contains several dice. In selection list (see indication on Figure 12). Multiple P/N can be selected in order to be compared. For a given P/N it is possible to set up to 5 parallel dice. This gives the possibility to compare a single die to several dice.

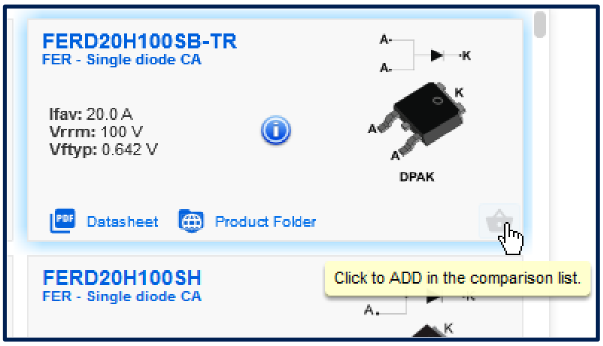


Figure 11: Select a P/N

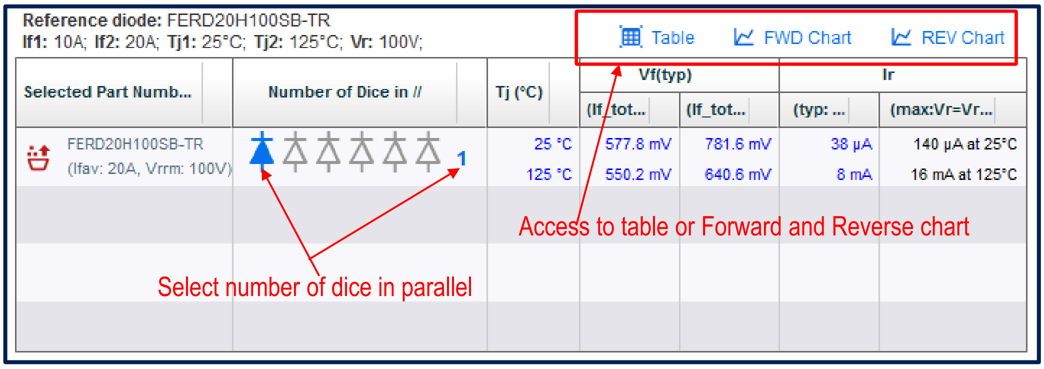


Figure 12: Selection list

2.5.1 Forward Chart

Figure 13 presents the *Forward Chart*. Forward current and voltage are plotted in an x-y chart: forward voltage is x abscissa and forward current y ordinate. To launch *Forward Chart,* click on the button FWD Chart

By default, typical V_F are plotted at two junction temperature (T_j) 25°C and 125°C, for a current range up to current rating per diode in the package.

By moving the cursor over a curve tooltip appears showing curve properties and V_F/I_F values.

Maximum V_F (estimated from the typical values) can also be displayed on the graph by clicking the button Maximum values (estimated from typical)

Typical V_F values can be disabled by clicking on the button Typical values , in order to show maximum V_F only.

The legends in the graphic give information on the number diodes in parallel (choice made during the selection step).

2.5.1.1 *Add/Remove Temperature*

To add or remove temperature write T_j value in temp box: 

Then click on '+' to add, or '-' to remove.

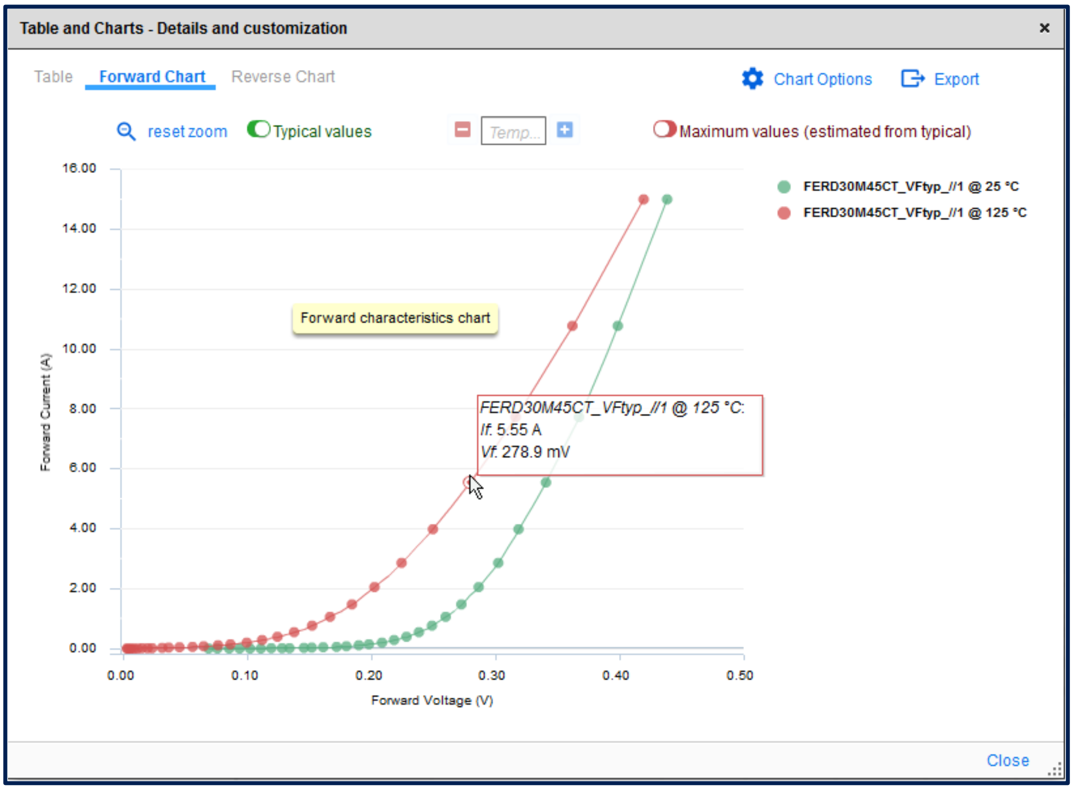


Figure 13: Forward Chart

2.5.1.2 *Forward Chart Options*

2.5.1.2.1 *Plot properties*

The button '*I-V Charts option*' gives access to options that allow to customize the chart (Figure 14). Options are:

- Number of points per curve
- Temperature range
- Forward current range

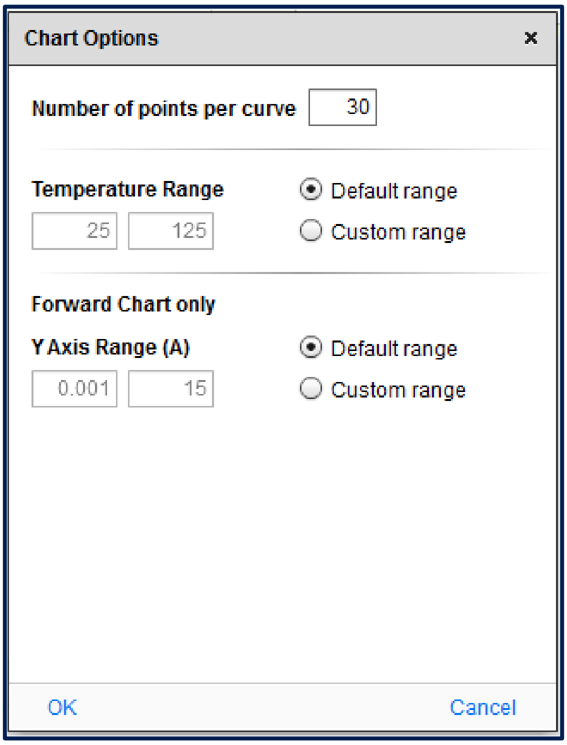


Figure 14: Forward Chart options

2.5.1.2.2 *Zoom option*

To zoom into an area of the graph: right-click with the right mouse button and drag the mouse while keeping the click pressed. To reset zoom, click on the button reset zoom

2.5.2 Reverse Chart

In *Reverse Chart* (Figure 15) typical I_R is plotted versus reverse voltage V_R. To launch *Reverse Chart* click on the button REV Chart

2.5.2.1 *Reverse Chart Options*

Options of *Reverse Chart* are similar to options of *Forward Chart*.

Figure 15: Reverse Chart

2.5.3 Summary Table

A summary table is given to see directly numerical values of typical V_F, typical I_R at forward current, reverse voltage level, and temperature that can be changed. By default, a preview of this table is given in main window. To access full functions of the table with possibility to change parameters click on the button Table

Figure 16 presents the table with only one diode selected.

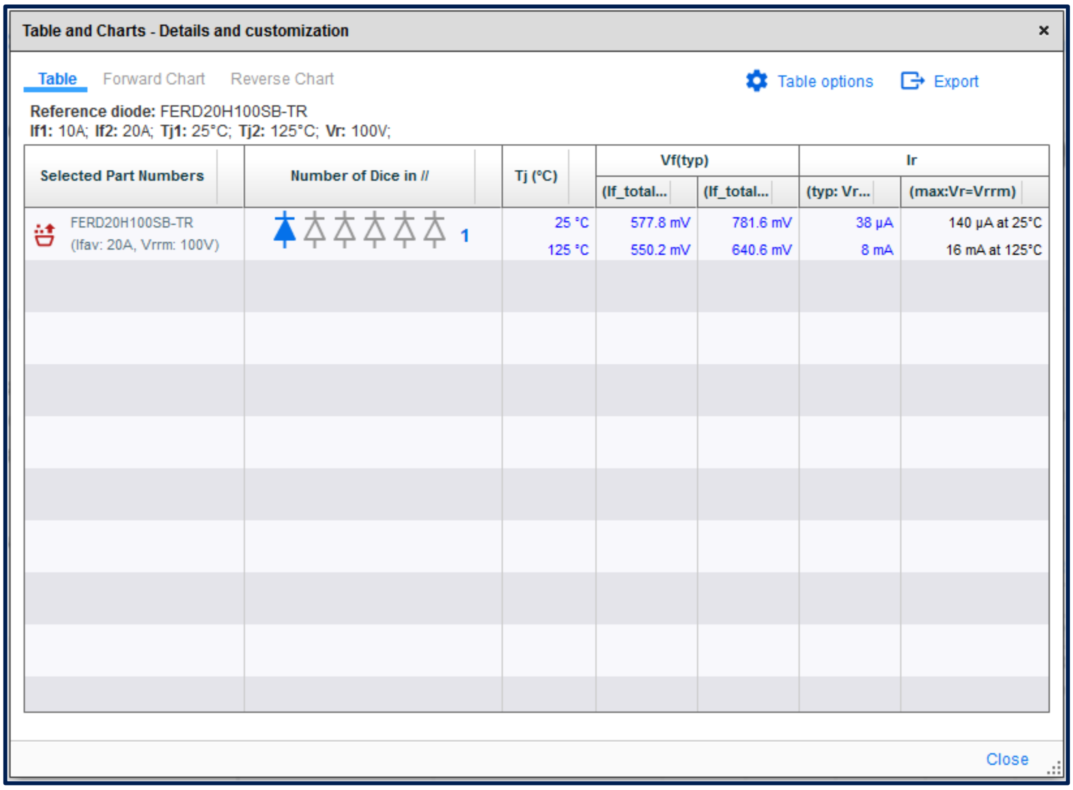


Figure 16: I-V Table

2.5.3.1 Modify table parameters

To modify the table settings click on the button Table options

Then Figure 17 shows up. Forward, reverse bias level and temperature can be changed.

Note that I_{F1} value corresponds to $I_{F1} = I_{F2}/2$.

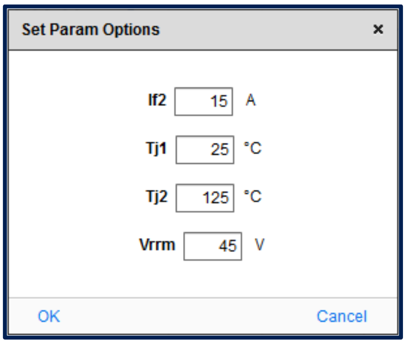


Figure 17: Table parameters

2.6 From Application Waveforms to Power Losses

Schottky&FERD eTool offers the possibility to calculate power losses based on application waveforms: forward current flowing into the diode, and blocking voltage across the diode. This is a two steps process:

a) Create application waveforms (reproduction of application conditions)
b) Associate waveforms with P/N to calculate power losses

As shown in Figure 18, 'Power Losses' mode should be selected[1] first. Then waveform creator tool can be launched to reproduce application waveforms, and finally to set branches that are reproduction of application circuit branches. Power losses are automatically calculated.
This process is detailed in the subsections below.

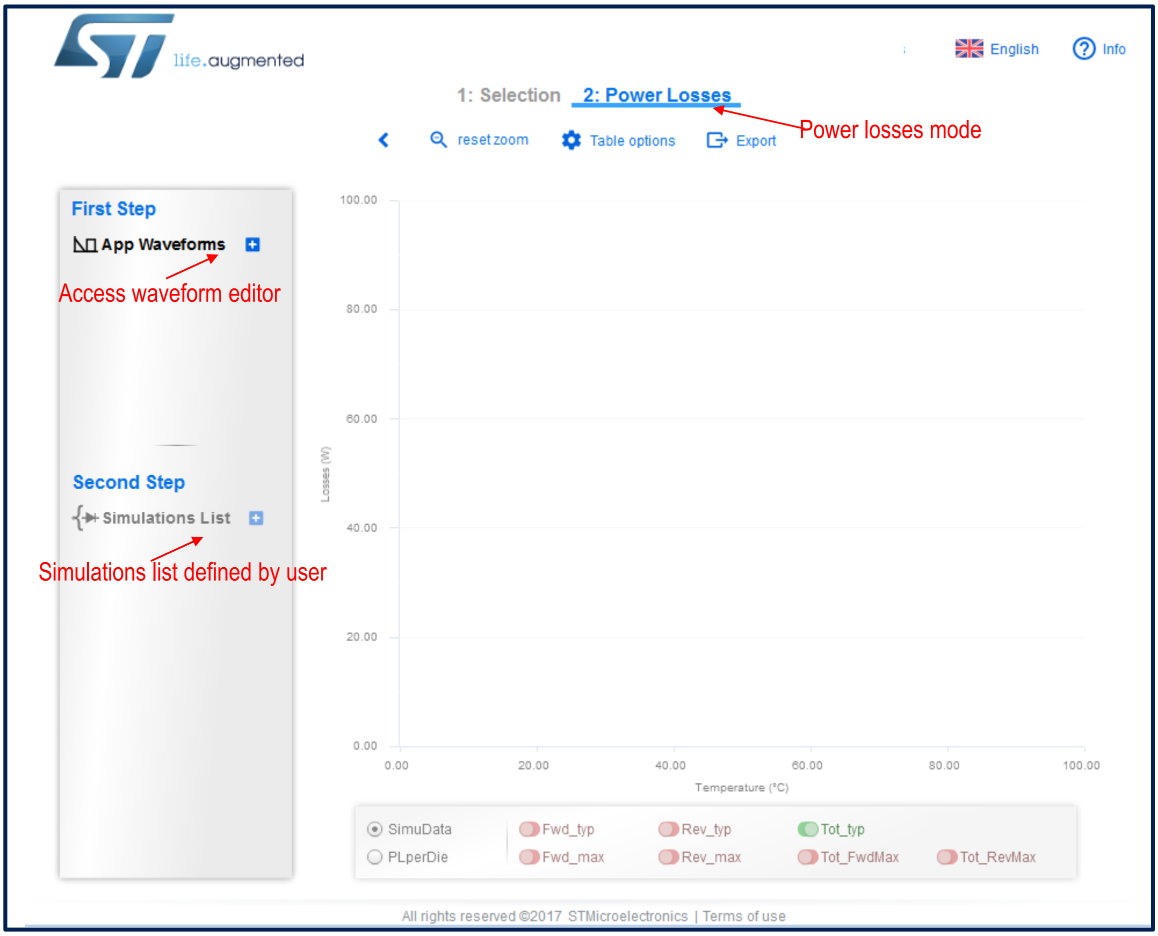


Figure 18: Power losses steps selection

2.6.1 Step 1: Create Application Waveform

To create/edit application waveform click on this button 

Waveform creator shows up (Figure 19).

[1] 'Power Losses' mode is accessible only if at least one P/N is selected.

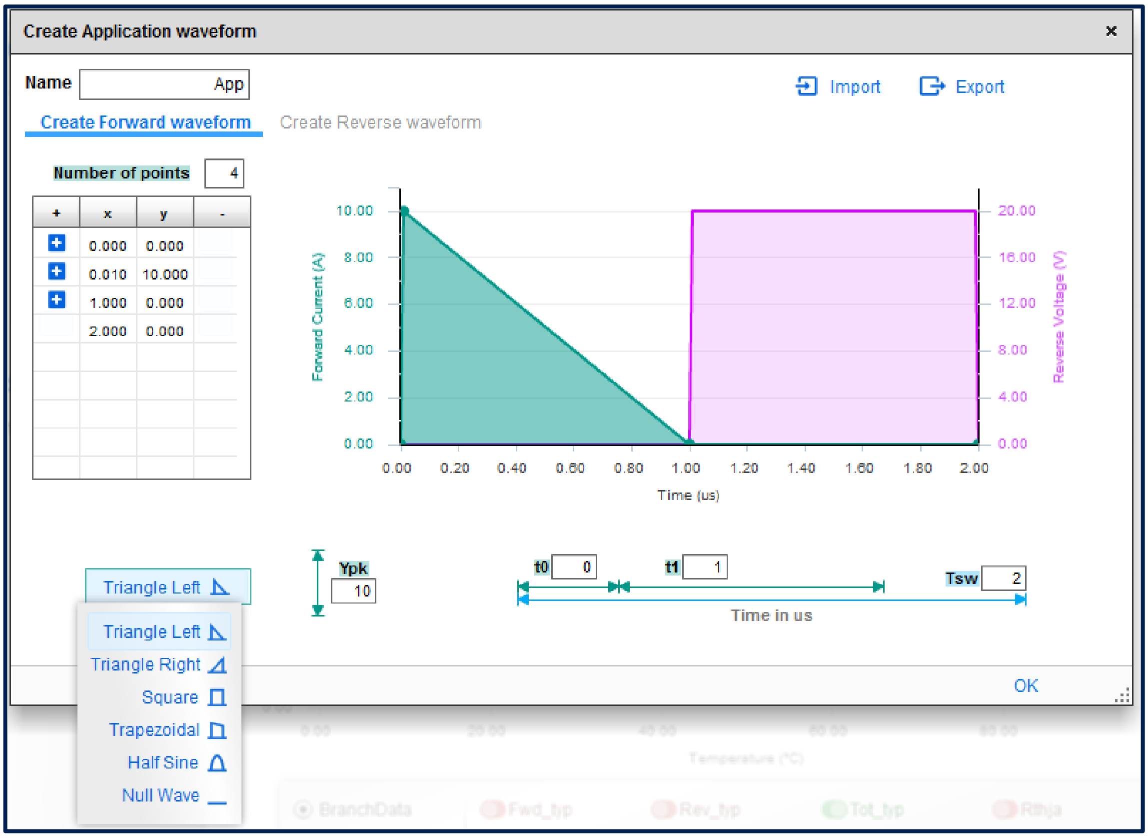


Figure 19: Application waveform creator tool

2.6.1.1 *Fill/Edit predefined waveforms*

Current and voltage are edited separately: tab '*Create Forward Waveform*' and tab '*Create Reverse Waveform*'. Several waveforms can be created by specifying a name 

The widget is designed to reproduce repetitive waveforms like those in Switch Mode Power Supply (SMPS). The most common waveforms in SMPS are already predefined:

- Triangle
- Square
- Trapeze
- Half sinus

Null wave option is used in a case where the diode is either always in blocking mode or conduction mode.

Parameters of predefined waveforms:

1. T_{sw} (period of the signal). Common to both current and voltage, which is the case in an SMPS. By default, time unit is micro second.
2. Conduction or blocking time: represented by t_1 in the editor.
3. t_0 represent delay time before conduction or blocking. t_0 is used to represent the two waveforms in a time sequence similar to what happens in real word.
4. Y_{pk}, Y_{pk1}: Amplitude of the current/voltage waveform.

2.6.1.2 Custom waveforms

Custom arbitrary waveforms can be defined using two methods:

1) By editing existing predefined waveform using graphical editor
2) By import waveforms defined in a csv[2] text file

2.6.1.2.1 Graphical editor

Waveforms can be directly edited, like showed in Figure 20. Use one of the following way to customize the waveforms.

a) Pair points values can be inserted in the table. Use '+' to insert additional pair points
b) Drag and drop using mouse.

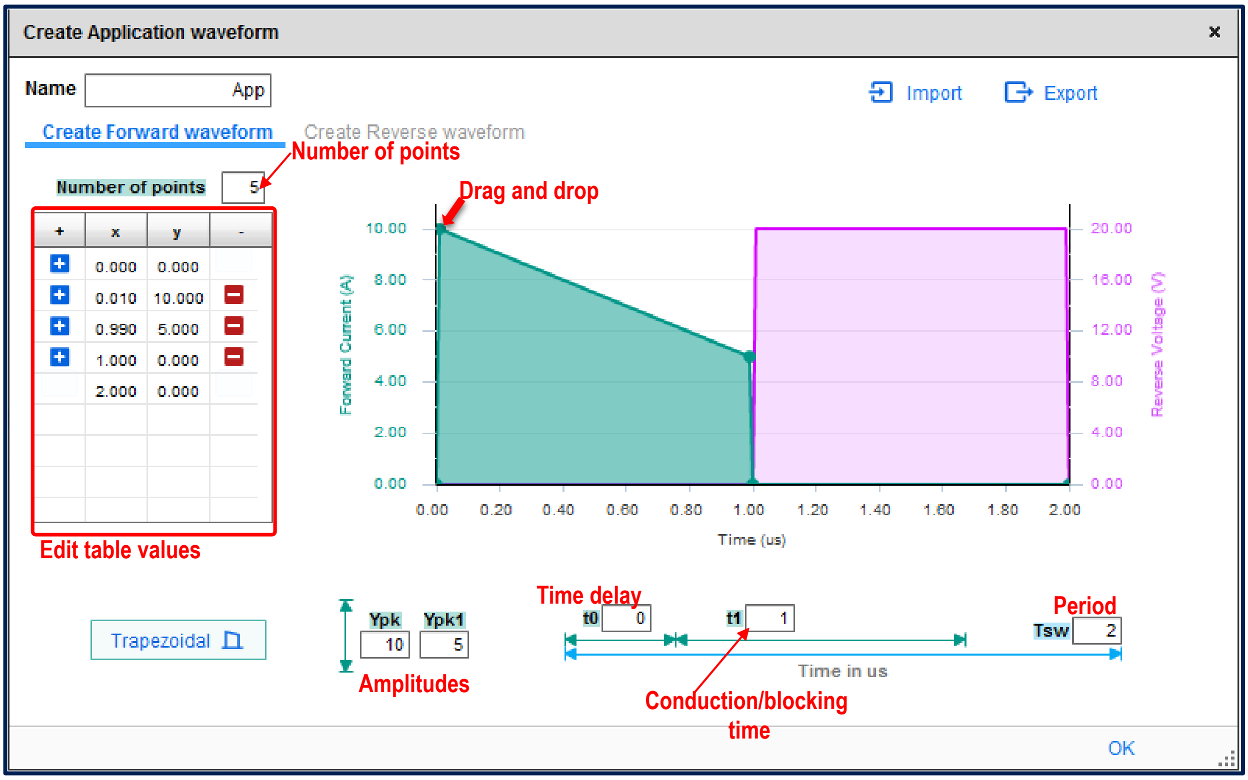


Figure 20: Application waveforms - Editing mode

2.6.1.2.2 Import custom waveforms

An alternative way to create waveform is to import predefined waveform saved in csv format. The syntax is quite simple. The first line corresponds to the waveform name. All numeric lines with a pair points separated with a comma are interpreted as waveforms points. Note that the waveform period should be entered manually in graphical interface of waveform creator tool.
Figure 21 (a) illustrates an example of file used to generated waveforms in Figure 21 (b).

[2] CSV: Comma-Separated Values

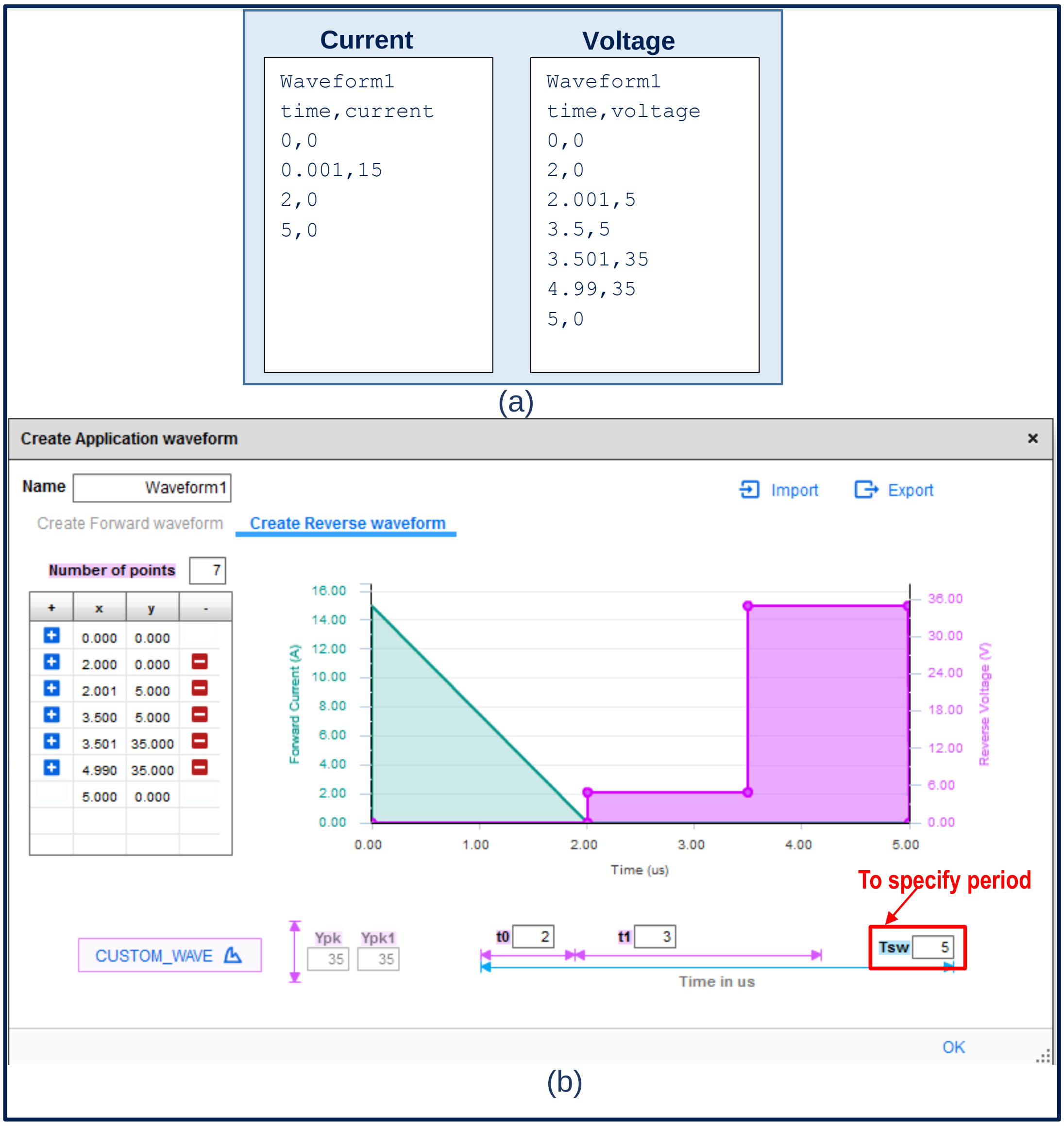


Figure 21: Importing waveform example

2.6.1.3 Edit/Delete existing waveform

Waveforms defined by user are collected in a list like presented on Figure 22.
Up to maximum 5 waveforms can be defined.
To edit a waveform, click on its label, waveform editor will open.
To delete a waveform click on the button

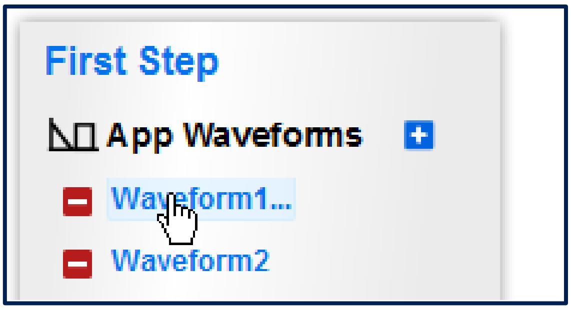


Figure 22: Waveforms list

2.6.2 Step 2: Simulation profile creation

Figure 23 presents simulation profile creation window. The branch concept (Figure 25) refers to each leg of the application circuit where one or more parallel diodes are used. So it is possible to create several branches and affect more than one die in parallel[3] per branch.

If several diodes are used in parallel, the current associated with the branch must be the total current of all parallel diodes, see illustration on Figure 25.

Figure 24 details selection steps.

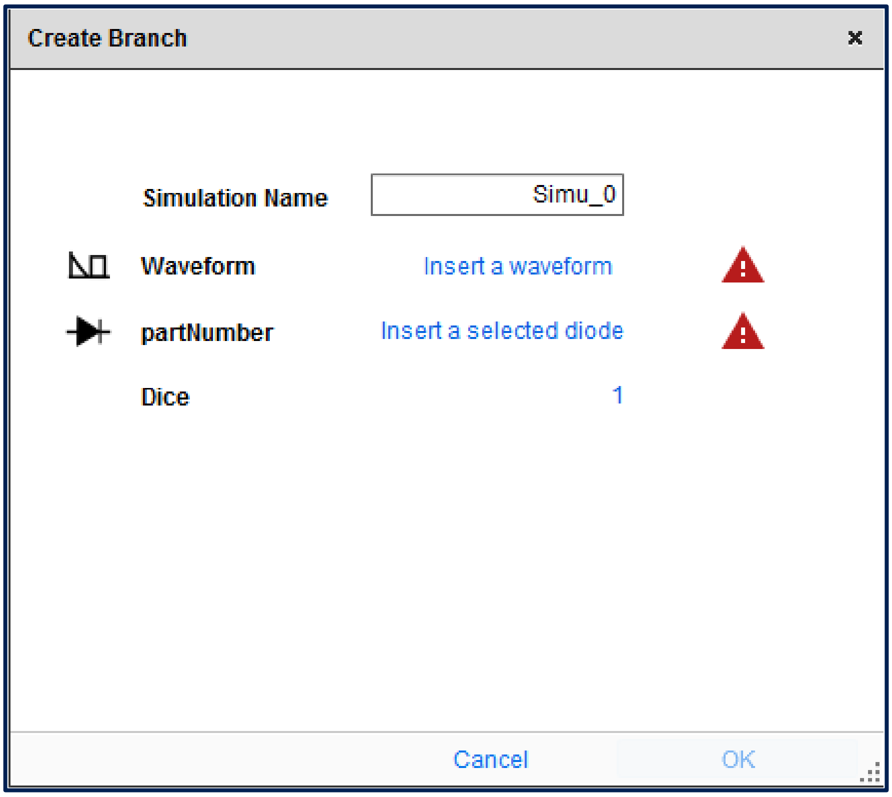
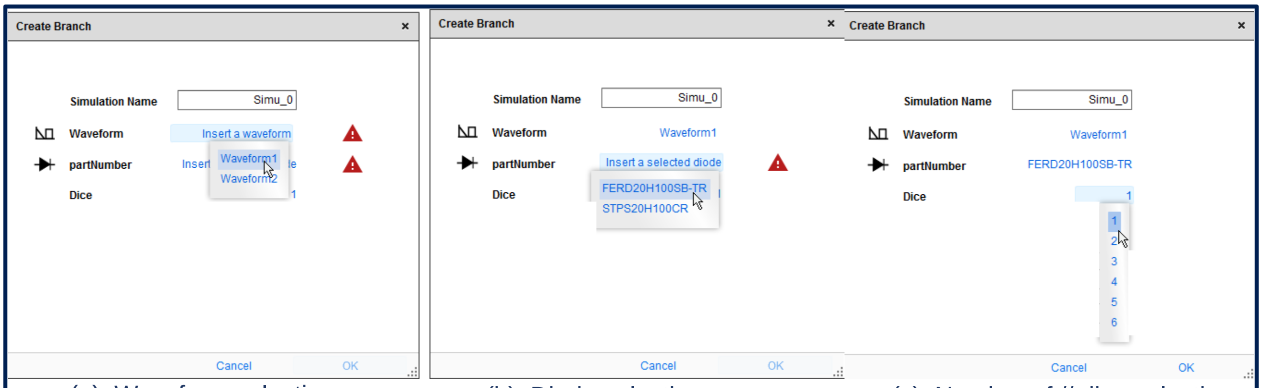


Figure 23: Branches creation window

[3] Maximum 5 dice in parallel



(a): Waveform selection (b): Diode selection (c): Number of // dice selection

Figure 24: Simulation configuration: selection steps

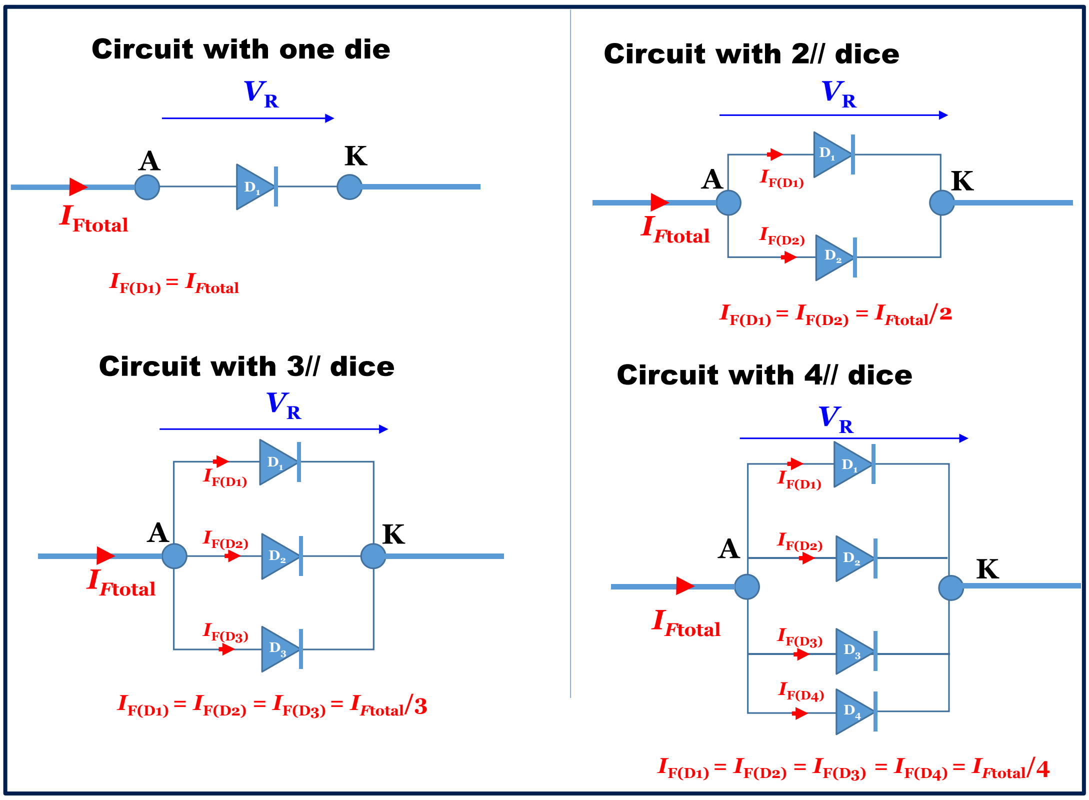


Figure 25: Simulation and parallel dice representation

2.6.3 Power Losses

Once a simulation profile has been validated power losses can be calculated as presented in Figure 26. Power losses are calculated after clicking on the button

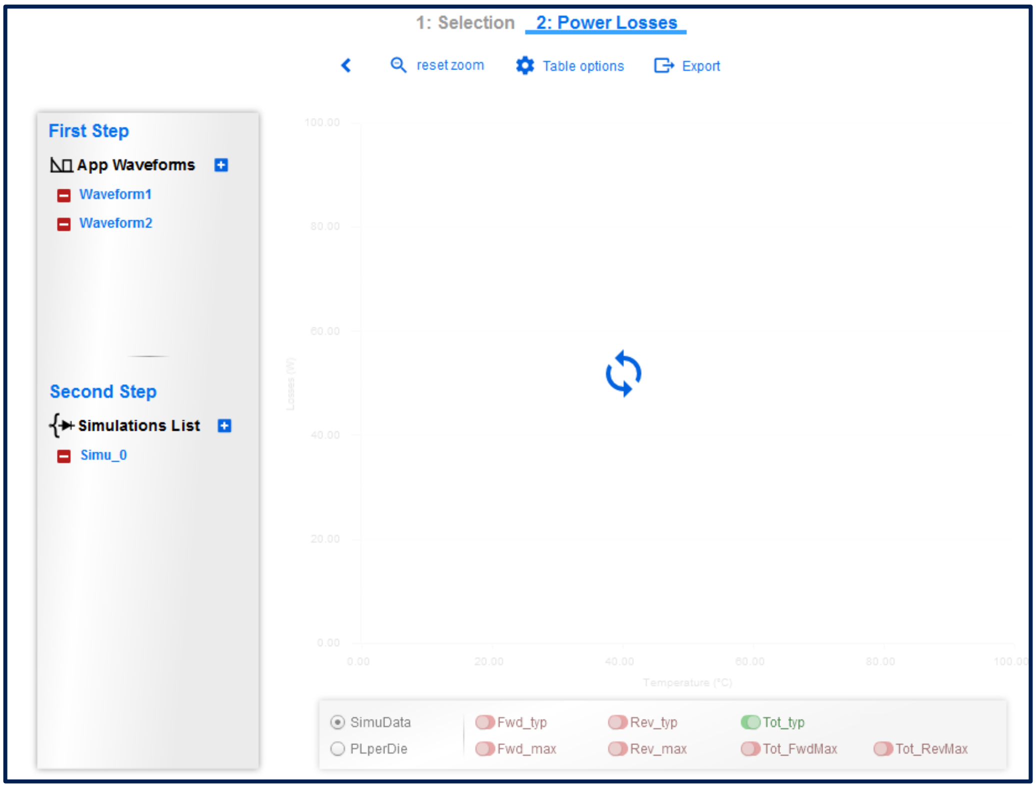


Figure 26: Power Losses validation

Figure 27 shows an illustration of power losses function of junction temperature. By default, power losses are plotted for T_j range 25°C to 125°C. Move the cursor over points on curve to see information the curve and values.

Calculated power losses are classified as follows:

- Typical conduction losses with typical V_F ('*Fwd_typ*')
- Maximum conduction losses with maximum V_F ('*Fwd_max*')
- Typical reverse losses with typical I_R ('*Rev_typ*')
- Maximum reverse losses maximum I_R ('*Rev_max*')
- Total:
  - Typical conduction + typical reverse losses ('*Tot_typ*')
  - Typical conduction + maximum reverse losses ('*Tot_RevMax*')
  - Maximum conduction + typical reverse losses ('*Tot_FwdMax*')

Power losses of a branch is total power losses of all dice in the branch is several diodes are used in parallel. The is plotted by default. To access power losses per die click on the button DieData

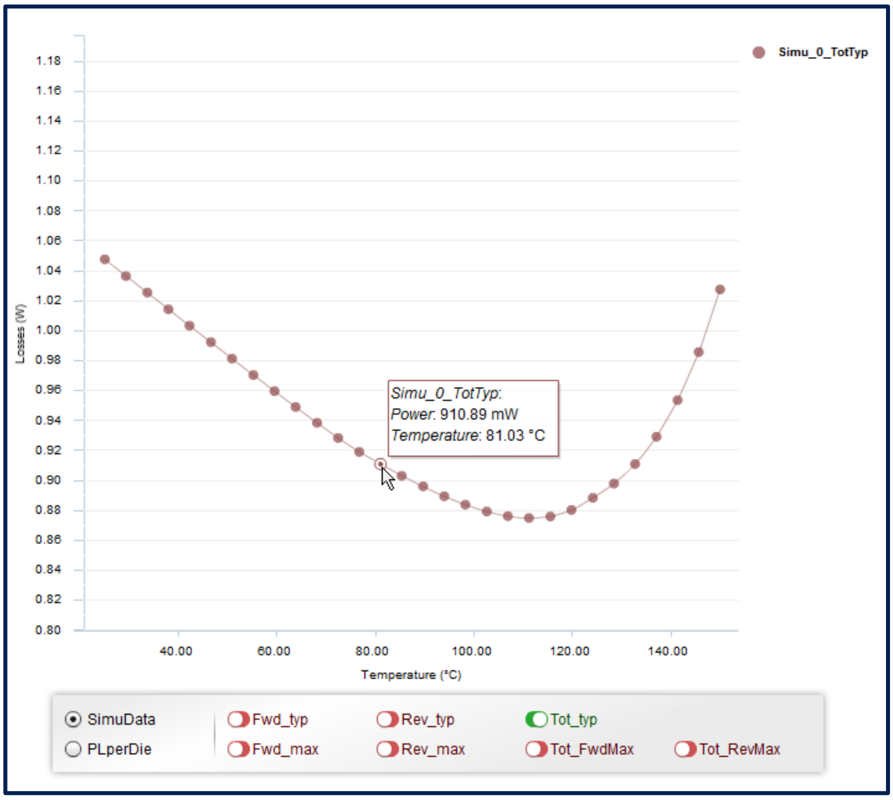


Figure 27: Power Losses Chart

2.6.3.1 Power Losses chart options

Figure 28 presents power losses chart options. Click on button Options to the display options window. The number of points per curve, and temperature range can be modified.

Note also that is possible to zoom with the mouser cursor by keeping left button pressed, or zoom/de-zoom with mouse wheel. To reset zoom, use the reset button reset zoom

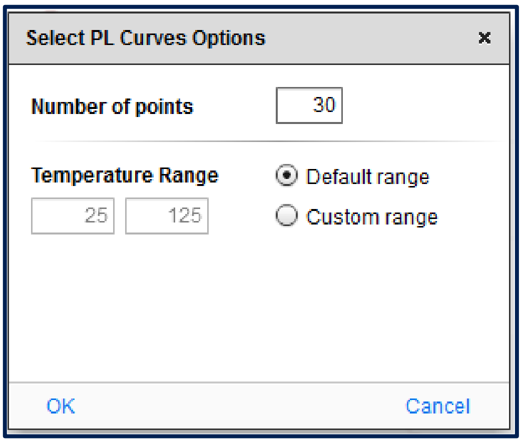


Figure 28: Power Losses Chart Options

1.1.1 Export Power Losses Data

Power losses can be exported as image or numerical data. Figure 29 shows export options.

Figure 29: Power Losses Export Options

To export the graph as image, select ‘JPG’ format.
To export numerical data, select either ‘TXT’ or ‘CSV’ format. Data are formatted as comma separated values, and can be imported in spreadsheet programs like Microsoft Excel.

3 Examples based on common applications

3.1 Example 1: Power losses in the output rectifier of a flyback converter

Let's consider an example of a Schottky diode used in a flyback converter. The converter is a 45 W notebook adapter with 19.5 V/2.31 A output.

The rectifier at flyback output is a STPS30SM100ST. We want to evaluate its power losses.

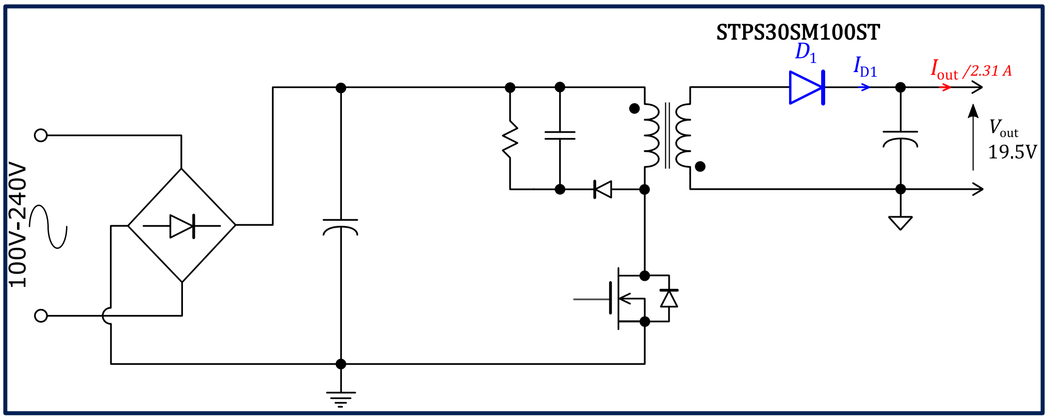


Figure 30: 45 W flyback converter

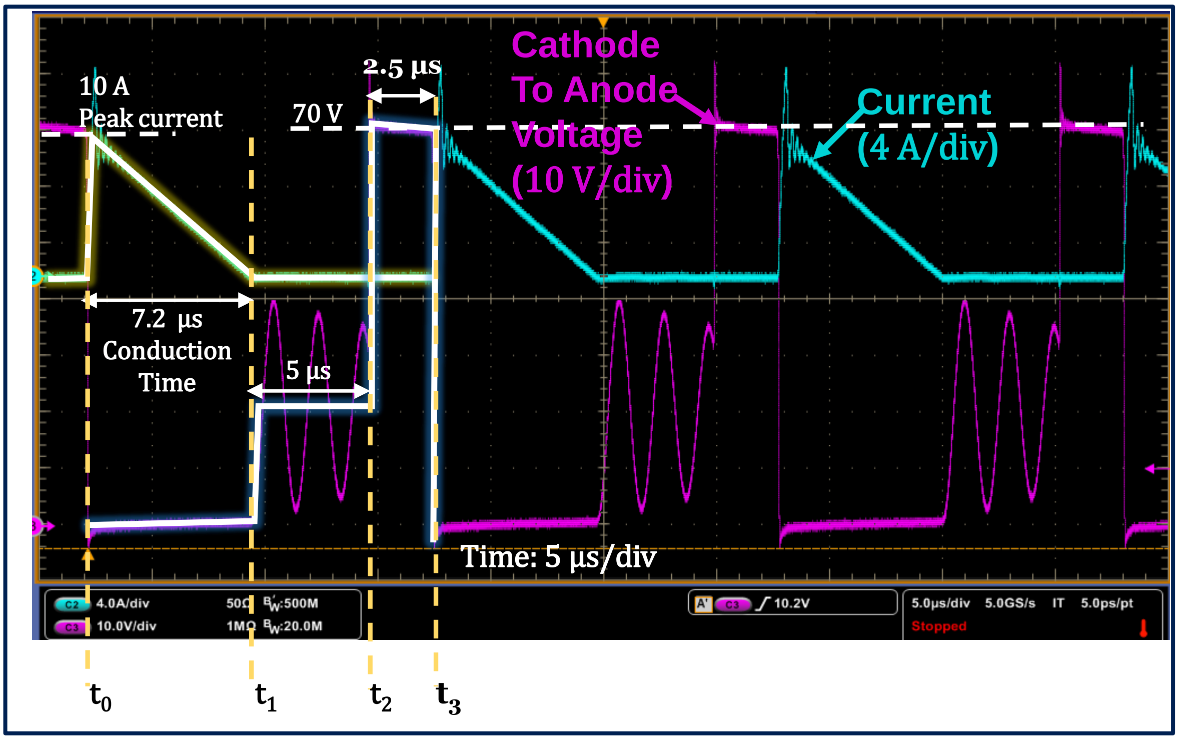


Figure 31: 45 W flyback, waveform in the output diode

The waveforms in the diode at full load and 240 Vac input voltage are presented in Figure 31. At each switching period (14.7 µs) D_1 operates with different phase as described below:

a) At $[t_0, t_1]$ D_1 is working in forward mode with a triangular current shape (10 A peak, 7.2 µs conduction time)

b) At $[t_1, t_3]$ D_1 is blocked with two different phases:
   1. $[t_1, t_2]$ as the flyback is operating in *Discontinuous Conduction Mode* the voltage across D_1 is oscillating around the output voltage with an average value of $19.5\ V$ (during $5\ \mu s$).
   2. $[t_2, t_3]$ the primary switch of the flyback is ON, the voltage across D_1 is the $70\ V$ during $2.5\ \mu s$.

Now, sequences of current and voltage across are known, we can reproduce them in ***Schottky&FERD eTool***.
The current is easily entered using predefined triangular waveform (refer to Figure 32).

The reverse voltage has more complex shape than the current. There are two ways to enter the waveform:

1. Using text file like described in section Import custom waveforms. This is the most straightforward way. The text below is an example.:
```
Time, Voltage
Flyback_w1
0, 0
7.2, 0
7.201, 19.5
12.2, 19.5
12.201, 70
14.699, 70
14.7, 0
```
2. By editing directly, the pair points in the tool to create a custom waveform. Figure 33 shows how to do this in two steps:
   a. Select '*Create Reverse waveform*'.
      i. Leave square shape by default.
      ii. In t_0 enter $7.2\ \mu s$. This is the time when the diode starts working in reverse mode.
      iii. In t_0 enter $7.5\ \mu s$ ($5\ \mu s + 2.5\ \mu s$): blocking time
      iv. In Y_{pk} enter $19.5\ V$
      v. Click on '*Edit'* button to modify the pair points
   b. The widget is in editing mode now:
      i. In the table on the left fill each cell by starting by the beginning like in Figure 33 (b). Validate each row by pressing '*Enter'* key of the keyboard.

Current and voltage waveforms are available now, then by choosing STPS30SM100ST diode its power losses are plotted as shown in Figure 34.

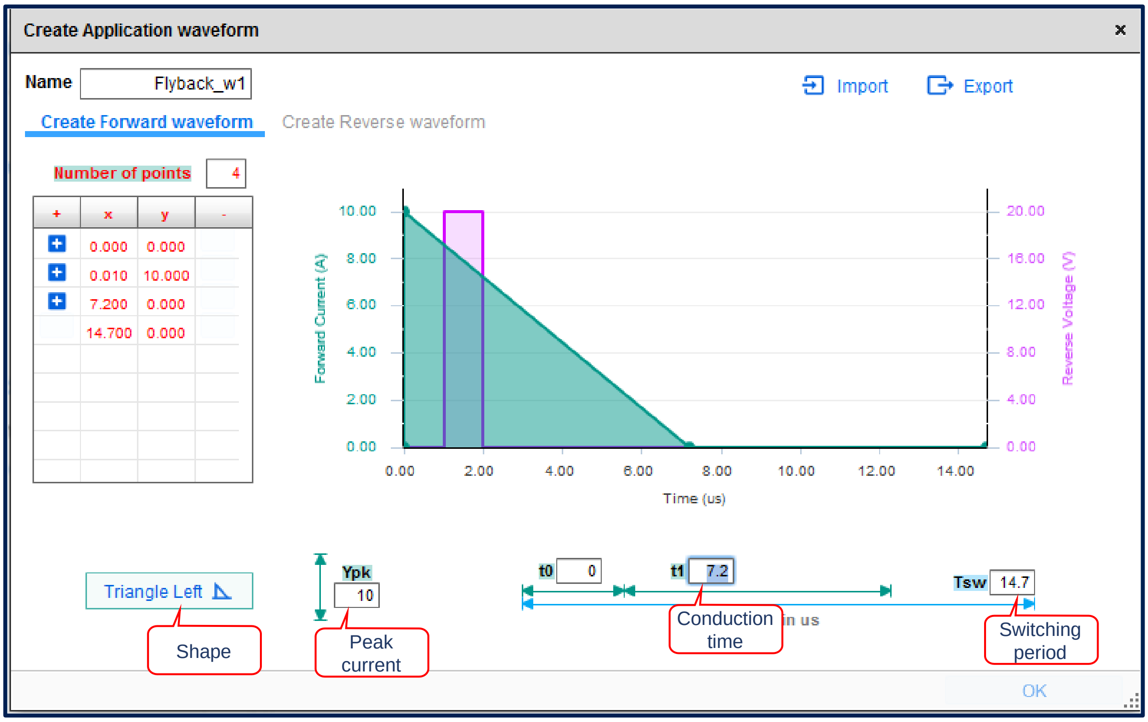


Figure 32: Entering flyback current waveform

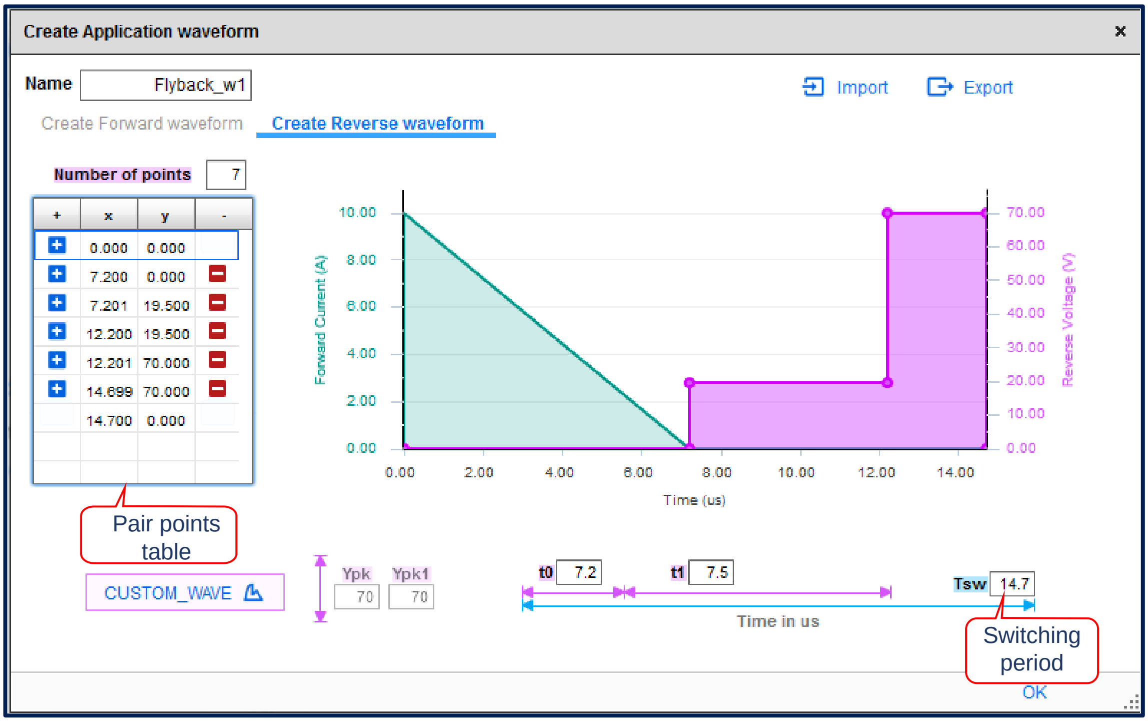


Figure 33: Entering flyback reverse voltage waveform

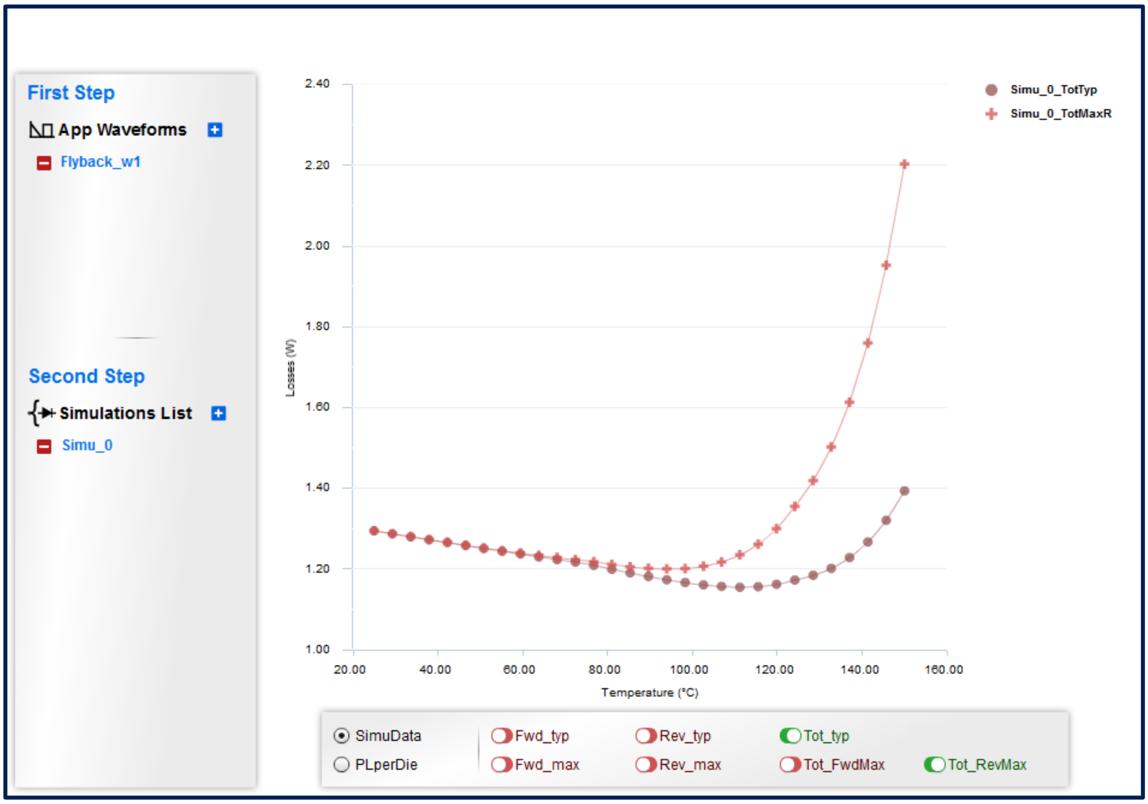


Figure 34: STPS30SM100ST power losses in the 45 W flyback adapter

3.2 Example 2: Power losses of two diodes in a Forward Converter

Let's consider the rectification diodes of forward converter. These two diodes are represented by D_1 and D_2 in the schematic of Figure 35 (a). The conditions are the following:

- DC input voltage 380 V
- Output voltage 12 V
- Output current 20 A
- Switching frequency 60 kH
- D_1 and D_2: STPS40M60CT (dual diodes in TO-220)

Current and voltage waveforms of D_1 and D_2 are given with above conditions in Figure 35 (b). They can be easily reproduced in *Diode Selector* by selecting pair points on the waveforms in order to generate piecewise waveforms. Example of pair point's extraction is presented in Figure 36.

Figure 37 shows the waveforms reproduction.

Once the waveforms are ready, power losses are easily obtained by selecting the diode. Figure 38 shows conduction and reverse losses for STPS40M60CT.
In this example each diode (D_1 and D_2) is treated separately. It is possible to export power losses data to exploit them for further analysis. For example, Figure 39 shows total power losses of D_1 and D_2 plotted using Microsoft Excel.

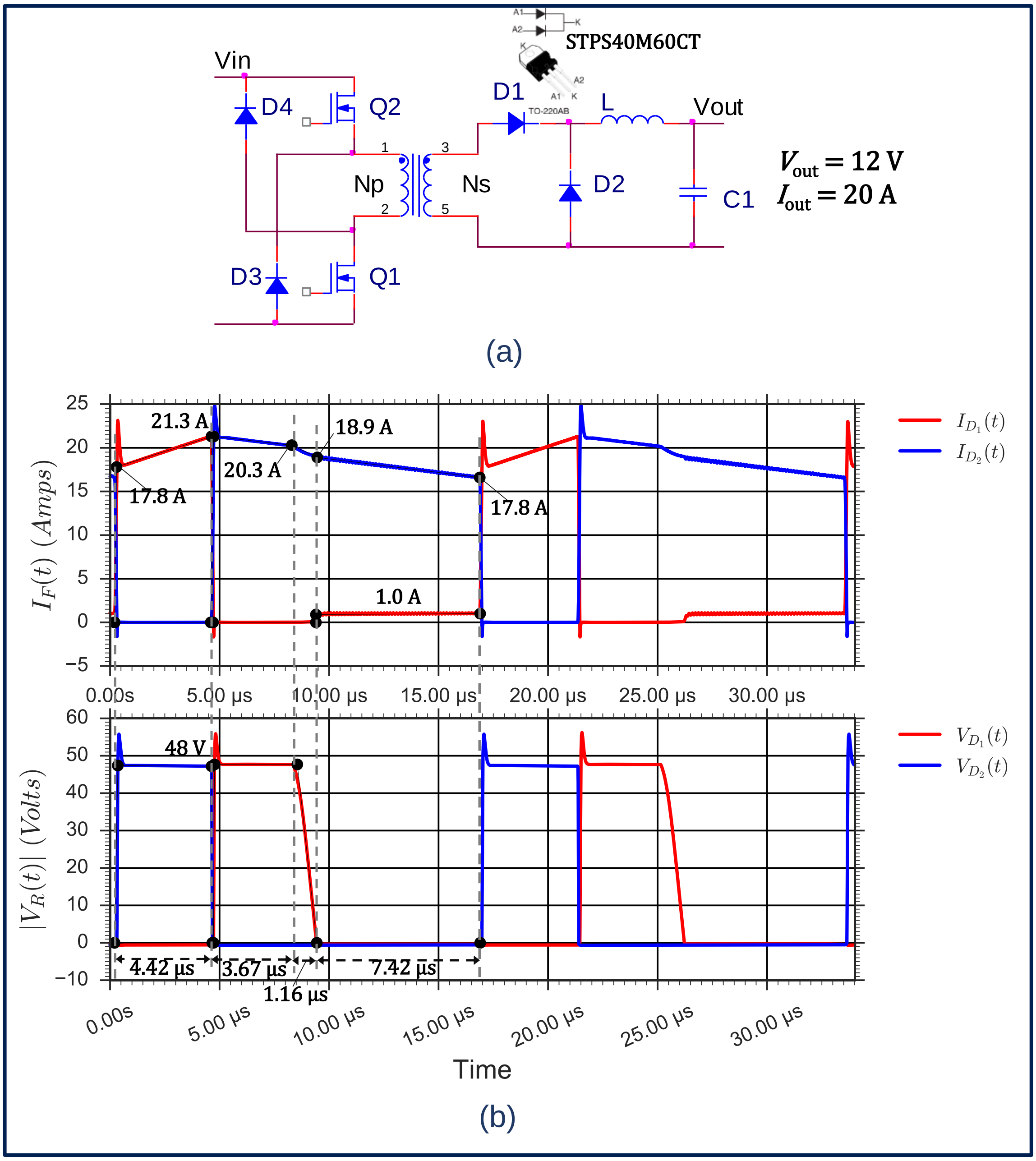


Figure 35: Diodes waveforms in a 12 V/20 A forward converter

D_1 current

```
Wav_D1
time,current
0,0
0.1,17.8
4.42,21.3
4.43,0
9.25,0
9.26,1
16.6,1
16.67,0
```

D_1 voltage

```
Wav_D1
time,voltage
0,0
4.42,0
4.43,48
8.1,48
9.25,0
16.67,0
```

D_2 current

```
Wav_D2
time,current
0,0
4.42,0
4.43,21.3
8.1,20.3
9.25,18.9
16.6,17.8
16.67,0
```

D_2 voltage

```
Wav_D2
time,voltage
0,0
0,48
4.42,48
4.43,0
16.67,0
```

Figure 36: File to generate D_1 and D_2 waveforms

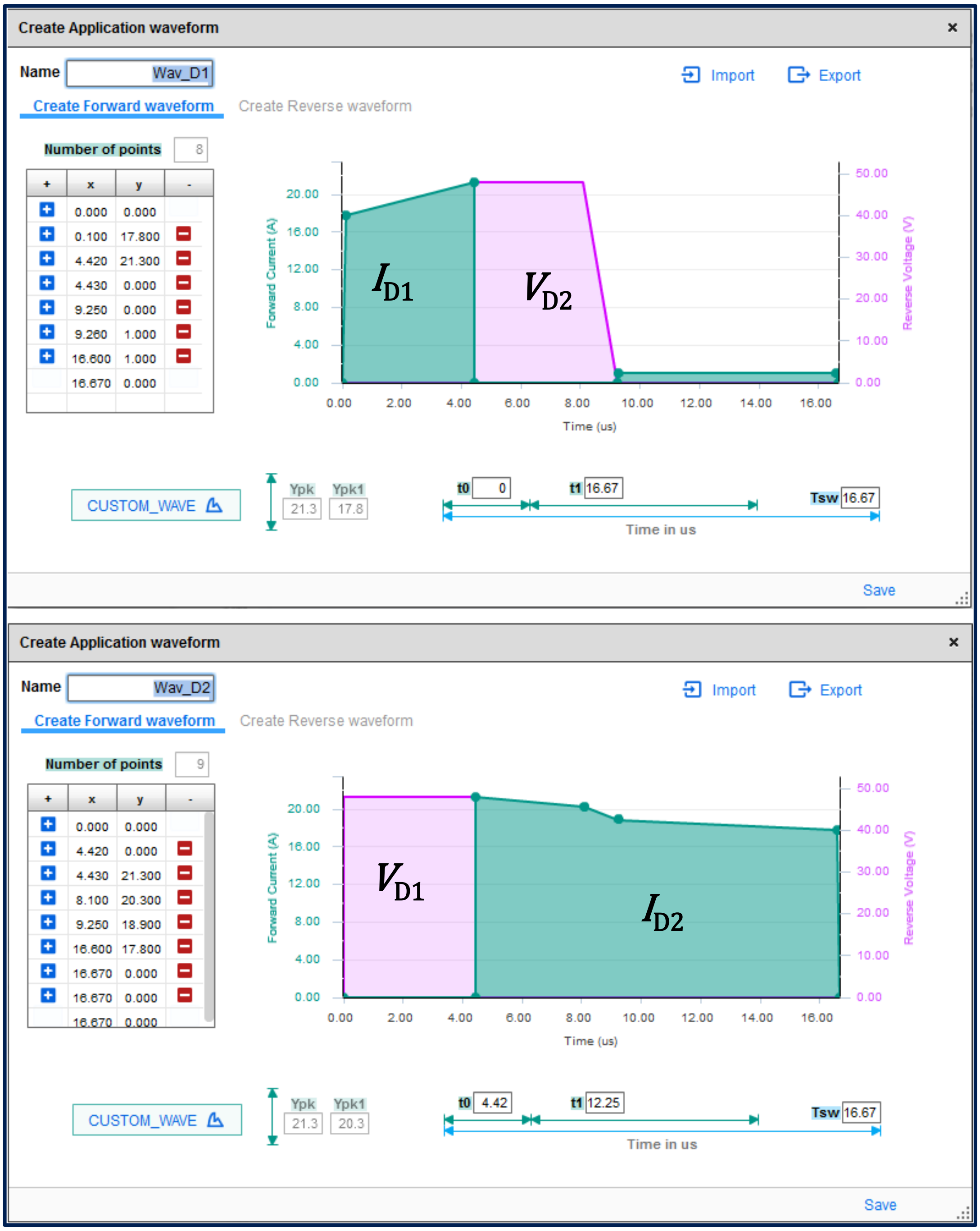


Figure 37: Reproduction of the forward waveforms

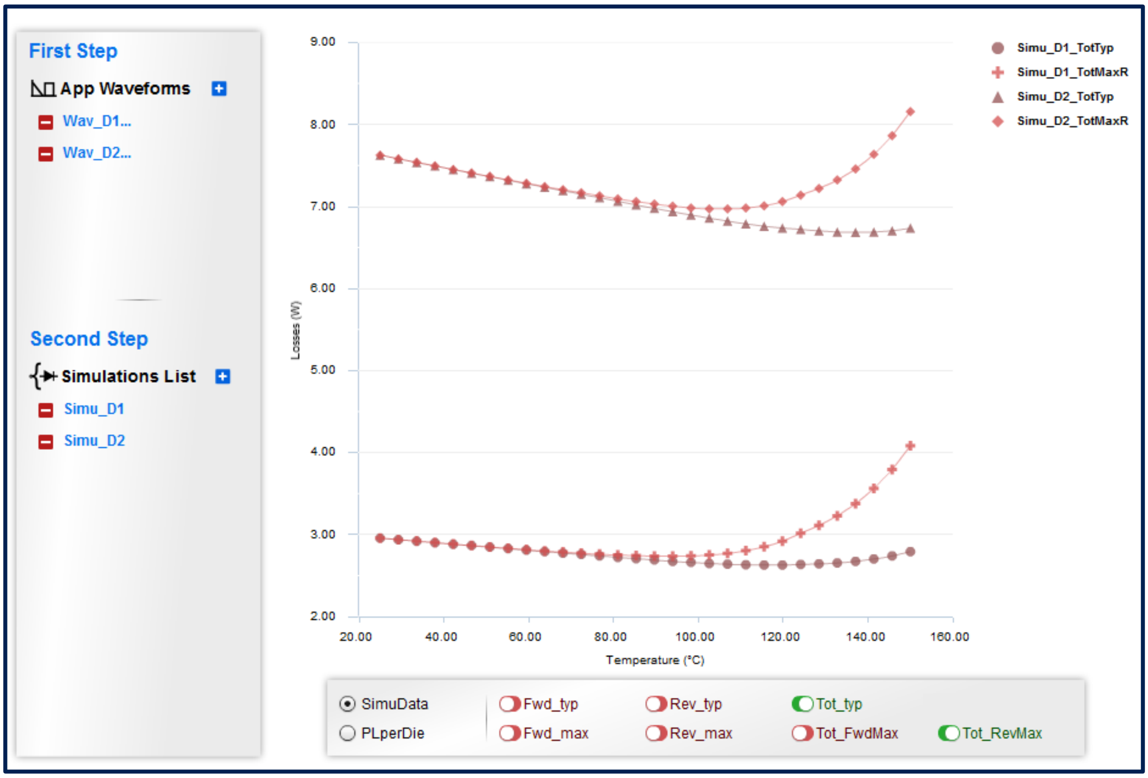


Figure 38: Conduction and reverse losses in D_1 and D_2

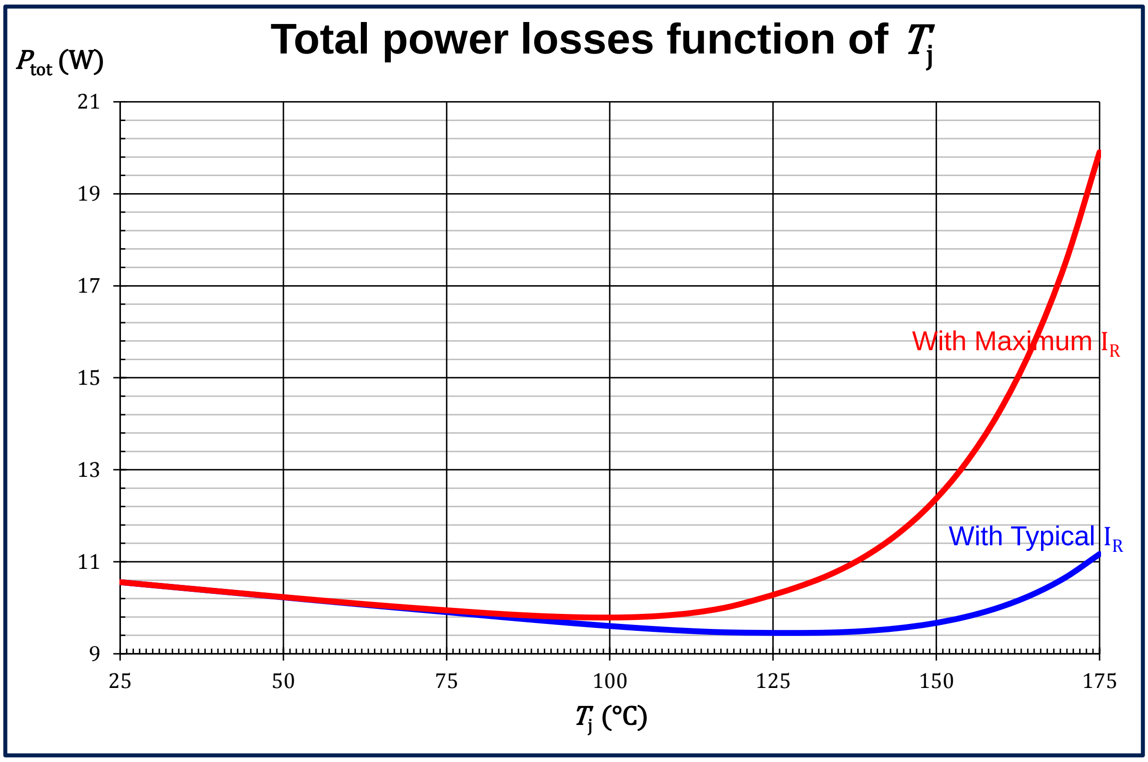


Figure 39: Total power losses plotted in Microsoft Excel using exported data

3.3 Example 3: Power Losses in a bypass diode of solar panel

In this example we are going to consider a solar bypass diode application. Diodes are used to protect solar panel cells in case some part of the solar panel is shaded, or in case of malfunction. Basically the bypass principle is illustrated in Figure 40. When all the cells are illuminated, a current is flowing through each cell, and the bypass diode is reverse biased. When one or several cells are shaded, they behave like a reverse diode connected in series with other active cells. Therefore, the current produced by active cells would flow in the avalanche characteristics of the shaded cells. The bypass diode acts like a shunt to propose an alternative path to the current in order to protect the shaded cells.

In summary the diode is either in conduction mode, or in reverse mode.

Let's consider an example with following conditions:

- Panel short-circuit current $I_{sc} = 8\ A$
- Panel voltage: $25\ V$
- Bypass diode: STPS2045CG

Here we are interested in:

1. Reverse power losses in the diode when all cells of the panel are working normally
2. Conduction power losses in the diode when a cell is shaded.

STPS2045CG is a dual common cathode diode. This means half of the current flows in each die. This yield to $4\ A$ per diode, and reverse losses is the sum of two dice.

Waveforms to calculate power losses are easily generated as illustrated in Figure 41. Then, total power losses of the two dices are plotted in Figure 42: conduction and reverse power losses respectively.

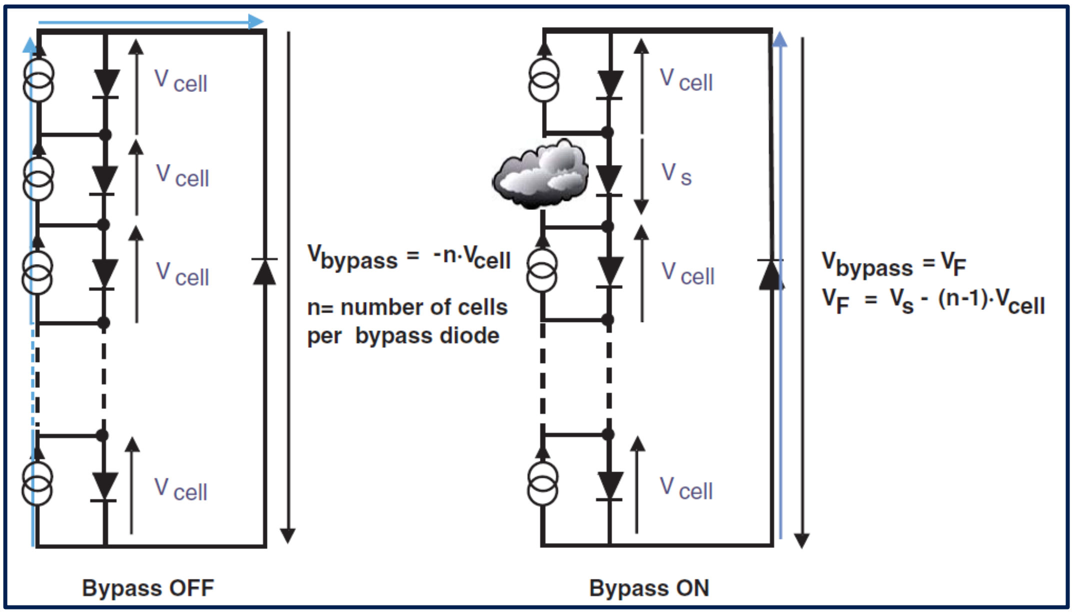


Figure 40: Bypass diode operation

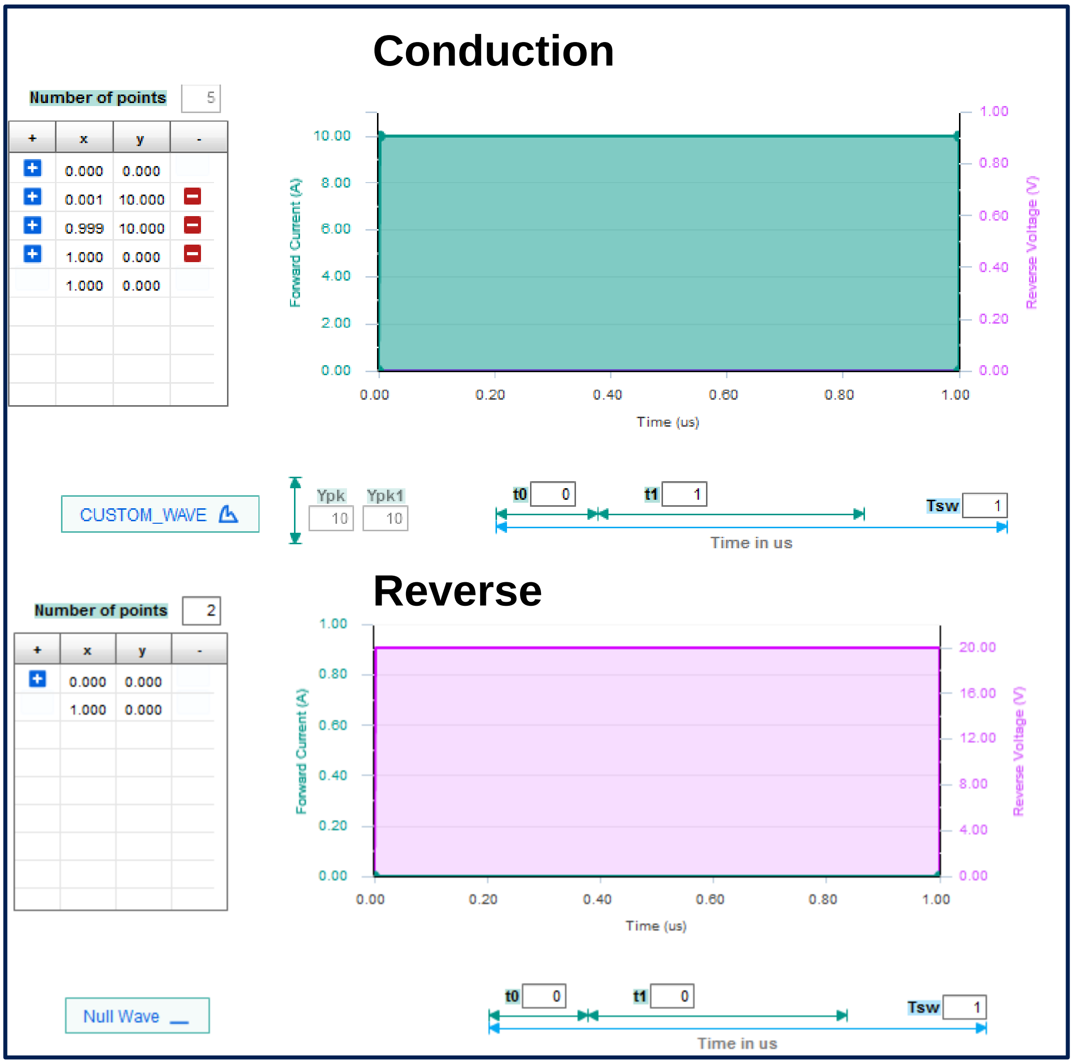


Figure 41: Conduction and reverse waveforms

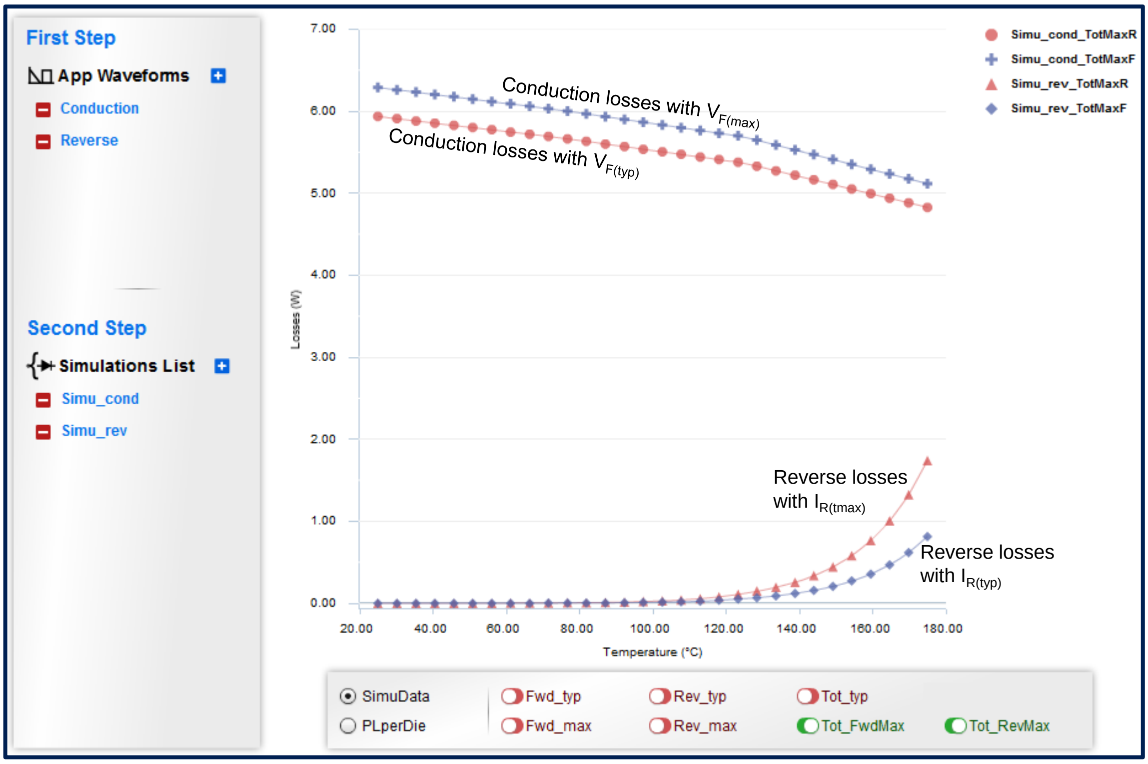


Figure 42: Power losses of STPS2045CG

4 Revision history

Date	Revision	Description of Changes
28/04/2016	1	Initial release
05/02/2018	2	Update according to version 2.0 of the software