User Manual for HPD GD BOARD G1 SiC

Gate Driver Board

About this document

Scope and purpose

This application note describes the features of and how to operate the evaluation gate driver board **HPD GD BOARD G1 SiC** for HybridPACK™ Drive CoolSiC™ modules.

Intended audience

Experienced engineers designing gate drive boards for HybridPACK™ Drive CoolSiC™ modules.

Evaluation Board

This board is to be used during the design-in process for evaluating and measuring characteristic curves, and for checking datasheet specifications.

The evaluation gate driver board was designed to support customers during their first steps in designing applications with the HybridPACK™ Drive power module and gate driver EiceDRIVER™. An evaluation board is not intended to be an optimal design for every specific requirement. But it gives a good starting point and useful design hints for serial development. Furthermore, practical experience from the power module switching characteristic as well as the gate driver features can be obtained in the lab at a minimum effort by using such evaluation tools.

Note: PCB and auxiliary circuits are NOT optimized for final customer design.

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Safety precautions

Note: Please note the following warnings regarding the hazards associated with development systems.

Table 1 Safety precautions

	**Warning:** *The DC link potential of this board is up to 500 VDC. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	**Warning***: The evaluation or reference board 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.*
	**Warning:** *The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by oscilloscope. 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.*
	**Warning:** *Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. 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.*
	**Caution:** *The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.*
	**Caution:** *Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.*
	**Caution:** *The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.*
	**Caution:** *A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.*
	**Caution:** *The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.*

Table of Contents

1 How to order Gate Driver Boards (HPD GD BOARD G1 SiC)

The evaluation gate driver board *HPD GD BOARD G1 SiC*, compatible for HybridPACK™ Drive CoolSiC™ 1200V SiC modules FS0xMR12A6MA1x, can be ordered via Infineon Sales Partners:

- SAP ordering number for **HPD GD BOARD G1 SiC: SP005592047.**

The shipping content includes:

- ✓ Gate driver board compatible with FS0xMR12A6MA1x.
- ✓ Interface PCB.

The typical appearance of the gate driver board is shown in Figure 1, where also the small interface PCB can be seen. This interface PCB provides a 1-1 connection to the 80pin signal connector and can be used to connect to a MCU board (not included).

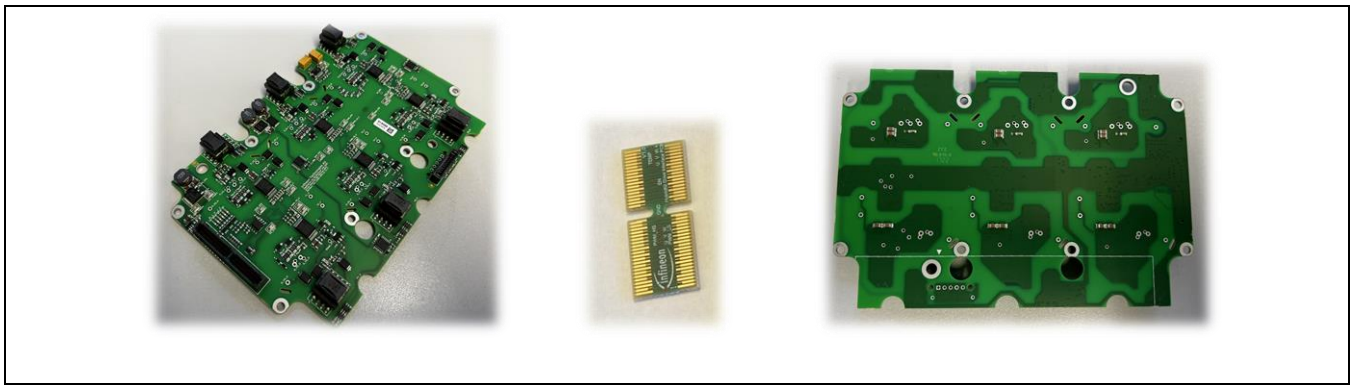


Figure 1 Typical appearance of the gate driver evaluation board HPD GD BOARD G1 SiC (SP005592047) from the side, top, and bottom view.

2 Feature and Limitations Overview

The evaluation gate driver board HPD GD BOARD G1 SiC is an isolated six-channel gate driver board dedicated for the evaluation purpose of HybridPACK™ Drive CoolSiC™ modules. It comes with Infineon automotive EiceDRIVER™ gate driver ICs. The evaluation gate driver board supports the customers in their first steps designing applications with HybridPACK™ Drive CoolSiC™ or EiceDRIVER™.

2.1 Block Diagram & Key Features

Figure 2 shows the block diagram of the gate driver board with simplified signal and power flow.

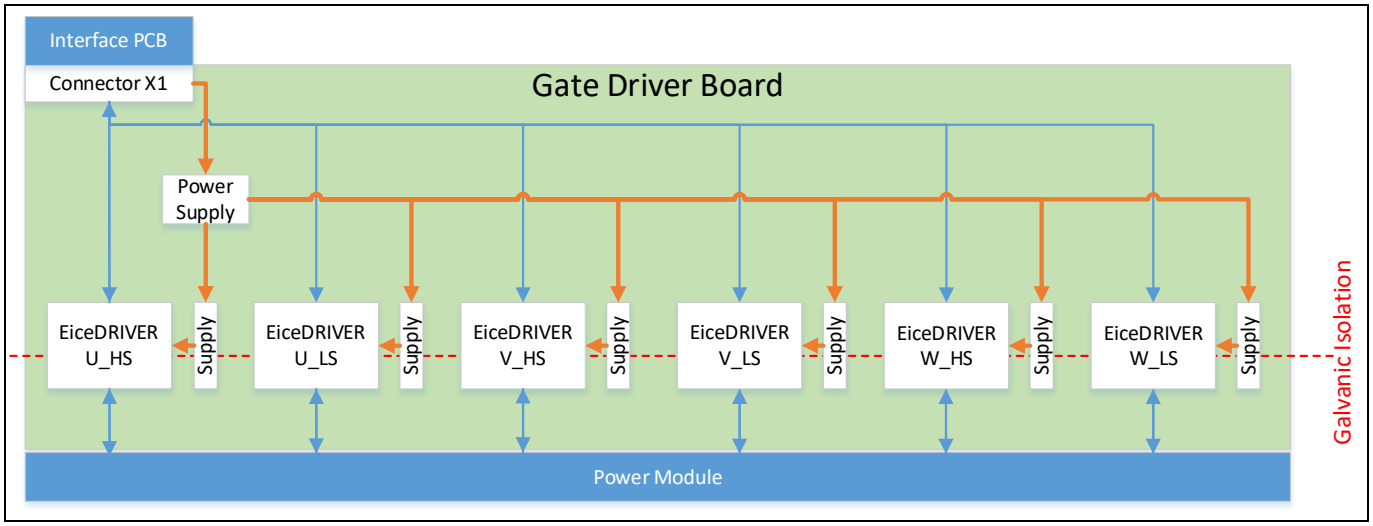


Figure 2 Simplified block diagram of the gate driver board.

The key features can be summarized:

- 6x isolated gate driver channels compatible for HybridPACK™ Drive CoolSiC™ power modules with 1200V SiC chipset (FS0xMR12A6MA1x)
- Gate driver solution based on EiceDRIVER™ 1EDI3033AS
- SiC desaturation (short circuit) detection
- DC-Link voltage measurement featured by ADC of EiceDRIVER™
- NTC temperature measurement featured by ADC of EiceDRIVER™
- Power supply with reverse polarity protection for 8..18V input voltage featured by TLE8386-2EL
- 6x isolated power supply for +15V/-5V gate driver supply
- High clearance, creepage distance design, suitable up to 500V working voltage according to IEC 60664-1

2.2 Recommended Operating Conditions

The following recommended operating conditions describe the targeted lab testing environment.
Testing beyond the given area may be possible in specific cases when all individual parts are driven within their specification. On the other hand, the evaluation gate driver board together with the power module should not be regarded as a protected system. It is not a considered product for end customers. The evaluation gate driver board is to support engineers in their first steps designing with the Infineon EiceDRIVER™ and HybridPACK™ Drive CoolSiC™. Please see also section 2.3 only to understand the limitations.

Table 2 Operating Conditions

Type	Symb	Min	Max	Conditions
Gate Driver Board Supply	V_{supply}	8V	18V	
Working Voltage Capacitor DC-Link Voltage	V_{DC}	0V	500V	Gate driver board's creepage and clearance distances comply with norm IEC-60664-1 for 500V.
Ambient Temperature	T_{amb}	0°C	75°C	Use fan for testing >75°C.
Switching frequency	f_{sw}		20kHz	Limited by PCB temperature. A higher f_{sw} is achievable at low ambient temperature or active cooling like a fan

The operating temperature is mainly limited by the power dissipation of the power supply implemented on the gate driver board. The gate drivers, gate resistances are not the limitation in this design.

2.3 Limitations of the Evaluation Kit

The gate driver board with the power module should not be regarded as a protected system. It was designed for evaluation under lab conditions with minimum automatic shutdown routines. The design was intended to be usable also under extreme conditions where protection mechanisms would limit the evaluation possibilities. The evaluation gate driver board is not protected against:

- Over- & under- voltages on the signal connectors.
- Overvoltages of the HV working voltage.
- Overtemperature of the PCB and module.
  The power module NTC temperature info can be obtained by ADC feature, but no shutdown limit is set by the gate driver board.
- Testing at high switching frequencies may require an active cooling of the gate driver board, especially at high ambient temperature.
- **Please read and understand the manual and the safety precautions.**

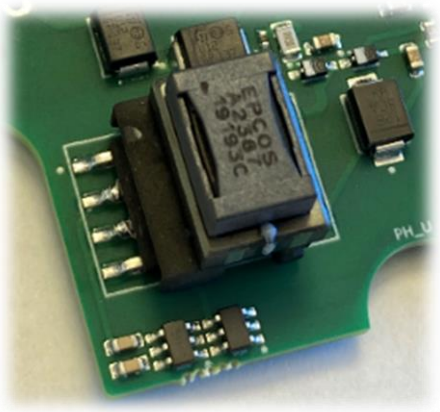
Please note that the list are giving examples and should not be seen exhaustive.

2.4 Key Components List

Some key components can be found in Table 3. The gate driver board uses more active and passive components which are not listed here.

Table 3 Key components list

Part Number	Manufacturer	Description / Implementation
1EDI3033AS	Infineon Technologies AG	Automotive Isolated Gate Driver EiceDRIVER™
TLE8386-2EL	Infineon Technologies AG	Automotive SMPS controller used in 500kHz SEPIC converter
IPG20N06S4L-26	Infineon Technologies AG	Automotive Optimos used in 500kHz SEPIC converter
BSL207SP	Infineon Technologies AG	Automotive p-channel MOSFET used for reverse polarity protection
TLE7274-2D	Infineon Technologies AG	Automotive LDO linear 5V regulator used for driver input supply
IND784775122	Würth	Automotive Power Inductor (used in 500kHz SEPIC converter)
P301085-A2 (B78308-A2387-A003)	TDK/Epcos	Automotive Transformer 1:1.07 for isolated bipolar gate drive supply with 10mm creepage distance



B78308-A2387-A003

Figure 3 TDK/Epcos Transformer P301085-A2 (B78308-A2387-A003) with 10mm creepage distance

3 Quickstart Guide

This chapter explains briefly the recommended lab equipment and how the gate drivers can be switched.

3.1 Recommended equipment for evaluation

To evaluate the gate driver board and HybridPACK™ Drive modules, the following equipment is minimum recommended.

- Power Supply: 8-18V, 2A
- Signal pulse generator with 0V...5V output
- 4 channel oscilloscope
- Load: HybridPACK™ Drive CoolSiC™ FS0xMR12A6MA1x.

See application note “assembly instructions” for correct PCB and power module assembly [1].

3.2 Interface and Testpad Description

3.2.1 Signal Connector X1 & Interface PCB

The evaluation gate driver board is equipped with a Samtec board to board connector. It is compatible with the Infineon Aurix Microcontroller logic board, which is used for all HybridKits. The small interface PCB is designed as 1:1 connector.

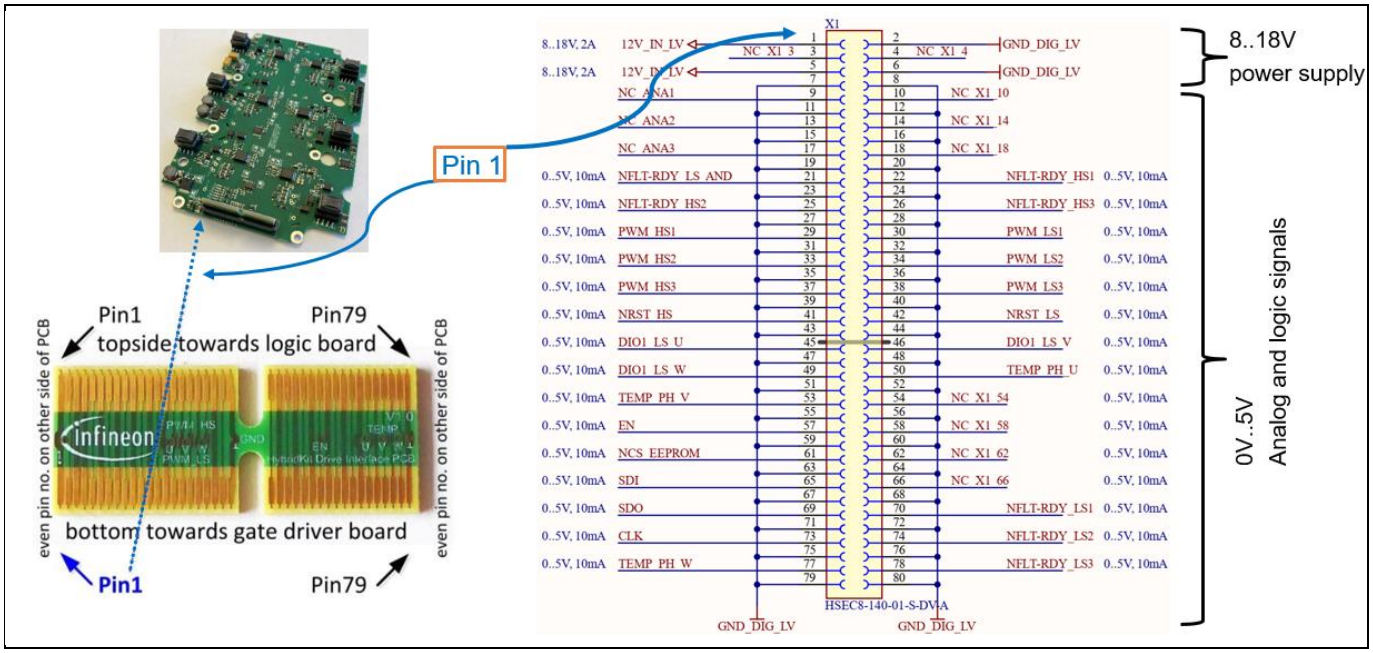
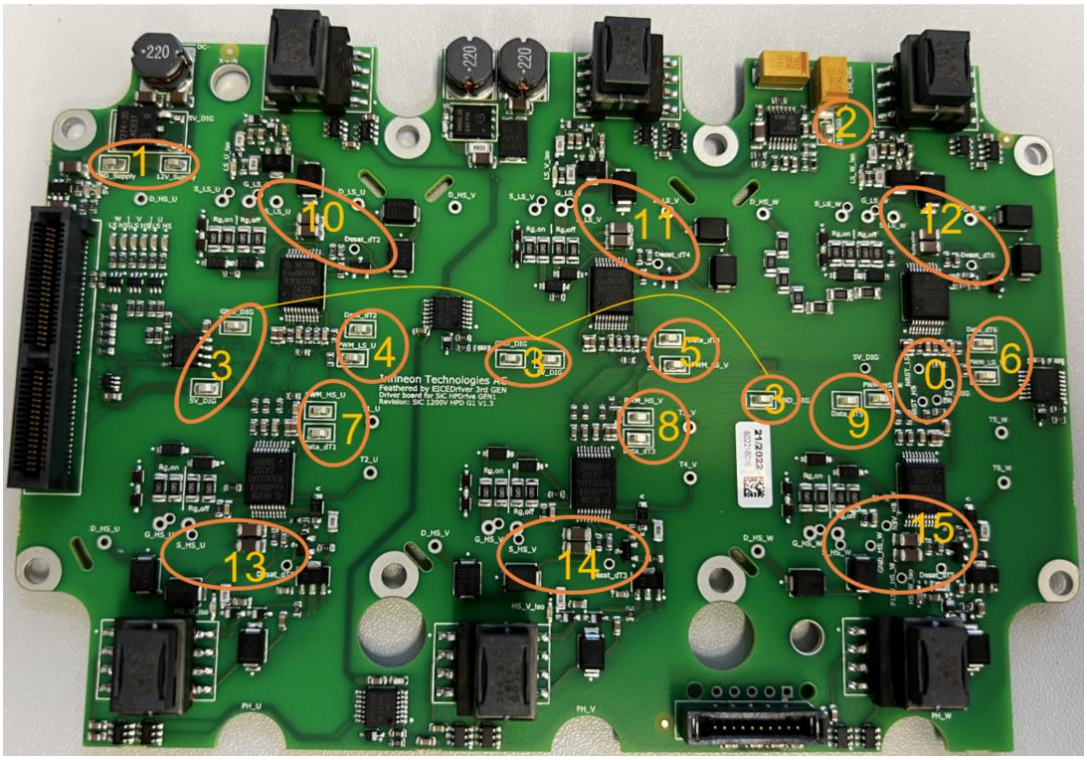


Figure 4 Board to board signal connector and pinout.

3.2.2 Overview of Test pads

The gate driver board is equipped with several test pads. These test pads are located across the whole board, each with a signal marking. Figure 5 and Table 4 give an overview of the available test pads.

a)



b)

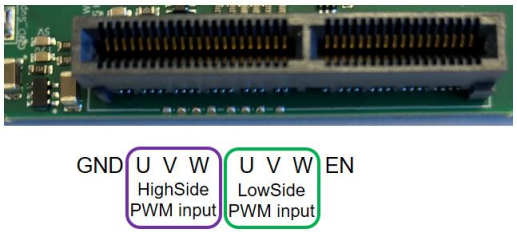


Figure 5 The test pad areas indicated on the gate driver board (a). See Table 4 for a description. Important test pads are positioned also at the side of the signal connector (b).

Table 4 Testpad overview

Category	Area No.	Testpad Marking	Description
Primary side DC power supply	1	12V_Supply	DC voltage supply to the board 8..18V (2A)
		GND_Supply	
	2	15V_DIG	Pre-regulated output voltage of 15V
	3	GND_DIG	GND (testpad quantity: 3)
		5V_DIG	Regulated 5V (testpad quantity: 2)
Primary side EiceDRIVE™ signals	4	PWM_LS_U Data_dT2	phase U low-side (LS_U): PWM input Data signal
	5	PWM_LS_V Data_dT4	phase V low-side (LS_V): PWM input Data signal
	6	PWM_LS_W Data_dT6	phase W low-side (LS_W): PWM input Data signal

	7	PWM_HS_U Data_dT1	phase U low-side (HS_U): PWM input Data signal
	8	PWM_HS_V Data_dT3	phase V low-side (HS_V): PWM input Data signal
	9	PWM_HS_W Data_dT5	phase W low-side (HS_W): PWM input Data signal
	0	NRST_HS NRST_LS EN	Reset signal of all three high-side EiceDRIVER ICs Reset signal of all three low-side EiceDRIVER ICs Enable signal of all six EiceDRIVER ICs
Secondary side (isolated)	10	Desat_dT2 S_LS_U	phase U low-side (LS_U): Desat signal Ground
	11	Desat_dT4 S_LS_V	phase V low-side (LS_V): Desat signal Ground
	12	Desat_dT6 S_LS_W	phase W low-side (LS_W): Desat signal Ground
	13	Desat_dT1 S_HS_U	phase U high-side (HS_U): Desat signal Ground
	14	Desat_dT3 S_HS_V	phase V high-side (HS_V): Desat signal Ground
	15	Desat_dT5 S_HS_W GND_HS_W P15_HS_W N5V_HS_W	phase W high-side (HS_W): Desat signal Ground Ground 15V -5V

3.3 Power Supply to the Gate Driver Board

The gate driver board requires a DC voltage supply between 8V and 18V for the operation. For a long testing time, a DC voltage at about 14V is recommended.
The voltage supply can be connected to the interface connector X1, where pin 1 or 5 for “+” polarity, pin 2 or 6 for “GND” polarity. By this method, reverse polarity protection is implemented. Alternatively, the voltage supply can be connected directly on the PCB test pads marked “12V_Supply” and “GND_Supply”. **Please respect the right supply polarity when using the test pads!**

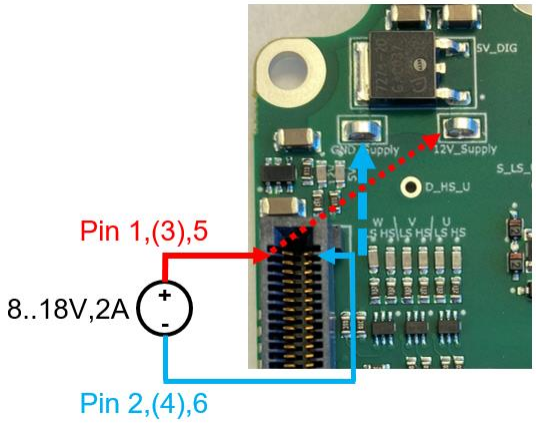


Figure 6 The gate driver board can be supplied from the signal connector e.g. via the interface PCB (reverse polarity protected) or alternative directly on the PCB test pads. Please respect the right supply polarity when using the test pads!

The two green LEDs (marked with “12V” and “5V” on the PCB top located of the connector) indicate the correct power supply of the gate driver board.

3.4 Double Pulse Test (without a MCU board)

3.4.1 Enabling gate driver EiceDRIVER™

The evaluation gate driver board is designed with the new automotive gate driver EiceDRIVER™ 1EDI3033AS. For first evaluation tests, like the double pulse test, it is possible to operate the gate driver board without a MCU board. To enable EiceDRIVER™, the following two steps need to be performed sequentially. Figure 7 shows the position of necessary signal pins of signal connector X1 and corresponding test pads for the EiceDRIVER™ enabling process.

1. apply low to high (0V→ 5V) transition signal to test pad NRST_HS (or pin 41) and test pad NRST_LS (or pin 42), then this transition signal can be removed. This transitions the driver into “Ready Mode”;
2. connect 5V signal to test pad EN (or pin 57) to enable PWM switching by transitioning the driver into “Normal Mode”.

Figure 8 shows the operating modes state diagram of EiceDRIVER™ 1EDI3033AS. For a detailed representation of the different driver operating modes please refer to the 1EDI3033AS datasheet.

The ground potential of this 5V signal is the same as the DC voltage supply described in section 3.3. After performing the two steps, six green LEDs (marked as “W LS HS/V LS HS/U LS HS” close to signal connector X1, referring to Figure 6) are on, indicating the gate driver board is ready.

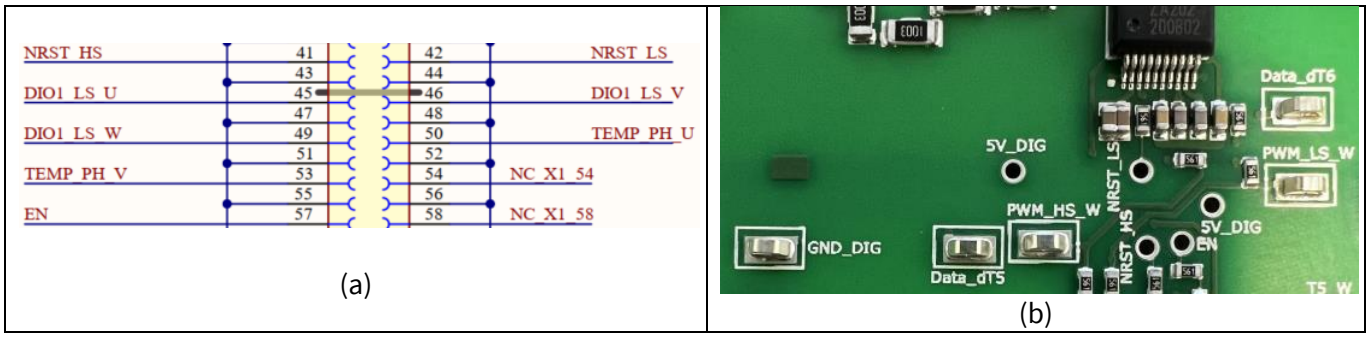


Figure 7 (a) position of pins 41 (NRST_HS), 42 (NRST_LS) and 57 (EN) of signal connector X1 for EiceDRIVER™ enabling process; (b) corresponding test pads of signals NRST_HS, NRST_LS, and EN.

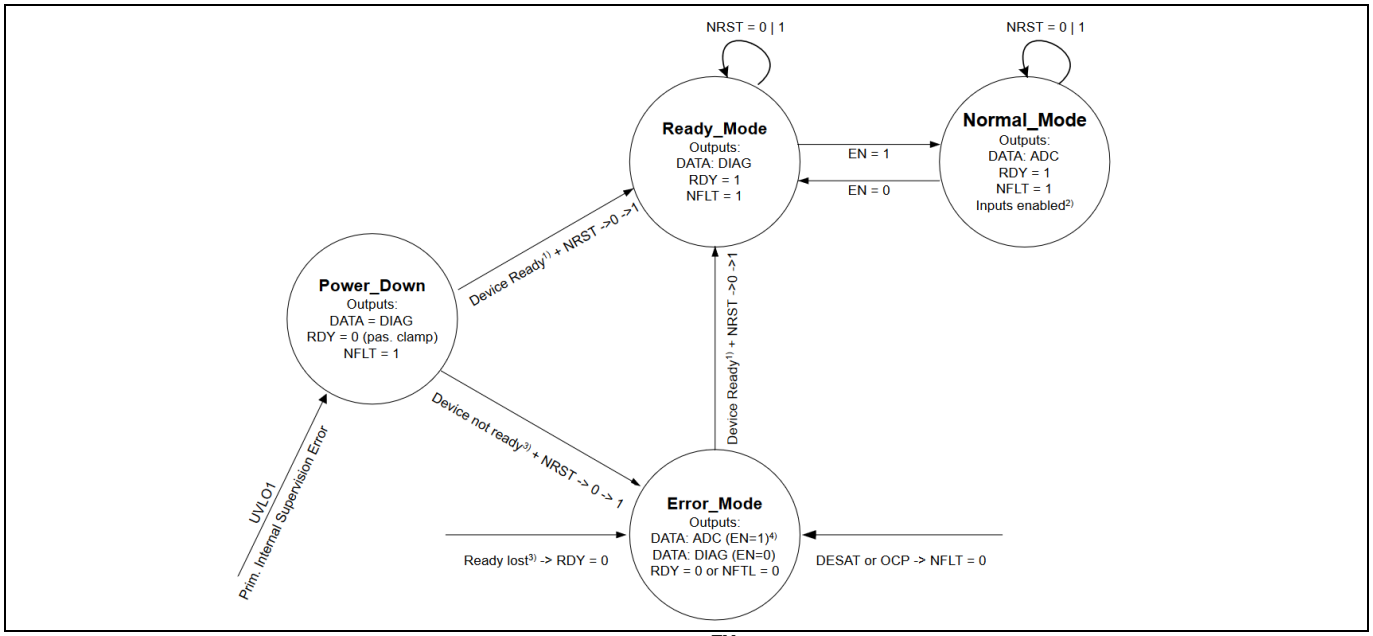


Figure 8 Operating modes state diagram of EiceDRIVER™ 1EDI3033AS. Refer to datasheet for more detail.

3.4.2 Switching the gate driver

After the EiceD3RIVER™ is enabled (section 3.4.1), it is ready to switch the EiceDRIVER™ with e.g. a pulse generator. Now the gate can be controlled by the PWM signal:

- Connect 5V PWM signal to PWM_xx pins in signal connector X1 or to PWM_xx test pads shown in Figure 5 and Table 4.

The ground potential of this 5V PWM signal is the same as the DC voltage supply described in section 3.3.

3.4.3 Gate resistance

An essential feature of the CoolSiC™ MOSFET is that both voltage slopes for turn-on and turn-off are fully controllable by the external gate resistor. To cope with any dv/dt limitations required by the system, combined with the right driver circuit, different external gate resistors can be used for turn-on and turn-off. This allows setting switching speeds for turn-on and turn-off independently.

As shown in Figure 9, turn-on resistance Rgon consists of two resistors in parallel connection, turn-off resistance Rgoff consists of another two resistors in parallel connection. By default setting, both Rgon and Rgoff are configured to be 5Ω.

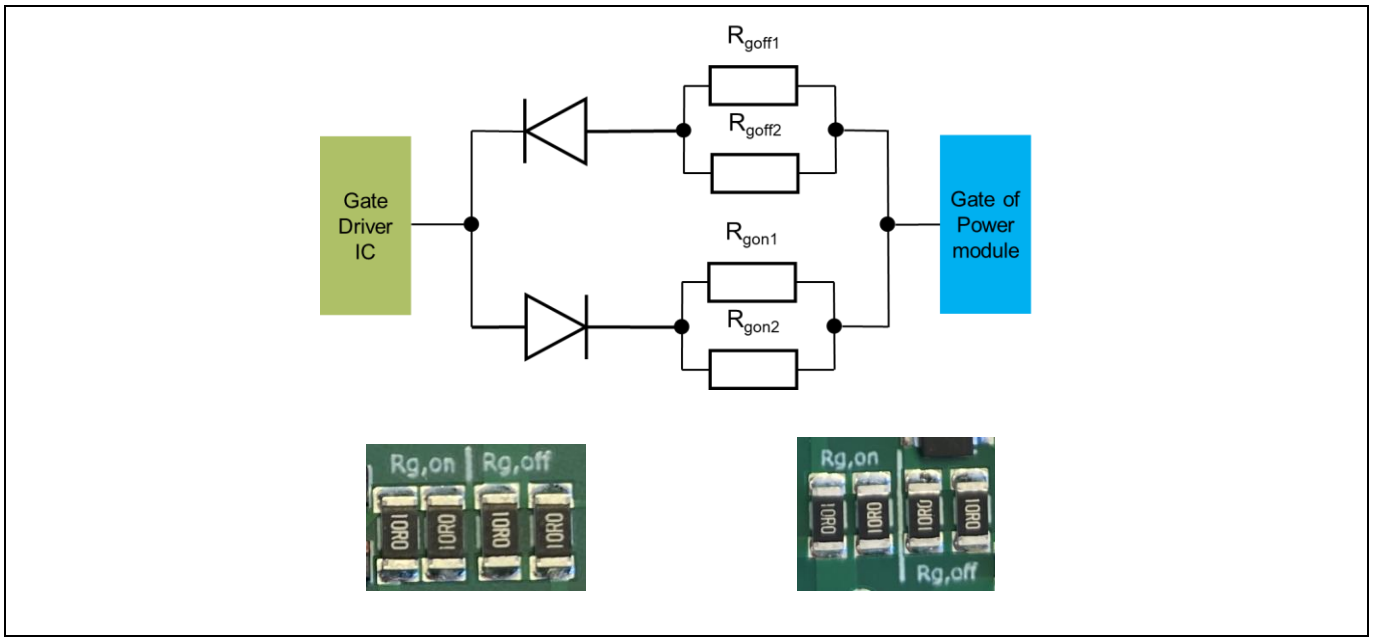


Figure 9 Turn-on and turn-off speed can be controlled independently by configuring gate resistors

3.5 Monitoring feature

3.5.1 LED diagnosis

This gate driver board integrated 15 LEDs providing some diagnosis information of the board. These LEDs are located across the whole board, each with a marking. If an LED is on, it indicates the corresponding function or feature is in order. If an LED is off, it indicates the corresponding function or feature has a fault.

Table 5 List of LEDs

Category	LED Marking	Description
Primary side DC power supply	12V	DC voltage supply to the board
	5V	5V generated from the DC voltage supply
	15V_DIG	Pre-regulated output voltage of 15V
Secondary side (isolated) DC power supply	LS_U _iso	Isolated DC voltage supply at phase U low-side
	LS_V _iso	Isolated DC voltage supply at phase V low-side
	LS_W _iso	Isolated DC voltage supply at phase W low-side
	HS_U _iso	Isolated DC voltage supply at phase U high-side
	HS_V _iso	Isolated DC voltage supply at phase V high-side
	HS_W _iso	Isolated DC voltage supply at phase W high-side
Primary side diagnosis of NFLT and RDY signals	W LS	When an LED is on, NFLT=RDY=1 of corresponding EiceDRIVER™, it is in order; When an LED is off, NFLT=0 or RDY=0 of corresponding EiceDRIVER™, there is a fault.
	W HS	
	V LS	
	V HS	
	U LS	
	U HS	

3.5.2 DESAT protection

Detection of Short Circuit (desaturation) or MOSFET open: a desaturation (DESAT) event happens, the gate driver performs a safe turn-off and transitions into “Error Mode” to prevent from performing output pulses. It can be reactivated by the following step:

- apply low to high (0V→ 5V) transition signal to pin 41 (NRST_HS) and pin 42 (NRST_LS). This will clear the error and transition the driver back into “Normal Mode”. The transition signal can be removed afterwards.

3.5.3 Fault signal NFLT and ready signal RDY

Fault signal NFLT and ready signal RDY of a gate driver IC are connected, generating a logic “AND” signal as shown in Figure 10. These “AND” signals are listed in Table 6, and are accessible from signal connector X1 as shown in Figure 4.

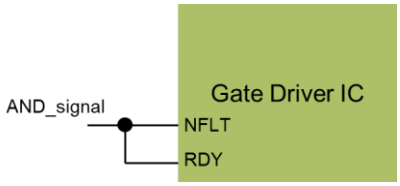


Figure 10 NFLT and RDY signals connection

Table 6 NFLT-RDY signal pins on Signal connector X1

Pin name	Pin #	Description
NFLT-RDY_HS1	22	U phase High-side: NFLT RDY “AND” signal
NFLT-RDY_HS2	25	V phase High-side: NFLT RDY “AND” signal
NFLT-RDY_HS3	26	W phase High-side: NFLT RDY “AND” signal
NFLT-RDY_LS1	70	U phase Low-side: NFLT RDY “AND” signal
NFLT-RDY_LS2	74	V phase Low-side: NFLT RDY “AND” signal
NFLT-RDY_LS3	78	W phase Low-side: NFLT RDY “AND” signal
NFLT-RDY_LS_AND	21	Logic “AND” signal out of three NFLT RDY “AND” Low-side signals

3.6 NTC temperature and DC-Link voltage Measurement

The gate driver EiceDRIVER™ has an ADC to measure DC-Link voltage or NTC temperature. The gate driver board has in total six EiceDRIVER™ ICs. Three EiceDRIVER™ ICs measure NTC temperature of three phases U, V and W. One EiceDRIVER™ ICs measures DC-Link voltage of phase W.
Details of six ADC output DATA pins can be found in Table 7. Figure 11 shows six EiceDRIVER™ ICs locations on the board.

Table 7 Connector X1 signal pins and their corresponding DATA pins

Connector X1 pin	DATA pin of EiceDRIVER™ IC	Description
DIO1_LS_U	U_LS: Phase U low-side	-
DIO1_LS_V	V_LS: Phase V low-side	-
DIO1_LS_W	W_LS: Phase W low-side	DC-Link voltage sensing
TEMP_PH_U	U_HS: Phase U high-side	NTC temperature sensing (phase U)
TEMP_PH_V	V_HS: Phase V high-side	NTC temperature sensing (phase V)
TEMP_PH_W	W_HS: Phase W high-side	NTC temperature sensing (phase W)

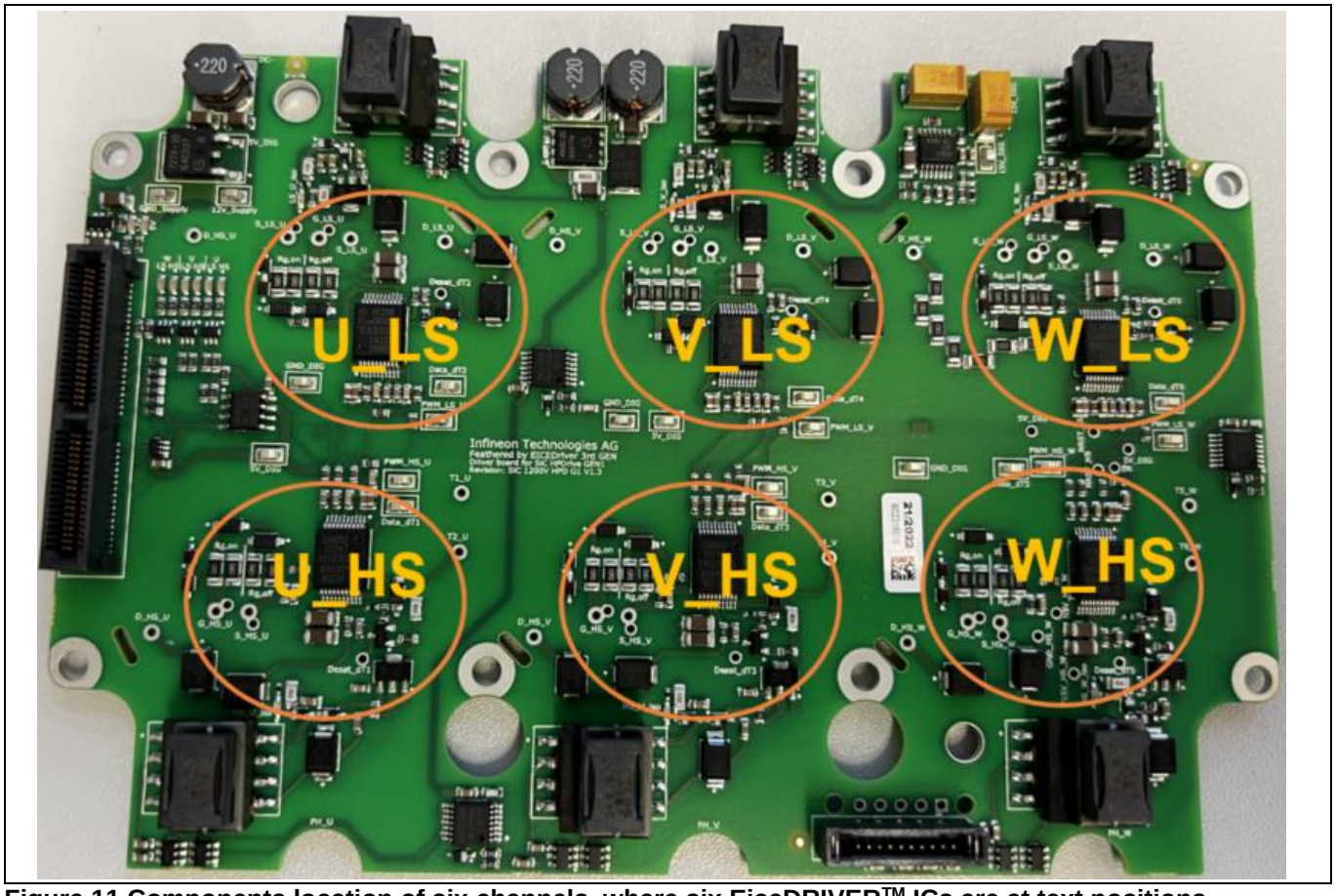


Figure 11 Components location of six channels, where six EiceDRIVER™ ICs are at text positions

3.6.1 NTC temperature measurement

The HybridPACK™ Drive modules contain NTC resistors, which have specified resistance value as a function of the temperature. The main challenge is to get this signal robust and with a good resolution to the microcontroller. Furthermore, as the NTC is very close to the high voltage switching MOSFETs such an NTC should be isolated because in case of severe system failures, arcing for example can cause high voltage potentials on

the NTC which has to be isolated from the microcontroller for safety reasons. Digital signals are much easier to transfer via galvanic isolated barriers compared to analog signals.
The integrated ADC of gate driver EiceDRIVER™ allows isolated temperature sensing. The NTC resistance value is converted to a voltage level by a voltage divider circuit. A typical NTC sensing circuit is shown in Figure 12. On this gate driver board, a resistor R_{pu1} of 1.6kΩ and a Zener diode of 4.7V regulate VCC2 voltage to 4.7V, a resistor R_{pu2} has a value of 3kΩ. The voltage signal V_{AIP} is encoded to a PWM signal that is passed through the isolation to the DATA pin on the primary side. The gate driver acts as a galvanic isolation barrier.

As a reference, Table 8 provides typical values of AIP pin sensed voltage level and its corresponding NTC temperature.

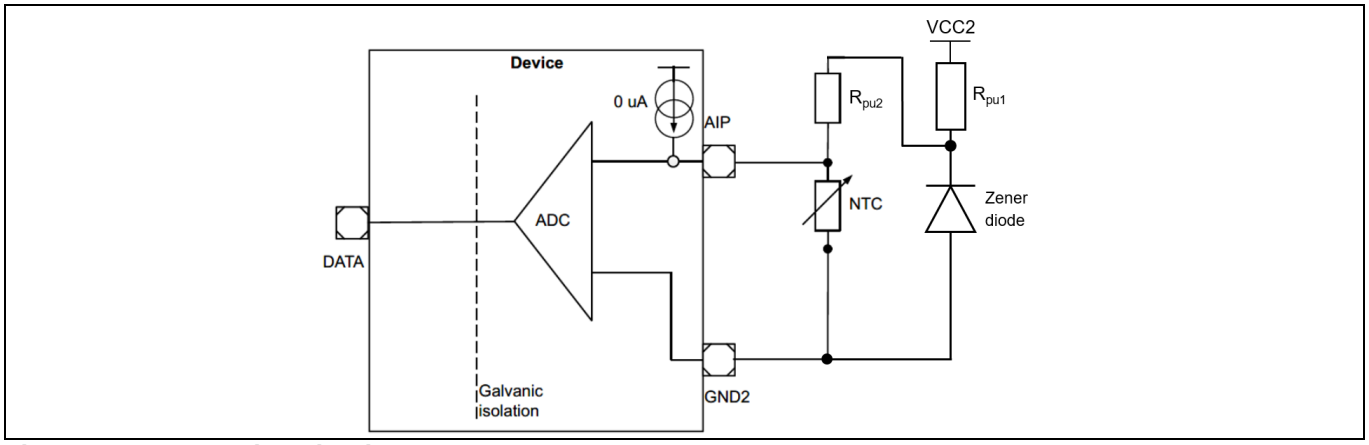


Figure 12 NTC sensing circuit

Table 8 AIP pin sensed voltage level and its corresponding NTC temperature (typical values)

Temperature [°C]	-40	0	25	40	60	80	100	120	130
AIP voltage [V]	4.58	3.87	2.94	2.31	1.57	1.03	0.66	0.44	0.36

3.6.2 DC-Link voltage measurement

Similarly, the integrated ADC of gate driver EiceDRIVER™ allows the measurement of the DC-Link voltage. The voltage divider circuit is shown in Figure 13. In the gate driver board, resistor R_{div1} has a value of 700kΩ, while R_{div2} is of 2.6kΩ, which gives a DC-Link voltage sensing ratio of $\frac{R_{div2}}{R_{div1}+R_{div2}} \cong 0.0037$.

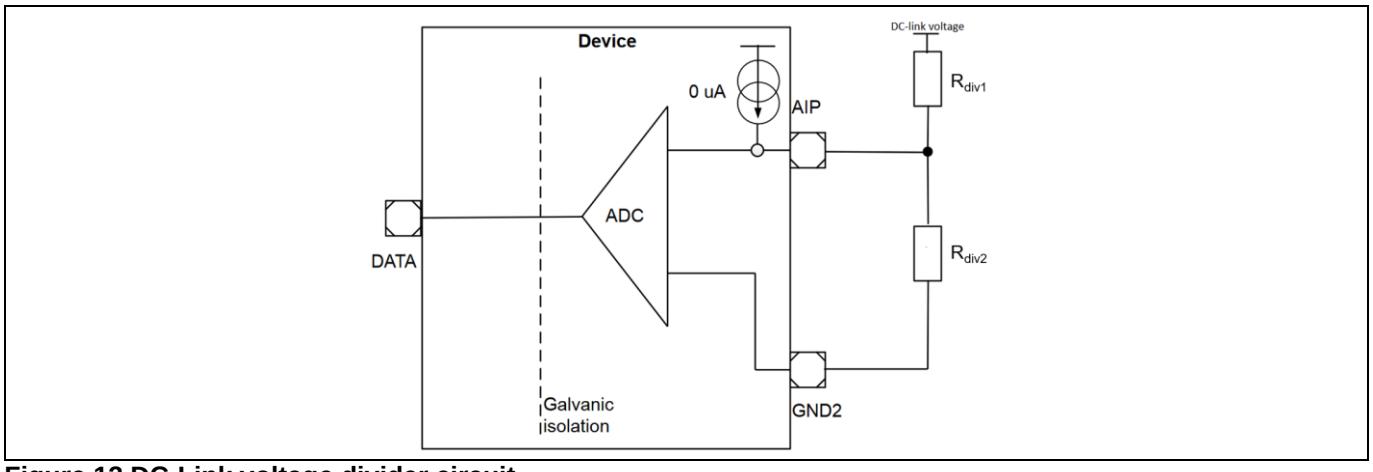


Figure 13 DC-Link voltage divider circuit

4 References and Revision History

The referenced application notes can be found at http://www.infineon.com

[1] Infineon Application Note AN-HPDPERF-ASSEMBLY, “Assembly Instructions for the HybridPACK Drive Performance”.

[2] Infineon Application Note AN-HPDKIT-QUICKSTART, “HybridKit Drive Quickstart Guide”.

[3] Infineon Application Note AN-HPDKIT-ADVANCED-FEATURES, “HybridKit Drive Advanced Features”.

[4] Infineon Application Note AN-HPDKIT-GATEDRIVE, “HybridKit Evaluation Gate Driver Board for 1200V IGBT4”.

[5] Infineon Application Note Z8F80039908, “EiceDRIVER 1EDI302xAS/ EiceDRIVER 1EDI303xAS”.

Revision History

Date	Version	Changed By	Change Description
2022-May	1.0	Dehuai Jiang (IFAG ATV HP HMD TM)	Initial Version

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