

Evaluation Board for CoolSiC™ Easy1B half-bridge modules

Evaluation of CoolSiC™ MOSFET modules within a bidirectional buck-boost converter

About this document

Scope and purpose

SiC MOSFET based modules are a revolutionary step towards highly efficient power electronic devices with benchmarking power density. Switching frequencies beyond 100 kHz as well as more than 99 % power conversion efficiency are simple to be realized by using Infineon EasyPACK modules with CoolSiC™ Trench-MOSFET devices.

This board has the purpose to enable the evaluation of the FF11MR12W1M1_B11 and FF23MR12W1M1_B11 CoolSiC™ MOSFET modules. The evaluation board allows the performance of double-pulse measurements as well as functional tests as DC/DC converter. Therefore the board is designed as bidirectional buck-boost converter. Figure 1 shows a picture of the board.

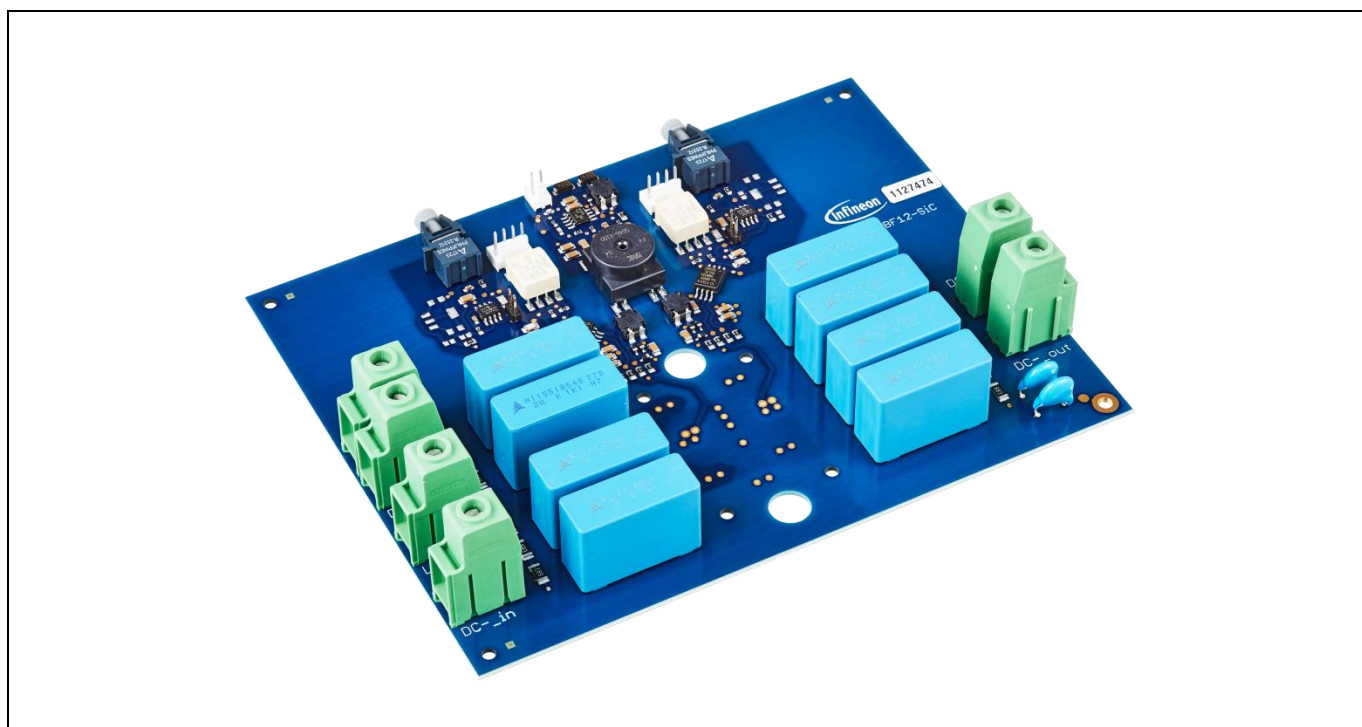


Figure 1 Evaluation board EVAL-PS-E1BF12-SiC.

The properties of this board are described in the design features chapter of this document. The remaining sections provide information to enable copy, modification and qualifying of the design for production, according to the customer specific requirements.

Environmental regulations have been considered in the design of the EVAL-PS-E1BF12-SiC board. Components qualified for a lead-free reflow soldering process have been selected. The design has been tested as described

Design Features

in this document, but not qualified regarding manufacturing and operation over the whole operating temperature range or lifetime.

Note: The evaluation boards provided by Infineon, are only designed for functional testing and available in small quantities.

Due to their purpose, evaluation boards are not subject of the same procedures in context of Returned Material Analysis (RMA), Process Change Notification (PCN) and Product Discontinuation (PD) as regular products.

Read the legal disclaimer and warnings for further restrictions on Infineon’s warranty and liability.

Warnings



Attention: The described evaluation board is dedicated for a laboratory environment only. It operates at high voltages. This board must be operated by qualified and skilled personnel familiar with all applicable safety standards.

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Design Features

1 Design Features

The following sections provide an overview of the evaluation board. Section 1 includes the description of main features, key data, pin assignments and mechanical dimensions. Figure 2 shows the circuit topology used in the described evaluation board.

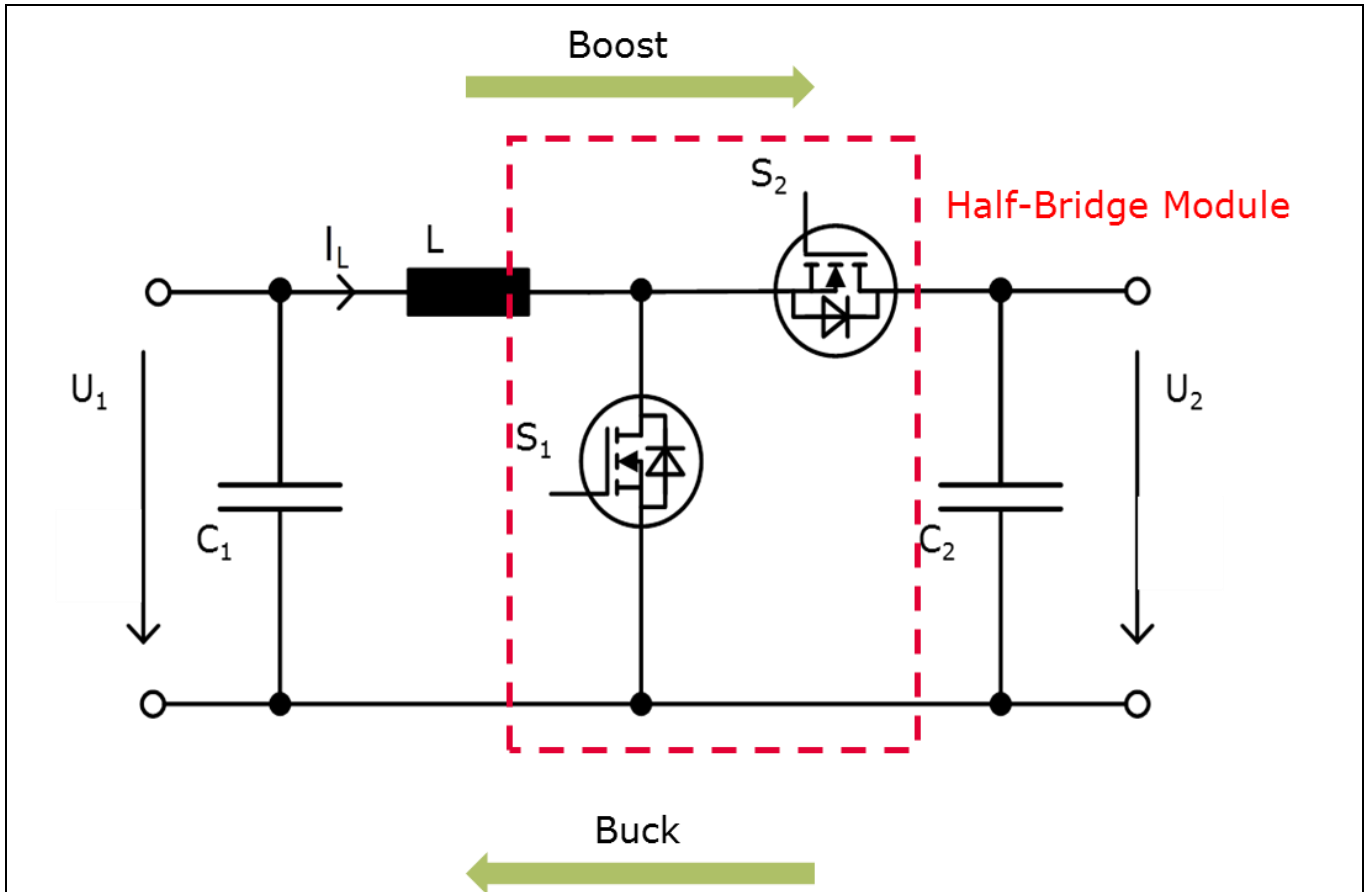


Figure 2 Bidirectional buck-boost converter using a CoolSiC™ MOSFET half bridge.

The EVAL-PS-E1BF12-SiC evaluation board has been designed as bidirectional buck-boost converter. It enables users to make basic electrical tests like double-pulse measurements as well as a functional testing in buck and/or boost operation.

The main function of this board is the evaluation of the FF11MR12W1M1_B11 and the FF23MR12W1M1_B11 in combination with the EiceDRIVER™ Compact 1EDI60IH12AHF driver.

1. A bidirectional buck-boost converter is a useful converter in today's power electronics. As an example transformer less chargers are using it to charge and discharge high voltage batteries. In the the boost operation mode S1 is the active switch, while S2 is operated as diode, while the buck operation works with S2 as active switch and S1 as diode.
2. The evaluation board is electrically and mechanically suitable for the FF11MR12W1M1_B11 and the FF23MR12W1M1_B11 CoolSiC™ MOSFET modules. The initial configuration of the board is equipped with the required components to do:
 - Double pulse characterization.
 - Monitoring for short circuit test detection.
 - Functional testing of the buck-boost operation using electrical loads at the input or output stage.

Design Features

1.1 Key data

General Key data and characteristic values are given in Table 1. These are typical values, measured at an ambient temperature of $T_{amb} = 25\text{ °C}$.

Table 1 Electrical Parameters

Parameter	Description DC-link	Value	Unit
V_{DC}	Maximal input DC-link voltage	900	V
I_{out}	Maximal Output current	25	A
C_{DC}	DC-link capacitance at the board delivery (input and output)	8	μF
T_{op}	Operation temperature (design target)	-40...+85	$^{\circ}\text{C}$
T_{stg}	Store temperature (design target)	-40...+85	$^{\circ}\text{C}$
Parameter	Description Driver and SMPS	Value	Unit
V_{CC}	Driver input voltage	15	V
V_{GS}	Drive voltages at the SiC MOSFET switches	-8/15	V
I_G	Maximum and minimum gate driver current for each driver channel	6	A

Pin assignments

2 Pin assignments

The evaluation board allows an optical or an electrical pulsing of the two SiC MOSFET switches. The connector names are highlighted in figure 3. The pin numbering is from right to left.

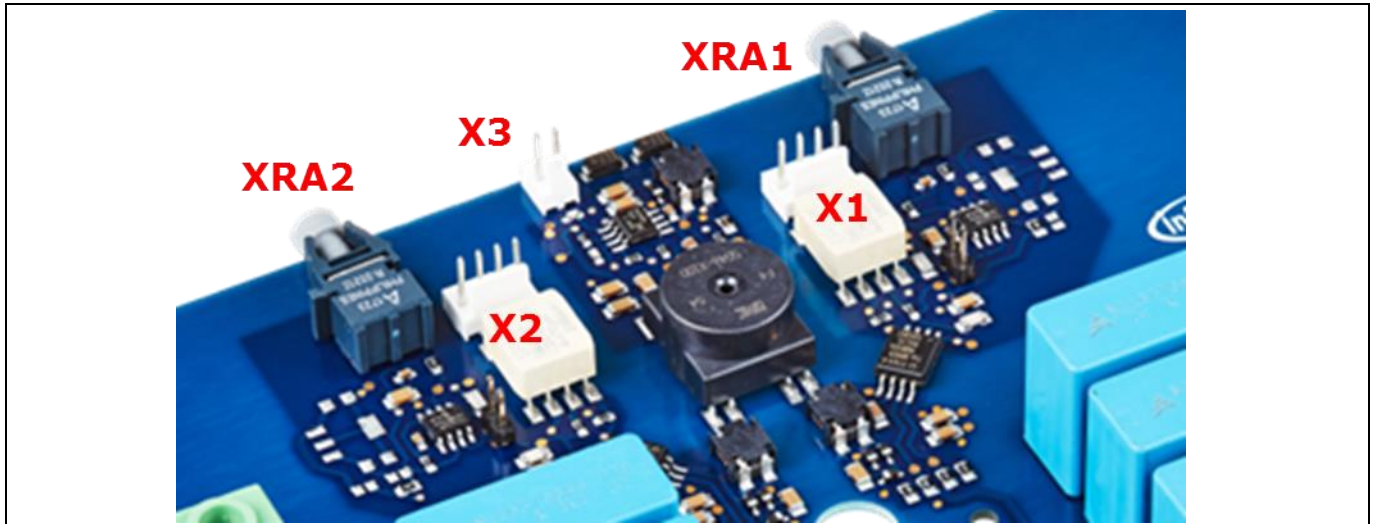


Figure 3 Connectors of the evaluation board’s driver circuit

The board is powered by the connector X3 as listed in the Table 2;

Table 2 Pin assignment of the connector X1

Pin name	Pin
X3-1	+15 V
X3-2	GND

X1 and X2 pin assignment

Each SiC MOSFET switch has a separate driver circuitry. The interfaces for external signal measurement are offered by X1 and X2 as listed in Table 3 and Table 4.

Table 3 Pin assignment of connector X1 for the driving of S2

Pin name	Pin
X1-1	+5 V
X1-2	GND
X1-3	PWM
X1-4	GND

Pin assignments**Table 4** Pin assignment of connector X2 for the driving of S1

Pin name	Pin
X2-1	+5 V
X2-2	GND
X2-3	PWM
X2-4	GND

The optical pulsing of S1 is possible via XRA2, while S2 is pulsed using XRA1. Additionally the corresponding jumpers JP1 (XRA1) resp. JP2 (XRA2) have to be activated.

The inductor of the bidirectional buck-boost converter is connected between the connectors L1 and L2 of the board. The respective DC-source connections depends weather the board is used as buck or boost converter.

3 Functionality

The EVAL-PS-E1BF12-SiC board has the purpose to evaluate the CoolSiC™ MOSFET half bridge modules in Easy1B package. The functional schematics of the board are drawn in figure 4.

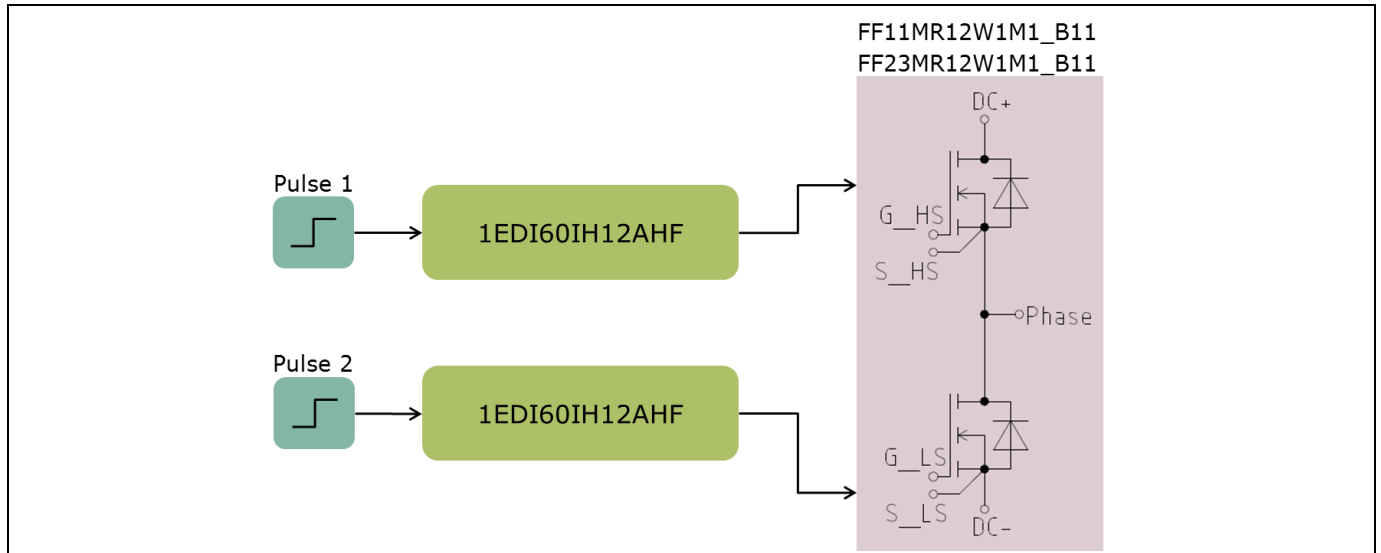


Figure 4 Driver board principle

Electrical or optical pulses are translated within the evaluation board to signals for the 1EDI60IH12AHF driver. Each driver is controlling one of the SiC MOSFET switches within the FF11MR12W1M1_B11 or FF23MR12W1M1_B11 modules. The driving voltages are -8 V/15 V.

3.1 Driver stage

The driver stage can be seen in figure 6. The upper part of the picture shows the optical driver input. XRA2 converts the optical signal into an electrical signal the driver stage TC4426EOA is transforming the electrical signals to an input voltage for the EiceDRIVER™ Compact 1EDI60IH12AHF.

An optional + 15 V supply can be used to ensure a voltage of 15 V at the input of the EiceDRIVER™ driver. The electrical driver input can be seen on the bottom left part of figure 6. They electrical input is decoupled from the driver stage by a transformer (B82792-C2) to ensure a disturbance free operation.

The driver output can be seen in the bottom right part of figure 6. The driver voltages of -8 V/15 V are decoupled from the Ground by capacitors. The turn-on and turn-off resistors of the EiceDRIVER™ output are realized by a parallel connection of two SMD resistors.

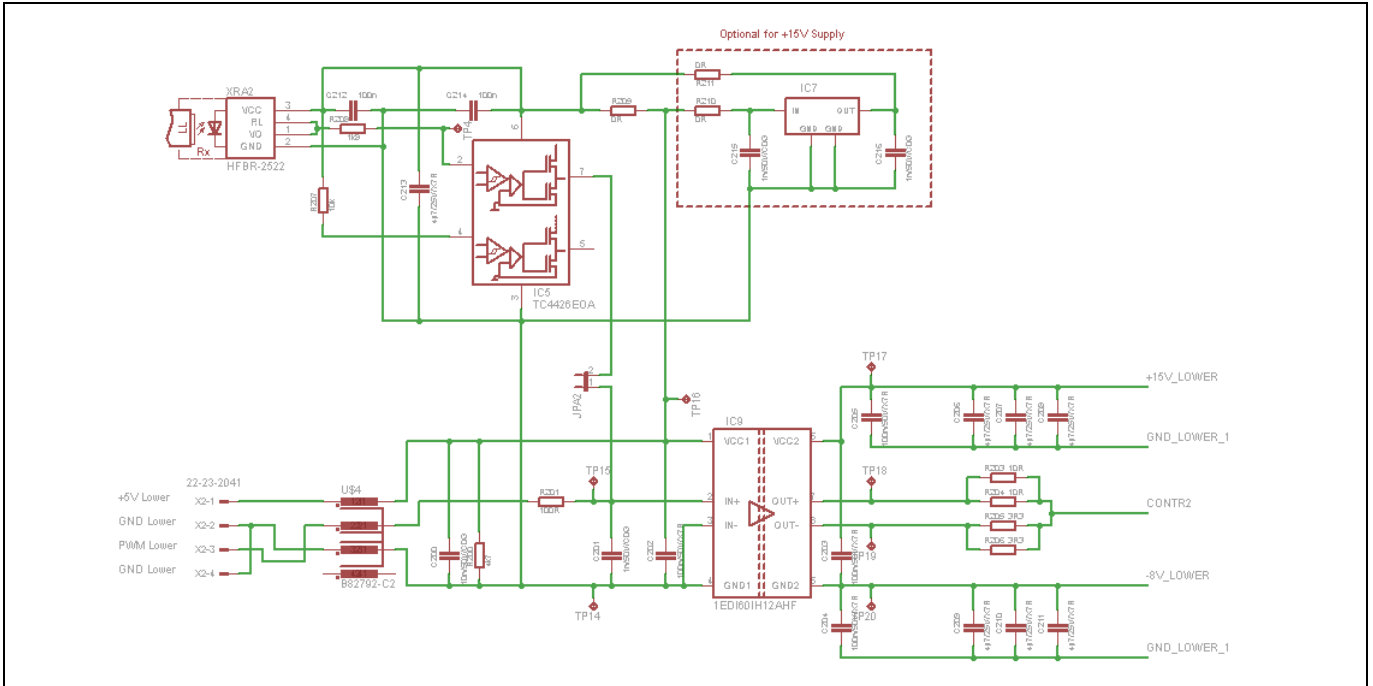


Figure 5 Schematic details of the input stage for a single MOSFET driver

3.2 Current measurement

The source current measurement of S1 and S2 can be done with the help of copper rivet adapters and Rogowski current sensors. Figure 6 shows the way to do this

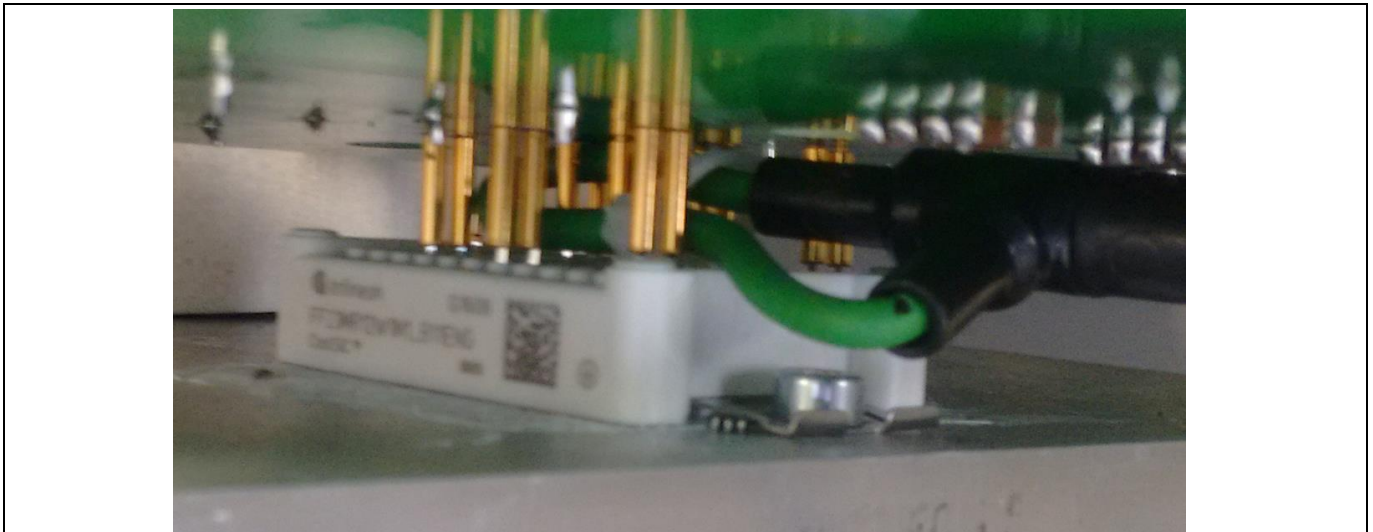


Figure 6 Current measurement with the help copper rivets and a Rogowski coil.

All current measurements shown in this application note have been performed with the highlighted method. It has to be considered that the bandwidth of a Rogowski coil is much smaller than of a Pearson current measurement unit, which is leading to failures in the di/dt determination and noise.

4 Characterization

4.1 Waveforms

The following chapter will present some extracted waveforms. Therefore a FF11MR12W1M1_B11 Easy1B power module has been characterized with the help of the evaluation board. Figure 7 shows the turn-on behavior.

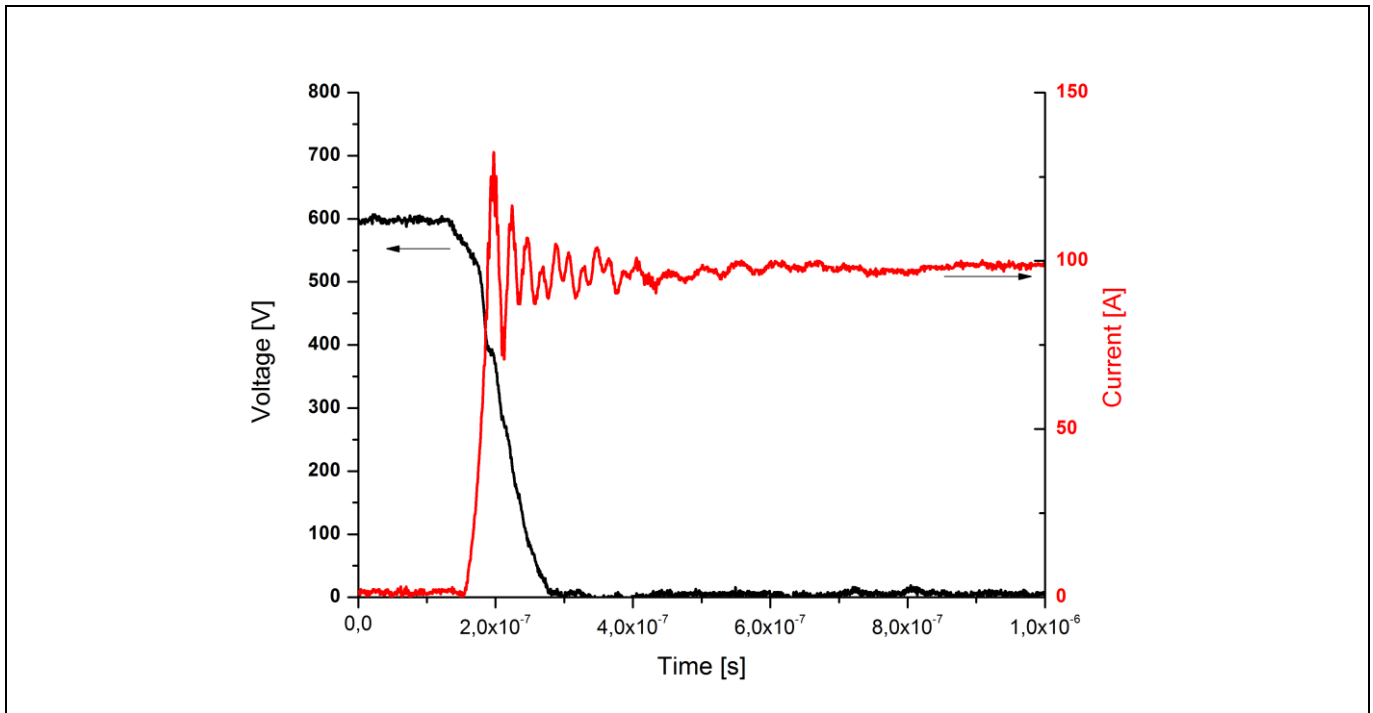


Figure 7 Turn-on of a FF11MR12W1M1_B11 devices at 100 A and 600 V.

A current of 100 A has been switched with a DC voltage of 600 V using a gate resistance of 1 Ohm. The ringing in the current measurement is most probably related to the short bandwidth of the Rogowski coil. Nevertheless the switching is overall relatively clean for switching a SiC MOSFET at this operational point, showing the performance of the low board inductance and the low inductive Easy1B module.

Figure 8 shows the turn-off behavior of the device under test at the same operation point. During turn-off the overvoltage peak of V_{DS} has to be properly analyzed as the di/dt of the FF11MR12W1_B11 is up to ten times higher than a comparable IGBT current gain leading to a high overvoltage with respect to

$$V_{DC} = V_0 + \frac{di}{dt} \times L_{\sigma}$$

The low stray inductances of the power module and the board are leading to a low overvoltage of about 100 V, which is acceptable for a power electronic application using CoolSiC™ MOSFET modules.

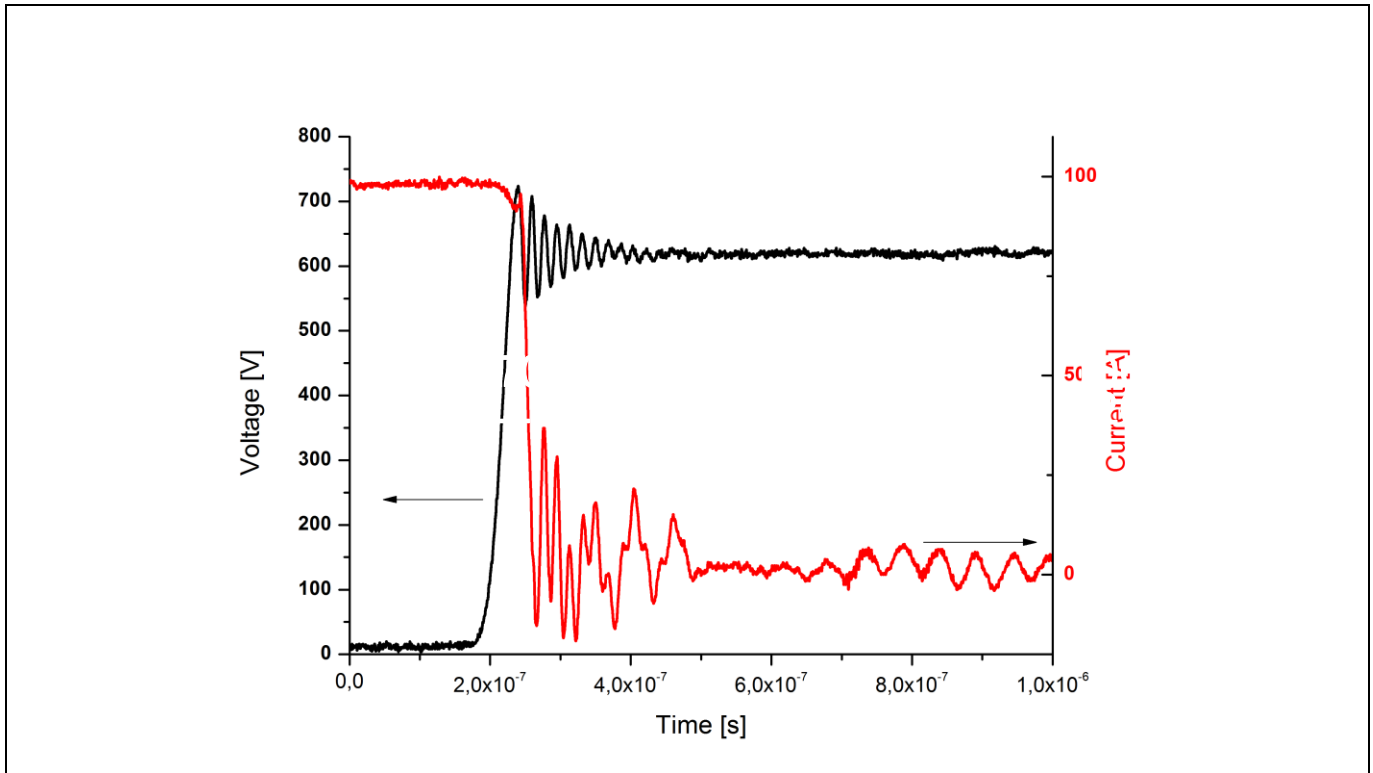


Figure 8 Turn-off of a FF11MR12W1M1_B11 device at 100 A and 600 V.

4.2 Characterization of the upper device

One of the most important aspects of designing half-bridge topologies with SiC MOSFET devices is characterizing the possibility of a parasitic turn-on of the upper device during the switching of the lower device.

This is caused by the high dv/dt of an SiC MOSFET which can be larger than $50 \text{ kV}/\mu\text{s}$ for the CoolSiC™ MOSFET. Figure 9 measures the ringing of the upper device's gate source voltage during switching the lower device with a gate resistance of 1 Ohm at 600 V.

Even V_{GS} is ringing the voltage stays below the threshold voltage of the CoolSiC™ MOSFET of $V_{th}=4.5 \text{ V}$. As a consequence users of the -8 V/15 V gate voltages are safe with using CoolSiC™ MOSFET modules, even at low gate resistances. Furthermore the use of -5 V/15 V is expected to be uncritical as the measured offset is larger than 3 V.

In the case of unipolar switching (0 V/15 V) the dv/dt can be reduced by using larger gate resistance to mind parasitic turn-on events, which is a significant advantage of the simple gate controllability of CoolSiC™ MOSFET devices.

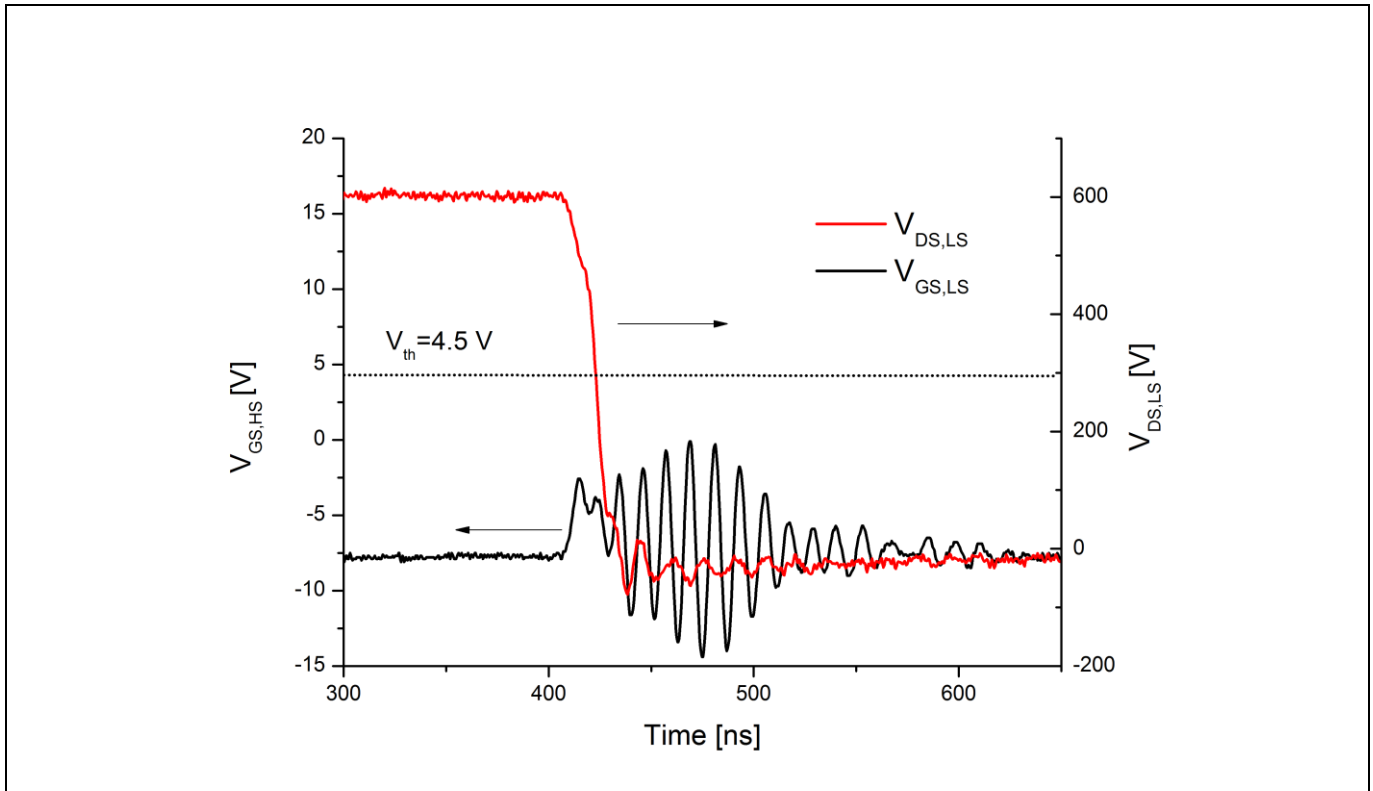


Figure 9 Behavior of the upper V_{GS} while turning-off the lower switch at 1 Ohm and 600 V.

4.3 Current sharing

The use of fast switching devices requires a high level of symmetry in module as well as in PCB design. This aspect has been taken into account during the design of the EVAL-PS-E1BF12-SiC board. Figure 10 shows the connection of the DC-link to the board input and the module. As it can be seen the PCB layer design achieves a high level of symmetry.

Figure 11 shows the results of this symmetrical design. The output current flows with nearly no current mismatch from the four output pins into the board. Consequently this approach is leading to higher level of power density as the current mismatch is not creating a bottleneck.

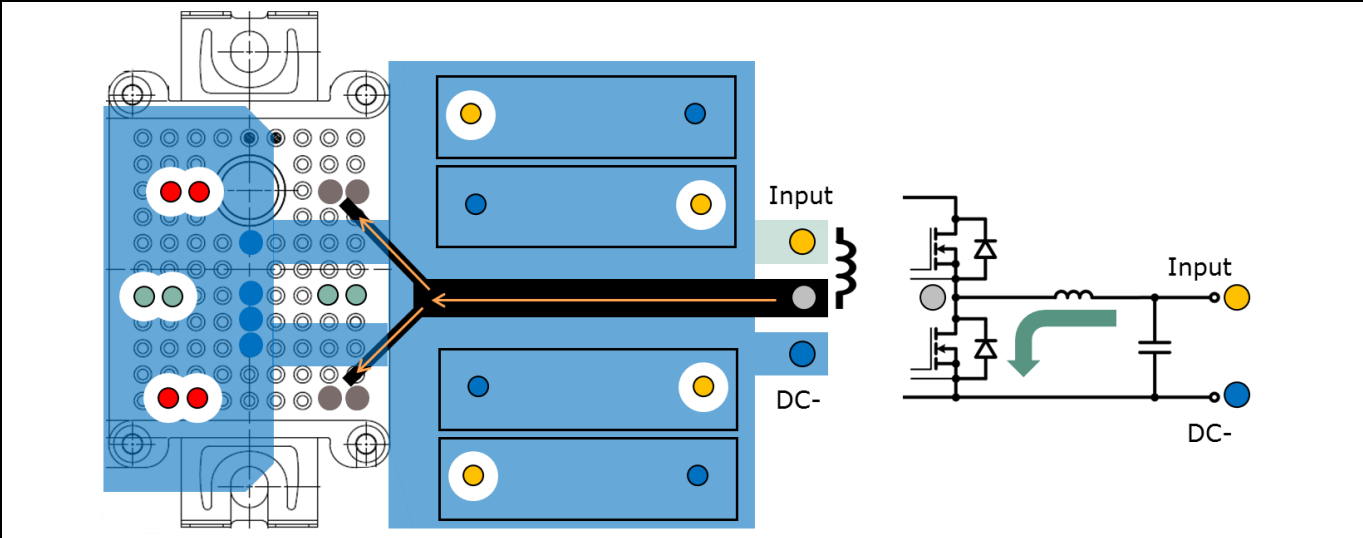


Figure 10 PCB layer design of the input DC-link.

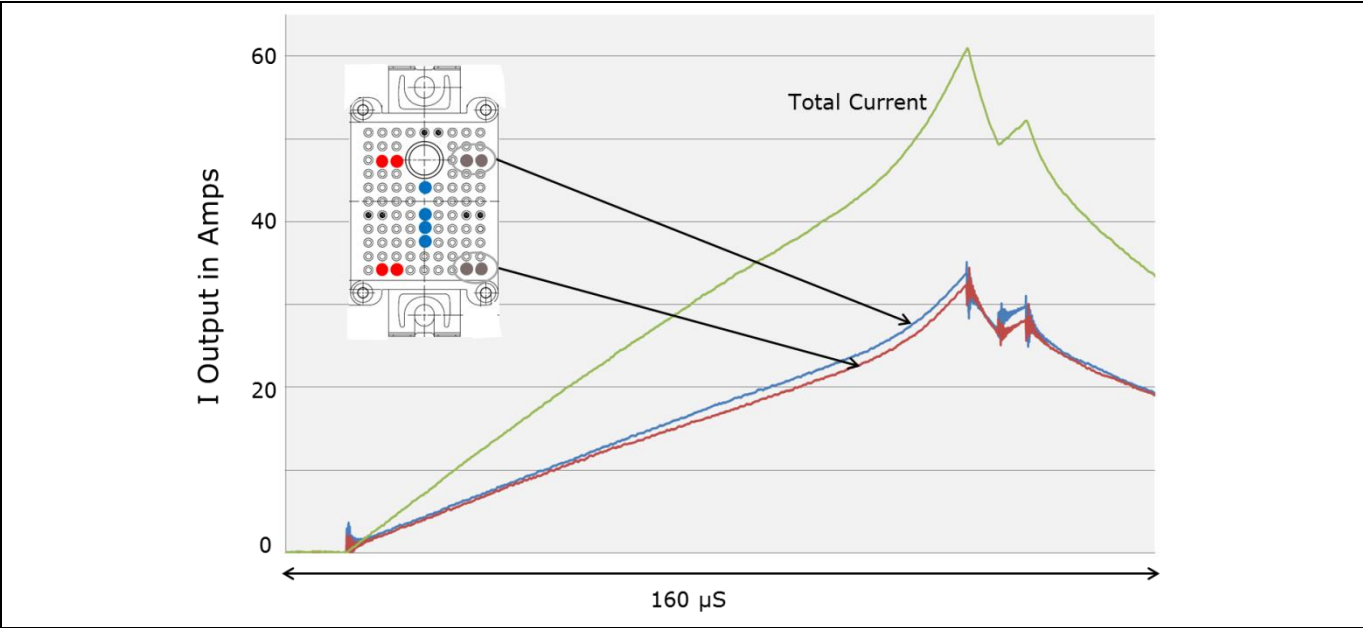


Figure 11 Current sharing of the EVAL-PS-E1BF12-SiC board toward the inductor terminals.

5 Conclusion

The evaluation board EVAL-PS-E1BF12-SiC demonstrate ways to design low inductive boards to get full access to the superior properties of CoolSiC™ MOSFET Easy power modules. The low board inductance has been achieved by the appliance of strip line concepts into the board design.

Furthermore the PCB layer symmetry has been a focus aspect during the board development. The symmetric board layout is leading to a very low current mismatch, which allows the maximum achievable power density with CoolSiC™ MOSFET modules.

The board allows an extensive evaluation of the FF11MR12W1M1_B11 and FF23MR12W1M1_B11 properties. In this application note the general turn-on and turn-off behavior as well as the safety against parasitic turn-on of the upper device has been shown.

Further investigations are possible with the EVAL-PS-E1BF12-SiC board like determination of the power conversion efficiency during buck or boost operation, the behavior at different R_g values, temperature dependent measurements or short circuit tests.

6 How to Order

Every evaluation driver board has its own IFX order number and can be ordered via your Infineon sales partner.

Information can also be found at the Infineon Web Page: www.infineon.com

CAD-data for the board described here are available on request. The use of this data is subjected to the disclaimer given in this AN. Please contact: WAR-IGBT-Application@infineon.com

IFX order number for EVAL-PS-E1BF12-SiC: SP001798382

Reference

Following literature can be helpful:

- [1] Slawinski, M., Villbusch, T., Heer, D., & Buschkuehle, M. (2016, May). Demonstration of superior SiC MOSFET Module performance within a Buck-Boost Conversion System. In *PCIM Europe 2016; International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management; Proceedings of* (pp. 1-8). VDE.
- [2] Infineon Technologies AG, AN2017-04 Advanced Gate Drive Options for Silicon-Carbide (SiC) MOSFET using EiceDRIVER™, April 2017, www.infineon.com
- [3] Heer, D., Domes, D., & Peters, D. (2016, May). Switching performance of a 1200 V SiC-Trench-MOSFET in a low-power module. In *PCIM Europe 2016; International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management; Proceedings of* (pp. 1-7). VDE.



Revision History

Major changes since the last revision

Page or Reference	Description of change

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