# 1SP0330V2M1R
# SCALE™-2 Driver Family

Main Plug-and-Play Gate Driver for Driving
up to 6500 V IGBT Modules
via Versatile Fiber-Optic I/O Interface

**Advanced Information**

## Product Highlights

### Highly Integrated, Compact Footprint

- Ready-to-use gate driver solution for up to 6500 V blocking voltage power modules
- Single-channel gate driver
- 35 A peak output gate current
- 1.6 W output power at maximum operating temperature
- Supports parallel connection of up to four power modules
- -40 °C to +85 °C operating ambient temperature range
- Optical status indicator

### Protection / Safety Features

- Short-circuit protection
- Dynamic Advanced Active Clamping (DA²C)
- Undervoltage lock-out (UVLO) protection
- Double-sided conformally coated (ELPEGUARD SL 1307 FLZ/2 from Lackwerke Peters)
- RoHS compliant

### Applications

- Railway inverter
- Industrial drives
- Other industrial applications

## Description

The 1SP0330V2M1R Plug-and-Play main gate driver is a compact single-channel gate driver family designed to support a range of IGBT modules. It features a versatile fiber-optic interface.

The 1SP0330V2M1R can be used as stand-alone driver or in conjunction with up to three 1SP0335D2S1R peripherals to drive up to four parallel-connected identical IGBT modules. The power supply (isolated DC-DC converter ISO5125R-xx) 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 to support the IGBT off-state for up to 60 seconds. This is ideal for railway and regenerating applications.

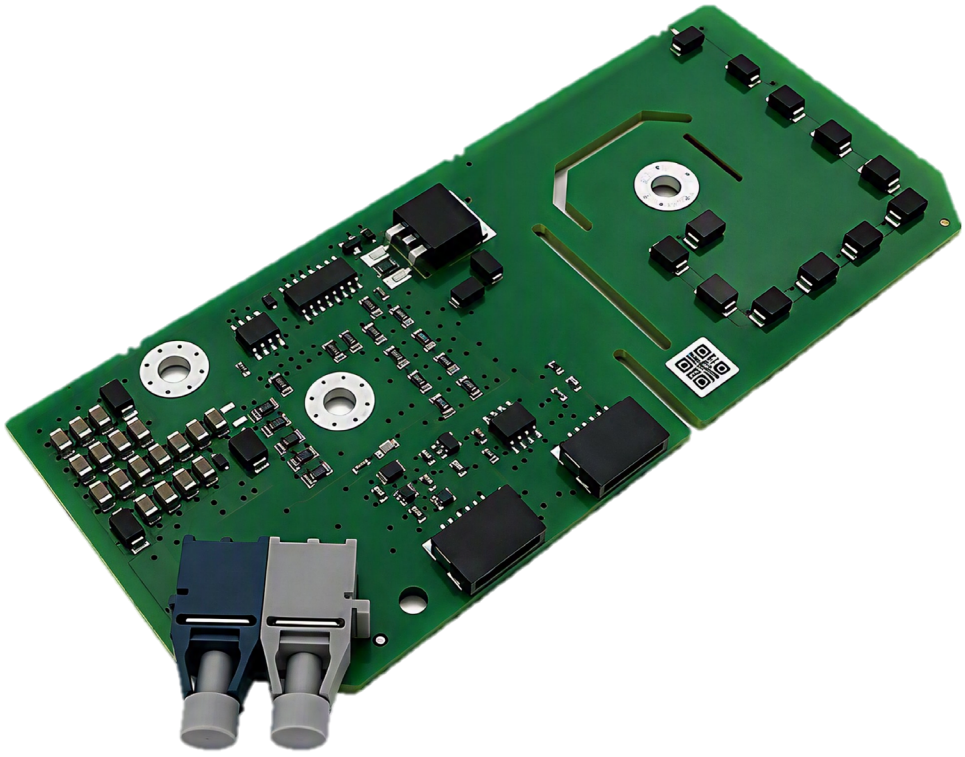


Figure 1. Exemplary 1SP0330V product picture.



This Product is Covered by Patents and/or Pending Patent Applications.

## Pin Functional Description

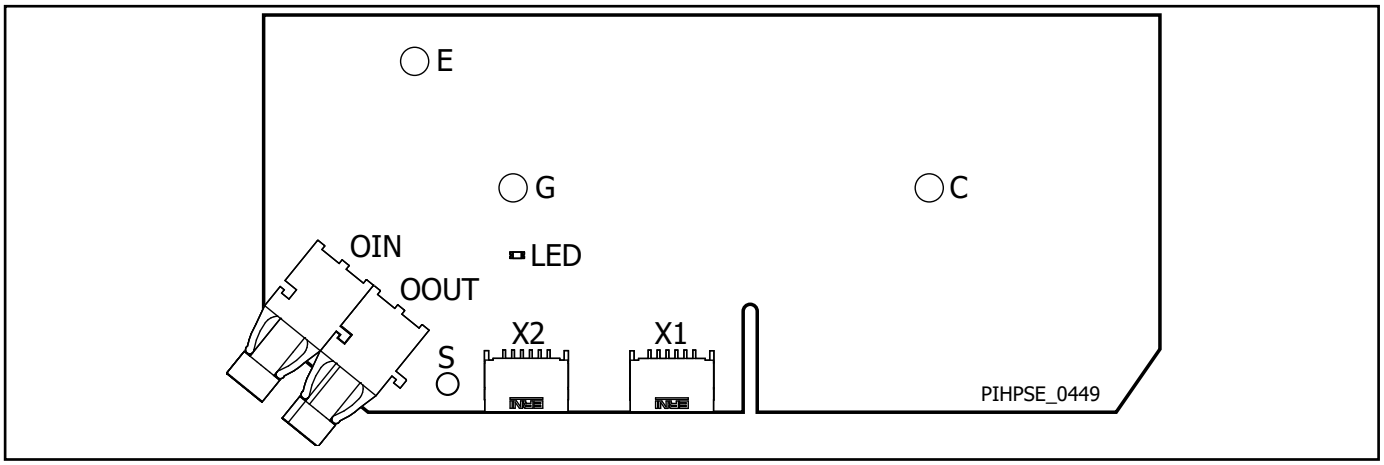



Figure 2. 1SP0330V2M1R Interfaces.

### Connection to DC-DC Converter or to Peripheral Driver

**Connector X1 and X2**
MicroBridge interface to connect main driver to external DC-DC converter or peripheral driver. X1 and X2 are interchangeable.
Part number: TE CONNECTIVITY 504275-E.

### Connection to Semiconductor

**Terminal G**
Gate contact of IGBT.

**Terminal E**
Auxiliary emitter contact of IGBT.

**Terminal C**
Auxiliary collector contact of IGBT.

**Fiber-Optic Interface**
Main driver to 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

**Optical Indicator P**
Green LED for monitoring the status output. In the event of a fault the indicator is turned off.

## Functional Description

The basic topology of the 1SP0330V2M1R driver is shown in Figure 4. This driver can be used alone or together with peripheral drivers when parallel connection of IGBT modules is required. This driver can be connected to a peripheral driver via X1 or X2 connectors. Up to three peripheral drivers (and the main driver) can be directly connected in parallel. The X1 and X2 interfaces are identical.

The driver is equipped with the following features:

- Dynamic $V_{CE}$ monitoring (short-circuit protection)
- Dynamic Advanced Active Clamping DA²C (overvoltage protection at turn-off)
- Gate monitoring
- Gate clamping to positive rail
- Power supply monitoring

The main driver 1SP0330V2M1R board is not equipped with a DC-DC converter. The electrical isolation is provided by the main driver (fiber optics) and the external DC-DC converter ISO5125R-xx. The signals are isolated with versatile fiber optics links.

Power and input gate driver signals are provided to the peripheral drivers by the main driver. No fiber optic connections are present on the peripheral drivers as isolation is already implemented on the 1SP0330V2M1R main driver. Desaturation protection is not implemented on the peripheral drivers.

### Description of X1 and X2

The connector X1/X2 is used to connect main driver to ISO5125R-xx DC-DC converter. In case of parallel operation, one of these connectors is used to connect the main to peripheral driver. X1 and X2 are interchangeable.

It requires a cable to establish the electrical connection from the DC-DC converter to the main driver. Note that no galvanic isolation for the power supply is implemented on the driver. Therefore, it is recommended to use the external DC-DC converter ISO5125R-xx for the power supply.

### Screw Terminals

The main driver is mounted on top of the power module and fixed by screws.

### Connection Cables for X1/X2

For recommended cables, please refer to the data sheet RLC-IMS-61-xxx-0
It is important to note that the cables are at high voltage (secondary-side potential). The user is responsible for applying sufficient isolation to all cables.

### Power Supplies and Electrical Isolation

The power supply and electrical isolation are provided by the external DC-DC converter. The DC-DC converter needs a stabilized 15V supply voltage.

In addition, a signal insulation of 200 $V_{PEAK}$ is provided on the peripheral drivers. This allows for dynamic voltage differences between parallel-connected drivers when switching operation is not symmetrical.

Signal isolation is realized via a planar transformer. Coreless common mode coils are placed in the supply conductors in order to limit the dynamic equalizing currents flowing to and from the main during asymmetric switching operation. It is recommended that the resulting equalizing current flowing is measured via the paralleling interface (see absolute maximum value).

Note that if required, the peak value as well as the RMS value of the equalizing current can be reduced by positioning a ferrite core around the paralleling cables.

### Fiber Optic Receiver OIN

The input signal OIN is received by a 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

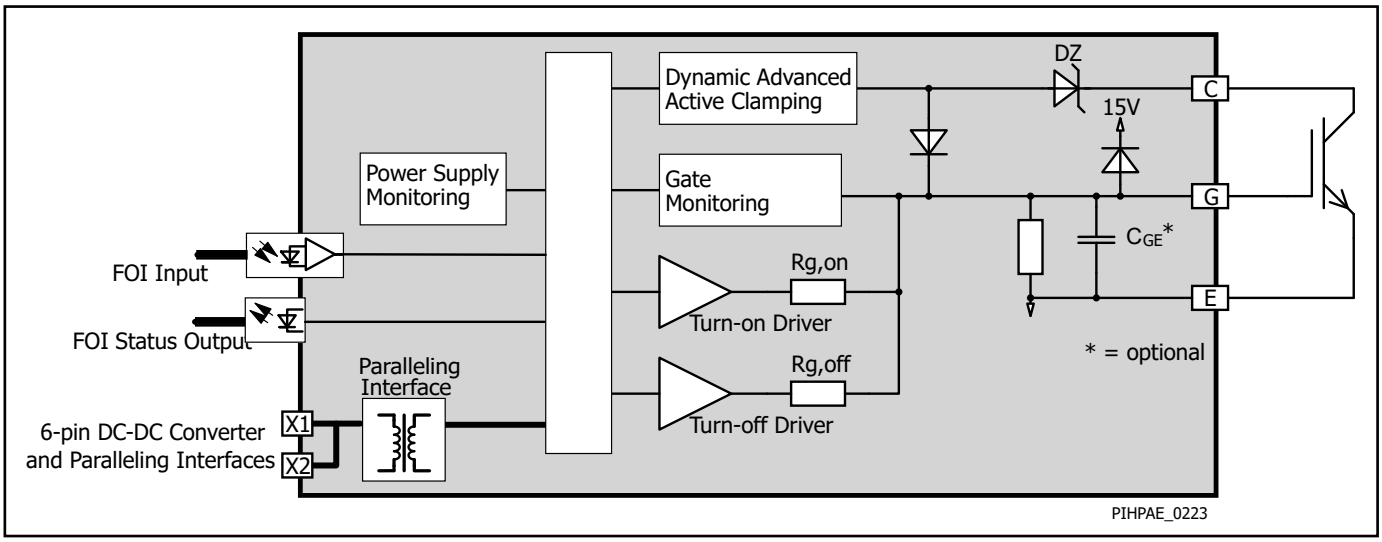



Figure 3. Functional Block Diagram.

monitoring of all drivers and fiber-optic links in the system. Figure 6 shows the control and response signals of a gate driver during normal operation.

**Short-Circuit Detection**
Figure 7 shows the response of the driver in the event of a short-circuit fault. The fault status is transferred to the status feedback terminal after the response time $t_{RES}$. The light is then driven "off" during the delay to clear the fault state $t_{FAULT(SC)}$. The IGBT can be turned on again by applying a positive edge to the fiber-optic input after the fault status has disappeared.

**Undervoltage Detection**
In the event of an undervoltage fault being detected on the main driver, the fault status remains active and the driver is locked for as long as the undervoltage remains. During power-up, the status feedback will also show a fault condition until the supply undervoltage is resolved.

**Gate Monitoring Fault**
In the event of a gate monitoring fault, the fault status is transferred to the status feedback terminal after the filter delay $t_{D(FILTER)}$ (refer to Figure 8 and the timing information) and remains active as long as the gate-monitoring fault is present.

**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 1SP0330V2M1R 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 5.

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 (<60s).

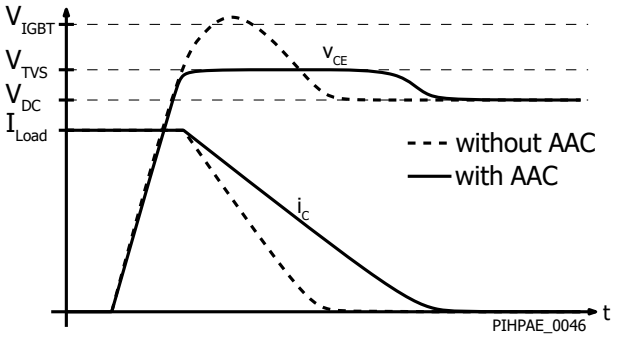



Figure 4. Advanced Active Clamping.

**Optical Indicators**
To facilitate verification, the driver is equipped with a green status LED. The LED lights up under normal operation. A turned-off LED indicates that the driver is not supplied with voltage, the supply voltage is too low, or the gate monitoring function has detected a fault. Moreover, in case of IGBT short-circuit, the LED on the main driver is switched off during the delay to clear the fault state (refer to timing information).

**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-On of the IGBT / Commutation of Diode Current**
When a driver input goes high (light on), the gate driver turns on the corresponding IGBT. The driver includes the gate resistors, matched to the appropriate IGBT module.

The driver is optimized to achieve minimum switching losses when paired with relatively low inductances within the power stack. It is therefore recommended to check the commutation behavior of the system assembly.

**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.

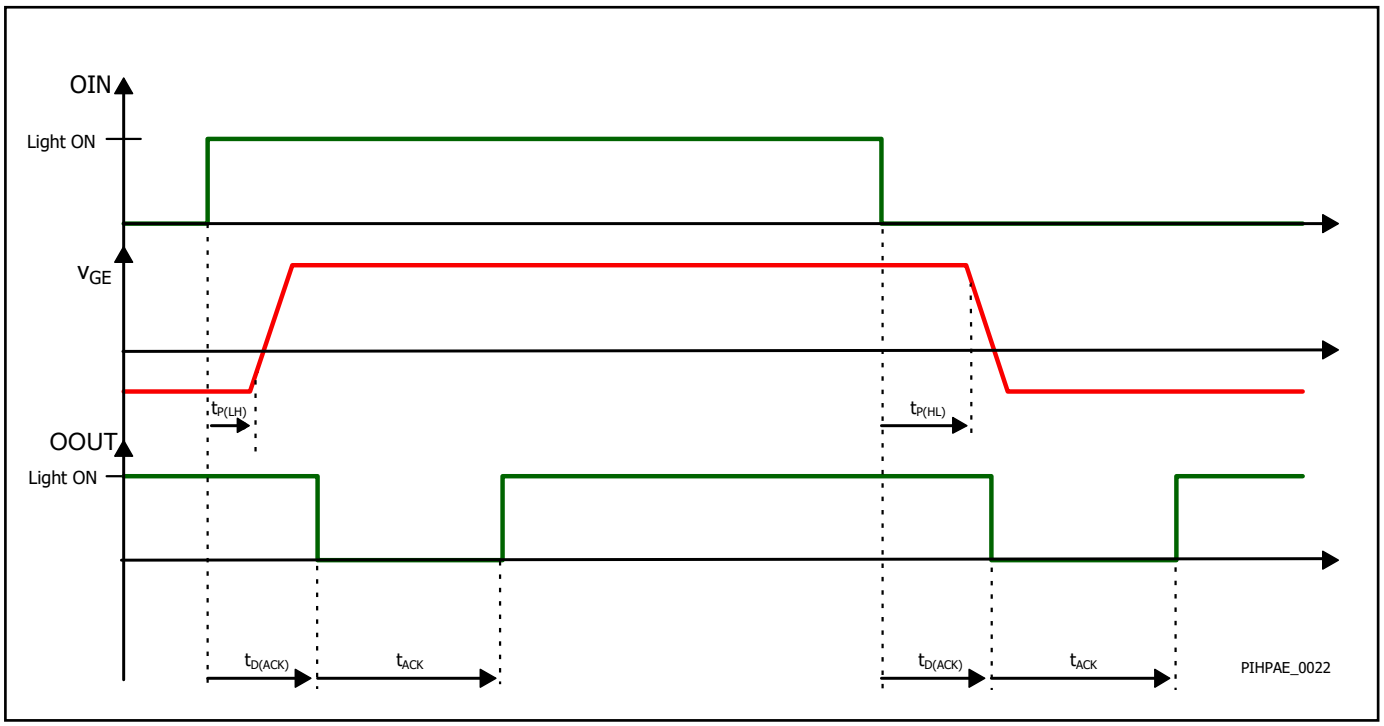



Figure 5. Fiber Optic Feedback of the Driver in Normal Operation Mode.

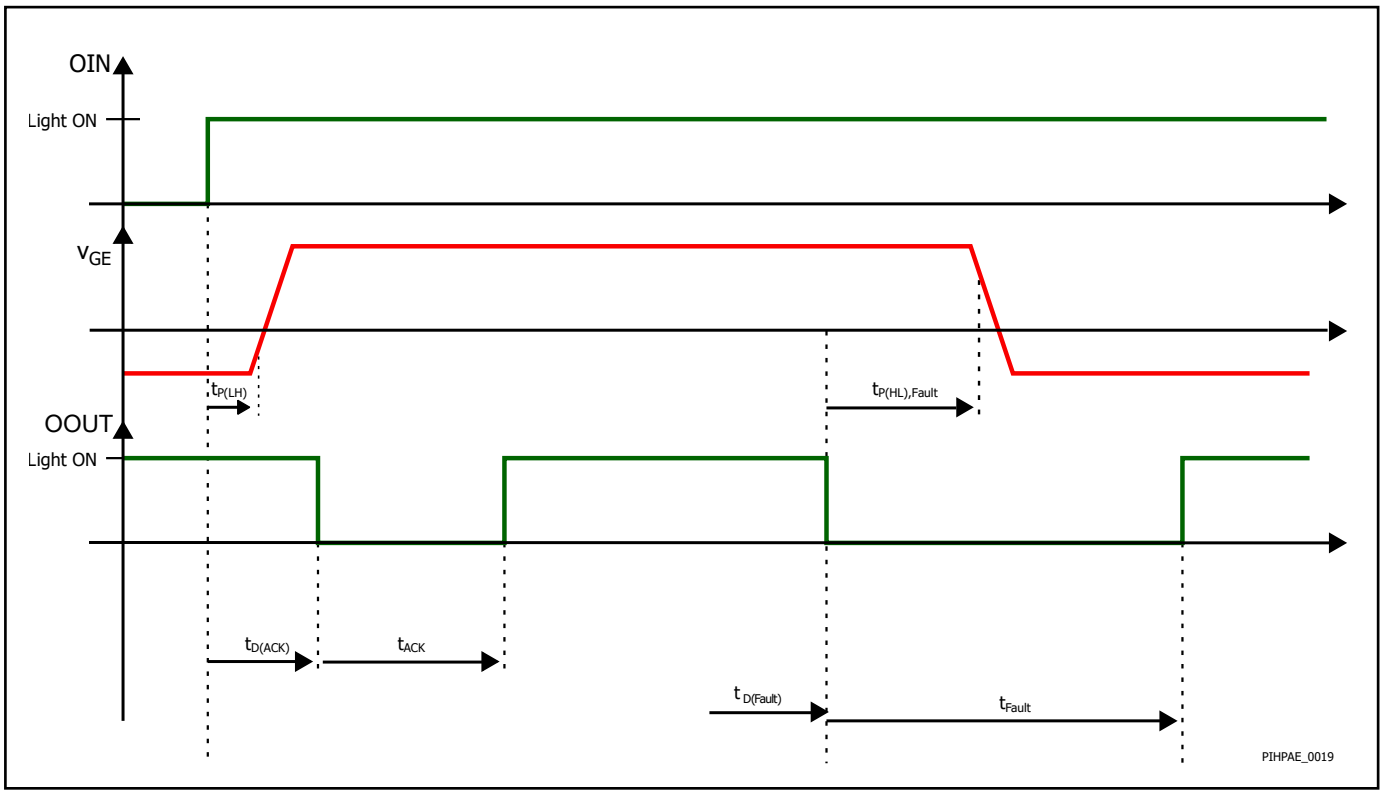



Figure 6. Fiber Optic Feedback from the Driver in Short-Circuit Fault Mode.



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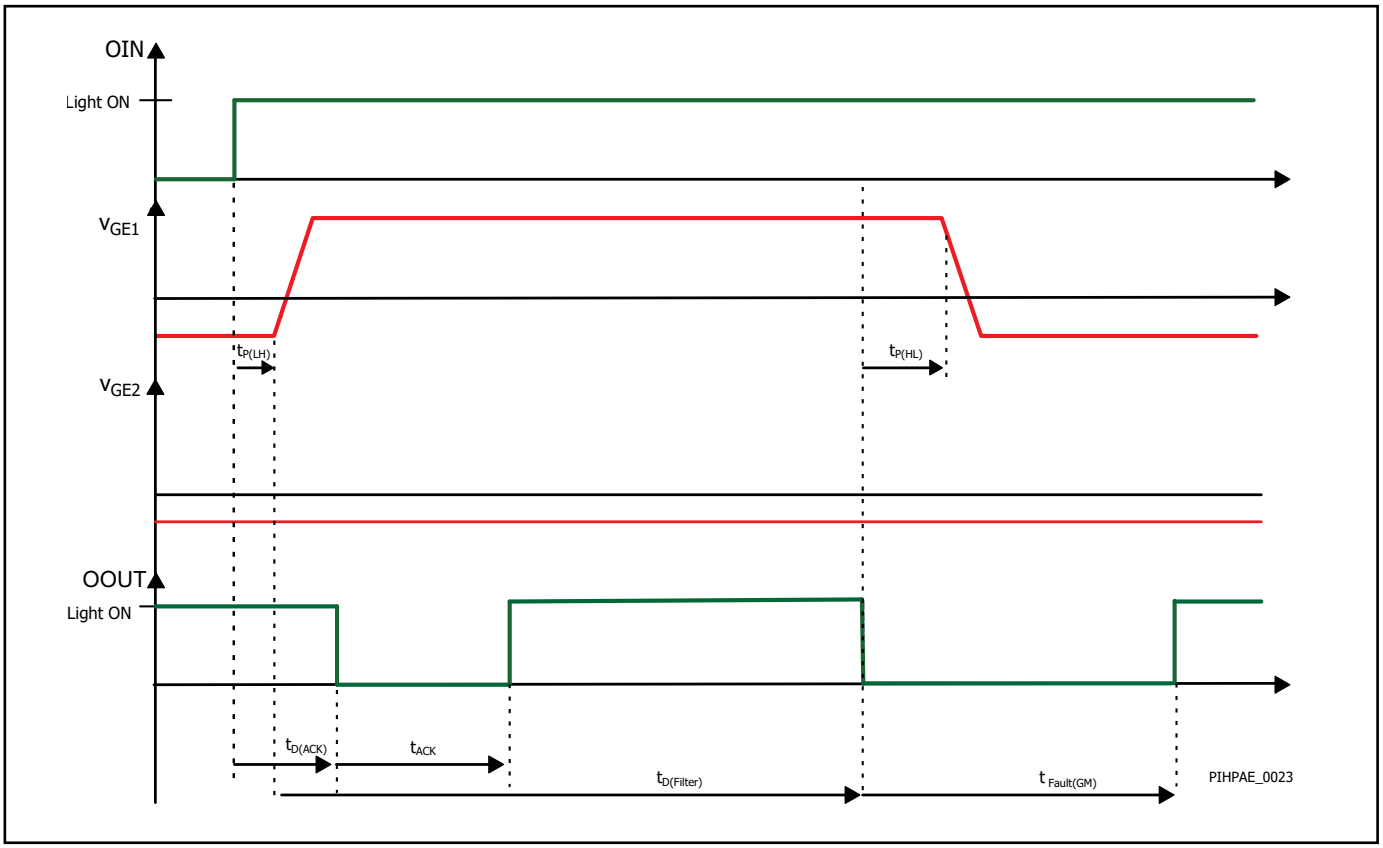



Figure 7. Fiber Optic Feedback from the Driver in Gate Monitoring Fault Mode.

**3-Level and Multilevel Topologies**

1SP0330V2M1R drivers can be used in 3-level or multilevel topologies, please refer to application note AN-0901.

**Parallel Connection of Main and Peripheral Drivers**

If parallel connection up to four IGBT modules is required, one main and up to three peripheral drivers are used. The electrical isolation is provided by the main driver and the external DC-DC converter ISO5125R-xx. The electrical isolation of signals is realized on the main driver (via the fiber optic interface for the input signal and the status feedback). The power supply for the peripheral drivers as well as input signal and gate monitoring feedback are transmitted between the peripheral and the main driver via the interface bus connected to the paralleling interfaces X1 and/or X2 respectively. X1 and X2 are identical and interchangeable on the main driver and on the peripheral driver. The paralleling interface connections X1 and X2 ensure that all paralleled drivers switch on and off synchronously.

For more information about the paralleling of this diver family and recommendations about optimizing the mechanical layout of the converter set-up, please refer to the AN-2201.

## Absolute Maximum Ratings

| Parameter | Symbol | Conditions | Min | Max | Units |
|---|---|---|---|---|---|
| **Absolute Maximum Ratings[1]** | | | | | |
| **Supply Voltage** | $V_{VISO-COM}$ | VISO to COM | | 30 | V |
| **Average Supply Current** | $I_{DC}$ | Main driver only 1SP0330V2M1R | | 260 | mA |
| | | 1SP0330V2M1R with three 1SP0335D2S1R | | 500 | |
| **Switching Frequency[2]** | $f_{SW}$ | | | 10 | kHz |
| **Gate Output Power** | $P_G$ | $T_a \leq 85$ °C | | 1.6 | W |
| | | $T_a \leq 70$ °C | | 2.2 | |
| **DC-Link Voltage** | $V_{DC-LINK}$ | Switching operation[3] (4.5 kV driver versions) | | 3000 | $V_{DC}$ |
| | | Off State[4] (4.5 kV driver versions) | | 3550 | |
| | | Switching operation[3] (6.5 kV driver versions) | | 4400 | $V_{DC}$ |
| | | Off State[4] (6.5 kV driver versions) | | 5200 | |
| **Operating Voltage** | $V_{CE}$ | 4.5 kV driver versions | | 4500 | $V_{PEAK}$ |
| | | 6.5 kV driver versions | | 6500 | |
| **Emitter to Emitter Voltage** | $V_{E1-E2}$ | Between parallel connected drivers | | 200 | $V_{PEAK}$ |
| **Common-Mode Transient Immunity** | \|dv/dt\| | | | 50 | kV/µs |
| **Interface Current (Main or Peripheral Driver to Peripheral Driver)[5]** | $I_{INTERFACE}$ | RMS value | | 4 | $A_{RMS}$ |
| | | Peak value | | 20 | $A_{PEAK}$ |
| **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 Condition

| Parameter | Symbol | Conditions $T_A$ = -40 °C to 85 °C | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Power Supply** | | | | | | |
| **Supply Voltage** | $V_{VISO-COM}$ | VISO to COM | 23.5 | 25 | 26.5 | V |


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## Characteristics

| Parameter | Symbol | Conditions $V_{ISO-COM}$ = 25 V, $T_A$ = 25 °C | | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|
| **Power Supply** | | | | | | | |
| **Supply Current** | $I_{DC}$ | Main driver only, without load | | | 34 | | mA |
| | | Without load, per addiitonal 1SP0335D2S1R | | | 19 | | |
| **Power Supply Monitoring Threshold (Secondary-Side)** | $UVLO_{VISO}$ | Referenced to E | Clear fault (resume operation) | 11.6 | 12.6 | 13.6 | V |
| | | | Set fault (suspend operation) | 11 | 12.0 | 13 | |
| | | | Hysteresis | 0.35 | | | |
| | $UVLO_{COM}$ | | 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 | | | 170 | | ns |
| **Turn-Off Delay** | $t_{P(HL)}$ | OIN-Light OFF to 90% of $V_{GE(OFF)}$, no load attached, 1m FO cable to external control | | | 160 | | 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 | | | 265 | | ns |
| **Propagation Delay of Fault State Condition** | $t_{D(FAULT)}$ | OIN-Light ON/OFF to OOUT-Light OFF | | | 110 | | ns |
| **Gate monitoring[9]** | | | | | | | |
| **Turn-On Threshold** | $V_{GE(ON)MIN}$ | $G_{MEAN}$ to E, set fault | | | 13 | | V |
| **Turn-Off Threshold** | $V_{GE(OFF)MAX}$ | $G_{MEAN}$ to E, set fault | | | -7.4 | | V |
| **Duration of Fault State Gate Monitoring Condition** | $t_{FAULT(GM)}$ | Length of fault pulse | | | 1 | | µs |
| **Filter Delay** | $t_{D(FILTER)}$ | Turn-on | | | 31 | | µs |
| | | Turn-off | | | 47 | | |
| **Short-Circuit Protection** | | | | | | | |
| **Static $V_{CE}$-Monitoring Threshold** | $V_{CE(SAT)}$ | 4.5 kV driver versions | | | 170 | | V |
| | | 6.5 kV driver versions | | | 247 | | V |


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## Characteristics (cont.)

| Parameter | Symbol | Conditions $V_{ISO-COM}$ = 25 V, $T_A$ = 25 °C | | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|
| **Short-Circuit Protection (cont.)** | | | | | | | |
| **Response Time** | $t_{RES}$ | 10% to 90% of $V_{GE}$ | DC-link voltage = 3000 V | | 6.2 | | µs |
| | | | DC-link voltage = 2000 V | | 6.3 | | |
| | | | DC-link voltage = 1500 V | | 6.3 | | |
| | | | DC-link voltage = 1000 V | | 8.1 | | |
| | | | DC-link voltage = 4400 V | | 6.6 | | |
| | | | DC-link voltage = 3000 V | | 6.6 | | |
| | | | DC-link voltage = 2200 V | | 6.8 | | |
| | | | DC-link voltage = 1500 V | | 10.0 | | |
| **Delay to IGBT Turn-Off After Short-Circuit Detection** | $t_{P(HL)FAULT}$ | | | | 0.3 | | µs |
| **Duration of Fault State Short Circuit Condition** | $t_{FAULT(SC)}$ | Length of fault pulse<br>Under UVLO condition the fault signal is present as long undervoltage is present | | | 9 | | µs |
| **Mounting[10]** | | | | | | | |
| **Mounting Torque** | $M_{MAIN}$ | Screw M4, as per IGBT data sheet | | | | | Nm |
| **Bending** | $I_{BEND}$ | According to IPC | | | | 0.75 | % |
| **Gate Output** | | | | | | | |
| **Turn-On Gate Output Voltage** | $V_{GE(ON)}$ | | | | 15 | | V |
| **Turn-Off Gate Output Voltage** | $V_{GE(OFF)}$ | | | | -10 | | V |

NOTES:

1. Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device.
2. 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.
3. This limit is due to active clamping.
4. Due to the Dynamic Active Advanced Clamping Function (DA$^2$C) 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).
5. Dynamic voltages between auxiliary emitters of parallel connected drivers at turn-on and turn-off lead to currents over the interface. The peak and RMS values of the resulting current must be limited to the given value.
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 operating condition, 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 proper isolation coordination.
9. The mean value $V_{GE(MEAN)}$ of all gate voltages (main and all peripherals) is filtered and compared to the given values at turn-on and turn-off. If the specified values are exceeded ($V_{GE(MEAN)} < V_{GE(ON)MIN}$ at turn-on respectively $V_{GE(MEAN)} > V_{GE(OFF)MAX}$ at turn-off) after the given filter delay, the driver turns off all parallel connected IGBT modules and a fault is transmitted to the status output.
10. Refer to the data sheet of the IGBT module.


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## Product Dimensions

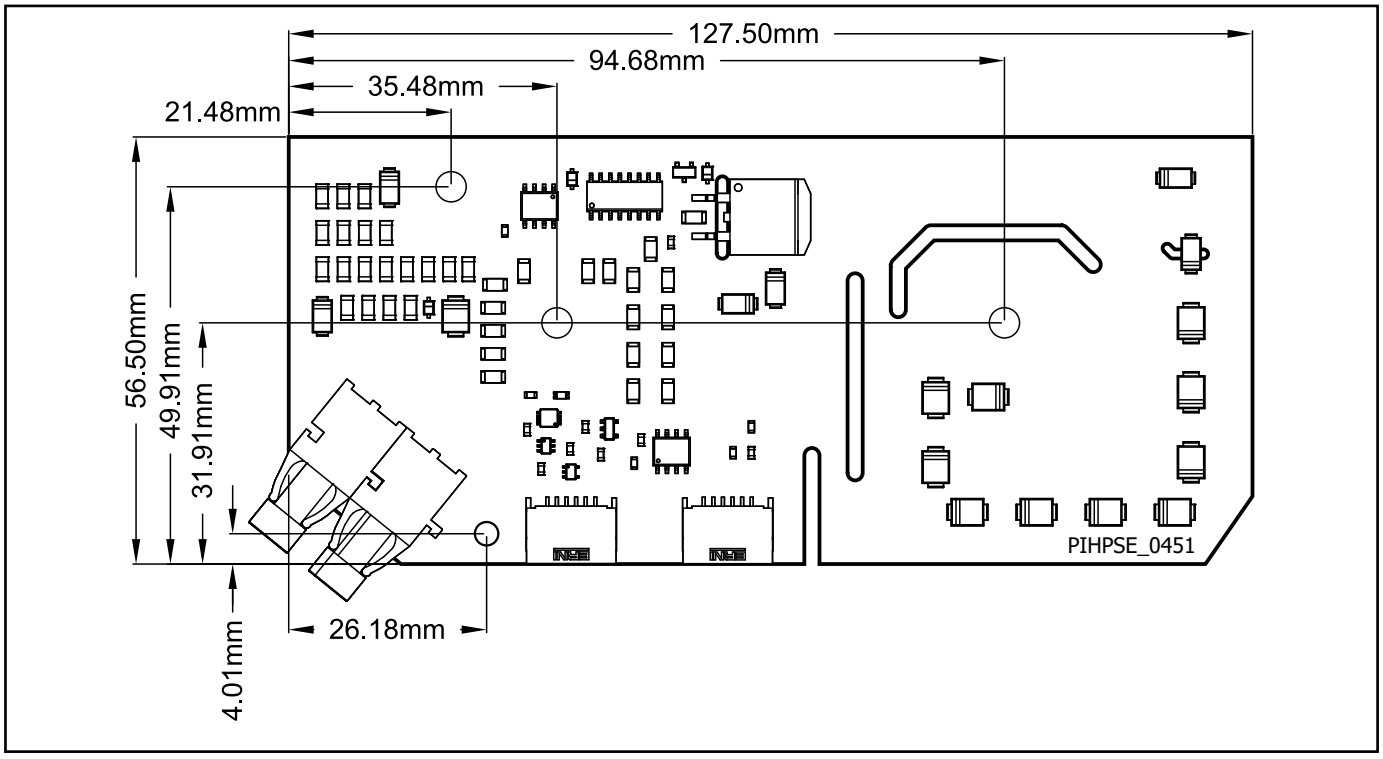



Figure 8. Top View. Horizontal fiber optics orientation.

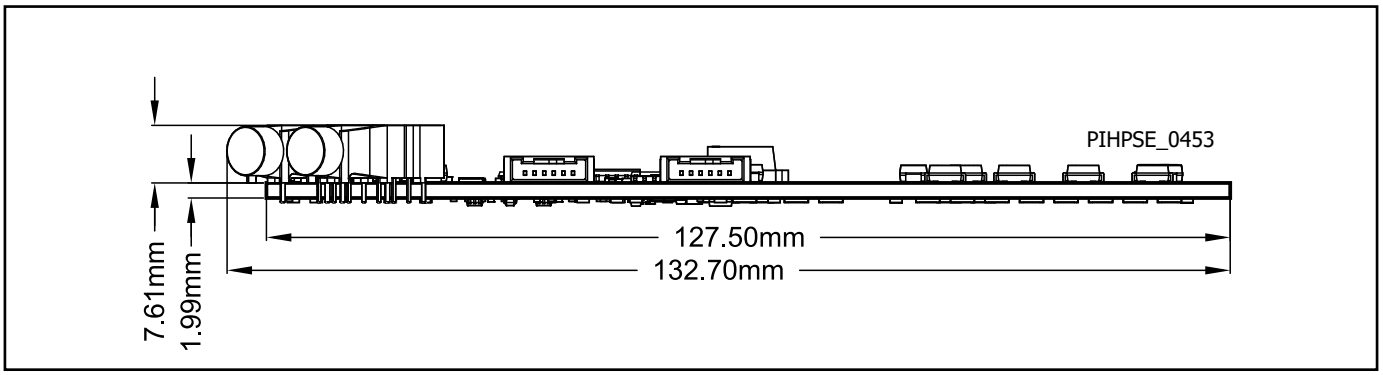



Figure 9. Side View. Horizontal fiber optics orientation.

## 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 to 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 | $R_{G(ON)}$ | $R_{G(OFF)}$ | $C_{GE}$ | Fiber Optics Orientation |
|---|---|---|---|---|---|---|---|---|---|
| **1SP0330V2M1R-CM1000HG-90X** | CM1000HG-90X | 4500 V | 1000 A | HV IGBT | Mitsubishi | 3.75 Ω | 45 Ω | Not assembled | horizontal |
| **1SP0330V2M1R-MBN1000FH45F-H** | MBN1000FH45F-H | 4500 V | 1000 A | HV IGBT | Minebea | 3.75 Ω | 4.875 Ω | Not assembled | horizontal |
| **1SP0330V2M1R-CM1500HG-90X** | CM1500HG-90X | 4500 V | 1500 A | HV IGBT | Mitsubishi | 2.5 Ω | 30 Ω | Not assembled | horizontal |
| **1SP0330V2M1R-CM600HG-130X** | CM600HG-130X | 6500 V | 600 A | HV IGBT | Mitsubishi | 6.375 Ω | 45 Ω | Not assembled | horizontal |
| **1SP0330V2M1R-FZ675R65KE4** | FZ675R665KE4 | 6500 V | 675 A | HV IGBT | Infineon | 1.025 Ω | 15 Ω | Not assembled | horizontal |


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| Revision | Notes | Date |
|---|---|---|
| A | Final Data Sheet. | 08/26 |

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