1200 V CoolSiC™ MOSFET in TO-247 3-/4-pin evaluation platform

About this document

Scope and purpose

This application note is a user's guide on how to operate the evaluation platform for 1200 V silicon carbide CoolSiC™ MOSFET in TO247 3-pin and 4-pin and the two reference design drive boards, one with bipolar supply and one with active Miller clamp.

Intended audience

This document is intended for owners and users of the evaluation board.

1. Disclaimer

Environmental conditions were considered in the design of the evaluation platform. The design was tested as described in this document but not qualified regarding safety requirements or manufacturing and operation over the whole operating temperature range or lifetime.

The boards provided by Infineon are subject to functional testing only under typical load conditions. Evaluation or Reference boards are not subject to the same procedures as regular products regarding Returned Material Analysis (RMA), Process Change Notification (PCN) and Product Discontinuation (PD).

Evaluation or Reference Boards are provided "as is". Infineon disclaims any and all warranties, express or implied, including but not limited to any warranties of non-compliance with any specification, non-infringement of third party rights and implied warranties of fitness for any purpose or for merchantability.

Evaluation or Reference Boards are not commercialized products and are solely intended to be used for evaluation and testing purposes. They shall not to be used for reliability testing or production. Hence, they may not comply with CE or similar standards (including without limitation the EMC Directive 2004/EC/108 and the EMC Act) and may not fulfill other requirements of the country in which they are operated by the Customer. The Customer shall ensure that each Evaluation or Reference Board will be handled in a way which is compliant with all relevant requirements and standards in the country in which it is operated.

The Evaluation or Reference Board is addressing only qualified and skilled technical staff for laboratory usage and shall be used and manage according to the terms and conditions set forth in the related documentation provided with the Evaluation or Reference Board.

Customer accepts the entire risk arising out of the use of the Evaluation or Reference Board for any purpose for which the Evaluation or Reference Board is not intended, including but not limited to any further processing or distribution of the Evaluation Reference Board. Infineon will not accept any liability or product warranty for these Evaluation or Reference Boards. Customer undertakes to indemnify and hold Infineon harmless from any third party claims in connection with or arising out of the use and/or handling of the Evaluation or Reference Boards by the Customer.

2. Safety precautions

In addition to the precautions listed throughout this manual, please read and understand the following statements regarding hazards associated with development systems.

Table 1 Safety Precautions

	Attention: Only personnel familiar with the drive, power electronics and associated machinery should plan or implement the installation, start-up and subsequent maintenance of the system. Failure to comply may result in personal injury and/or equipment damage.
	Caution: The Eval-xxx system contains DC bus capacitors which take time to discharge after removal of the main supply. Before working on the drive system, wait five minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.
	Attention: The Power board using xxx and xxx is connected to the grid input during testing. Hence while measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.
	Attention: The heat sink and IGBT module surfaces of the power board may become hot during testing. Hence necessary precautions are required while handling the board, failure to comply may cause injury.
	Attention: Power board using xxx contains parts and assemblies sensitive to Electrostatic Discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing this assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to applicable ESD protection handbooks and guidelines.
	Caution: Remove or disconnect power from the drive before you disconnect or reconnect wires or perform service. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.
	Attention: A drive, incorrectly applied or installed, can result in component damage or reduction in product lifetime. Wiring or application errors such as under sizing the motor, supplying an incorrect or inadequate AC supply or excessive ambient temperatures may result in system malfunction.
	Attention: Power board using xxx is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials which are unnecessary for system installation may result in overheating or abnormal operating condition.

3. Table of contents

About this document **1**
2. Safety precautions **3**
3. Table of contents **4**
4. Introduction **5**
4.1 Purpose of the board 5
4.2 Scope of delivery & Order information 6
5. Hardware **7**
5.1 Circuit and main components 7
5.2 Main board 8
5.3 Driver card with bipolar supply 9
5.4 Driver card with active Miller clamp 10
5.5 Optional accessories 12
6. Usage **13**
6.1 Double-pulse principle 13
6.2 Operation 13
7. Summary **17**
8. Appendix **18**
8.1 Main board 18
8.1.1 Schematic 18
8.1.2 Board layout 20
8.1.3 Bill of material 21
8.2 Driver board V1 – Bipolar Supply 22
8.2.1 Schematic 22
8.2.2 Board layout 23
8.2.3 Bill of material 24
8.3 Driver board V2 – Miller clamp 24
8.3.1 Schematic 24
8.3.2 Board Layout 24
8.3.3 Bill of material 25
9. References **26**
10. Revision history **27**

4. Introduction

The CoolSiC™ MOSFET 1200 V evaluation platform including EiceDRIVER™ gate driver IC was developed to show the driving options of the silicon carbide CoolSiC™ MOSFET in TO247 3-pin and 4-pin. To show these options, the design was split into one motherboard and currently, two drive cards. The modular approach was chosen to allow the platform to be expanded with new drive cards in the future. The first drive card contains the EiceDRIVER™ 1EDC Compact 1EDC20I12MH with an integrated active Miller clamp preventing parasitic turn-on [3]. The second drive card includes the EiceDRIVER™ 1EDC Compact 1EDC60H12AH allowing a bipolar supply, where VCC2 is +15 V and GND2 is negative. The motherboard was designed for a maximum voltage of 800 V and a maximum pulsed current of 130 A. More drive cards with different driver ICs and CoolSiC™ MOSFETs are planned.

4.1 Purpose of the board

Infineon's silicon carbide CoolSiC™ MOSFET has a typical gate-source threshold voltage of 4.5 V, where the recommended turn-on gate voltage is +15 V and the recommended turn-off gate voltage is 0 V. To evaluate CoolSiC™ MOSFET performance with negative turn-off gate voltage, a bipolar power supply is designed to give the flexibility of gate voltage selection.

Considering this information into account, the two drive cards mentioned above were designed and tested. They are described in detail in dedicated chapters. The assembly of the motherboard with one daughter card is shown in Figure 1.

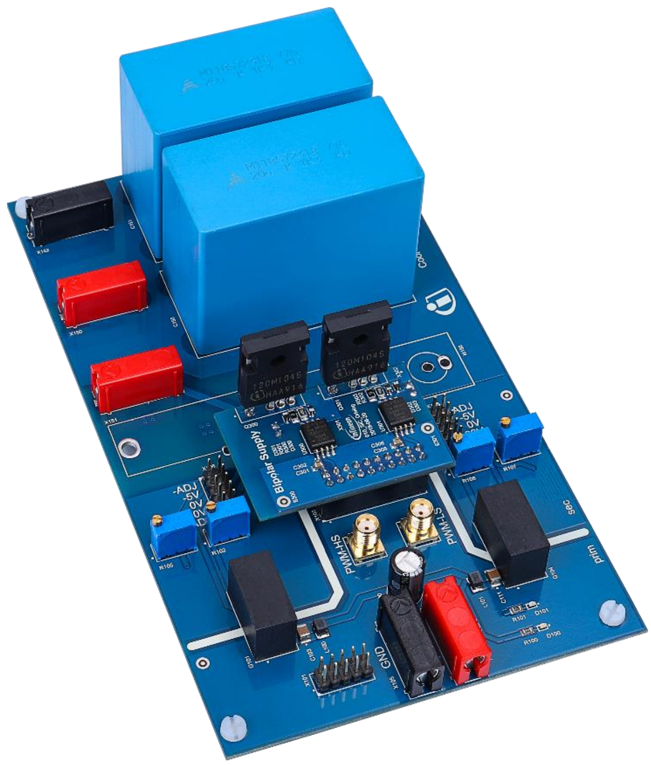


Figure 1 CoolSiC™ evaluation platform

4.2 Scope of delivery & Order information

The evaluation board is delivered together with spare parts and complete documentation in an environmentally friendly carton box. As depicted, the carton box contains:

- Evaluation platform motherboard 1200 V CoolSiC™ MOSFET in TO247 3-pin / 4-pin **IMZ120R045M1**
- Driver board V1 – Bipolar supply **1EDC60H12AH**
- Driver board V2 – Miller clamp **1EDC20I12MH**

Table 1

Product description name	**CoolSiC™ MOSFET 1200 V evaluation platform including EiceDRIVER™ gate driver IC**	**Miller clamp function board for CoolSiC™ MOSFET 1200 V evaluation platform**	**Bipolar supply function board for CoolSiC™ MOSFET 1200 V evaluation platform**
Sales product name	EVAL_PS_SIC_DP_MAIN	REF_PS_SIC_DP1	REF_PS_SIC_DP2
OPN	EVALPSSICDPMAINTOBO1	REFPSSICDP1TOBO1	REFPSSICDP2TOBO1
SP number	SP005412616	SP005412618	SP005412619
Content	• Motherboard (CoolSiC™ MOSFET 1200 V evaluation board) – 1 pc • Daughterboard (Miller clamp and bipolar supply boards) – 1 pc each (total 2 pcs) • IMZ120R045M1 (CoolSiC™ MOSFET 1200 V 45 mΩ in TO-247-4) – 4 pcs	• Daughterboard (Miller clamp function board) – 1 pc • IMZ120R045M1 (CoolSiC™ MOSFET 1200 V 45 mΩ in TO-247-4) – 2 pcs	• Daughterboard (bipolar supply function board) – 1 pc • IMZ120R045M1 (CoolSiC™ MOSFET 1200 V 45 mΩ in TO-247-4) – 2 pcs •

5. Hardware

In this section the hardware of the power and auxiliary circuity and their main components will be described.

5.1 Circuit and main components

Figure 2 shows the block diagram of the platform. The core of the board is the half-bridge consisting of S1 and S2 in TO247-3-pin or 4-pin. For both switches, independent gate drivers are used. The inductor L1 is mounted externally and is not included in the scope of delivery.

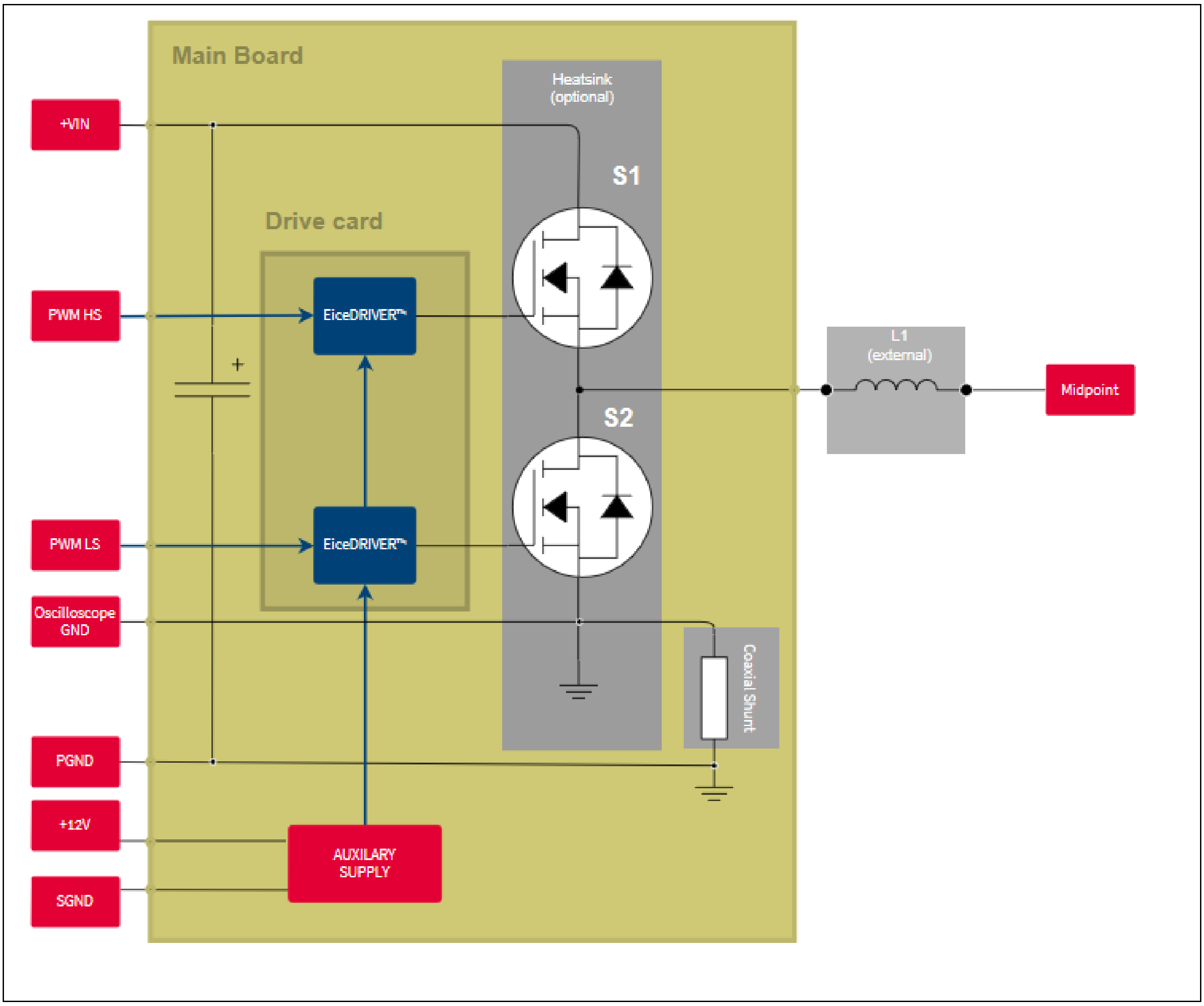


Figure 2 Evaluation platform block diagram

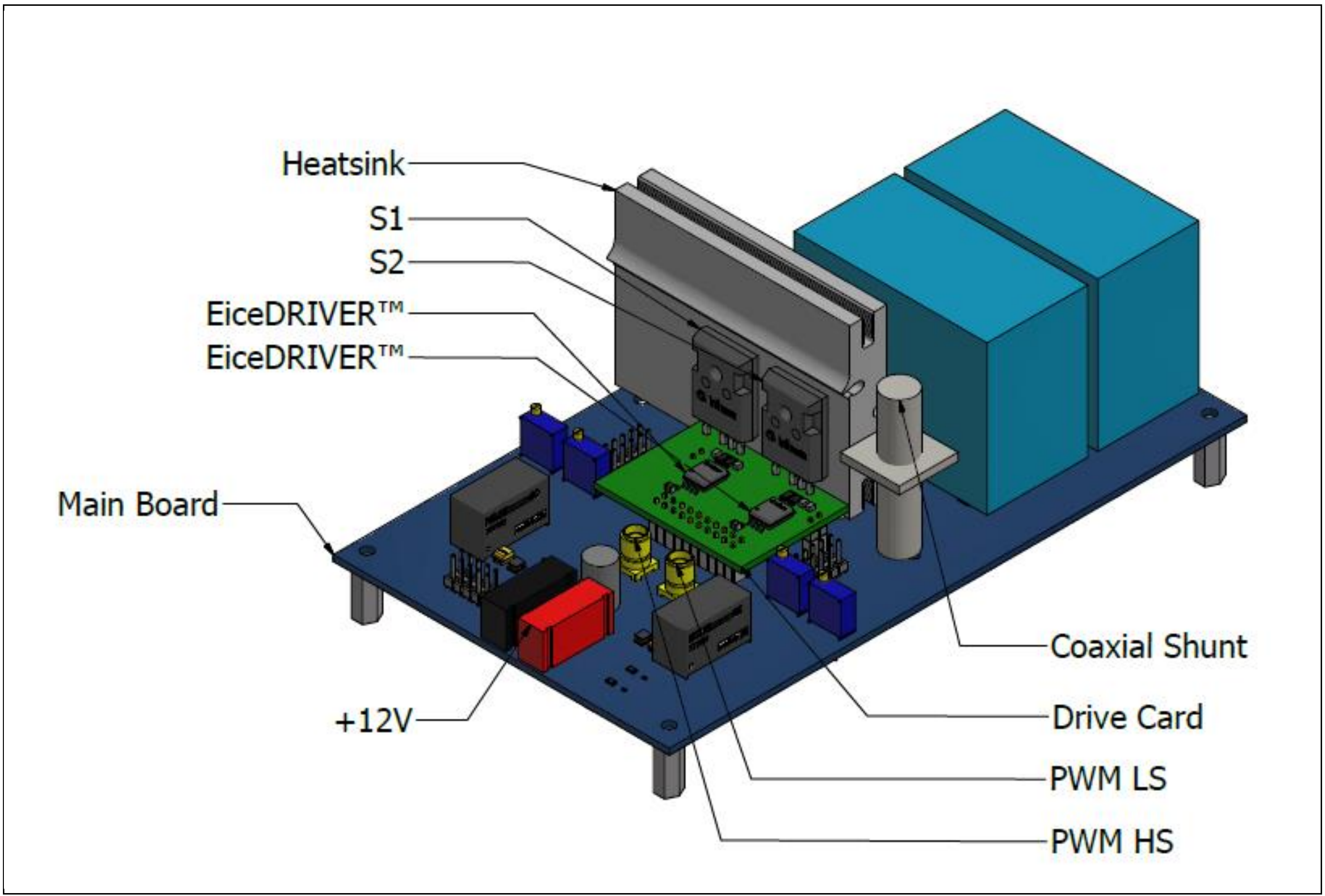


Figure 3 Evaluation platform components

5.2 Main board

The main board shown in Figure 4 is split into two sections, the primary supply side on the left and the power circuit indicated as secondary side on the right. On the primary side, the 12 V supply (X102, X105) and the PWM will be connected. The half bridge connectors (X150 – X152) are located on the secondary side. R102 and R108 adjusts the VCC2 of the drivers between +7.5 and +20 V. R105 and R107 regulates the negative voltage between -1 V and -4.5 V. +20 V and -5 V are fixed voltages coming from the DC/DC converter G101 and G104. HS150 is optional and not needed for double pulsing. For measuring at higher temperatures, e.g. up to 175°C, the heatsink can be used together with a heating element.

The yellow boxes in Figure 4 indicate the pin header for setting the driving voltages via two jumpers. The possible configurations are visualized in Table 1. Average consumption of the +12 V supply is 100 mA.

Table 2 Jumper configurations

+ADJ	+20 V	0 V	-5 V	-ADJ
X		X		
X			X	
X				X
	X	X		
	X		X	
	X			X

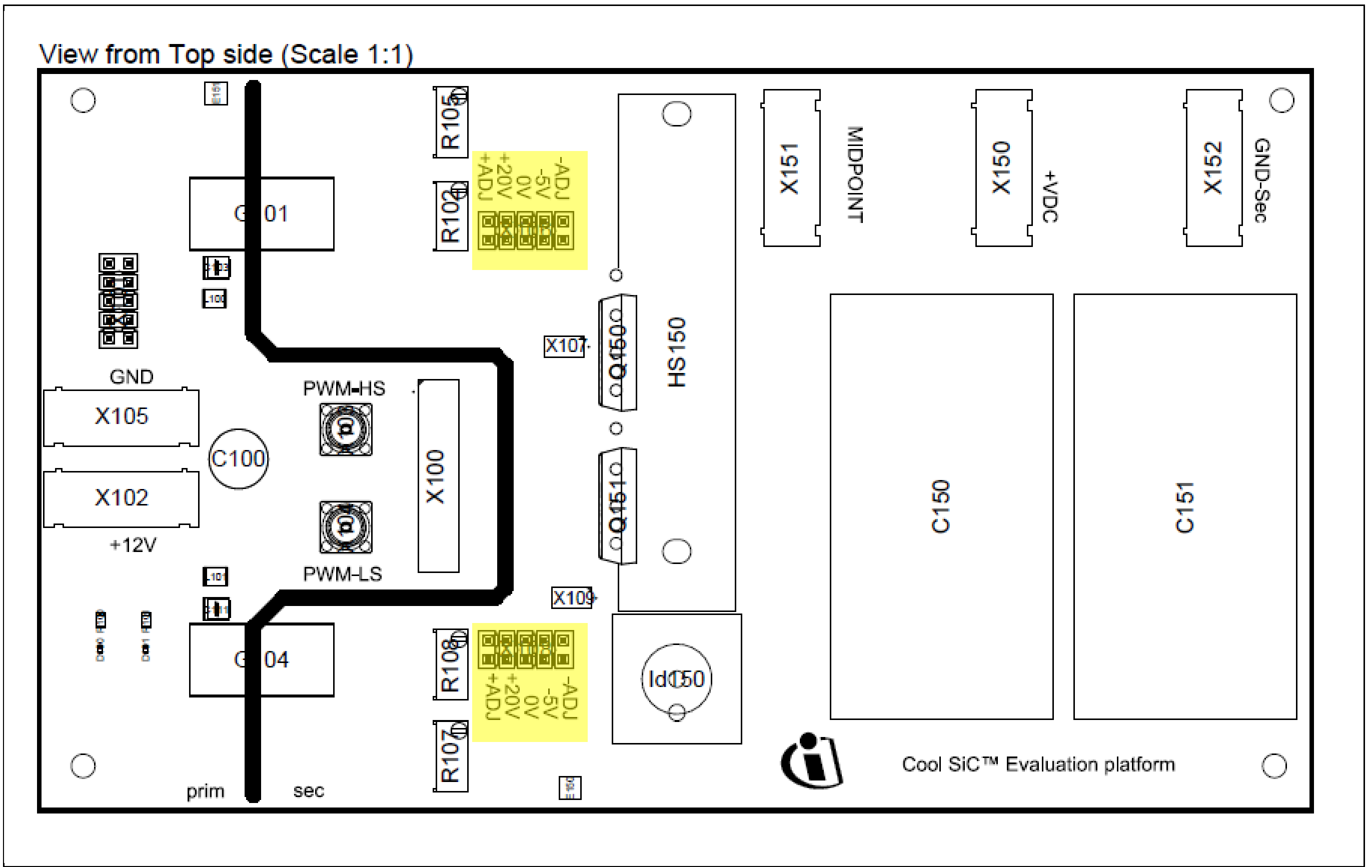


Figure 4 Main board assembly view

5.3 Driver card with bipolar supply

Figure 5 displays the functions of the BP driver card with the wide body gate driver **1EDC60H12AH**.

Table 3 Jumper configurations for BP

+ADJ	+20 V	0 V	-5 V	-ADJ
X			X	
X				X
	X		X	
	X			X

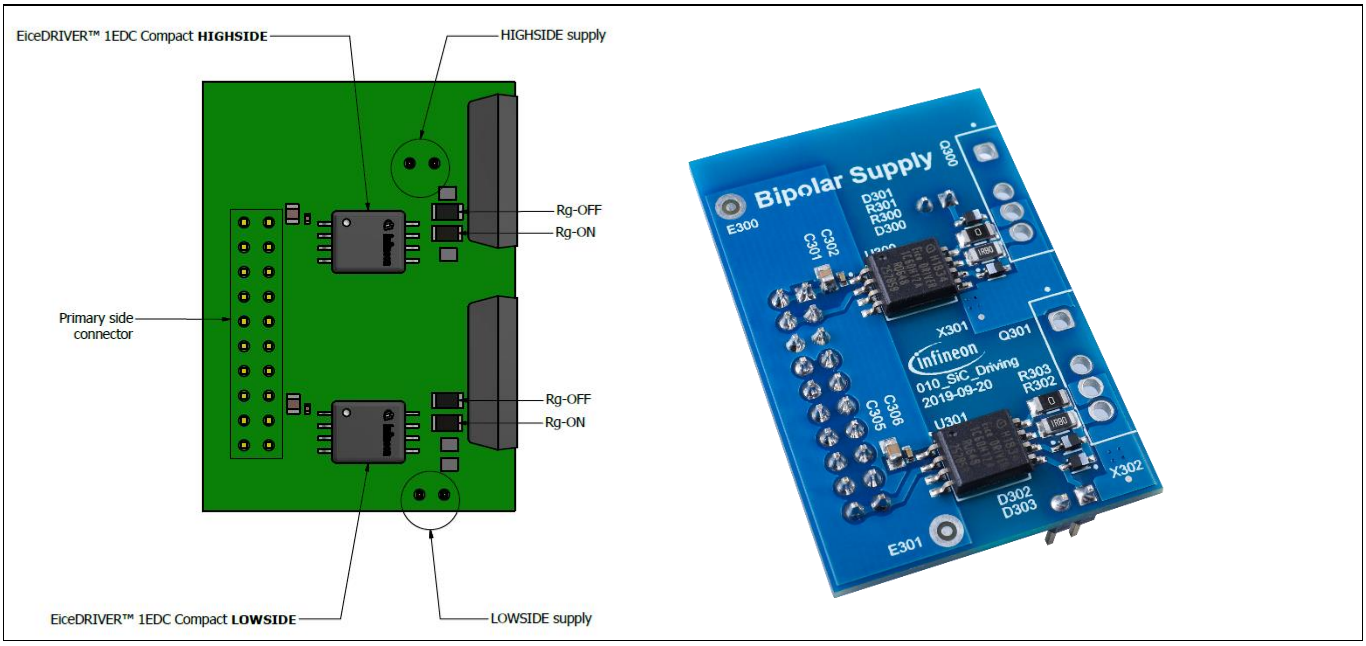


Figure 5 Drive card BP description

In Figure 6, a distance of approx. 6.5 mm from the driver output to the gate lead of the device is visualized. As commonly known, the distance between driver output and gate should be kept as short as possible [1].

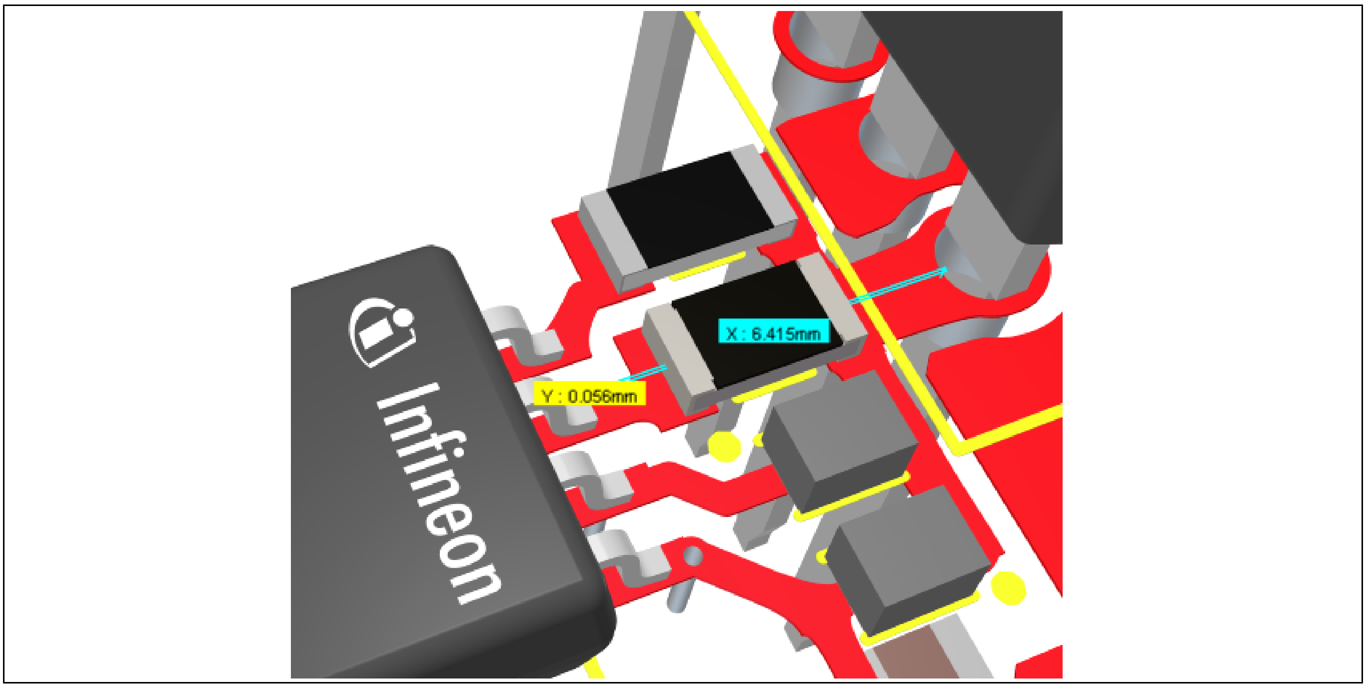


Figure 6 Gate driving distance

5.4 Driver card with active Miller clamp

Miller clamp functionality ties the output to GND2 to avoid parasitic turn-on. This driving solution is in relation to the CoolSiC™ MOSFET the preferred one [5]. Figure 7 shows the functions of the MC driver board with the **1EDC20I12MH**.

Table 4 Jumper configurations for MC

+ADJ	+20 V	0 V	-5 V	-ADJ
X		X		
	X	X		

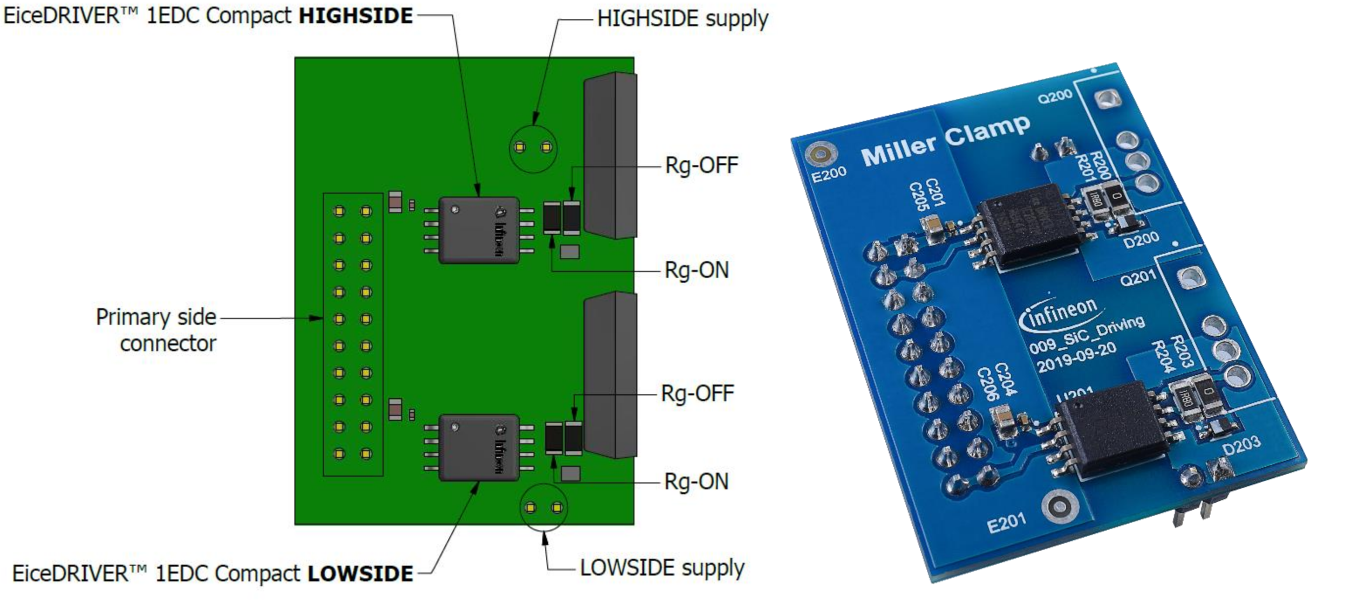


Figure 7 Drive card MC description

Figure 8 displays the layout of the gate driver containing Rg-on, Rg-off and the respective diode.

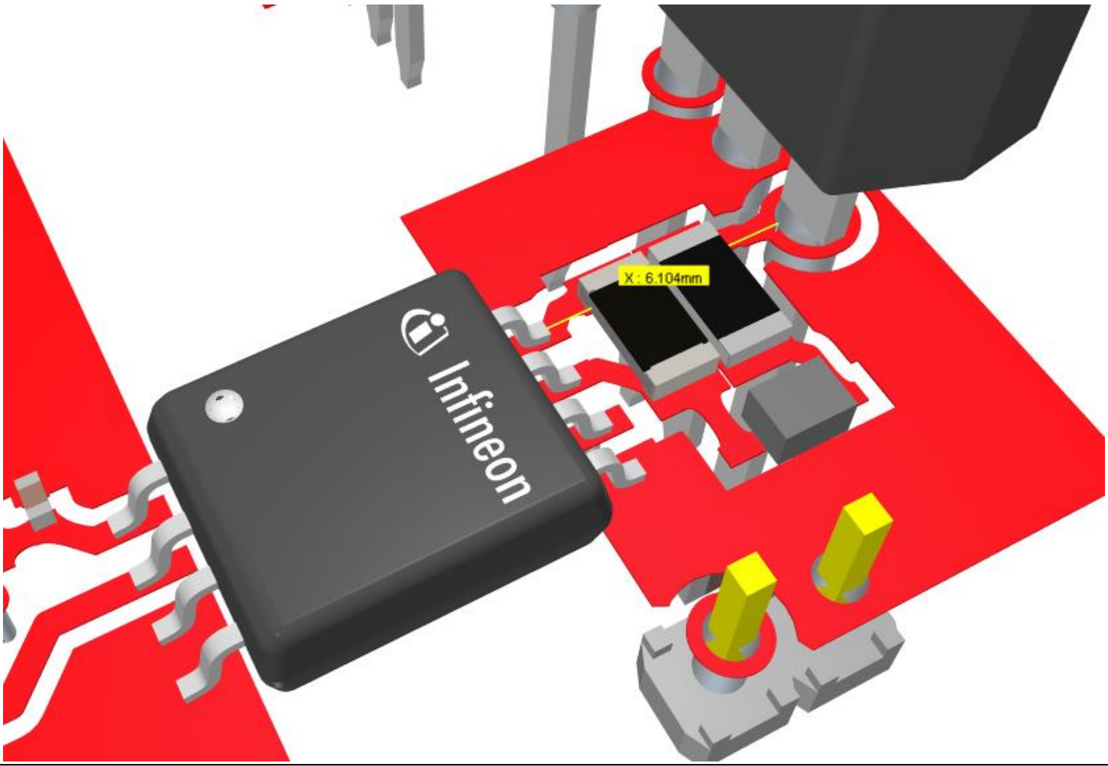


Figure 8 PCB Layout showing distance between driver output and gate pin

5.5 Optional accessories

To be able to measure the drain current of the MOSFET, Infineon suggests using a coaxial shunt shown in Figure 9. The transient time of the CoolSiC™ MOSFET is in the Nano-second range. Therefore, a high bandwidth shunt is necessary. In this board a SDN-414-xxx shunt is used, where the resistance selection depends on $R_{DS(on)}$ of the DUT (device under test) and the measurement equipment.

Figure 9 Coaxial shunt

The voltage measurement of VDS and VGS was not foreseen in the platform. The recommendation is to connect a high-voltage probe directly on the package leads for VDS, and a low-voltage probe for VGS.

6. Usage

6.1 Double-pulse principle

The double-pulse principle can be used to characterize e.g. the "Turn-on" and "Turn-off" of the IGBT.

Pulse 1 visualized in Figure 5 defines the desired current in the inductive load (L1 in Figure 2) via its length. The turn-off event of pulse 1 leads to a constant current through the body diode of S1, which can also be replaced by a discrete diode. Turn-on of pulse 2 causes a current overshoot coming from the reverse recovery charge of S1 or the respective diode.

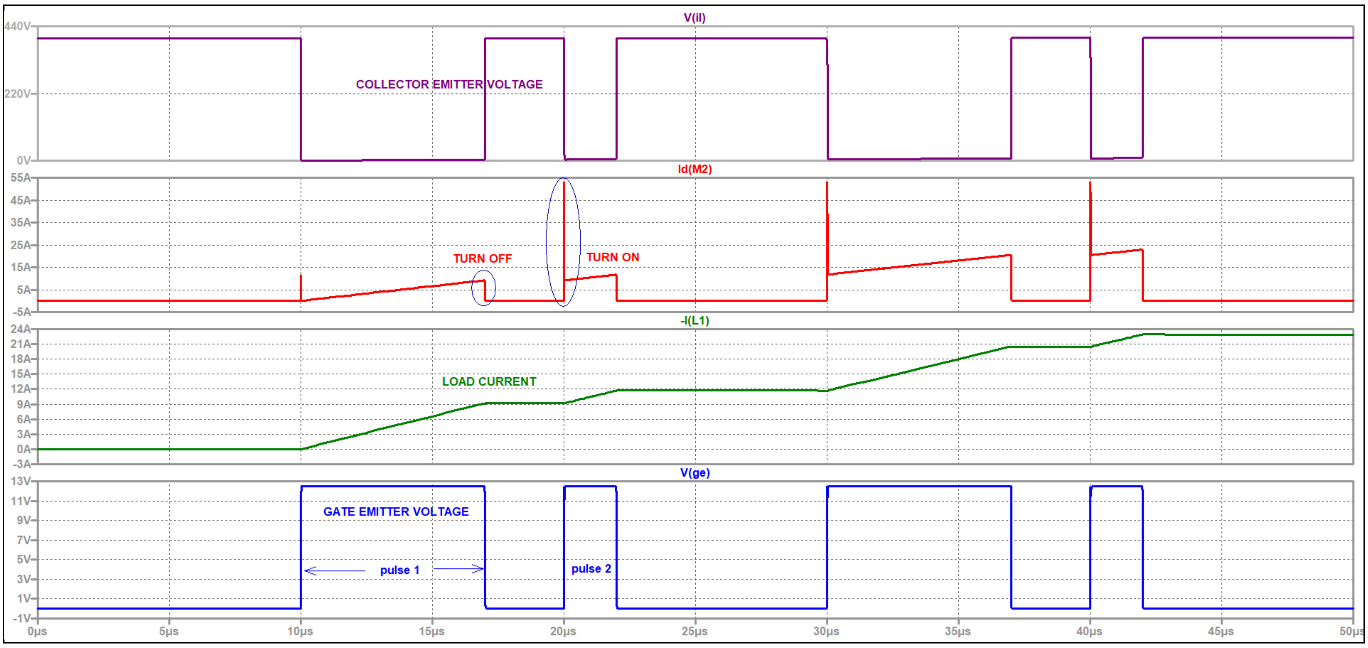


Figure 10 **Double-pulse simulated waveforms**

6.2 Operation

This paragraph describes the two operation modes planned for this evaluation platform. Needed equipment is an auxiliary power supply providing the +12 V, a function generator for the PWM and a high-voltage source (up to 800 V):

Figure 11 & Figure 12 show the first option where the double pulse is applied to the low side switch measuring its voltages and current. Optionally the diode behavior on the high side can be evaluated. Figure 13 & Figure 14 as second option describe the configuration for testing the high side switch and the low side diode or switch.

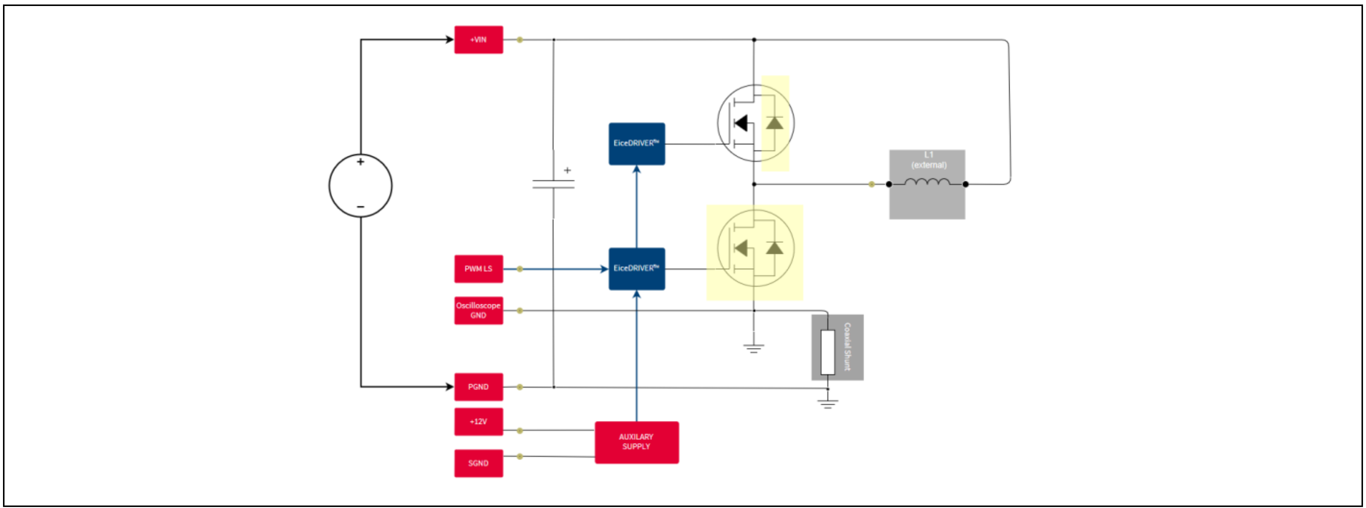


Figure 11 Half bridge configuration for low side MOSFET or high side diode testing

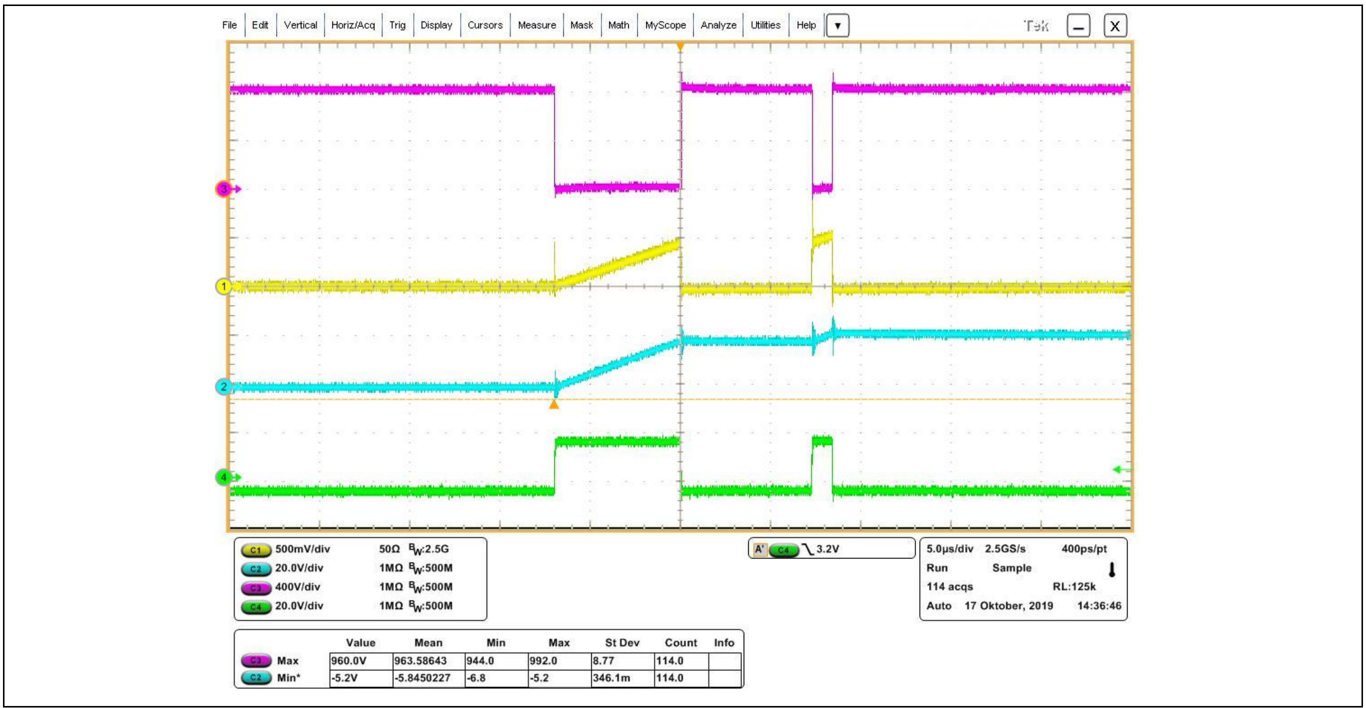


Figure 12 Low side testing waveforms example (VDS, Id, IL, VGS)

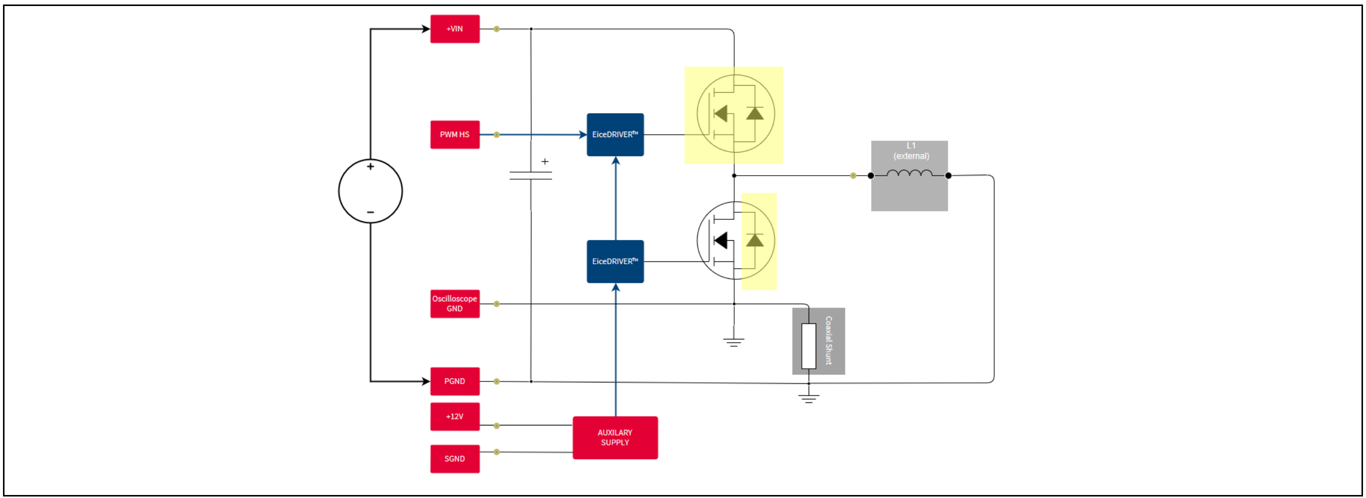


Figure 13 Half bridge configuration for high side MOSFET or low side diode testing

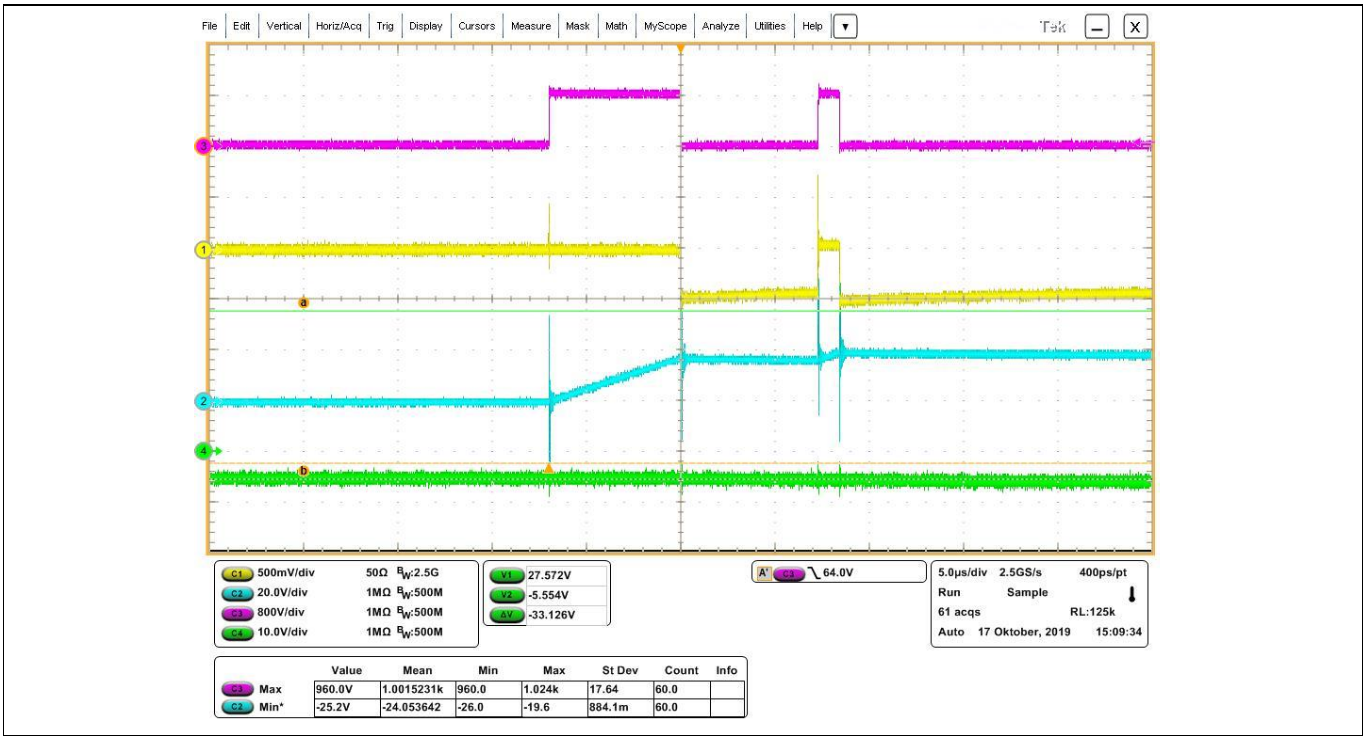


Figure 14 High side testing waveforms example(VDS, Id, IL, VGS LS)

Start-up procedure

1. Mount drive card on motherboard and set the jumpers for the required supply voltage
2. Solder the DUTs and the coaxial shunt on the platform. For other current measurements, bridge Id150
3. Connect power source (VDC up to 800 V), Auxiliary supply 12 V, function generator (for double pulse)
4. Connect the load inductor, either HS or LS
5. Plug in the desired probes (voltage, current)

6. Turn on: A) Apply 12 V and double pulse; B) Apply high voltage gradually until desired level; C) Do measurements
7. Turn off: A) Switch off the high-voltage source; B) switch off Aux supply and function generator

The start-up procedure can also be found on our homepage:

https://www.infineon.com/dgdl/Infineon-Operation_Manual_for_CoolSiC_MOSFET_1200V-ProductInformation-v01_00-EN.pdf?fileId=5546d4626f229553016f32054c4c231c

Max ratings: V_{DS}: 800V, $I_{D,pulse}$: 130A

7. Summary

Infineon's silicon carbide 1200 V CoolSiC™ MOSFETs are the next step towards an energy-smart world.

The evaluation platform introduced in Chapters 1 & 2 should help to understand these wide-bandgap devices and their driving possibilities. A modular board was developed on which several drive cards with different functionalities can be used. Chapter 3 explains the double-pulse principle, the two possible configurations and the captured measurements.

Currently, the portfolio contains two different drive cards which will be increased in future:

Driver board V1 – Bipolar supply 1EDC60H12AH can be supplied from +15V to -5V preventing parasitic return on in harsh environments. Drawback of this solution is a slightly reduced lifetime were the driving voltage is only one parameter among others. Figure 16 shows a V_{GS} max of -0.2V proofing the concept.

Driver board V2 – Miller clamp 1EDC20I12MH enables an Active Miller Clamp grounding V_{GS} to 0V. The parasitic overshoot of VGS in this board is 1.6V which is far below the threshold voltage of 4.5V.

8. Appendix

8.1 Main board

8.1.1 Schematic

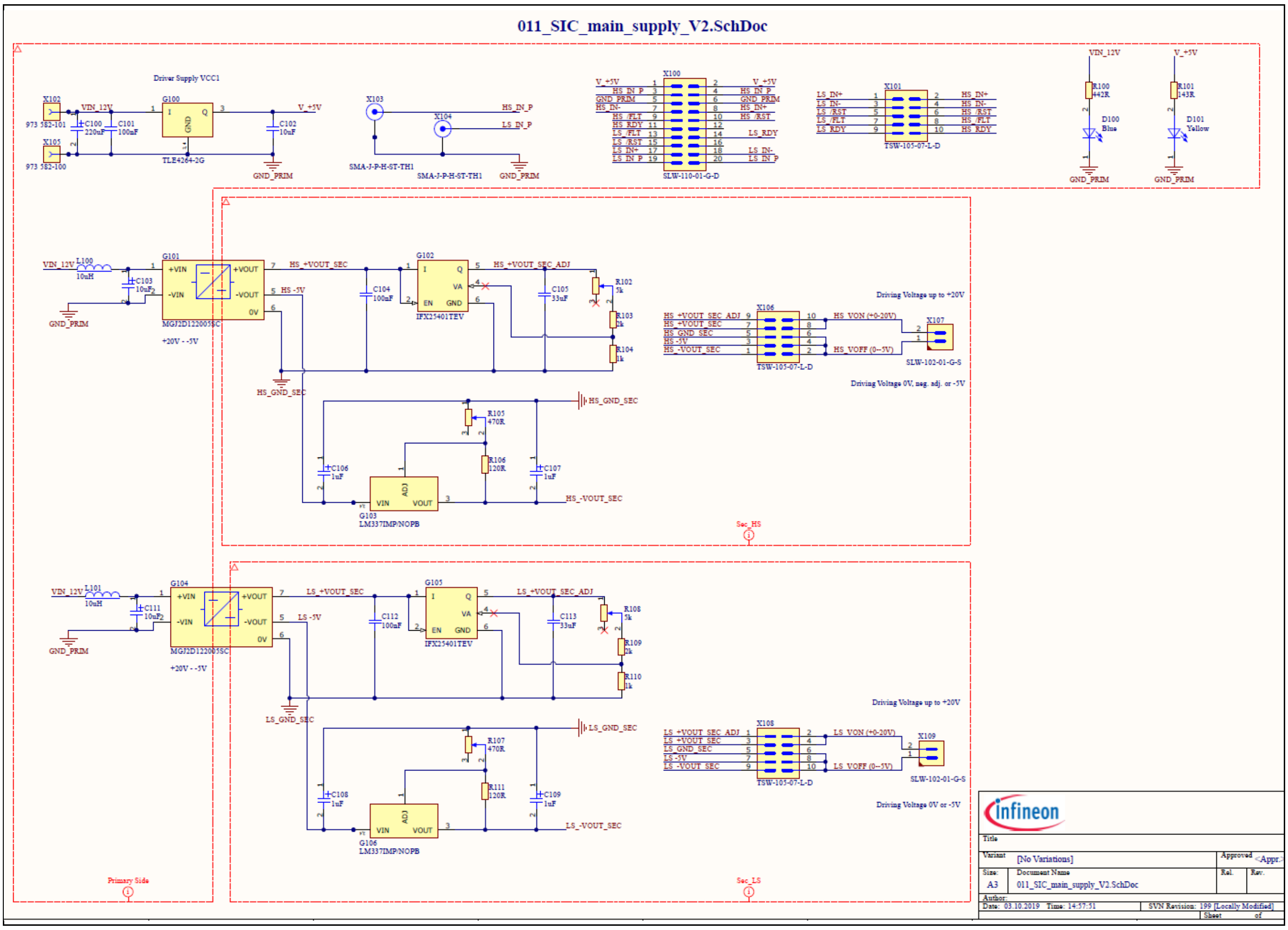


Figure 15 Main board Supply

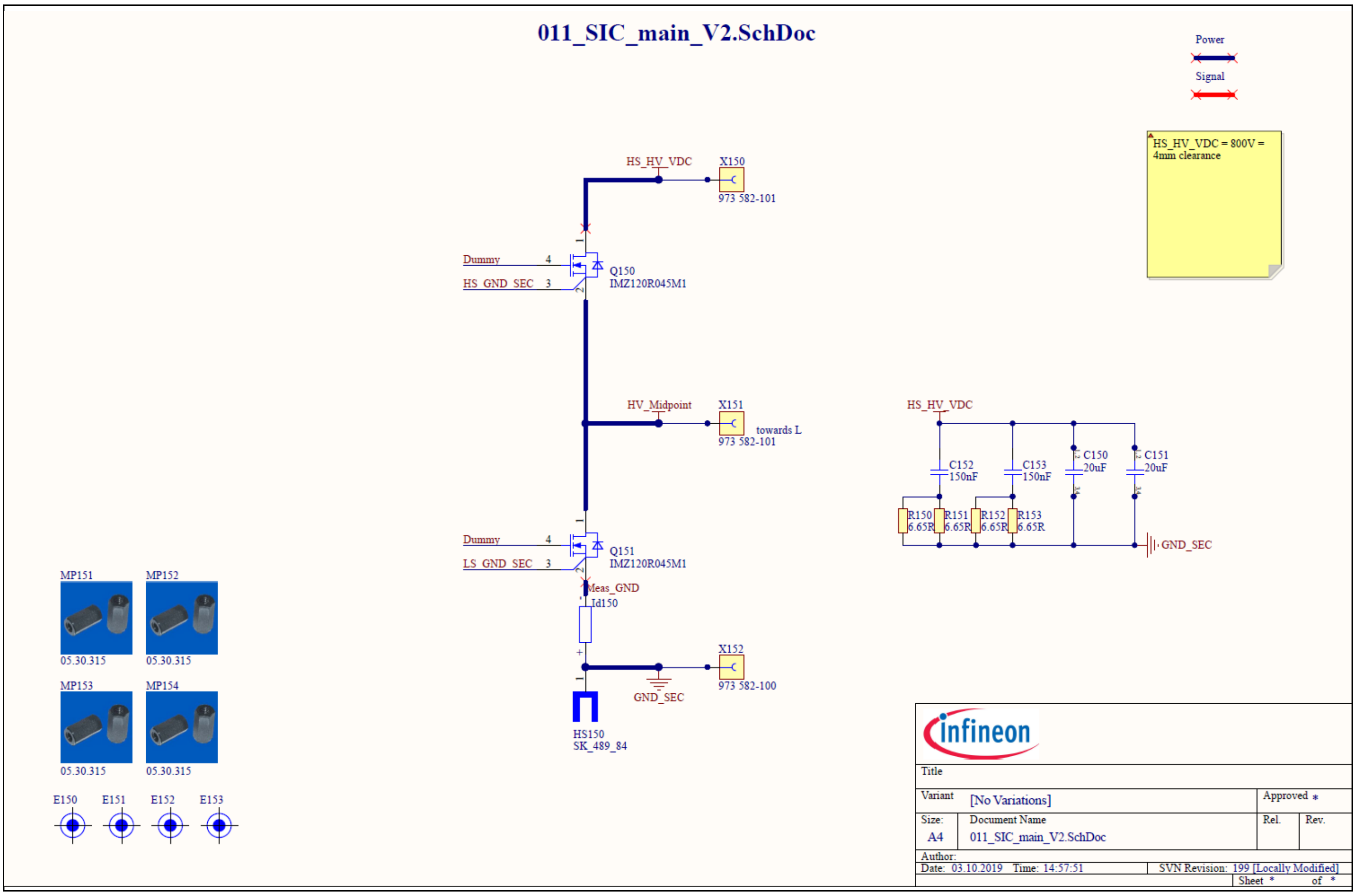
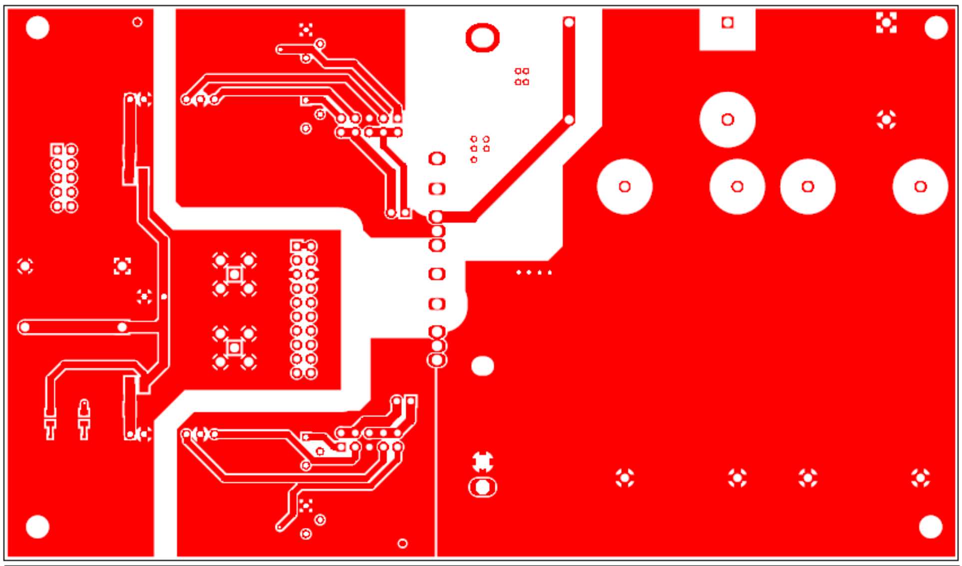


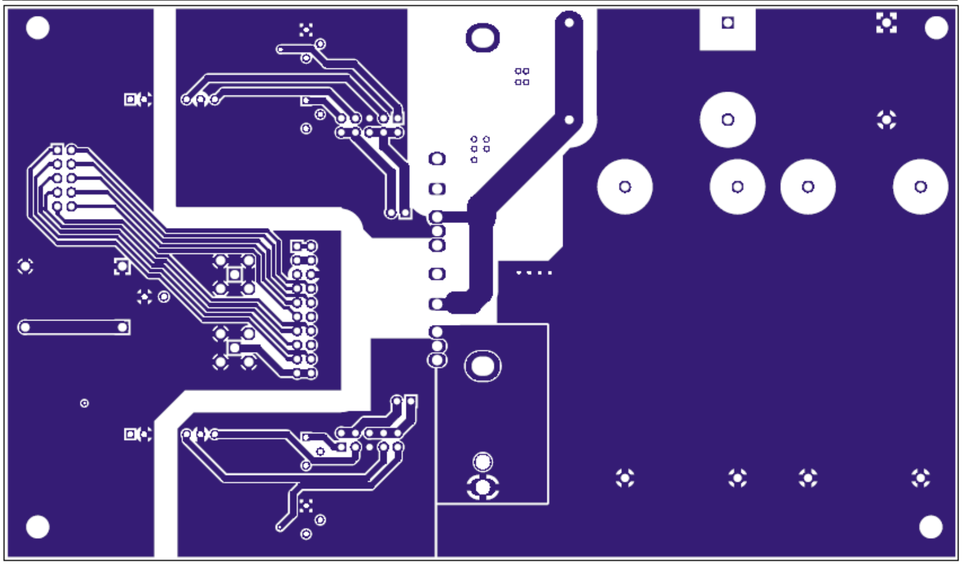
Figure 16 Main board Power Circuit

8.1.2 Board layout

Top Layer (Scale 1:1)



Layer 1 (Scale 1:1)



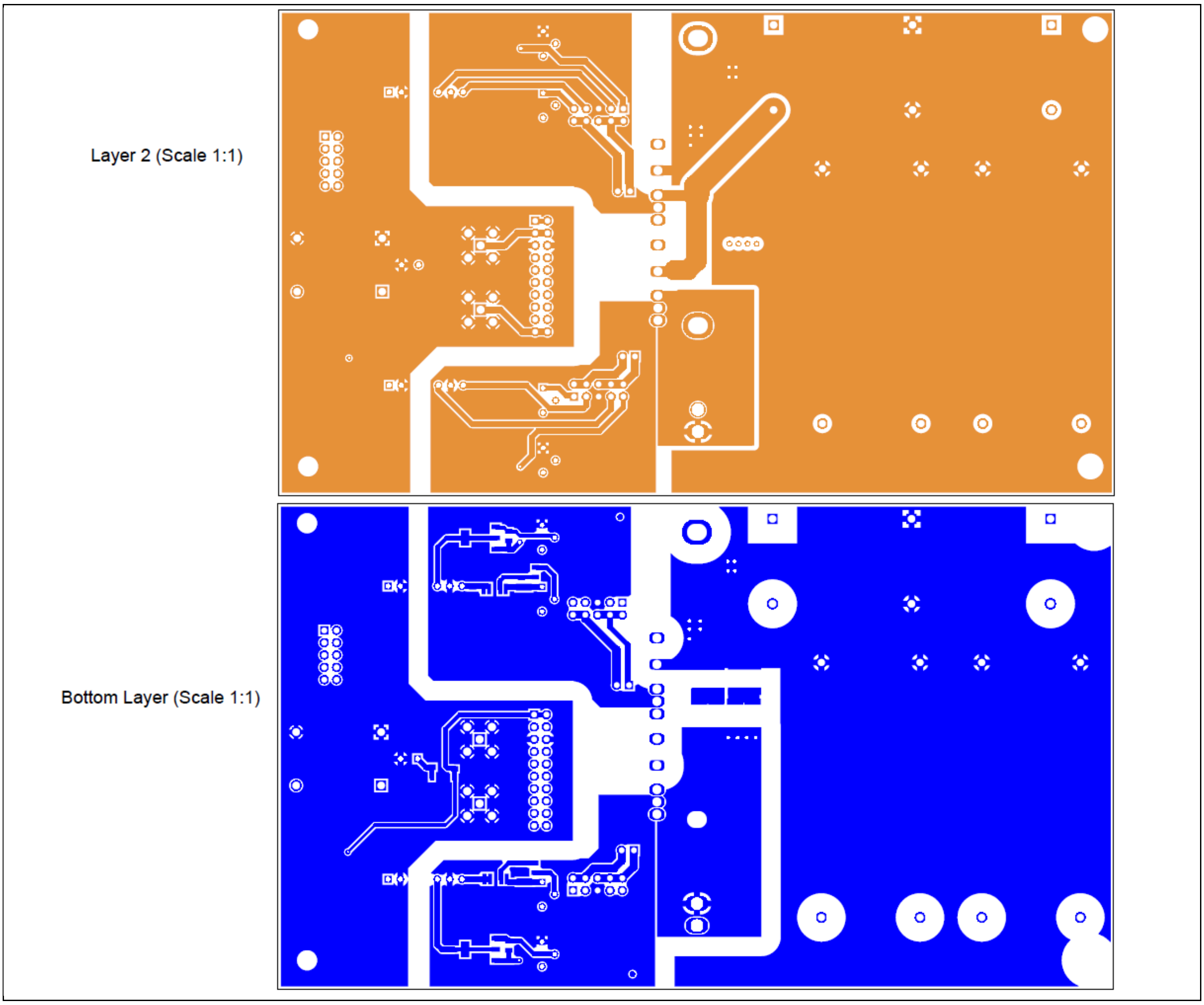


Figure 17 Main board PCB Layout

8.1.3 Bill of material

Table 5

Designator	Comment	Voltage DC (max)	Quantity	Manufacturer	Manufacturer Order Number
C100	220uF	25V	1	Panasonic	ECA1EHG221
C101, C104, C112	100nF	50V	3	Kemet	C0805C104J5RAC
C102	10uF	10V	1	Taiyo Yuden	LMK212ABJ106KGHT
C103, C111	10uF	16V	2	Kemet	T498B106K016ATE2K8
C105, C113	33uF	16V	2	TDK Corporation	CGA8P1X7R1C336M250KC
C106, C107, C108, C109	1uF	20V	4	AVX	TAJR105K010RNJ
C150, C151	20uF	1.3kV	2	Epcos	B32778G1206J000
C152, C153	150nF	1kV	2	Kemet	C2225C154KDRACTU
D100	Blue	na	1	ROHM Semiconductors	SMLP12BC7T
D101	Yellow	na	1	ROHM Semiconductors	SML-P12YTT86R
G100	TLE4264-2G	na	1	Infineon Technologies	TLE4264-2G
G101, G104	MGJ2D122005SC	na	2	Murata	MGJ2D122005SC
G102, G105	IFX25401TEV	na	2	Infineon Technologies	IFX25401TEV
G103, G106	LM337IMP/NOPB	na	2	Texas Instruments	LM337IMP/NOPB
L100, L101	10uH	na	2	muRata	LQH32PB100MNC
MP151, MP152, MP153, MP154	05.30.315	na	4	Ettinger	05.30.315
R100	442R	150V	1	Vishay	CRCW0805442RFK
R101	143R	150V	1	Vishay	CRCW0805143RFK
R102, R108	5k	500V	2	Bourns	3296Y-1-103LF
R103, R109	2k	150V	2	Vishay	CRCW08052K00FK
R104, R110	1k	150V	2	Vishay	CRCW08051K00FK
R105, R107	470R	500V	2	Bourns	3296Y-1-471LF
R106, R111	120R	150V	2	Vishay	CRCW0805120RFK
R150, R151, R152, R153	6.65R	500V	4	Vishay	CRCW25126R65FK
X100	SLW-110-01-G-D	na	1	Samtec	SLW-110-01-G-D
X101, X106, X108	TSW-105-07-L-D	na	3	Samtec	TSW-105-07-L-D
X102, X150, X151	973 582-101	na	3	Hirschmann Test & Measurement	973 582-101
X103, X104	SMA-J-P-H-ST-TH1	na	2	Samtec	SMA-J-P-H-ST-TH1
X105, X152	973 582-100	na	2	Hirschmann Test & Measurement	973 582-100
X107, X109	SLW-102-01-G-S	na	2	Samtec	SLW-102-01-G-S

8.2 Driver board V1 – Bipolar Supply

8.2.1 Schematic

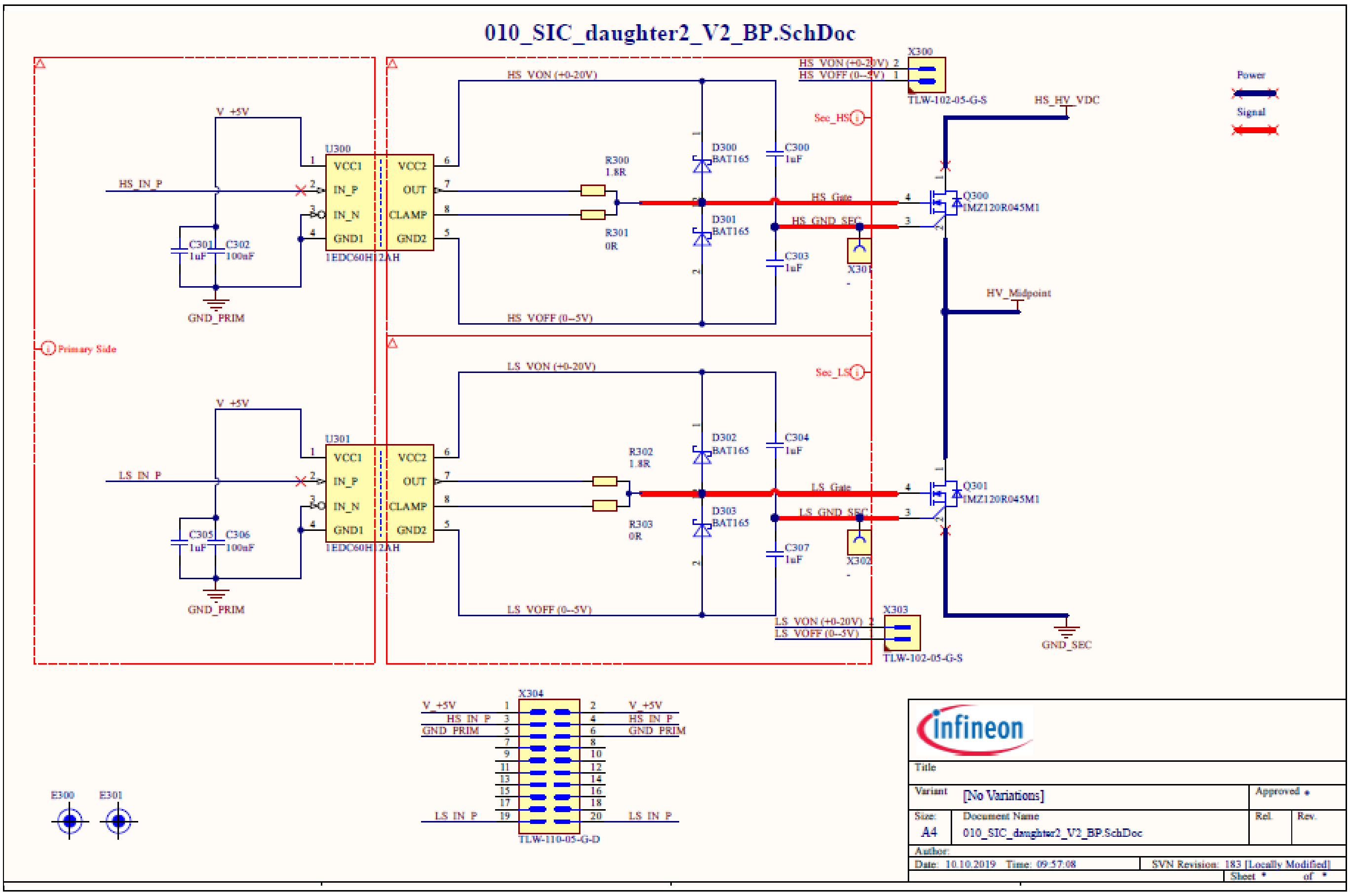


Figure 18 Driver board schematic- Bipolar supply

8.2.2 Board layout

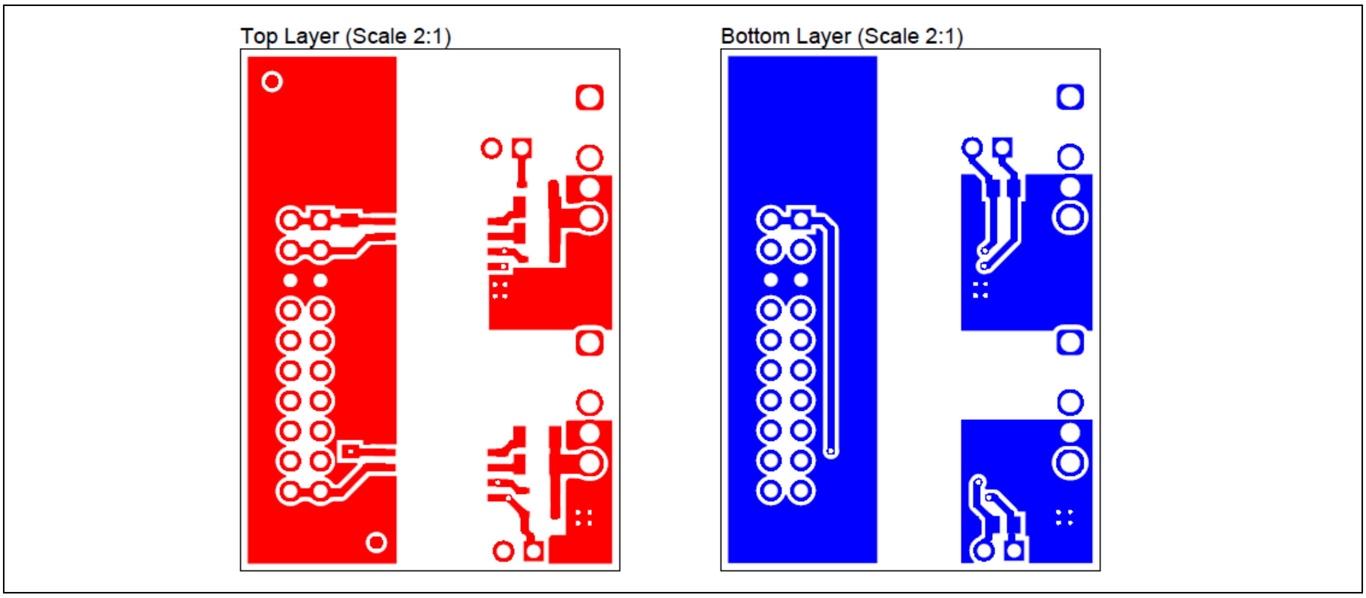


Figure 19 Driver board BP PCB Layout

8.2.3 Bill of material

Table 6

Designator	Comment	PackageReference	Voltage DC (max)	Quantity	Manufacturer	Manufacturer Order Number
C300, C301, C304, C305	1uF	0805	25V	4	AVX	08053D105KAT2A
C302, C306	100nF	0402 (1005)	16V	2	TDK Corporation	CGA2B1X7R1C104K050BC
D300, D301, D302, D303	BAT165	SOD323	na	4	Infineon Technologies	BAT165
R300, R302	1.8R	1206	200V	2	Yageo	RC1206FR-071R8L
R301, R303	0R	1206	200V	2	Vishay	CRCW12060000Z0
U300, U301	1EDC60H12AH	PG-DSO-8-59	na	2	Infineon Technologies	1EDC60H12AH
X300, X303	TLW-102-05-G-S		na	2	Samtec	TLW-102-05-G-S
X304	TLW-110-05-G-D		na	1	Samtec	TLW-110-05-G-D

8.3 Driver board V2 – Miller clamp

8.3.1 Schematic

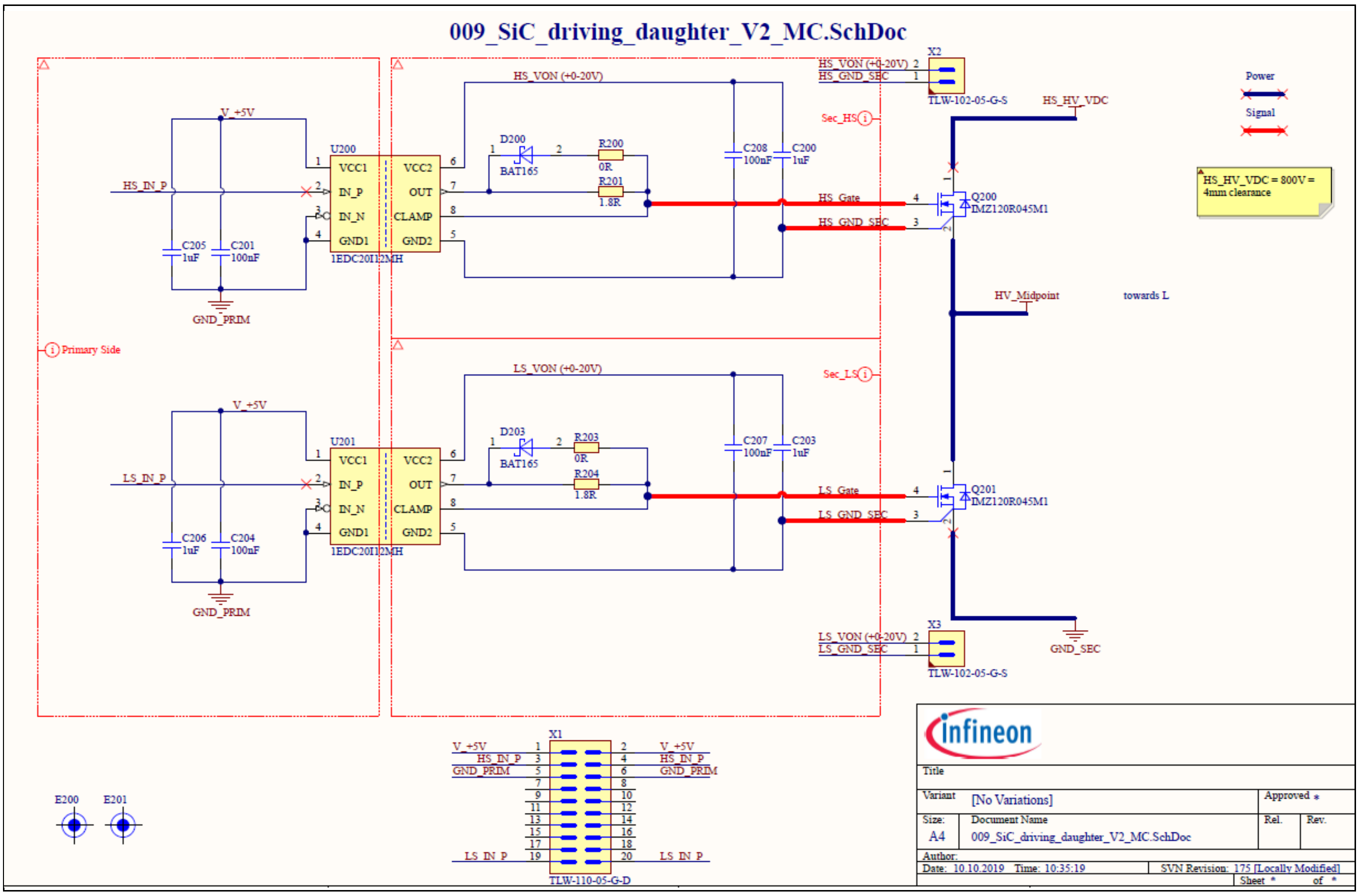


Figure 20 Driver board schematic- Miller clamp

8.3.2 Board Layout

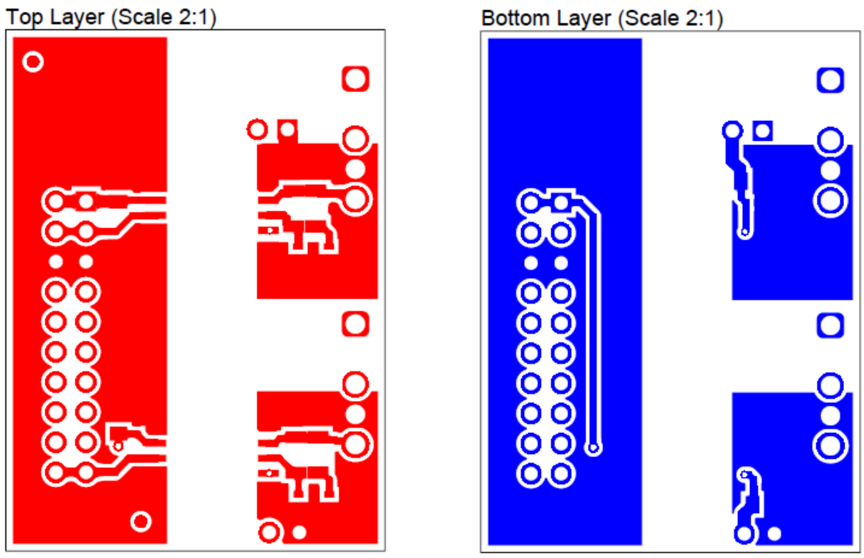


Figure 21 Driver board Miller Clamp Layout

8.3.3 Bill of material

Table 7

Designator	Comment	PackageReference	Voltage DC (max)	Quantity	Manufacturer	Manufacturer Order Number
C200, C203, C205, C206	1uF	0805	25V	4	AVX	08053D105KAT2A
C201, C204, C207, C208	100nF	0402 (1005)	16V	4	TDK Corporation	CGA2B1X7R1C104K050BC
D200, D203	BAT165	SOD323	na	2	Infineon Technologies	BAT165
R200, R203	0R	1206	200V	2	Vishay	CRCW12060000Z0
R201, R204	1.8R	1206	200V	2	Yageo	RC1206FR-071R8L
U200, U201	1EDC20I12MH	PG-DSO-8-59	na	2	Infineon Technologies	1EDC20I12MH
X1	TLW-110-05-G-D		na	1	Samtec	TLW-110-05-G-D
X2, X3	TLW-102-05-G-S		na	2	Samtec	TLW-102-05-G-S

9. References

[1] Infineon Technologies AG: AN_1801_PL52_1801_132230, PCB layout guidelines for MOSFET gate driver, Online

[2] Infineon Technologies AG: 1EDCxxI12AH and 1EDCxxH12AH Datasheet, Online

[3] Infineon Technologies AG: 1EDC20I12MH Datasheet, Online

[4] Infineon Technologies AG: AN2017-04, Advanced Gate Drive Options for Silicon Carbide (SiC) MOSFETs using EiceDRIVER™, Online

[5] Infineon Technologies AG: Guidelines for CoolSiC™ MOSFET gate drive voltage window, Online

10. Revision history

Document version	Date of release	Description of changes
Rev 1.0	2020-01-23	First release

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

Edition 2020-01-23
Published by
Infineon Technologies AG
81726 Munich, Germany

Do you have a question about this document?
Email: erratum@infineon.com

Document reference
AN2019-28