1SP0635S2M1R
SCALE-2 Family

Main Gate Driver for an IGBT Module up to 3300 V
ST Fiber-Optic I/O Interface

Product Highlights

Highly Integrated, Compact Footprint
- Ready-to-use single-channel gate driver solution for power modules up to 3300 V blocking voltage
- 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 ($V_{CE(SAT)}$ monitoring)
- Dynamic Advanced Active Clamping (DA^2C)
- Undervoltage lock-out (UVLO) protection
- Applied conformal coating on both sides of PCB
- RoHS compliant

Applications
- Railway inverter
- Industrial drives
- Other industrial applications

Description

The Plug-and-Play 1SP0635S2M1R main gate driver is a compact single-channel intelligent gate driver designed to support a range of IGBT modules.

The family features a ST fiber-optic interface with a built-in isolated DC/DC power supply. The 1SP0635S2M1R can be used as stand-alone driver or in conjunction with up to three 1SP0635D2S1R peripherals to drive up to four parallel-connected identical IGBT modules.

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.

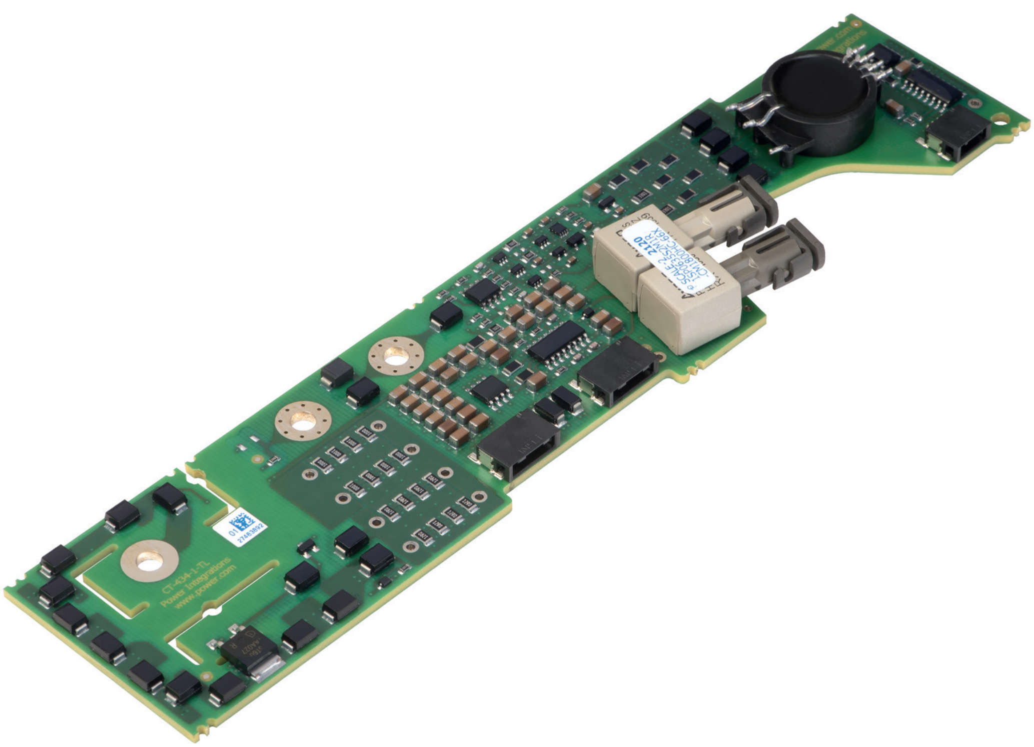

Figure 1. Board Photo of 1SP0635S2M1R.

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

Pin Functional Description

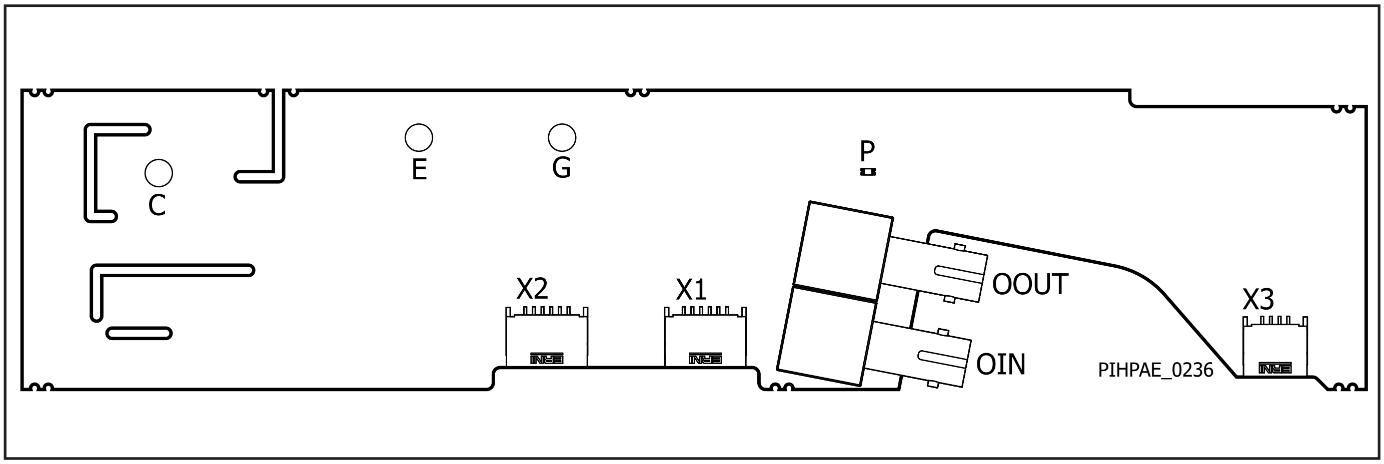

Figure 2. 1SP0635S2M1R Interfaces.

Connection to Another Peripheral Driver

Internal Interface X1/X2
ERNI interface to connect main driver to peripheral driver.
Part number: ERNI 504275, 6 pin, right angle.

Connector X3
ERNI interface to supply DC-DC converter on the main driver
Part number: ERNI 504255, 4 pin, right angle.

GND (Pin 1, 4)
This pin is the connection to primary-side ground potential.

VDC (Pin 2, 3)
This pin is the primary-side supply voltage connection.

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-2412Z

OOUT (Transmitter)
This fiber optic transmitter is the status output.
Part number: Broadcom HFBR-1412Z

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 1SP0635S2M1R driver is shown in Figure 3. 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 the paralleling X1/X2 interfaces. 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 DA^{2}C (overvoltage protection at turn-off)
- Gate monitoring
- Gate clamping to positive rail
- Power supply monitoring

The main driver 1SP0635S2M1R board is equipped with a DC-DC converter to provide an electrically isolated power supply for the gate driver circuitry. The signals are isolated with ST 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 1SP0635S2M1R main driver. Desaturation protection is not implemented on the peripheral drivers.

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.

Description of X1/X2 and X3
The paralleling interfaces X1/X2 are available on the gate driver. They allow one or two peripheral driver(s) to be connected to the main driver.

The main driver is equipped with a 4-pin interface connector X3. It is recommended to connect both GND and VDC pins

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

Connection Cables for X1/X2 and X3
For recommended cables, please refer to data sheets RLC-IMS-61-050-0 and RLC-PSI-41-050-0.

It is important to note that the paralleling 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 for peripheral drivers is delivered from the main driver 1SP0635S2M1R via the paralleling interfaces X1 or X2. Insulation is provided by the main driver.

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.

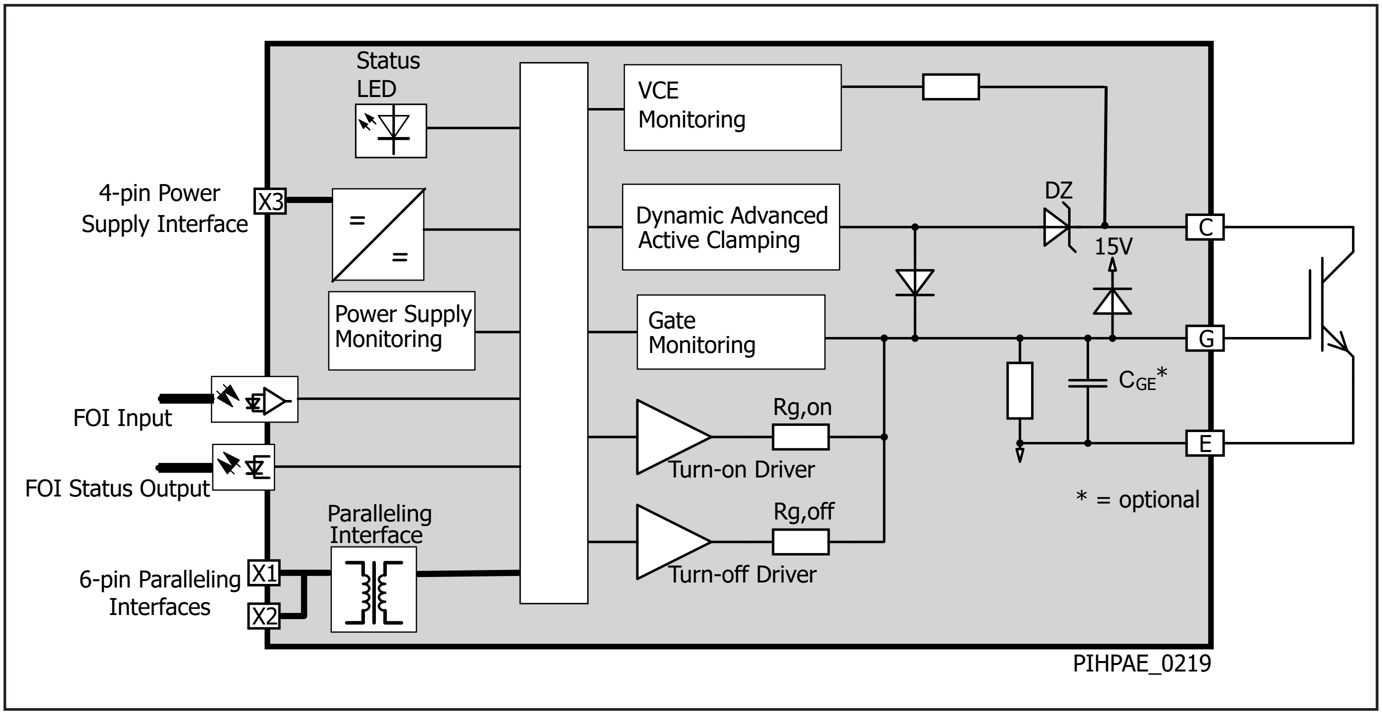

Figure 3. Functional Block Diagram.

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 5 shows the control and response signals of a gate driver during normal operation.

Short-Circuit Detection

Figure 6 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 the timing information) and remains active as long as the gate-monitoring fault is present.

If the driver goes from the "off-state" to the "on-state", and the gate-emitter voltage of one or more parallel connected drivers does not turn on, the fault status is transferred to the status feedback terminal after $t_{D(FILTER)}$. The driver shuts the IGBT off after $t_{D(FILTER)}$, to clear the fault condition.

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 1SP0635S2M1R 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 4.

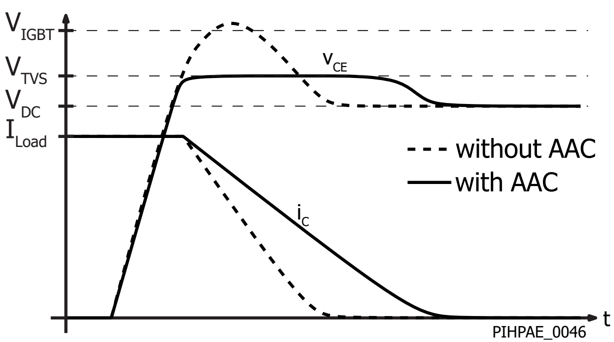

Figure 4. Advanced Active Clamping.

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 (<60s).

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.

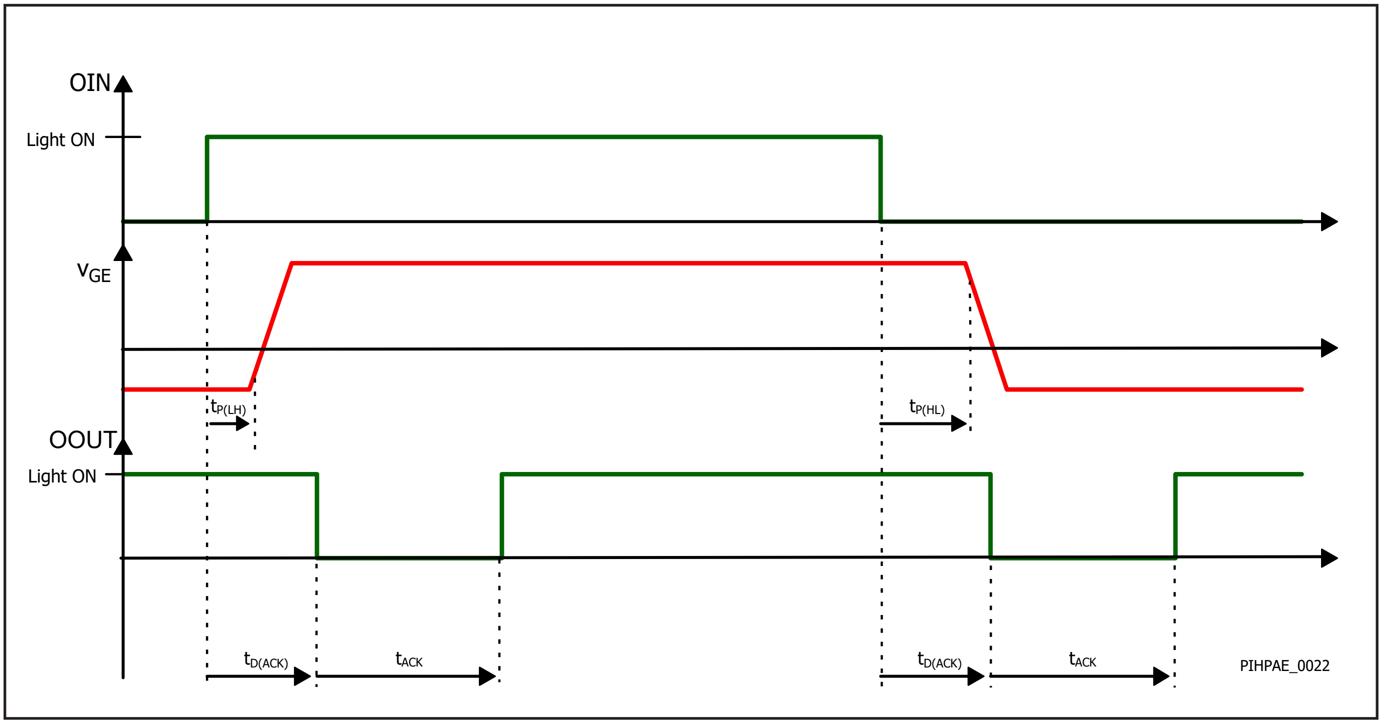

Figure 5. Fiber Optic Feedback of the Driver in Normal Operation Mode.

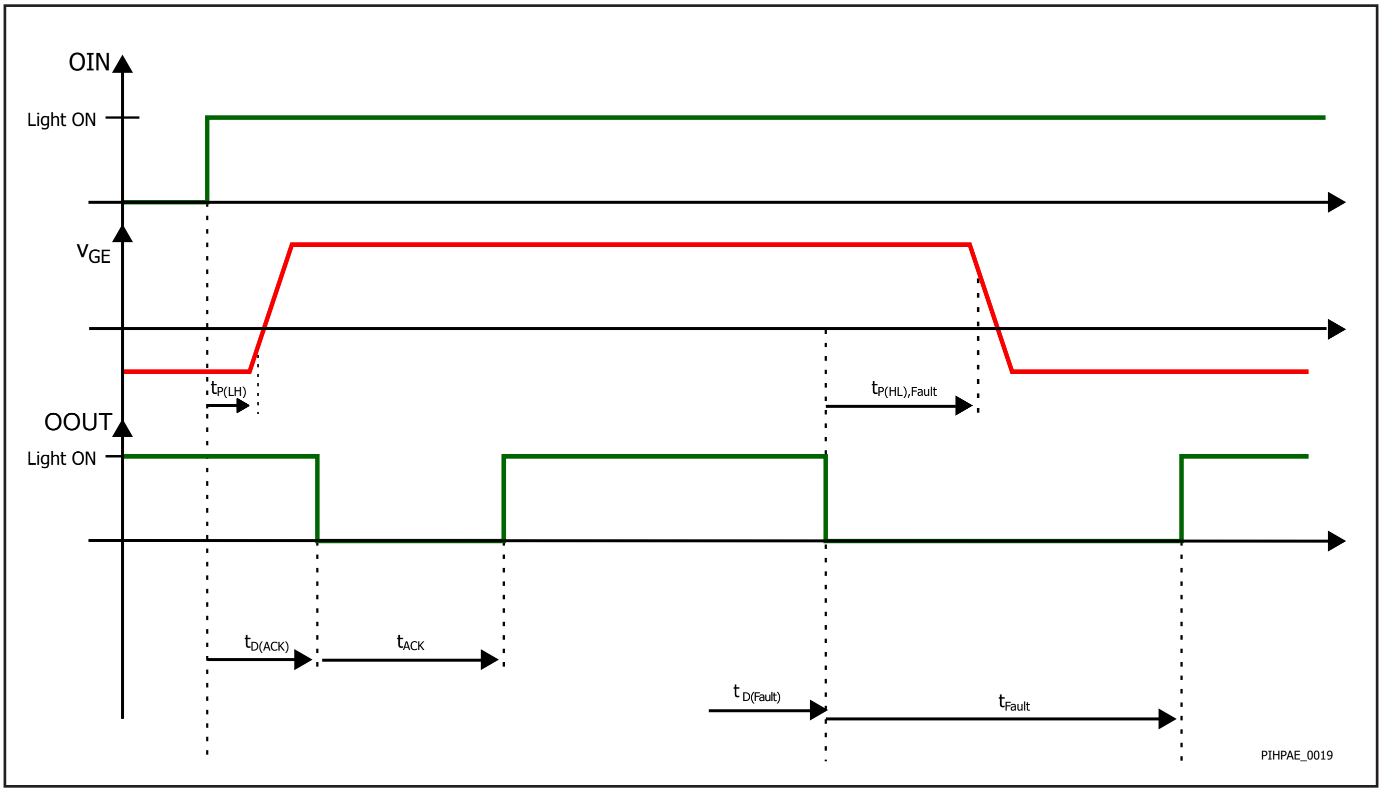

Figure 6. Fiber Optic Feedback from the Driver in Short-Circuit Fault Mode.

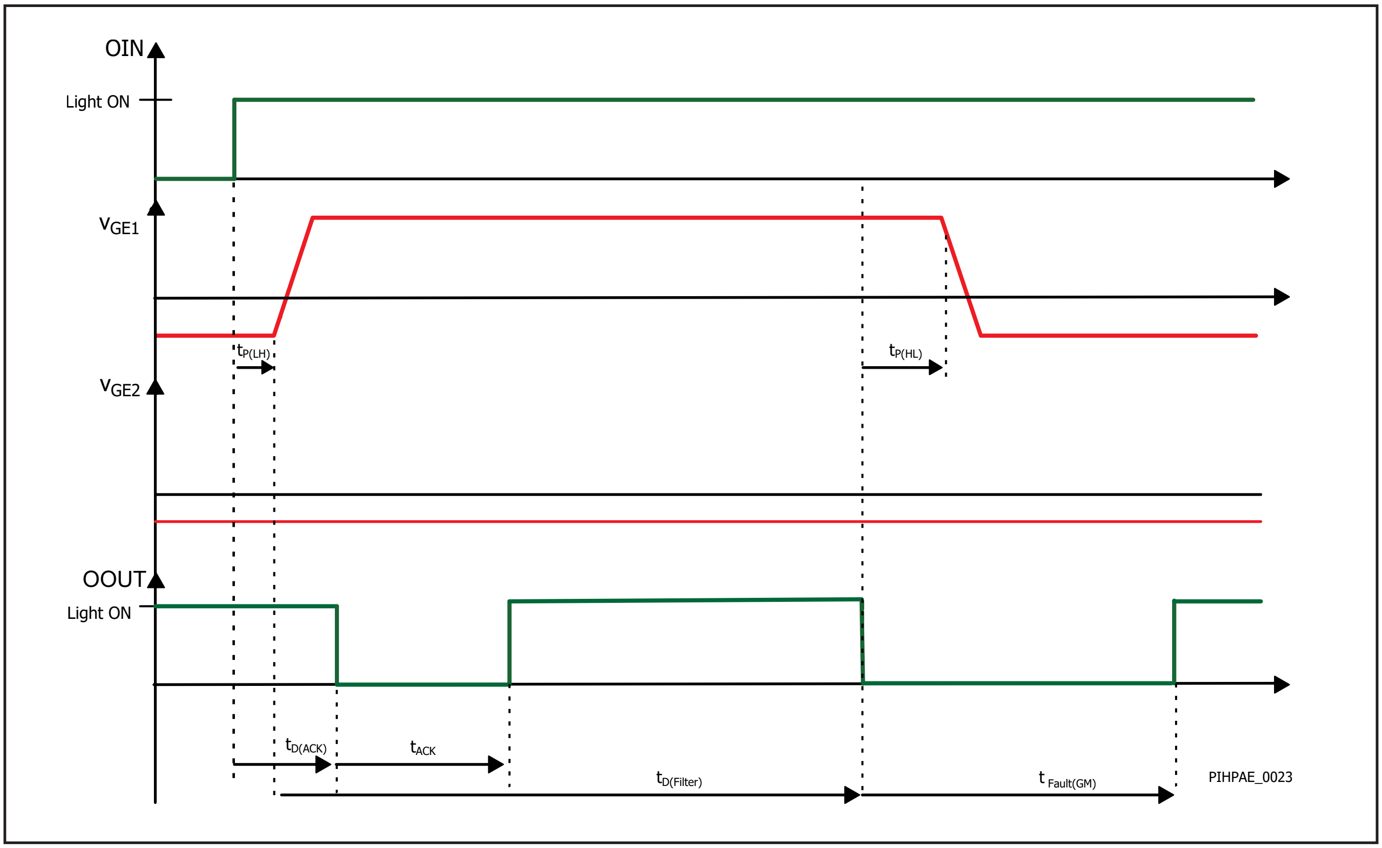

Figure 7. Fiber Optic Feedback from the Driver in Gate Monitoring Fault Mode.

3-Level and Multilevel Topologies
1SP0635x2x1R 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 with an embedded power supply. 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.

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: The accumulation of standing water (e.g. through condensation) on top of the coating layer must be prevented. Standing water will diffuse through the coating over time and will eventually form a thin film between the PCB surface and coating layer, causing leakage currents to increase. Such currents will interfere with the performance of the gate driver.

Absolute Maximum Ratings

Parameter	Symbol	Conditions	Min	Max	Units
Absolute Maximum Ratings[1]					
Supply Voltage	V_{DC}	VDC to GND		16	V
Average Supply Current	I_{DC}	Main driver only		310	mA
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	
Gate Peak Output Current	I_G	Limited by the gate resistors	-35	35	A
Test Voltage Primary-Side to Secondary-Side	$V_{ISO(PS)}$	50 Hz, 60 s (2.5 kV and 3.3 kV driver versions)		6000	$V_{AC(EFF)}$
		50 Hz, 60 s (1.2 kV and 1.7 kV driver versions)		4000	
DC-Link Voltage	$V_{DC\text{-}LINK}$	Switching operation[3] (3.3 kV driver versions)		2200	V_{DC}
		Off State[4] (3.3 kV driver versions)		2700	
		Switching operation[3] (1.7 kV driver versions)		1200	
		Off State[4] (1.7 kV driver versions)		1480	
		Switching operation[3] (1.2 kV driver versions)		800	
		Off State[4] (1.2 kV driver versions)		950	
Operating Voltage	V_{CE}	3.3 kV driver versions		3300	V_{PEAK}
		1.7 kV driver versions		1700	
		1.2 kV driver versions		1200	
Emitter to Emitter Voltage	$V_{E1\text{-}E2}$	Between parallel connected drivers		200	V_{PEAK}
Common-Mode Transient Immunity	|dv/dt|	Between parallel connected drivers		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_{DC}	VDC to GND	14.5	15	15.5	V

Characteristics

Parameter	Symbol	Conditions T_A = +25 °C, V_{DC} = 15 V	Min	Typ	Max	Units
Power Supply						
Supply Current	I_{DC}	Main driver only, without load		112		mA
		Main driver only, 1.6 W, f_{SW} = 1.6 kHz, 50% duty cycle		235		
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)	11.0	12.0	13.0	
		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		180		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		180		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		100		ns
Gate monitoring[9]						
Turn-On Threshold	$V_{GE(ON)MAX}$	G_{MEAN} to E, set fault		12.9		V
Turn-Off Threshold	$V_{GE(OFF)MIN}$	G_{MEAN} to E, set fault		-7.6		V
Duration of Fault State Gate Monitoring Condition	$t_{FAULT(GM)}$	Length of fault pulse		1		ms
Filter Delay	$t_{D(FILTER)}$	Turn-on		32		µs
		Turn-off		32		
Short-Circuit Protection						
Static V_{CE}-Monitoring Threshold	$V_{CE(SAT)}$	3.3 kV driver versions		143		V
		1.7 kV driver versions		51		
		1.2 kV driver versions		10.2		

Parameter	Symbol	Conditions T_A = +25 °C , V_{DC} = 15 V		Min	Typ	Max	Units
Short-Circuit Protection (cont.)							
Response Time	t_{RES}	10% to 90% of V_{GE} (3.3 kV versions)	DC-link voltage = 2200 V		5.8		µs
			DC-link voltage = 1500 V		5.8		
			DC-link voltage = 1100 V		5.9		
			DC-link voltage = 800 V		7.7		
		10% to 90% of V_{GE} (1.7 kV versions)	DC-link voltage = 1200 V		7.1		µs
			DC-link voltage = 800 V		7.9		
			DC-link voltage = 600 V		8.2		
			DC-link voltage = 400 V		9.5		
		10% to 90% of V_{GE} (1.2 kV versions)	DC-link voltage = 800 V		7.5		µs
			DC-link voltage = 600 V		7.6		
			DC-link voltage = 400 V		8.4		
			DC-link voltage = 300 V		9.9		
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 Under UVLO condition the fault signal is present as long undervoltage is present			9		µs
Mounting[10]							
Mounting Torque	$M_{PERIPHERAL}$	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	$V_{GE(OFF)}$	Idle (main + 1 peripheral)			-9.9		V
		Full load (1.6 W, main + 1 peripheral)			-9.6		
		Full load (2.2W, main + 1 peripheral)			-9.5		
Electrical Isolation							
Test Voltage (50Hz/1s)[11]	$V_{ISO(PS)}$	Primary to secondary-side (2.5 kV and 3.3 kV driver versions)		6000			$V_{AC(EFF)}$
		Primary to secondary-side (1.2 kV and 1.7 kV driver versions)		4000			
Partial Discharge Extinction Voltage[12]	PD_{P-S}	Primary-side to secondary-side (2.5 kV and 3.3 kV driver versions)		3630			V_{PEAK}
	PD_{P-S}	Primary-side to secondary-side (1.2 kV and 1.7 kV driver versions)		1870			
Creepage Distance	CPG_{P-S}	Primary-side to secondary-side		21			mm
		Primary-side to IGBT main emitter terminal		20			
Clearance Distance	CLR_{P-S}	Primary-side to secondary-side		21			mm
		Primary-side to IGBT main emitter terminal		13			

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 peripheral) 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 IGBTs and a fault is transmitted to the status output.
10. Refer to the data sheet of the IGBT module.
11. HiPot testing (= dielectric testing) must generally be restricted to suitable components. This gate driver is suited for HiPot testing. Nevertheless, it is strongly recommended to limit the testing time to 1s slots. Excessive HiPot testing may lead to insulation degradation.
12. Partial discharge measurement is performed on each transformer.

Product Dimensions

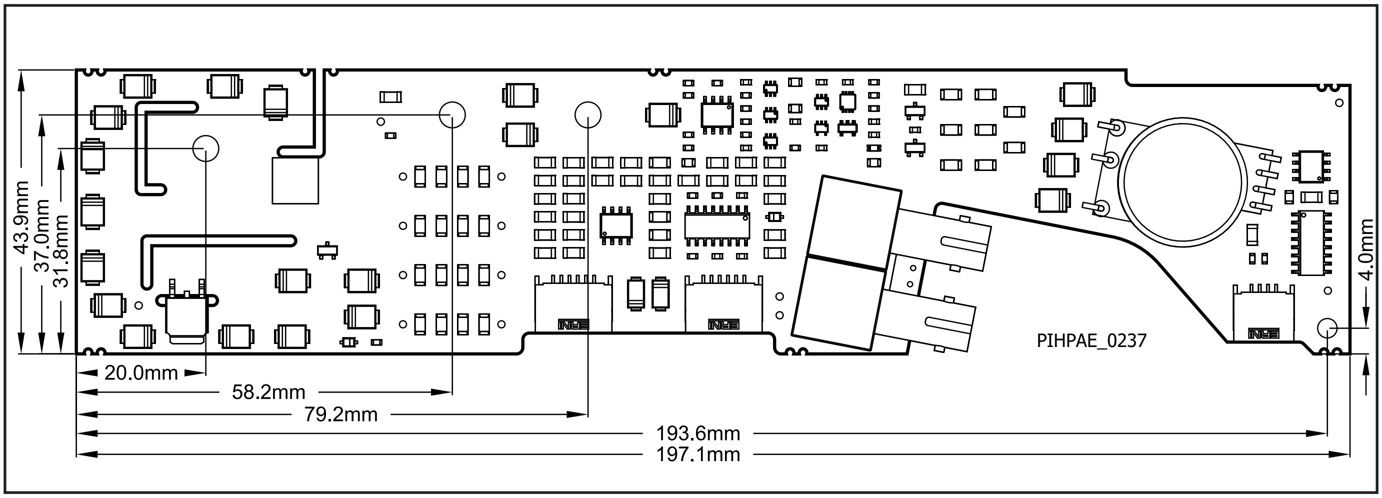

Figure 8. Top View.

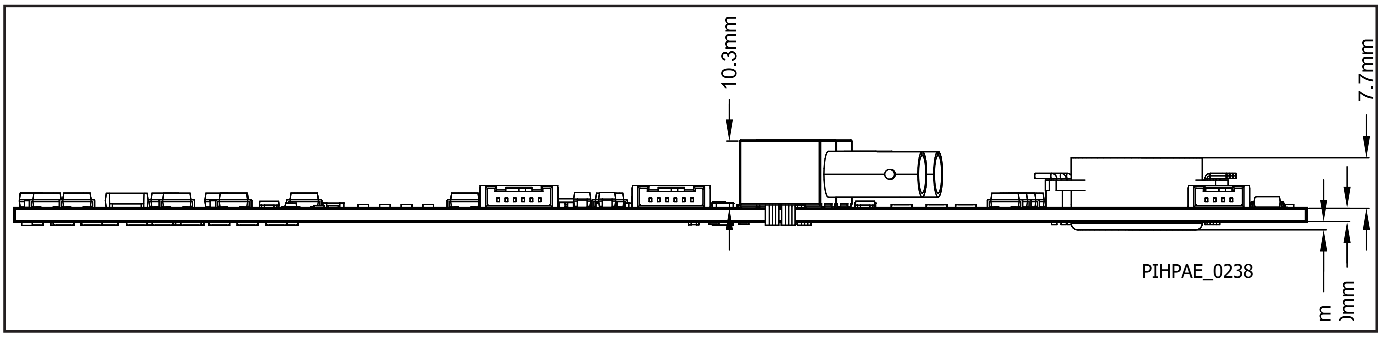

Figure 9. Side View.

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 described in 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}
1SP0635S2M1R-FZ2000R33HE4	FZ2000R33HE4	3300 V	2000 A	IHV	Infineon	0.4875 Ω	3.375 Ω	Not Assembled
1SP0635S2M1R-FZ1500R33HE3	FZ1500R33HE3	3300 V	1500 A	IHV	Infineon	0.4875 Ω	2.25 Ω	330 nF
1SP0635S2M1R-FZ1000R33HE3	FZ1000R33HE3	3300 V	1000 A	IHV	Infineon	0.775 Ω	3.375 Ω	220 nF
1SP0635S2M1R-CM1800HC-66X	CM1800HC-66X	3300 V	1800 A	HVIGBT	Mitsubishi	1.5 Ω	12.5 Ω	Not Assembled
1SP0635S2M1R-CM1200HC-66X	CM1200HC-66X	3300 V	1200 A	HVIGBT	Mitsubishi	2.25 Ω	18.75 Ω	Not Assembled
1SP0635S2M1R-FZ2400R17HP4_B29	FZ2400R17HP4_B29	1700 V	2400 A	IHM-B	Infineon	0.9375 Ω	1.25 Ω	Not Assembled
1SP0635S2M1R-CM2400HCB-34X	CM2400HCB-34X	1700 V	2400 A	HVIGBT	Mitsubishi	0.6375 Ω	5.875 Ω	Not Assembled
1SP0635S2M1R-DIM2400ESM17-PT500	DIM2400ESM17-PT500	1700 V	2400 A	IHM-B	Dynex	0.5375 Ω	0.775 Ω	Not Assembled

Revision	Notes	Date
A	Final Datasheet.	06/24

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

Power Integrations Worldwide Sales Support Locations

World Headquarters
5245 Hellyer Avenue
San Jose, CA 95138, USA
Main: +1-408-414-9200
Customer Service:
Worldwide: +1-65-635-64480
Americas: +1-408-414-9621
e-mail: usasales@power.com

China (Shanghai)
Rm 2410, Charity Plaza, No. 88
North Caoxi Road
Shanghai, PRC 200030
Phone: +86-21-6354-6323
e-mail: chinasales@power.com

China (Shenzhen)
17/F, Hivac Building, No. 2, Keji Nan
8th Road, Nanshan District,
Shenzhen, China, 518057
Phone: +86-755-8672-8689
e-mail: chinasales@power.com

Germany
(AC-DC/LED/Motor Control Sales)
Einsteinring 24
85609 Dornach/Aschheim
Germany
Tel: +49-89-5527-39100
e-mail: eurosales@power.com

Germany (Gate Driver Sales)
HellwegForum 3
59469 Ense
Germany
Tel: +49-2938-64-39990
e-mail: igbt-driver.sales@power.com

India
#1, 14th Main Road
Vasanthanagar
Bangalore-560052 India
Phone: +91-80-4113-8020
e-mail: indiasales@power.com

Italy
Via Milanese 20, 3rd. Fl.
20099 Sesto San Giovanni (MI) Italy
Phone: +39-024-550-8701
e-mail: eurosales@power.com

Japan
Yusen Shin-Yokohama 1-chome Bldg.
1-7-9, Shin-Yokohama, Kohoku-ku
Yokohama-shi,
Kanagawa 222-0033 Japan
Phone: +81-45-471-1021
e-mail: japansales@power.com

Korea
RM 602, 6FL
Korea City Air Terminal B/D, 159-6
Samsung-Dong, Kangnam-Gu,
Seoul, 135-728, Korea
Phone: +82-2-2016-6610
e-mail: koreasales@power.com

Singapore
51 Newton Road
#19-01/05 Goldhill Plaza
Singapore, 308900
Phone: +65-6358-2160
e-mail: singaporesales@power.com

Taiwan
5F, No. 318, Nei Hu Rd., Sec. 1
Nei Hu Dist.
Taipei 11493, Taiwan R.O.C.
Phone: +886-2-2659-4570
e-mail: taiwansales@power.com

UK
Building 5, Suite 21
The Westbrook Centre
Milton Road
Cambridge
CB4 1YG
Phone: +44 (0) 7823-557484
e-mail: eurosales@power.com