1SP0440V2M0C
SCALE™-2 Driver Family

Plug-and-Play Gate Driver for Driving
4500 V IHV Power Modules via
Optical I/O Interface

Product Highlights

Highly Integrated, Compact Footprint

- Ready-to-use gate driver solution for IHV IGBTs with 4500 V blocking voltage
- Single channel plug-and-play gate driver
- 25V gate voltage in on-state
- 1 W output power per channel at maximum ambient temperature
- ±25 A peak output gate current
- Short circuit protection by semiconductor's di_C/dt monitoring and desaturation effect
- Operation altitude up to 2000 m
- Optical interface
- - 40 °C to 85 °C operating ambient temperature

Protection / Safety Features

- Short circuit protection
- Dynamic Advanced Active Clamping (DA²C)
- Undervoltage lock-out (UVLO)
- Applied double sided conformal coating with a typical thickness of 50µm using ELPEGUARD SL 1307 FLZ/2 from Lackwerke Peters

Comprehensive Safety and Regulatory Compliance

- RoHS compliant

Applications

- VSC-HVDC

Description

The plug-and-play 1SP0440V2M0C gate driver is based on the SCALE™-2 chip set. It is optimized for the operation of 4500 V IHV IGBT power modules with 25V gate voltage in on-state.

The gate driver features optical interfaces. The power supply (isolated DC-DC converter ISO5125R-45) has not been integrated in the driver and needs to be purchased as seperate unit.

Power Integrations' Dynamic Advanced Active Clamping allows an extended DC-link voltage range in IGBT off-state for up to 60 s.

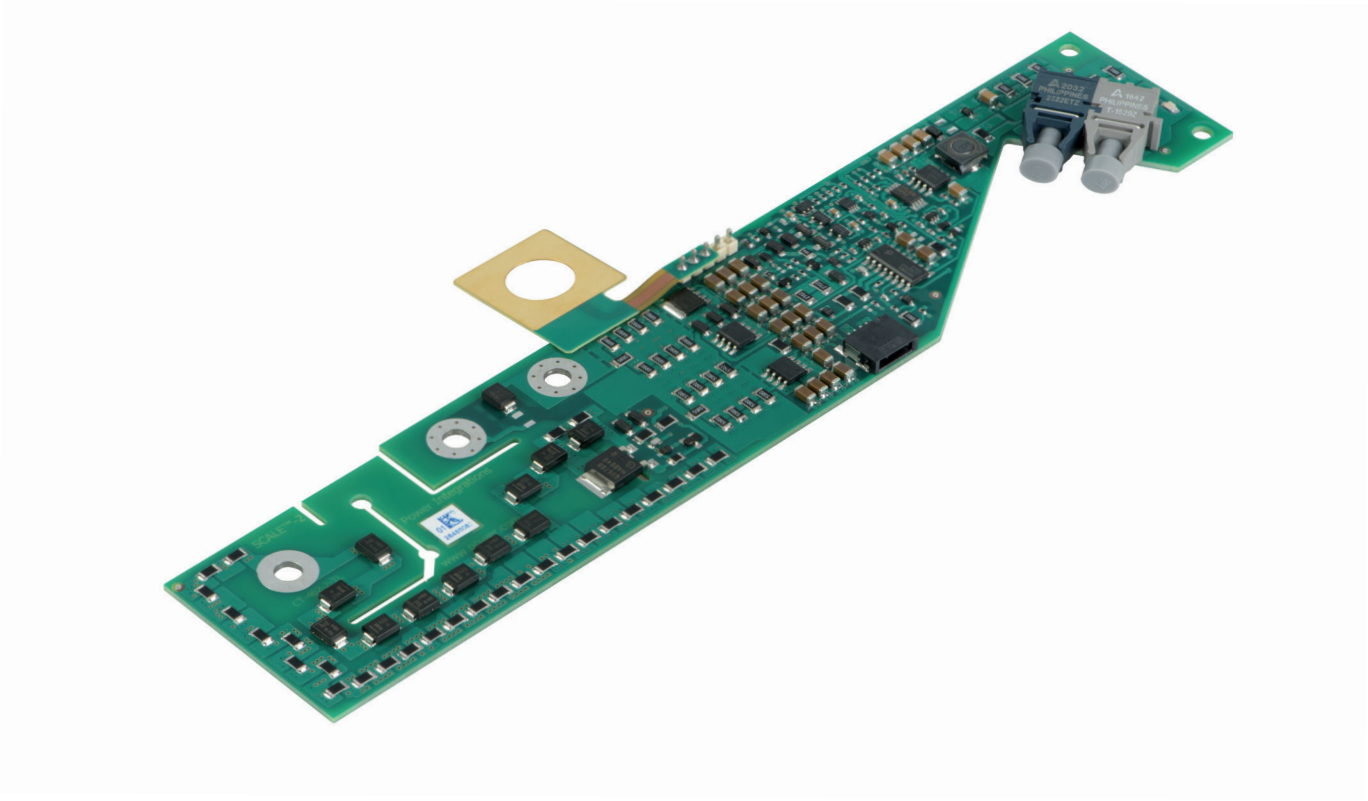

Figure 1. Board Photo of 1SP0440V2M0C.

Pin Functional Description

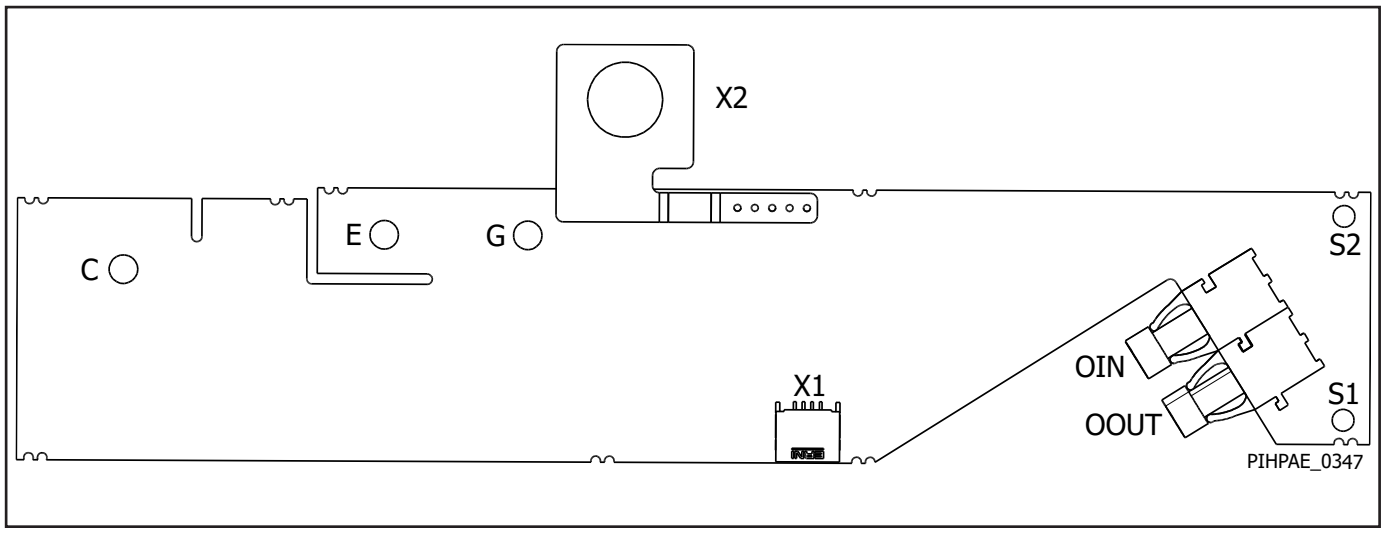

Figure 2. Pin Configuration.

Connector X1

ERNI MicroBridge 504255 interface to connect the driver to the external DC-DC converter ISO5125R-45.

VDC (Pins 2,3)
These pins are the 25 V supply voltage connection for the external DC-DC converter.

GND (Pins 1,4)
These pins are the connection for the supply ground potential.

Connector X2

Connection to the power emitter of the IGBT module which enables sensing the di_C/dt for the short circuit detection. The X2 connector is part of the product.

Fiber-Optic Interface

1SP0440V2M0C gate driver with the external controller (fiber optic receiver and transmitter).

OIN (Receiver)
This fiber optic receiver is the command input.
Part number: Broadcom HFBR-2522ETZ

OOUT (Transmitter)
This fiber optic transmitter is the status output.
Part number: Broadcom AFBR-1529Z

Connection to Semiconductor

Terminal C

Auxiliary collector contact of IGBT.

Terminal E

Auxiliary emitter contact of IGBT.

Terminal G

Gate contact of IGBT.

Screw Terminals S1, S2

Screw holes for mounting of the driver.

Functional Description

The 1SP0440V2M0C is a single channel Plug-and-Play gate driver for 4500 V high power IGBTs in IHM-B housings with $V_{GE(on)}$ = 25 V. As plug-and-play gate driver, the 1SP0440V2M0C characteristics match the requirements of the individual power module.

The driver 1SP0440V2M0C works as follows: It requires isolated 25V supply voltage at the input (e.g. delivered from ISO5125R-45). When a turn-on command is received, it turns on the IGBT with a gate voltage of 15V for about $t_{d(25V)}$. After that, the gate-emitter voltage is increased to 25V. The driver is equipped with the following features:

- Dynamic V_{CE} monitoring with di/dt monitoring (short-circuit protection)
- Dynamic Advanced Active Clamping DA^{2}C (overvoltage protection at turn-off)
- Gate clamping to positive rail
- Power supply monitoring

The power supply (isolated DC-DC converter ISO5125R-45) has not been integrated in the driver. It is a separate unit. All the components required for the optimal and safe driving of the relevant IGBT are included on the driver.

Plug-and-play capability means that the drivers are ready to operate immediately after mounting. The user does not need to invest any effort in designing or adjusting the driver to match a specific application.

Power Supplies

The connector X1 is used to connect the driver to DC-DC converter ISO5125R-45. The power supply and electrical isolation is provided by this external converter. The DC-DC converter needs a stabilized 15 V supply voltage. For recommended cable, please refer to data sheets RLC-PSI-641-050-0.

Screw Terminals

The gate driver 1SP0440V2M0C is mounted on top of the power module and fixed by screws.

Fiber Optic Receiver OIN

The input signal OIN is received by a "Versatile" fiber optic receiver. OIN has a positive logic (light on implies turn-on) and is edge triggered. The gate driver signal is transferred from the OIN receiver to the gate with a propagation delay of $t_{P(LH)}$ for the turn-on and $t_{P(HL)}$ for turn-off commands.

Fiber Optic Transmitter OOUT

During normal operation (i.e., the driver is supplied with power at nominal voltage, and there is no fault anywhere), the status feedback is given by a "light on" at the optical link. A fault condition is signalled by a "light off".

Each edge of the control signal is acknowledged by the driver with a short pulse (the light is off for a period of t_{ACK}). This pulse can be observed by the host controller and it allows for simple and continuous monitoring of all drivers and fiber-optic links in the system. Figure 3 shows the control and response signals of a gate driver during normal operation.

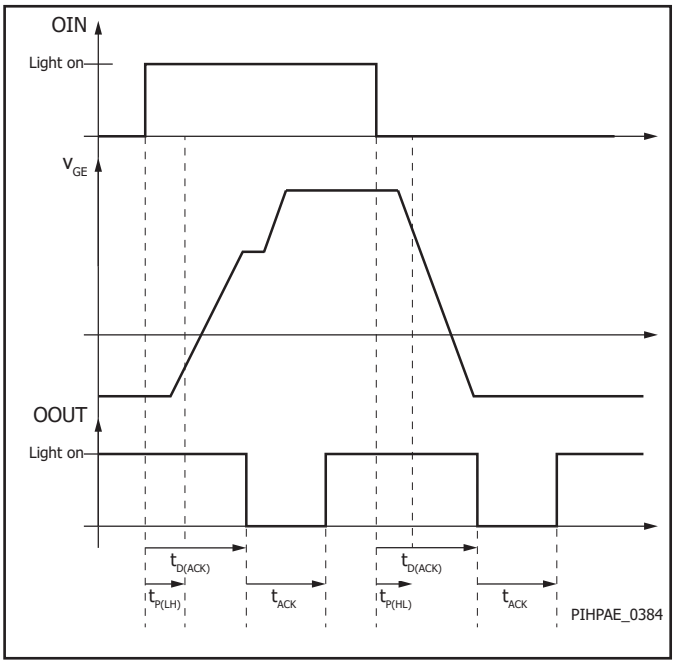

Figure 3. Fiber Optic Feedback in normal operation mode.

Undervoltage Monitoring

The supply voltages are closely monitored on 1SP0440V2M0C. In case of an UVLO, the fiber-optic signal OOUT is set to light-off and the corresponding power semiconductor is turned off. During fault condition, no gate signals are transmitted to the gate driver.

Figure 6 illustrates the timing of the fiber optic interface in a UVLO condition.

Short-Circuit Protection

The 1SP0440V2M0C monitors the collector di_C/dt together with the IGBT module desaturation to detect short-circuits of type 1 (SC1) and type 2 (SC2).

The IGBT external short-circuits are monitored via di_C/dt measurement only for SC2. This is achieved by sensing the power emitter of the IGBT using X2 connector. Di_C/dt protection is triggered when a typical voltage above 4 V is induced between the auxiliary and the power emitter. Considering a typical inductance of 2.5 nH between the auxiliary and the power emitter, this leads to a typical di_C/dt of 1.5 kA/µs. Di_C/dt is disabled at turn-on for $t_{(di/dt)(off)}$. When di_C/dt is detected, the driver reduces the external gate voltage to ~10 V to make the IGBT module short-circuit proof by allowing safe desaturation. If a desaturation is detected, the driver turns off the IGBT, otherwise, the driver increases the gate voltage back to 25 V after a specific time $t_{GE(LH)(25V)}$.

The desaturation is monitored on the driver by using a resistor sensing network. The collector-emitter voltage is checked after the response time t_{RES} at turn-on to detect a short-circuit. If the voltage is higher than the programmed threshold voltage $V_{CE(SAT)}$, the driver detects a short-circuit condition. The monitored power semiconductor is switched off after a delay of $t_{P(HL)(FAULT)}$ and a fault signal is transmitted via OOUT.

The fault feedback is automatically reset after the blocking time t_{BLK}. The semiconductor is turned on again as soon as the next on signal is applied to the corresponding fiber optic input OIN after the fault status has disappeared.

Figure 5 illustrates the timing of the fiber optic interface in SC1 condition.

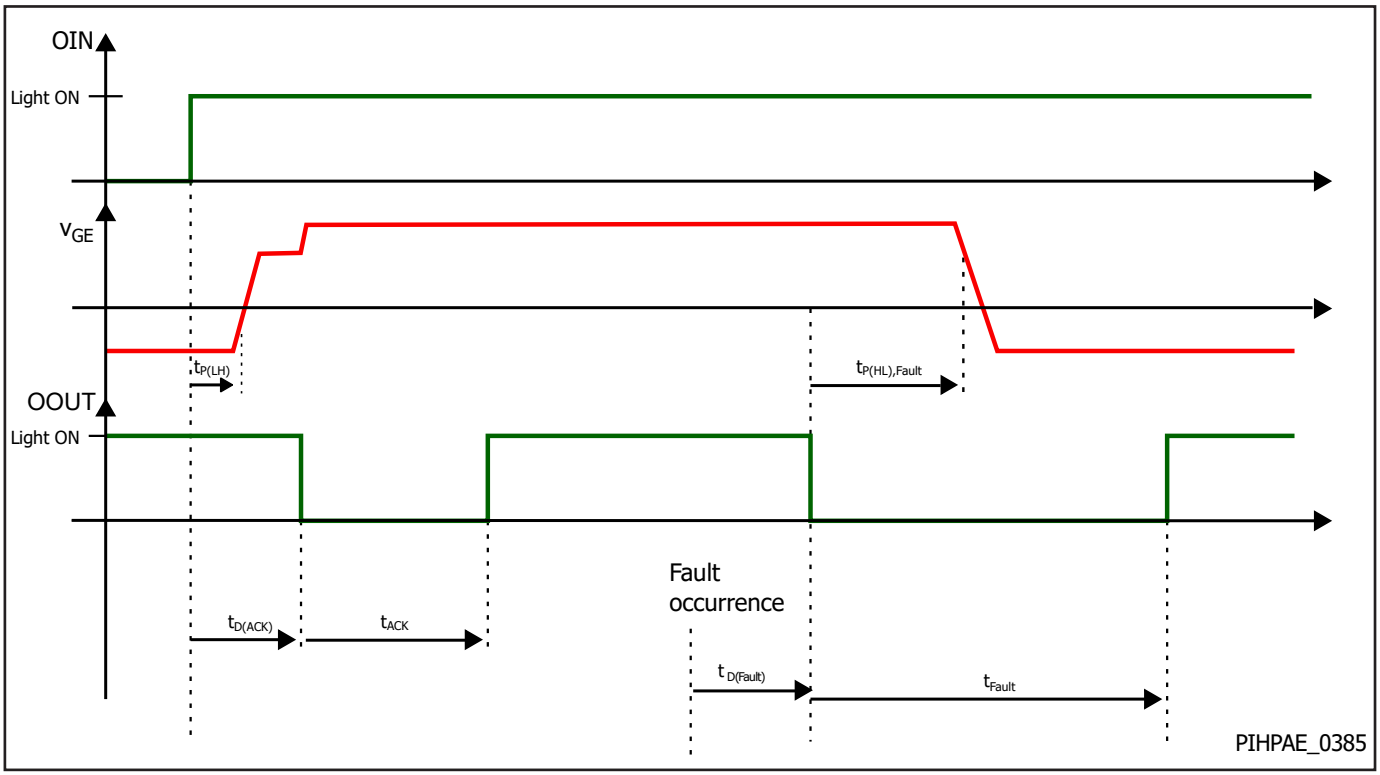

Figure 4. Fiber Optic Feedback in fault (UVLO) operation mode.

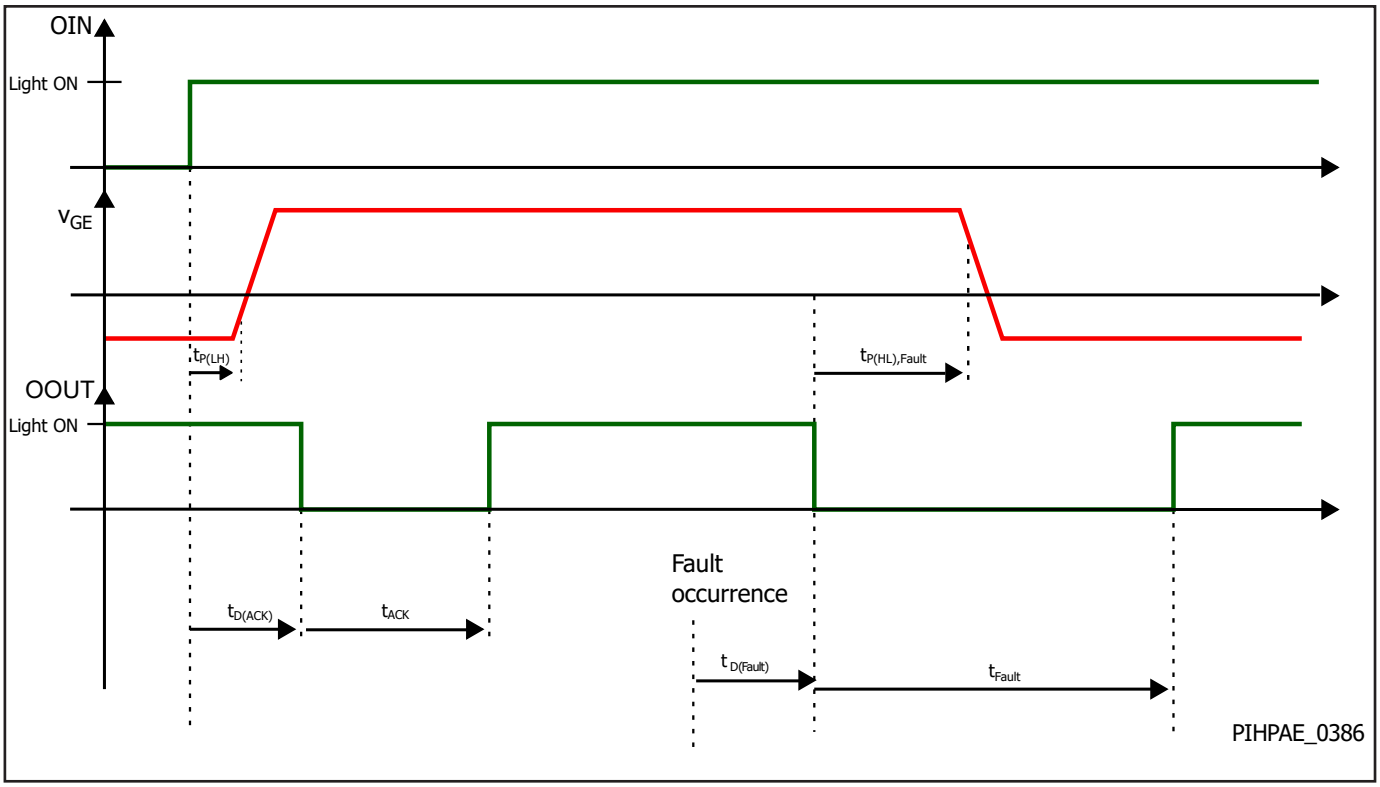

Figure 5. Fiber Optic Feedback in fault (SC1) operation mode.

Dynamic Advanced Active Clamping (DA²C)

Active clamping acts to partially turn on the IGBT in the event that the collector-emitter voltage exceeds a predefined threshold. The IGBT is then kept in linear operation. Basic active clamping topologies implement a single feedback path from the IGBT's collector through transient voltage suppressor (TVS) diodes to the IGBT gate. The gate driver in 1SP0440V2M0C contains Power Integrations' Dynamic Advanced Active Clamping (DA²C) that operates as follows:

When active clamping is activated, the turn-off MOSFET for the gate driver is switched off in order to improve the effectiveness of the active clamping and to reduce the losses in the TVS diodes. This feature is called as Advanced Active Clamping (AAC). The principle of AAC is illustrated in Figure 6.

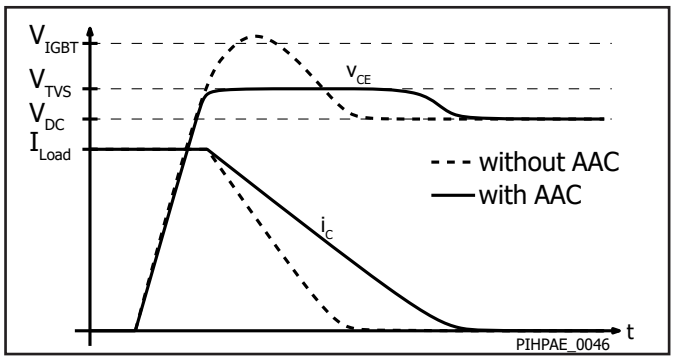

Figure 6. Advanced Active Clamping.

Additional TVS diodes are added in series with the TVS diodes required to withstand the maximum DC-link voltage during switching. These TVS diodes are short-circuited during the IGBT on-state for about 15 to 20 µs after the turn-off command is received to ensure efficient active clamping. After this delay, these additional TVS diodes are activated and allow the DC-link voltage to be increased to a higher value during the IGBT off-state. This feature together with Advanced Active Clamping – is called Dynamic Advanced Active Clamping (DA²C). Note that the time that the voltage can be applied above the value for switching operation should be limited to short periods (<60 s).

Dynamic Behavior of IGBT

Due to the different behavior of the included IGBT and diode chips, the dynamic behavior of the IGBT module depends on their type and manufacturer. Module construction and the distribution of the internal gate resistances and inductances also play a role in determining dynamic response. Note that different module types from the same manufacturer may also require a specific gate-driver adaptation.

Power Integrations therefore supplies specific versions of SCALE™-2 plug-and-play drivers adapted to each type of IGBT module. These drivers must not be used with IGBT modules other than those for which they were specified.

Turn-Off of the IGBT

The IGBT is turned off when the corresponding input turns low (light off). The gate resistance is already optimized and should not be altered.

Fast turn-off of the IGBT may cause overvoltage, which increases with DC-link voltage or load current. The turn-off overvoltage is approximately:

$$V_{TR} = L_S \times di_C/dt$$

where V_{TR} is the turn-off overvoltage, i_C the collector current and L_S the stray inductance.

Limiting overvoltage at turn-off is essential for high-power or high-voltage IGBTs. To ensure this, SCALE-2 plug-and-play drivers provide a Dynamic Advanced Active Clamping function DA²C.

Absolute Maximum Ratings

Parameter	Symbol	Conditions T_A = -40 °C to 85 °C	Min	Max	Units
Absolute Maximum Ratings[1]					
Supply Voltage	V_{DC}	VDC to GND		28	V
Average Supply Current	I_{DC}			110	mA
Gate Output Power[2]	P_G			1	W
Switching Frequency[3]	f_{SW}			500	Hz
DC-Link Voltage	$V_{DC-LINK}$	Switching operation[4]		3400	V_{DC}
		Off State[5]		3600	
Operating Voltage	V_{CE}			4500	V_{PEAK}
Storage Temperature[6]	T_{ST}		-40	50	°C
Operating Ambient Temperature	T_A		-40	85	°C
Component Surface Temperature[7]	T_{SURF}			125	°C
Relative Humidity	H_R	No condensation		93	%
Altitude of Operation[8]	A_{OP}			2000	m

Recommended Operating Conditions

Parameter	Symbol	Conditions T_A = -40 °C to 85 °C	Min	Typ	Max	Units
Power Supply						
Supply Voltage	V_{DC}	VDC to GND	23.5	25	26.5	V

NOTES:
1. Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device.
2. Actually achievable maximum power depends on several parameters and may be lower than the given value. It has to be evaluated in the final system. It is mainly limited by the maximum allowed surface temperature.
3. This limit applies to the whole product family. The actual achievable switching frequency may be lower for specific gate driver variants and has to be validated in final system as it is additionally limited by maximum gate output power in conjunction with the maximum allowed surface temperature.
4. This limit is due to active clamping.
5. Due to the Dynamic Active Advanced Clamping Function (DA²C) implemented on the driver, the DC link voltage can be increased in the off state condition (e.g. after emergency shutdown). This value is only valid when the IGBTs are in the off-state (not switching). The time during which the voltage can be applied should be limited to short periods (< 60 seconds).
6. The storage temperature inside the original package or in case the coating material of coated products may touch external parts must be limited to the given value. Otherwise, it is limited to 85 °C.
7. The component surface temperature, which may strongly vary depending on the actual operating conditions, must be limited to the given value to ensure long-term reliability of the product.
8. Operation above this level requires a voltage derating to ensure long-term reliability of the product.

Characteristics

Parameter	Symbol	Conditions V_{DC} = 25 V, T_A = 25 °C		Min	Typ	Max	Units
Power Supply							
Supply Current	I_{VDC}	Without load			40		mA
		$P_G = P_{G,max}$, f_{SW} = 500 Hz, 50% duty cycle			90		
Power Supply Monitoring Threshold	$UVLO_{VDC-VEE}$	Referenced to E	Clear fault (resume operation)	11.6	12.6	13.6	V
			Set fault (suspend operation)	11.0	12.0	13.0	
			Hysteresis	0.35			
	$UVLO_{VEE-GND}$		Clear fault (resume operation)		-5.15		V
			Set fault (suspend operation)		-4.85		
			Hysteresis		0.3		
Timing Characteristics							
Turn-On Delay	$t_{P(LH)}$	OIN-Light ON to 10% of $V_{GE(ON)}$, no load attached, 1m FO cable to external control			150		ns
Delay to increase V_{GE} to 25 V After Turn-ON	$t_{P(25V)}$				40		µs
Turn-Off Delay	$t_{P(HL)}$	OIN-Light OFF to 90% of $V_{GE(OFF)}$, no load attached, 1m FO cable to external control			150		ns
Duration of Acknowledge Pulse	t_{ACK}	Length of Acknowledge OOUT-Light OFF		400	700	1050	ns
Delay of Acknowledgment Pulse	$t_{D(ACK)}$	OIN-Light ON/OFF to OOUT-Light OFF, 1m FO cable to external control			250		ns
Propagation Delay of Fault State Condition	$t_{D(FAULT)}$	OIN-Light ON/OFF to OOUT-Light OFF, 1m FO cable to external control			80		ns
Gate Output							
Turn-On Gate Output Voltage	$V_{GE(ON)}$	Immediately after turn-on			15		V
		Steady-state			24.2		
Turn-Off Gate Output Voltage	$V_{GE(OFF)}$	Steady-state			-10		

Parameter	Symbol	Conditions V_{DC} = 15 V, T_A = 25 °C		Min	Typ	Max	Units
Short-Circuit Protection							
Delay Time to Increase VGE to 25V After di_C/dt Detection[9]	$t_{GE(LH)(25V)}$				38		µs
Deactivation of di_C/dt Detection After Turn-On	$t_{(di\_dt)(off)}$				27		µs
Static V_{CE}-Monitoring Threshold	$V_{CE(SAT)}$				115		V
Response Time	t_{RES}	10% to 90% of V_{GE}	DC-link voltage = 3200 V		5.0		µs
			DC-link voltage = 2600 V		6.0		
			DC-link voltage = 2200 V		6.8		
Turn-OFF Delay After Fault Detection	$t_{P(HL)FAULT}$				80		ns
Duration of Fault State Short Circuit Condition	t_{BLK}	Length of fault pulse Under UVLO condition the fault signal is present as long undervoltage is present			9		µs
Mounting[10]							
Mounting Holes	D_{HOLE}	Diameter of screw holes S1 - S2			4		mm
Mounting Torque	M	Screw M4, as per IGBT data sheet					Nm
Bending	I_{BEND}	According to IPC				0.75	%

NOTES:
9. Only applicable if no desat protection is triggered following the di_C/dt protection.
10. Refer to the data sheet of the IGBT module.

Product Dimensions

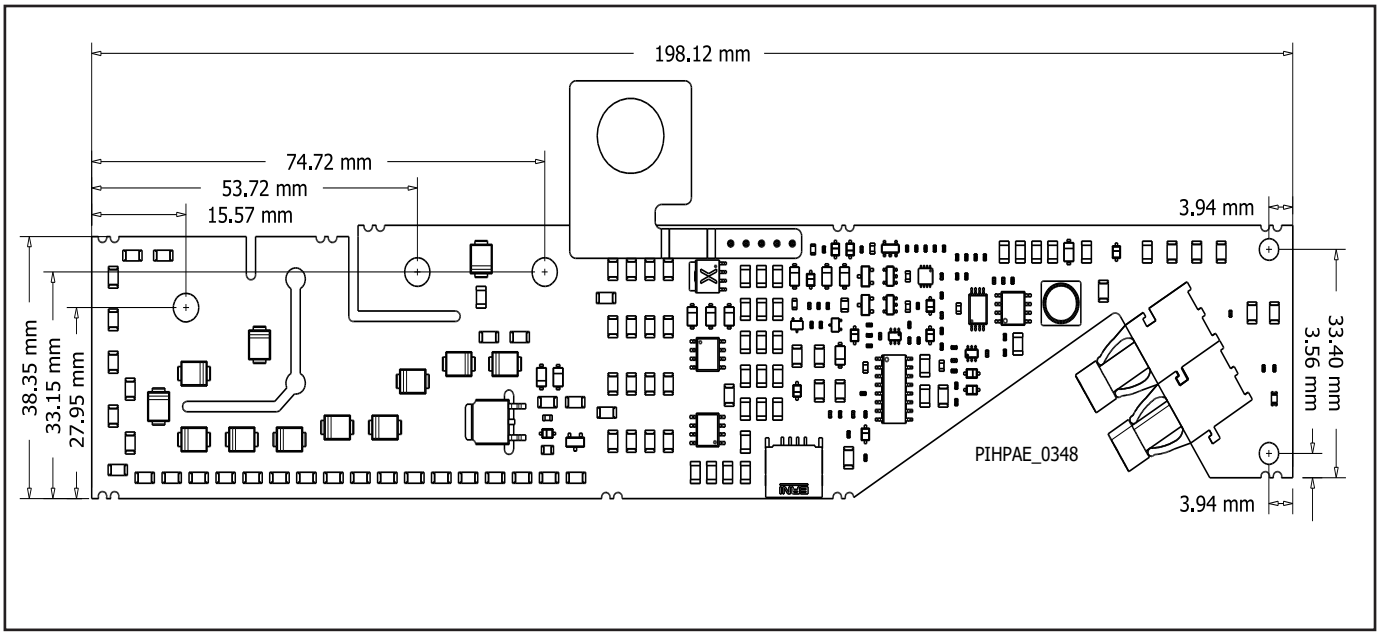

Figure 7. Top View

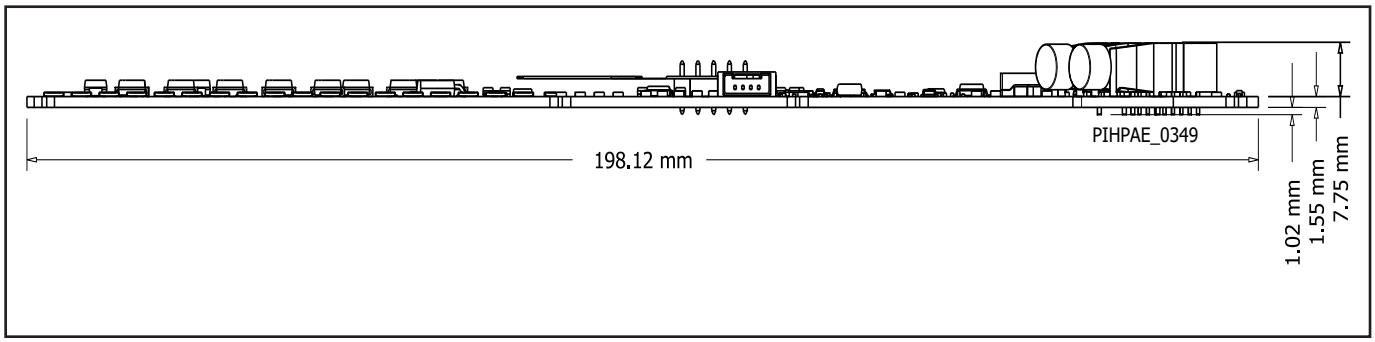

Figure 8. Side View.

Conformal Coating

The electronic components in the gate driver are protected by a layer of acrylic conformal coating on both sides of the PCB with a typical thickness of 50 µm using ELPEGUARD SL 1307 FLZ/2 from Lackwerke Peters. This coating layer increases product reliability when exposed to contaminated environments.

Note: Standing water (e.g. condensate water) on top of the coating layer must be prevented. This water will diffuse through the layer over time. If allowed to remain, it will eventually form a thin film between the PCB surface and coating layer, which will cause leakage currents to increase. Such currents will interfere with the performance of the gate driver.

Transportation and Storage Conditions

For transportation and storage conditions refer to Power Integrations' Application Note AN-1501.

RoHS Statement

We hereby confirm that the product supplied does not contain any of the restricted substances according Article 4 of the RoHS Directive 2011/65/EU in excess of the maximum concentration values tolerated by weight in any of their homogeneous materials.

Additionally, the product complies with RoHS Directive 2015/863/EU (known as RoHS 3) from 31 March 2015, which amends Annex II of Directive 2011/65/EU.

Product Details

Part Number	Power Module	Voltage Class	Current Class	Package	IGBT Supplier	$R_{G(ON)}$	$R_{G(OFF)}$	C_{GE}
1SP0440V2M0C-FZ1800R45HL4_S7	FZ1800R45HL4_S7	4500 V	1800 A	IHM-B	Infineon	0.76 Ω	5.67 Ω	Not Assembled

Revision	Notes	Date
A	Final Datasheet.	10/23

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