Graphical User Interface (GUI) for Bidirectional Bridgeless Totempole with CoolSiC™ and XMC™ control (EVAL_3K3W_TP_PFC_SIC2)

About this document

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Scope and purpose

This document presents the Graphical User Interface (GUI) to be used with the bidirectional 3.3kW SiC CCM totempole board (EVAL_3K3W_TP_PFC_SIC2). This GUI allows to modify the dead time for device test and comparision, as well as the injected power in inverter operation. The infineon components required to follow this document are:

- EVAL_3K3W_TP_PFC_SIC2: Infineon Technologies AG system solution for 3300W bidirectional bridgeless totempole converter, achieving 99.2% efficiency and high performance AC current in PFC and inverter mode.
- XMC™ Link: Isolated debug probe for all XMC™ microcontrollers (KIT_XMC_LINK_SEGGER_V1). The debug probe is based on SEGGER J-Link debug firmware, which enables use with DAVE™ and all common thirdparty compiler/IDEs (Altium Limited, Atollic, ARM/KEIL, IAR Systems, iSystem, Rowley Associates) known from the wide ARM® ecosystem.

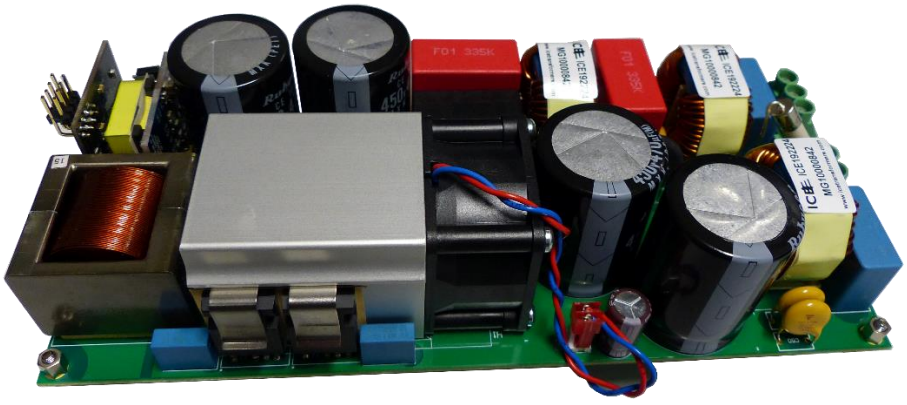

Figure 1 **EVAL_3K3W_TP_PFC_SIC2: 3300 W bridgeless totem-pole PFC with CoolSiC™, CoolMOS™ and XMC™ control.**



Figure 2 **XMC™ link isolated debug probe.**

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1 Introduction

The graphical user interface (GUI) for the bidirectional CCM totempole board (EVAL_3K3W_TP_PFC_SIC2) with CoolSiC™ provides communication with the XMC™ controller. The purpose of the GUI is:

- Dead time modification of the high frequency half-bridge (SiC devices) for testing and device benchmarking.
- Power control in inverter operation.

The provided zip file contains the user interface itself ("SMPS_GUI.exe"), some libraries (dll files) necessary for the correct operation of the GUI and a folder ("info") with files to be displayed in a specific GUI area.

By opening the executable "SMPS_GUI.exe" a welcoming window opens and **"ADVANCED"** mode has to be selected (Figure 3).



Figure 3 Selection window after opening "SMPS_GUI.exe"

Then the user interface starts and the overall looking of the software is as show in Figure 4

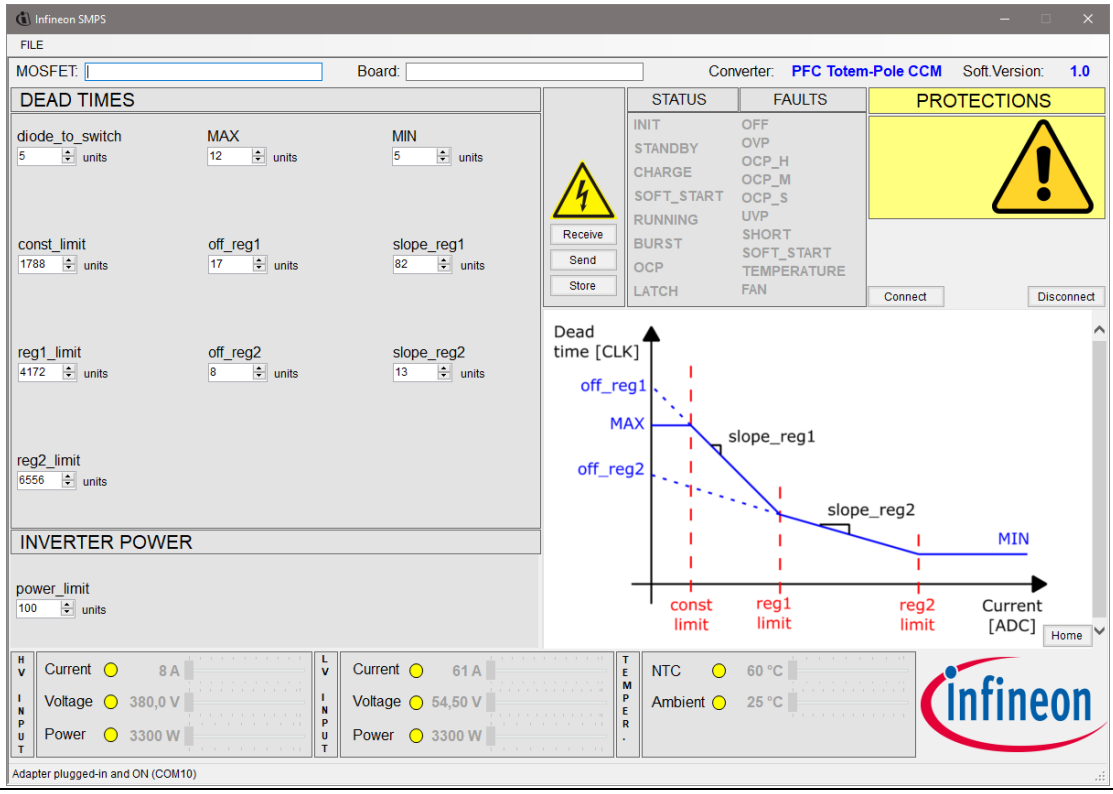

Figure 4 Overall view of the GUI for dead time adaptation in the CCM SiC PFC board.

1.1 Debugger connection to the control card

The use of the isolated programming/debugging board KIT_XMC_LINK_SEGGER_V1 is recommended for the communication to the control card of EVAL_3K3W_TP_PFC_SIC2 with the GUI presented in this document.

Figure 5 shows the correct connection of the XMC™ Link board to the control card by using the 8-pin XMC™ MCU debug connector and cable.

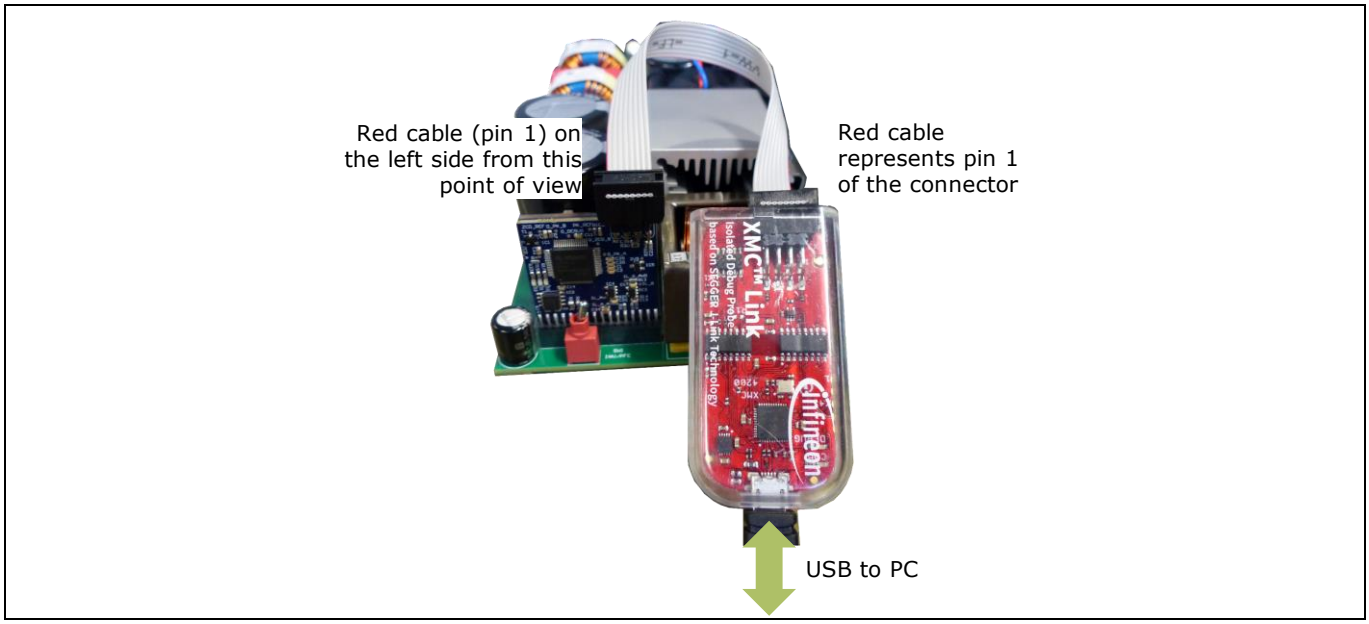

Figure 5 Connection between the debugger/programmer board and the control board.

1.2 Starting the GUI without the control card connected

If the GUI is started and neither the debugger board nor the application control board are connected, a different view of the GUI will open as shown in Figure 6 since the application board has not been recognized (red circle).

In that case connect the control card to the debugger/programmer board and click in “Connect” button. The “LINK LOST” (purple rectangle) message should disappear and the totempole PFC GUI will be loaded.

For control card connection to the debugger/programmer board, see section 1.1, Figure 5.

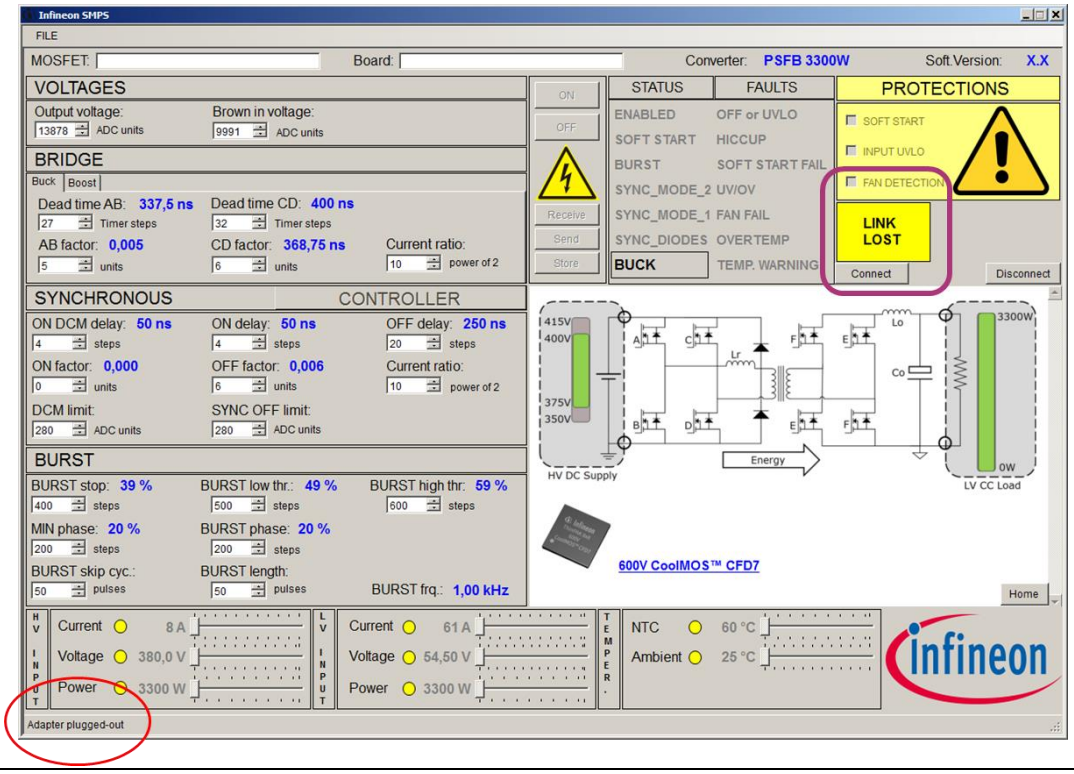

Figure 6 Defaut looking of the GUI when the PFC application board is not recognized.

1.3 SEGGER J-Link driver installation

The use of the XMC™ Link board requires that the computer has previously installed SEGGER J-Link drivers. If this is not the case, go to the following link and download the proper package for your machine. Then follow the steps to install the drivers. Figure 7 highlights the windows vesion available in the SEGGER website.

https://www.segger.com/downloads/jlink#J-LinkSoftwareAndDocumentationPack

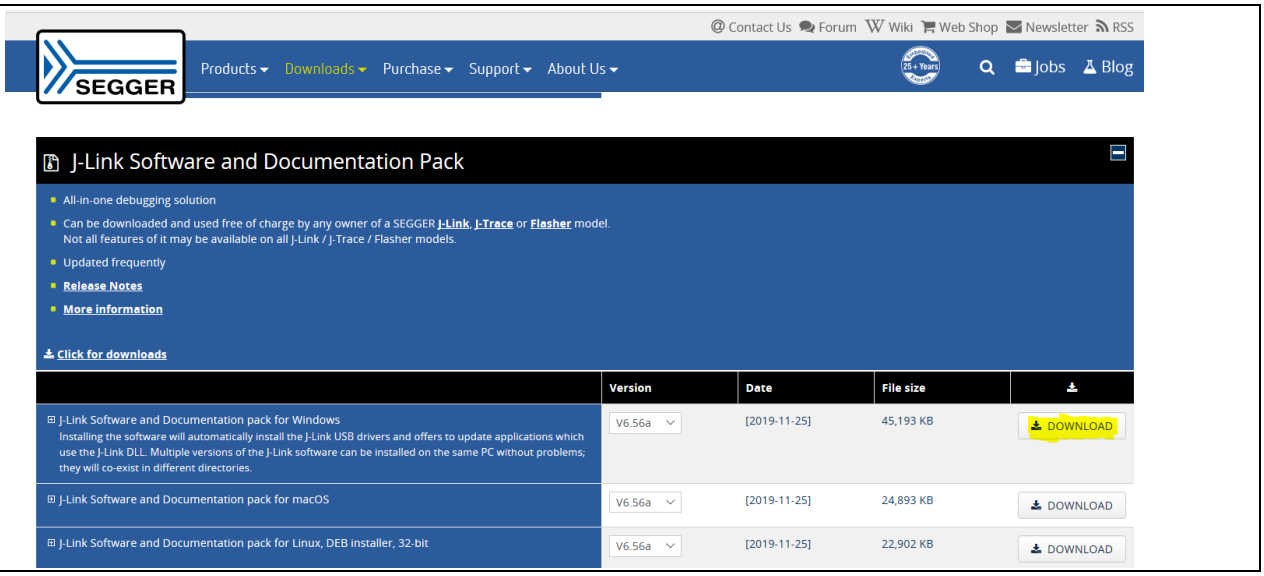

Figure 7 SEGGER J-Link driver download website with highlighted windows package download button (as in November 2019).

2 Dead time modification Graphical User Interface (GUI)

The GUI for the bidirectional CCM SiC board (EVAL_3K3W_TP_PFC_SIC2) has three main areas for the dead time adaptation parameters as shown in Figure 8. The non described areas are not used in this version of the GUI.

Note: *The released version of the SW for the XMC™ controller in the EVAL_3K3W_TP_PFC_SIC2 control card is already programmed with optimum dead time for the 62 mΩ 650 V CoolSiC™ (IMZA65R050M2), and no modification of the dead time is required for starting the board.*

Note: *The dead time modification is given as option for dead time investigation or test and benchmarking of different Rdson CoolSiC™ devices. Wrong applied dead time could damage the board and its modification is a responsibility of the final user.*

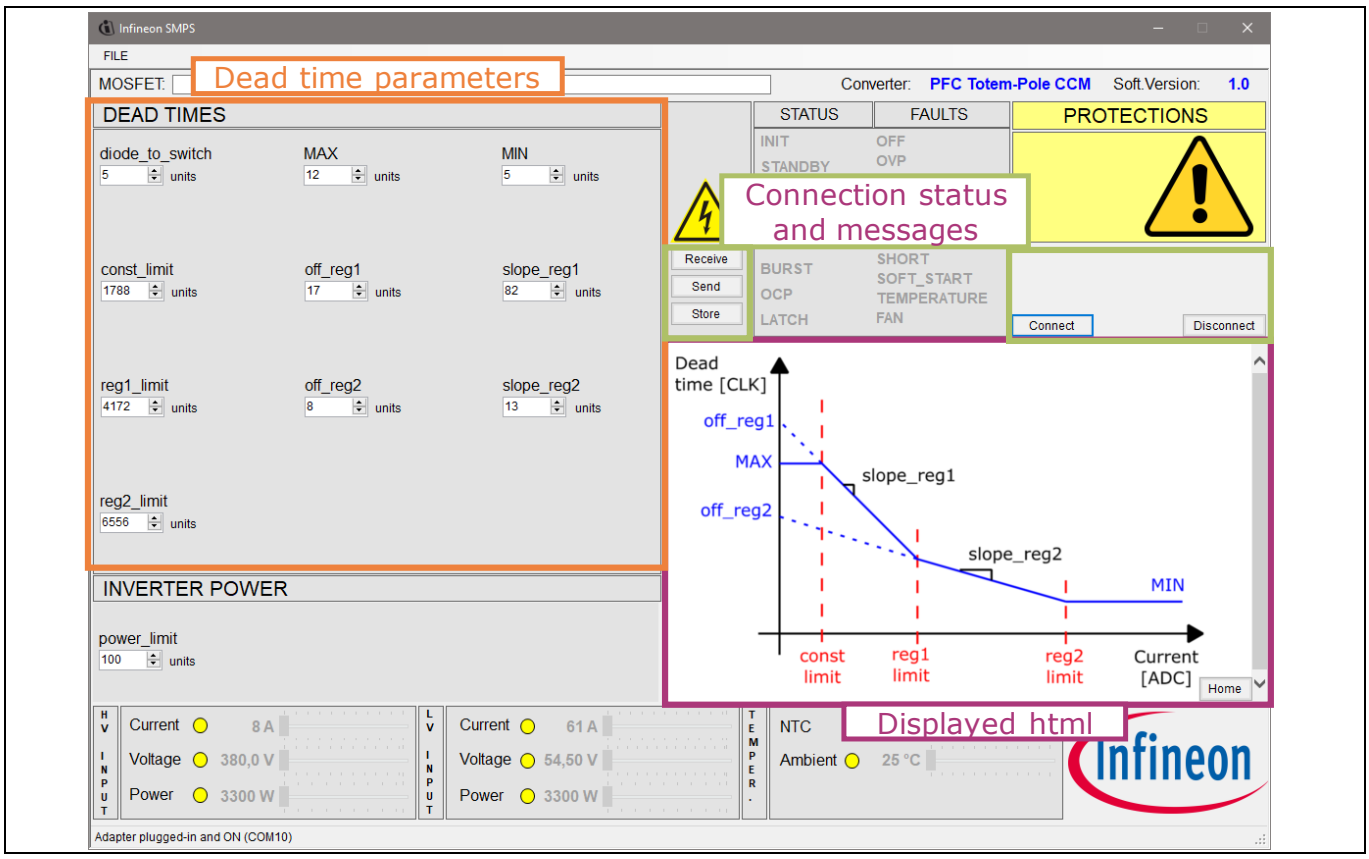

Figure 8 GUI areas for dead time modification of the EVAL_3K3W_TP_PFC_SIC2 board.

The orange section of the left side in the GUI is meant to read and write the dead time parameters in the memory of the microcontroller. The meaning of such parameters and how to calculate them will be presented in more detail later in section 2.1 of this document.

On the right side, the purple area is a web browser in which html files could be shown. The GUI for the EVAL_3K3W_TP_PFC_SIC2 shows the dead time dependency with current as implemented in the controller.

Over the browser, the connection related area (green rectangles) can be found. The three buttons on the left side, under the high voltage sign, are used to read (“Receive”) the stored parameters in the microcontroller or to download (“Send” and “Store”) new parameters into the microcontroller flash memory. The downloading procedure is presented in section 2.2.

- The “Send” button would download new values on the microcontroller but those values would be lost if the controller is reset, for instance the supply voltage is lost.
- To avoid this, the “Store” button has been introduced. In this case the parameters are saved in the flash memory (permanently stored) and can be used after controller reset.

Note: *Storage of new parameters will overwrite previous dead time configuration and therefore, previously stored parameters are lost.*

The right side green rectangle offers the possibility to stop (“Disconnect”) or resume (“Connect”) the connection between the GUI and the XMC™ microcontroller in the control board. In addition, guidance on the downloading process is given with the yellow messages. More details will be given in a section focus on how to use the GUI for dead time modification (section 2.2).

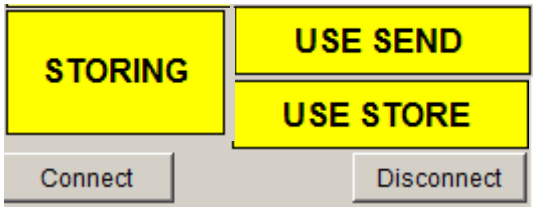

Figure 9 Connection related buttons and messages.

2.1 Current dependent dead time concept

The 3.3kW SiC CCM PFC board (EVAL_3K3W_TP_PFC_SIC) implements adaptive dead time modification according to the sensed average inductor current level. Dead time is considered optimum when ZVS is reached minimizing the diode conduction time. Figure 10 shows the programmed variable dead time structure.

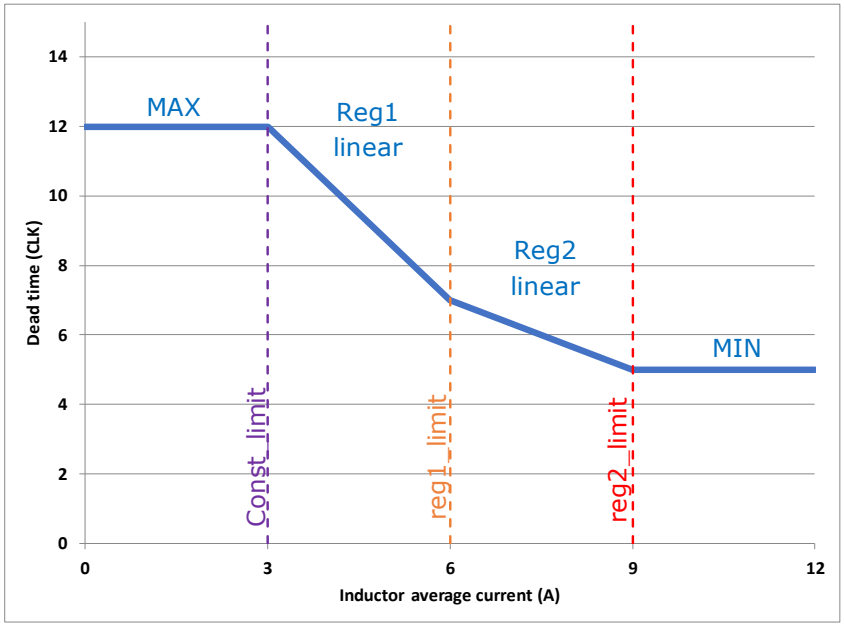

Figure 10 Concept of the programmed dead time modification according to the current level.

Under a certain current level (“const_limit” purple dotted line) a constant dead time (“MAX”) is applied, which corresponds to the maximum dead time in the application. When the current level increases during the AC cycle, the dead time is decreased following a linear approximation separated in two sections: linear region 1

under “reg1_limit” and linear region 2 under “reg2_limit”. This stracture has been thought for a more flexible dead time modification. For sensed current values over “reg2_limit” a constant minimum dead time (“MIN”) is then applied.

This dependency is applied to the switch to diode transition, which is the transition in which ZVS can be achieved (Figure 11) by charging/discharging the parasitic capacitors of the SiC devices.The Vds transition time depends on the available current in the PFC inductor, the higher the peak current in the inductor, the lower is the required dead time for ZVS operation and therefore, the presented dead time variation with current.

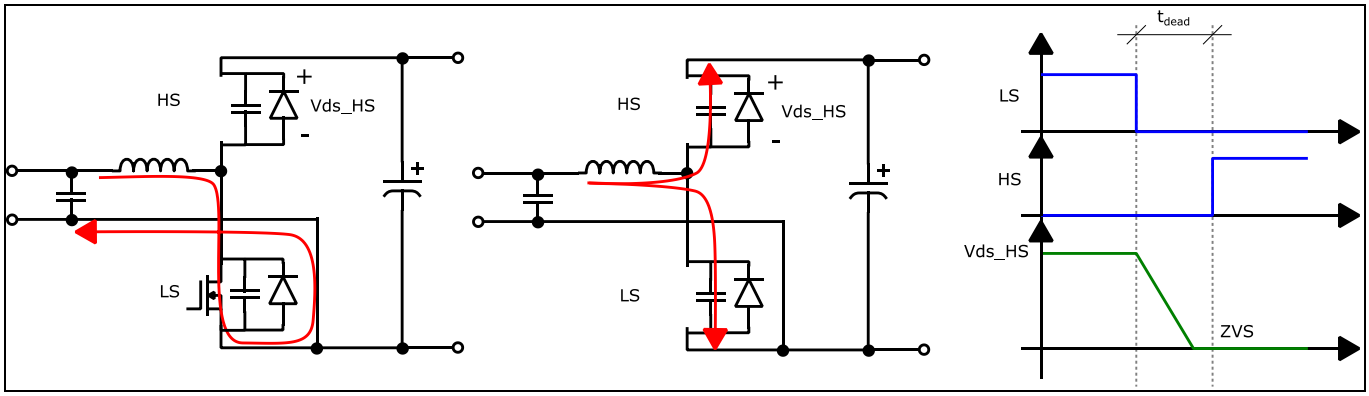

Figure 11 Switch to diode transitions in totempole boost converter for a given inductor peak current (LS operates as boost switch and HS as boost diode).

In the case of diode to switch transition, the dead time is kept constant regardless the current level since it is a hard commutation transition (Figure 12). The inductor valley current keeps flowing through the body diode when the HS switch (which operates as boost diode) and the voltage in the LS switch (boost switch function) is forced to zero by the PWM signal.

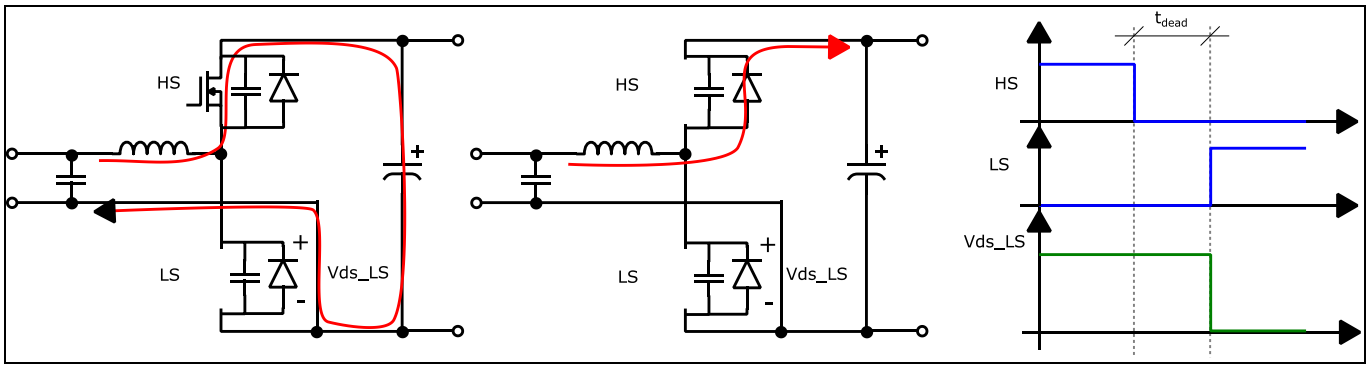

Figure 12 Diode to switch transitions in totempole boost converter for a given inductor valley current (LS operates as boost switch and HS as boost diode).

According to the presented dead time variation with current and the type of transition, 10 parameters can be modified from the GUI (orange area on Figure 8) in order to fit the curve in Figure 10:

- Diode_to_switch: diode to switch dead time
- MAX: maximum switch to diode dead time
- MIN: minimum switch to diode dead time
- const_limit: current under which the maximum dead time is applied
- off_reg1: dead time for zero current in linear region 1

- slope_reg1: slope of the linear variation in region 1
- reg1_limit: current under which the linear region 1 approximation is applied
- off_reg2: dead time for zero current in linear region 2
- slope_reg2: slope of the linear variation in region 2
- reg2_limit: current under which the linear region 2 approximation is applied. Minimum dead time is applied for current higher than this value.

These parameters to be introduced in the GUI are discrete CLK steps of the PWM timer module in the microcontroller. Since the PWM clock frequency of the utilized XMC1404 controller is 96 MHz, the actual applied dead time is the results of multiplying the CLK steps by 10.42 ns (96 MHz period).

An excel file is available for the parameter calculation. The calculation tool (Figure 13) considers the application gains and XMC™ timer clock frequency (96 MHz) to calculate the presented parameters (red cells - outputs) according to certain current levels and target dead time (green cells - inputs). Also the target and resulted linear approach are graphically presented in nanoseconds (left figure) and CLK steps (right figure) for a given current level and compared to the target dead time.

PFC_3k3W_totempole_DTcalc_GUI.xlsx

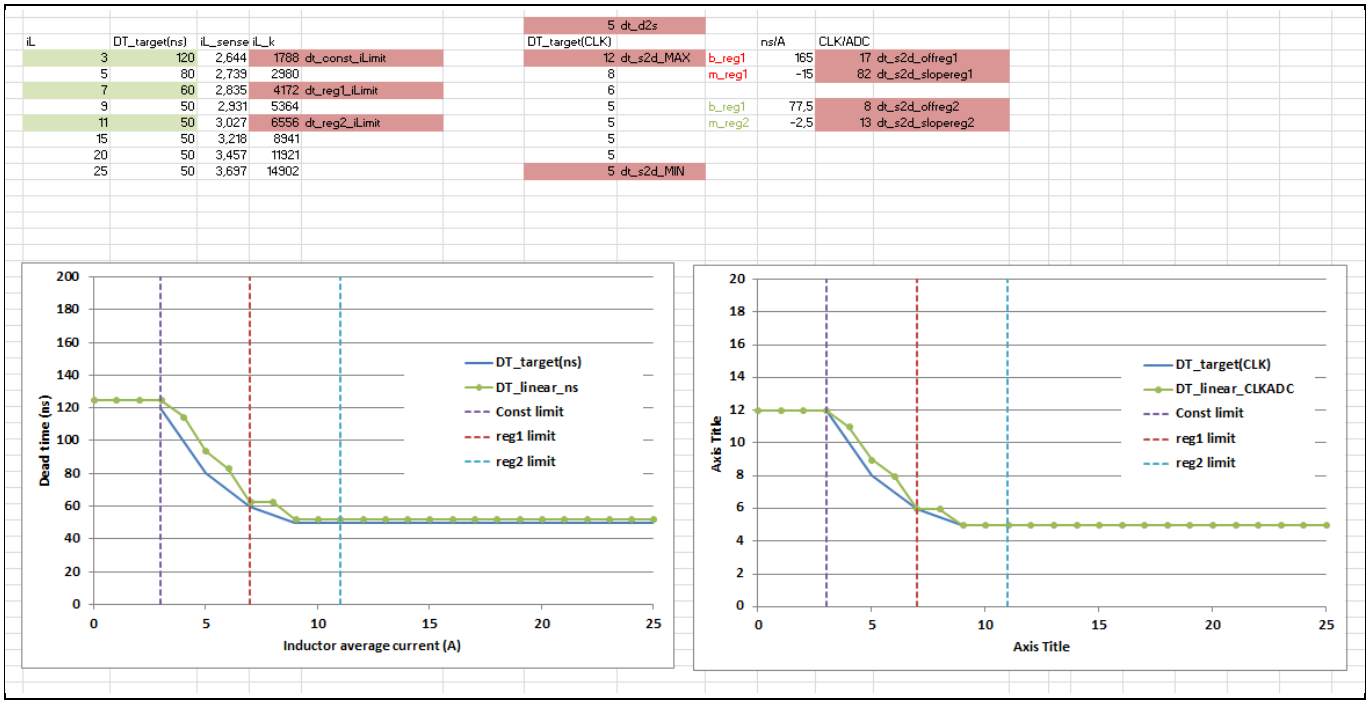

Figure 13 Excel calculation tool for dead time in CCM SiC totempole PFC

The three sets of green cells (current in amps, and target dead time in nanoseconds) are required for the linearization calculation. The rest of the values in those columns contribute to the graphical representation in the tool. The obtained parameters in the red cells are later to be introduced in the corresponding GUI fields.

2.2 Store new dead time parameters in the control card

It is recommended to store the calculated dead time parameters when **the PFC board is not running**. The control card is supplied from the bulk voltage and starts over 50V. The application will start with AC voltage

over 174V. Therefore, since XMC™ Link is a non isolated debugger, 60V can be applied to the AC voltage to supply the controller and avoid the PFC operation start. The correct connection between the debugger/programmer and the control board is shown in Figure 5.

Once the boards are connected and the control card is properly supplied, the GUI ("SMPS_GUI.exe" file) can be started in advance mode as shown in Figure 3. In that case the communication port is automatically detected and GUI will open like in Figure 4. After the presented procedure in this section is over, the new dead time calculation parameters will be used in the application when the AC source is connected the next time.

The saving process of a new parameter set is as follows:

- Connect the debugger/programmer to the control board as explained above. **Be sure that the AC voltage is not applied to the input terminals.**
- Apply 60V in the AC terminals.
- Start the user interface in ADVANCED mode. Or click connect if the GUI was already open.
- Read the parameter currently in used by using the "Receive" button.
- Modify the necessary parameters according to the excel tool output. The message ("USE SEND") will appear over the "Connect"/"Discconnect" buttons (Figure 9).
- Click "Send". The message ("USE STORE") will appear over the "Connect"/"Discconnect" buttons (Figure 9).
- Click "Store". The message ("STORING") will appear over the "Connect"/"Discconnect" buttons (Figure 9).
- Click "Disconnect". The message ("LINK LOST") will appear over the "Connect"/"Discconnect" buttons (Figure 9).
- Remove the AC voltage.
- **Remove the debugger/programmer board before starting the AC voltage again.** The application starts with 174Vrms in the AC terminals.
- The new set of parameters will be used when the AC source is applied.

3 Power command in inverter operation

The bridgeless totempole topology offers inherent bidirectional power flow capability, which has been explored in the EVAL_3K3W_TP_PFC_SIC2. The inverter operation mode can be selected before the application starts by choosing INV option in the available switch (SW1) on the main board.

Note: The power flow or operation mode is selected before the application starts and the power flow cannot be reverted during operation. Therefore, the EVAL_3K3W_TP_PFC_SIC2 board is able to operate as either PFC or inverter but the SW is not ready for dynamic change of operation mode.

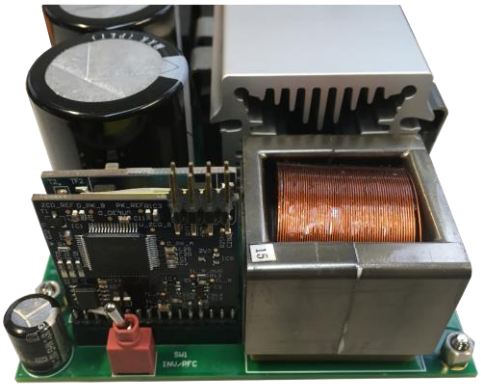

Figure 14 Switch to select the operation mode (PFC or Inverter) in the EVAL_3K3W_TP_PFC_SIC2.

In inverter operation, the totempole board behaves as a current source connected to DC and AC voltages. Therefore, the available power to be injected into the AC must be received by EVAL_3K3W_TP_PFC_SIC2. In the final application, the DC-DC stage will be in charge of this communication. However, if the board is tested alone, the GUI can be used to control the injected power. Figure 15 shows in orange the area of the GUI reserved for power control. The communication functions are the same than already presented for dead time modification.

In the case of the dead time modification is recommended to modify the values when the application is not running. However, the power limit value must be modified online if the inverter operation at different power levels wants to be evaluated. The connection of the recommend debugger (XMC™ Link) is shown in Figure 5.

After the XMC™ Link is connected to the control card of EVAL_3K3W_TP_PFC_SIC2 and the inverter operation switch is in INV position, the AC and DC voltages can be applied to the board and the inverter operation will start with the default power_limit value (100).

The power can be modified according to this value as shown in Figure 16. The procedure is as follows:

- The new power_limit value can be written in the corresponding box. The message (“USE SEND”) will appear over the “Connect”/”Discconnect” buttons (Figure 9).

Note: The power_limit value is limited to 20000 in the GUI and 11500 in the XMC™ controller implementation. At any moment the actual power-limit value used by the control can be read by clicking “Receive” buttom.

- Click “Send”. The inverter will ramp up/down the power to match the requested power-limit value.

Note: After clicking “Send”, the message “USE STORE” appears in the communication ares. In this operation mode it is not necessary to use the “Store” option.

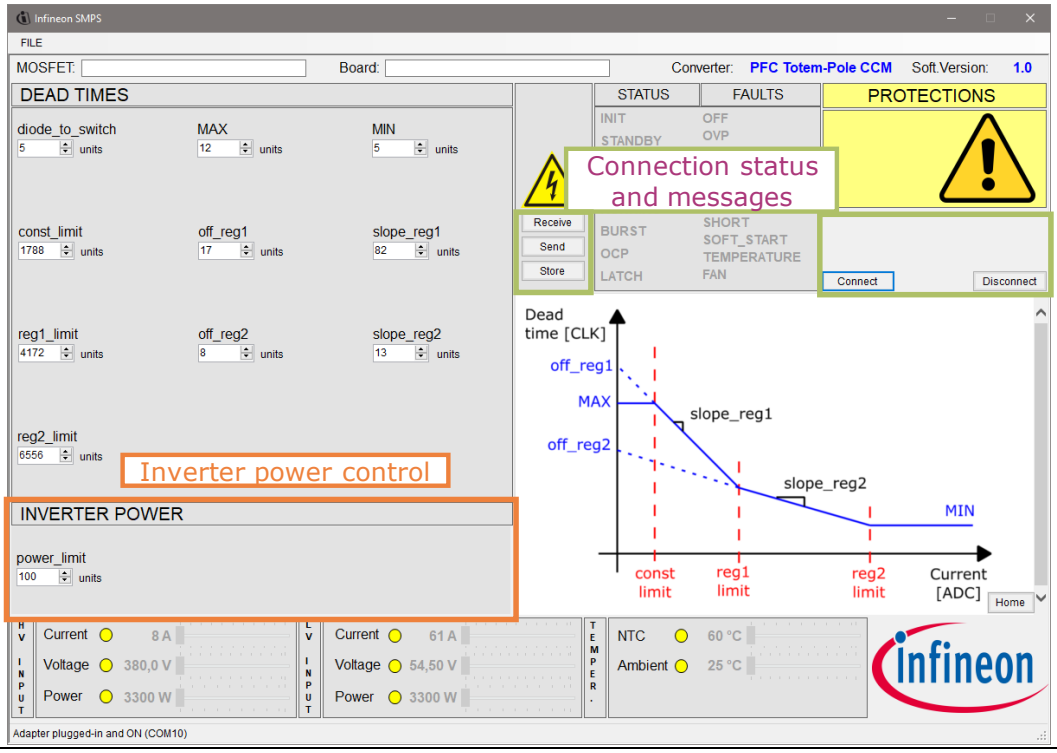

Figure 15 GUI areas for power control of the EVAL_3K3W_TP_PFC_SIC2 board in Inverter operation.

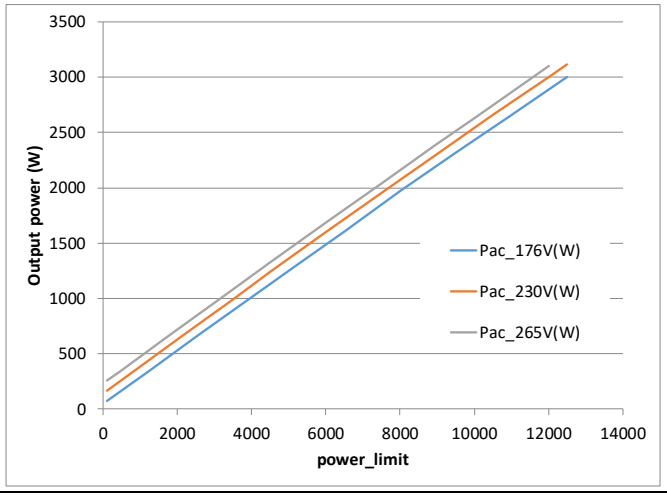

Figure 16 Measured output power (AC) according to the power_limit parameter from GUI.

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