

SCALE™-2 1SP0350V

Target Description & Application Manual

Driver solution for high-voltage and high-power IGBT modules and Press-Packs with fiber-optic interface for 2-level, 3-level and multilevel converter topologies

Abstract

1SP0350V are single-channel drivers with fiber-optics. The drivers are based on Power Integrations' SCALE™-2 chipset, a highly integrated technology for the reliable driving and safe operation of IGBTs and IEGTs.

Perfectly matched driver versions are available for Press-Packs and IGBT modules. The plug-and-play capability of the driver allows immediate operation after mounting. The user needs invest no effort in designing or adjusting it to a specific application.

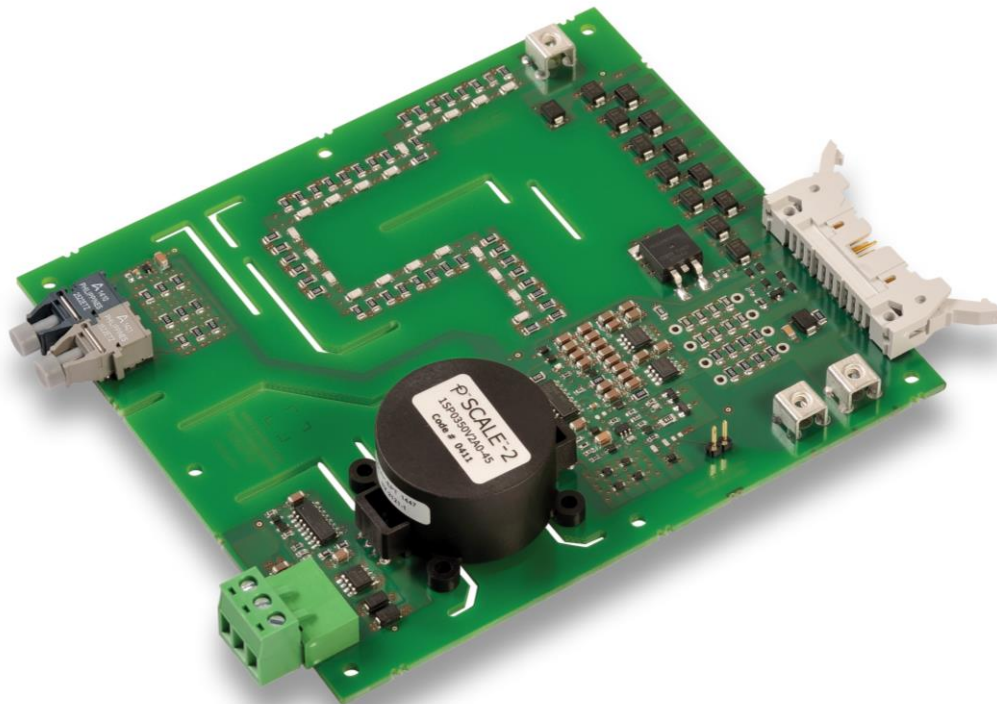


Fig. 1 1SP0350V Plug-and-Play driver

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System Overview

The 1SP0350V are plug-and-play gate drivers based on the highly integrated SCALE-2 chipset developed by Power Integrations /1/. This is a set of application-specific integrated circuits (ASICs) that cover the main range of functions needed to design intelligent gate drivers. The SCALE-2 driver chipset is a further development of the proven SCALE technology /2/.

1SP0350V drivers are specifically designed for the reliable and safe driving of high-voltage and high-power Press-Packs and IGBT modules from the 4500V voltage class.

The basic topology of the 1SP0350V drivers is shown in Fig. 2. The values for the gate resistors and other key components can be found in the driver data sheet /3/.

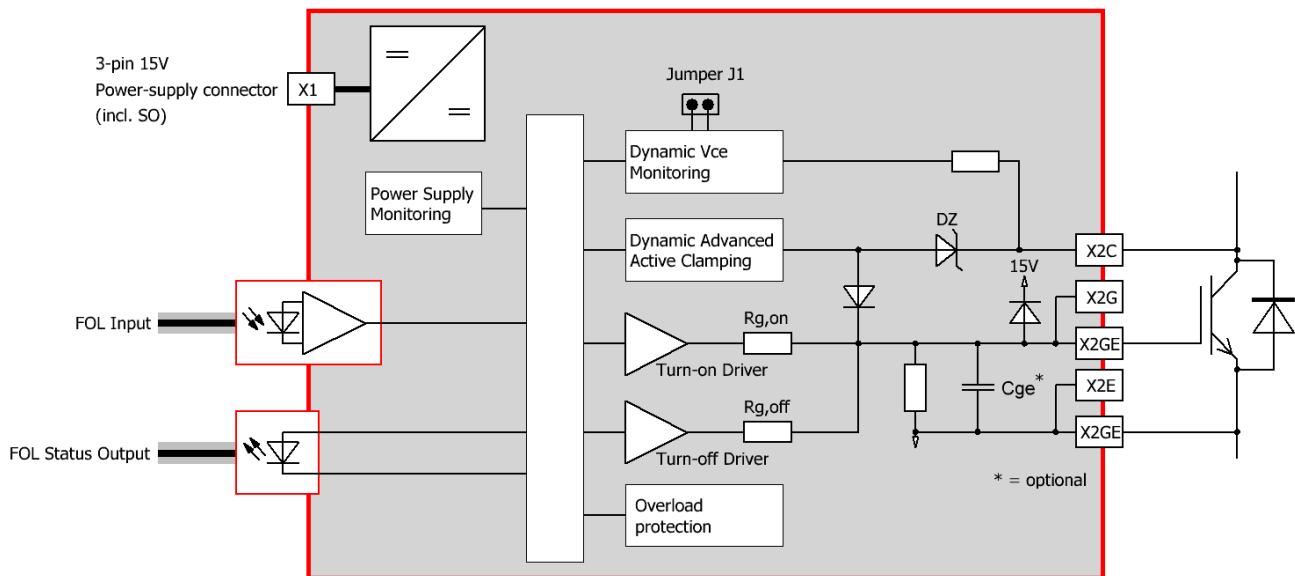


Fig. 2 Basic schematic of the 1SP0350V gate drivers

The gate driver contains all necessary components for optimal and safe driving of the relevant IGBT module: smallest recommended gate resistors in order to minimize switching losses, gate clamping, active-clamping diodes (overvoltage protection at turn-off), Vce monitoring (short-circuit protection) as well as the electrical and fiber-optic connectors. Moreover, it includes components for setting the turn-off trip level and the response time. Its plug-and-play capability means that it is ready to operate immediately after mounting. The user needs invest no effort in designing or adjusting the driver to a specific application.

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The Five Steps to Success

The following steps point out the easy way to use 1SP0350V gate drivers in power converters:

1. Choose a suitable driver

When applying 1SP0350V gate drivers, you should note that they are specifically adapted to a particular type of IGBT module.

These drivers are not valid for IGBT modules other than those specified. Incorrect use may result in failure.

2. Attach the drivers to the IGBT modules (one driver per IGBT module)



Any handling of IGBT modules or drivers is subject to the general specifications for protecting electrostatic-sensitive devices according to international standard IEC 60747-1, Chapter IX or European standard EN 100015 (i.e. the workplace, tools, etc. must comply with these standards).

If these specifications are ignored, both IGBTs and drivers may be damaged.

The driver can be easily mounted onto an IGBT module by connecting over cables the corresponding terminals.

3. Connect the driver to the control electronics

Connect the driver plug X1 to your control electronics and supply the driver with a voltage of +15V. Connect the fiber-optic transmitters and receivers.

4. Check the driver function

Check the gate voltage: For the off-state, the nominal gate voltage is specified in the relevant data sheet /3/. For the on-state, it is +15V. Also check the input current consumption of the driver according to its data sheet /3/ without clock signals and at the desired switching frequency.

These tests should be performed before installation, as the gate terminals may otherwise not be accessible.

5. Set up and test the power stack

Before starting up the system, it is recommended that each IGBT module be checked separately under power-cycling conditions. It is usually sufficient to apply the single or double-pulse technique. Power Integrations specially recommends users to check that the IGBT modules switch inside the SOA in the worst case condition.

Even if only single IGBTs are tested, all the system's gate drivers must be supplied with energy. All the other IGBTs are then kept in the off state by applying negative gate voltages. This is particularly important when switching the IGBTs under test.

The short-circuit behavior can also be verified at this point.

The system is then ready to start under real-world load conditions. This allows the thermal behavior of the whole arrangement to be determined.

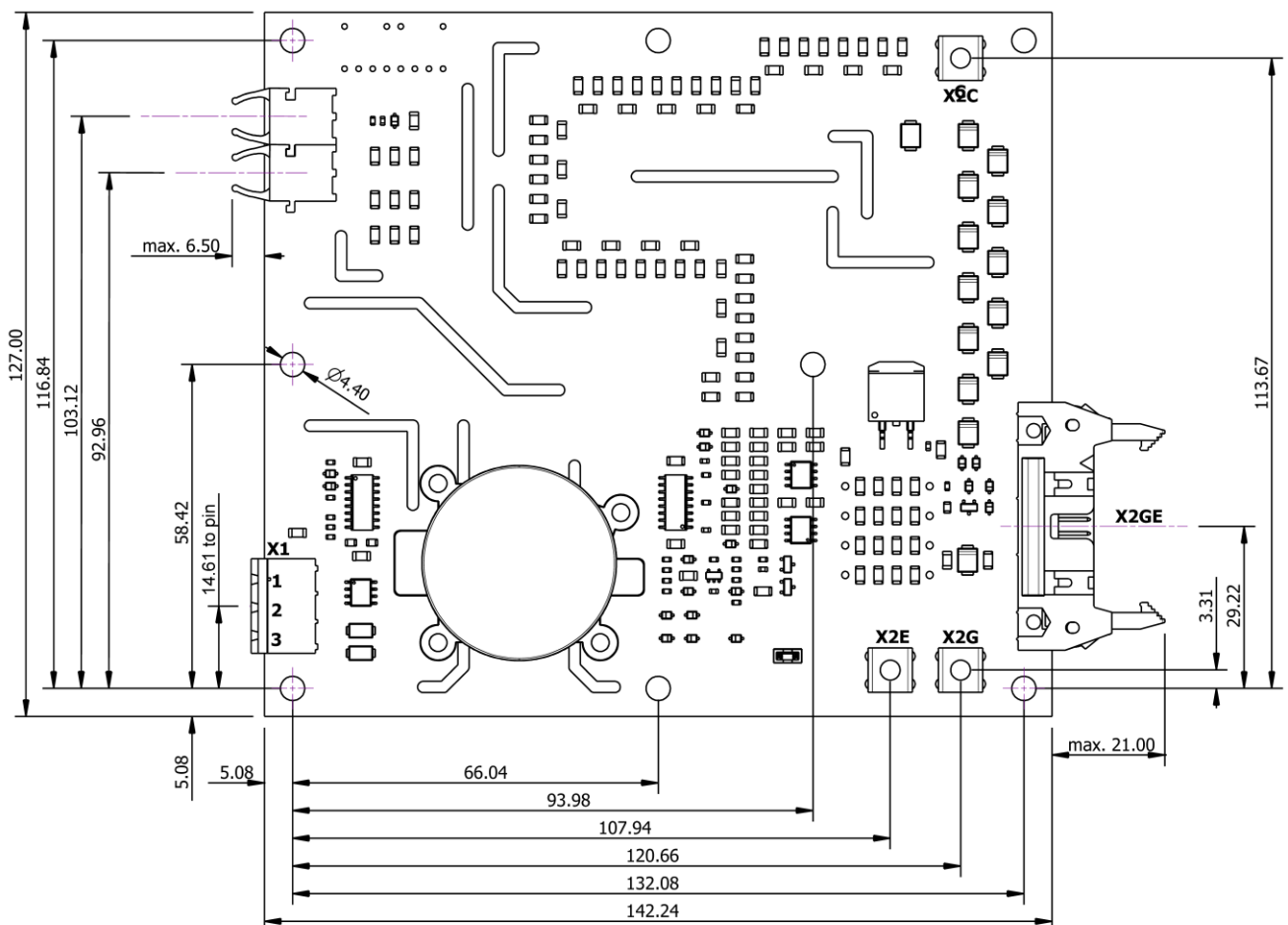
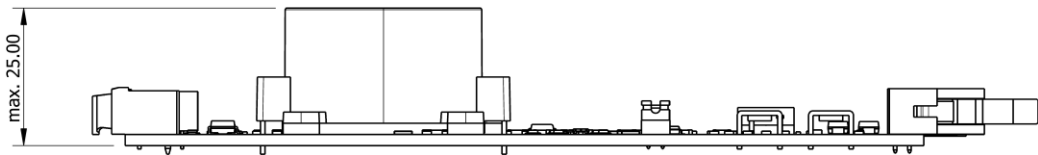
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The system must be re-qualified over the entire specified range of temperature and load conditions.



CAUTION: All handling with high voltages involves risk to life. It is imperative to comply with the respective safety regulations!

Mechanical Dimensions



Dimensions in mm

Fig. 3 Mechanical dimensions of 1SP0350V

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Recommended Cables and PCB Connectors

The following cables and PCB connectors for the interfaces X1 (power-supply terminal) and X2 (gate, emitter and collector terminals) are recommended:

Terminal	Recommended plug	Recommended cable
X1	CIF03005 (Sauro)	-
X2GE	3421-7600 (3M)	20-pole ribbon cable (Length ≤150mm)
X2G, X2E, X2C	-	Gate-emitter twisted (Cable length ≤150mm)

Note that X2C carries high potential referred to X2GE, X2G and X2E. Moreover, the X2GE, X2G, X2E and X2C cables may also carry high potential referred to the primary side (e.g. X1). The cables must be isolated to comply with the required insulation coordination.

Pin Designation of Connector X1 (Power Supply of 1SP0350V)

Pin	Des.	Function
1	VDC	+15V
2	GND	Ground
3	SO	Status DC/DC converter

Recommended Interface Circuitry for Connector X1

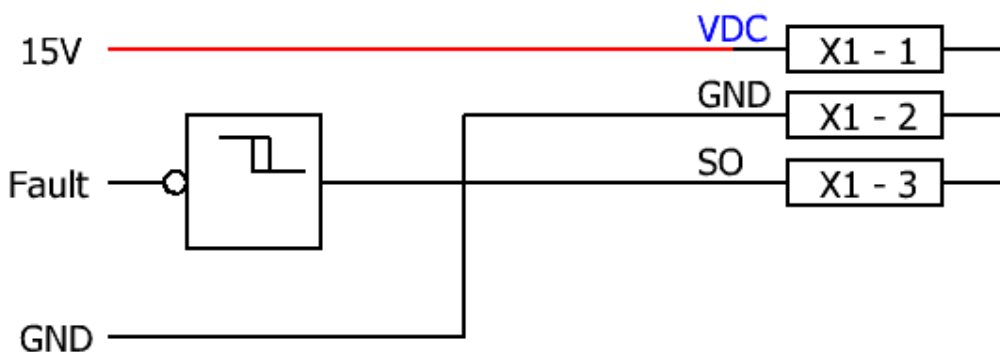


Fig. 4 Recommended user interface of 1SP0350V

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Description of Interface X1

General

The driver is equipped with a 3-pin interface connector. Pin 2 is used as GND connection. Pin 1 is used for the +15V voltage supply. Pin 3 is used as a status output to monitor the supply voltage VDC.

VDC terminal

The driver has one VDC terminal on the interface connector to supply the DC-DC converters for the secondary sides.

The VDC terminal must be connected to a single +15V power supply. The driver limits the inrush current at startup, and no external current limitation of the voltage source for VDC is needed.

SO (Status output power supply)

When no primary-side under-voltage condition is detected, an internal pull-up resistor of 10kΩ keeps the output level at the voltage level of VDC. When a primary-side supply under-voltage is detected, the status output SO goes to low (connected to GND). The SO output is automatically reset (returning to the voltage level of VDC) when the under-voltage on the primary side disappears.

The maximum SO current in a fault condition must not exceed the value specified in the driver data sheet /3/.

Note that the SO output is automatically reset about 90ms after the supply undervoltage fault disappears.

If not used, the SO output can be left open.

Description of the Fiber-Optic Input

This is the drive (command signal) input.

Description of the Fiber-Optic Output

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 malfunction is signaled 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 $t_{(ack)}$). Because this can be observed by the host controller, this method allows simple and continuous monitoring of all drivers and fiber-optic links of the system. Fig. 5 shows the control and response signals of a gate driver in normal operation.

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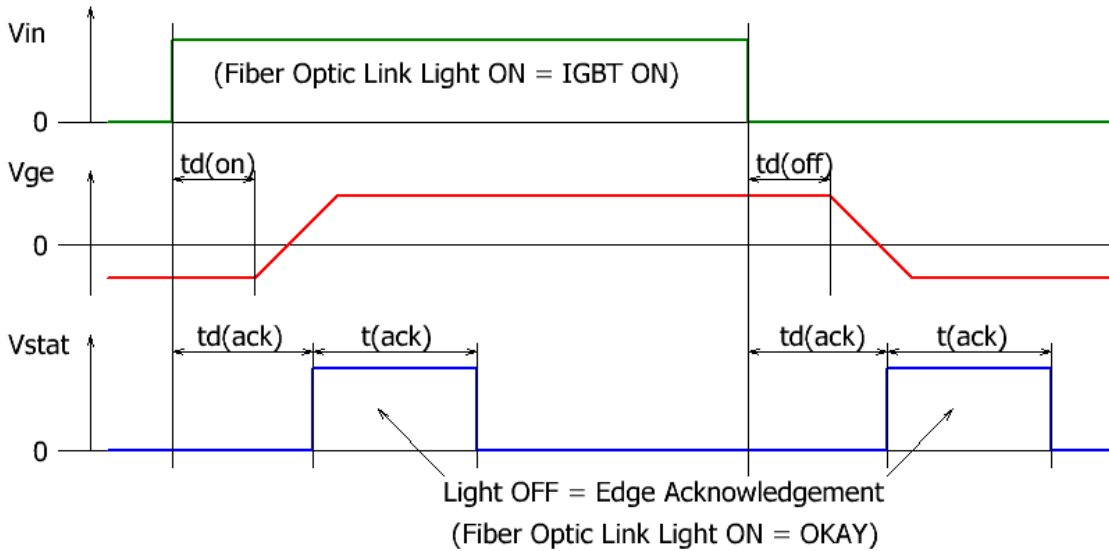


Fig. 5 Driver behavior and status feedback in normal operation

Fig. 6 shows the response of the driver in the event of a short-circuit fault (Jumper J1 not set). The fault status is transferred to the status feedback terminal after the response time. The light is then driven "off" during the delay to clear the fault state ($t_{(block)}$). The driver shuts the IGBT off with a delay of $t_{(cshd)}$ after the response time. Refer to /3/ for timing information. The IGBT can be turned on again by applying a positive edge to the corresponding fiber-optic input after the fault status has disappeared.

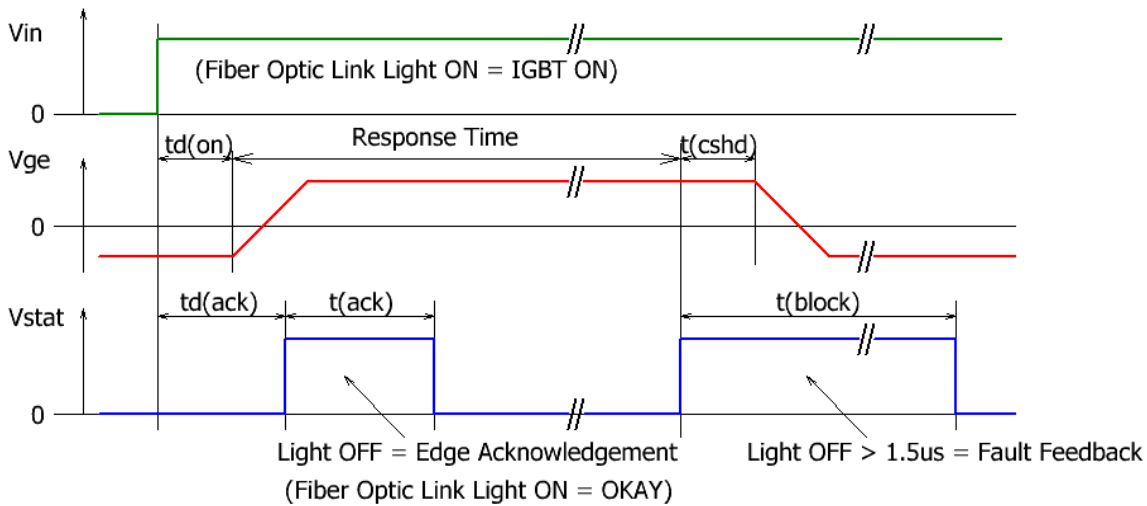


Fig. 6 Driver behavior and status feedback in the short-circuit condition (Jumper J1 not set)

In case of a secondary-side supply under-voltage fault, the fault status remains active as long as this under-voltage remains. The driver response in the event of a supply under-voltage on VISO-VE is shown in Fig. 7.

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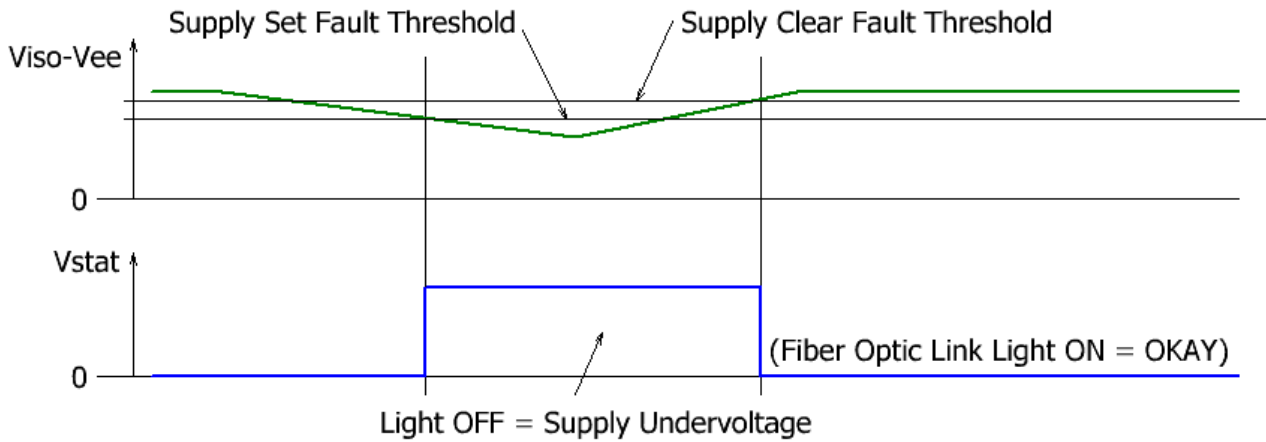


Fig. 7 Status feedback in the event of a supply undervoltage

In case of power supply short-circuit/overload, the fault status is repeatedly activated for about 1ms.

During power-up, the status feedback will also show a fault condition until the supply under-voltage/power supply overload protection disappears.

Recommended Interface Circuitry for Fiber Optics

The recommended circuitry for the fiber-optic links is given in Fig. 8.

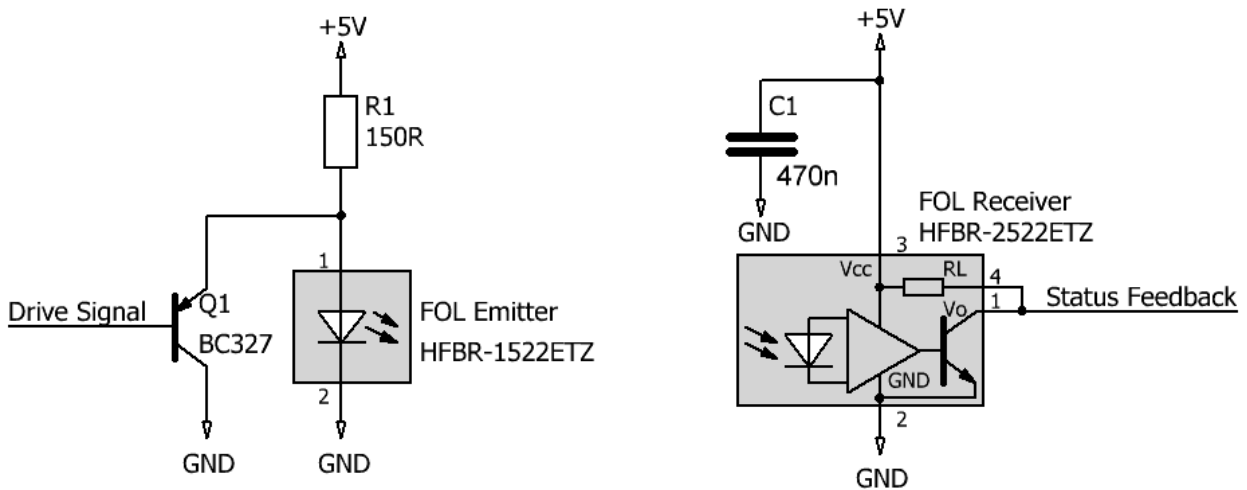


Fig. 8 Recommended circuitry for the fiber-optic links

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How Do 1SP0350V SCALE-2 Gate Drivers Work in Detail?

Overview

The 1SP0350V series of plug-and-play single-channel drivers is designed for high-power and high-voltage IGBT modules and Press-Packs. 1SP0350V SCALE-2 drivers are equipped with the usual protection functions such as dynamic V_{CE} monitoring for short-circuit protection, supply-undervoltage shutdown and status feedback. An overload protection function is also implemented on 1SP0350V drivers.

Outstanding features of 1SP0350V SCALE-2 drivers are: Dynamic Advanced Active Clamping function DA^2C , overload protection function and a very low propagation delay time. Active clamping describes an active scheme designed to protect the IGBTs against overvoltage during turn-off. It is particularly relevant when turning an IGBT off in cases of high DC-link voltage and collector current or short circuit.

Power supply and electrical isolation

The driver is equipped with a DC/DC converter to provide an electrically insulated power supply to the gate driver circuitry. The transformer features basic insulation according to IEC 61800-5-1 between the primary and secondary sides.

Note that the driver requires a stabilized supply voltage.

Power-supply monitoring

The driver's primary and secondary sides are equipped with a local under-voltage monitoring circuit.

In the event of a primary-side supply under-voltage, the under-voltage is signaled by the electrical status output SO. A primary-side under-voltage will not automatically cause a gate turn-off command. This condition has to be detected by the control logic which has to switch off and block the gate drive signal.

In case of a secondary-side supply under-voltage, the corresponding power semiconductor is driven with a negative gate voltage after the delay in IGBT turn-off to keep it in the off-state (the channel is blocked) and a fault condition is monitored on the fiber-optic status feedback with the light off until the supply voltage exceeds the reference level for enabling (Jumper J1 not set).

The driver 1SP0350V is further equipped with an output short-circuit/overload protection. The driver detects any short-circuit/overload current higher than the detection threshold (refer to the data sheet /3/ for more information) between gate and emitter as well as between VISO and COM. There is no protection against light overload of the power supply.

Note that a short circuit between gate and emitter might not be detected in the IGBT off-state (GL is connected to COM). The short circuit would then be detected when the driver turns on (GH is switched to VISO). A short-circuit/overload between VISO and COM is detected immediately.

In the event of a driver's power supply short-circuit/overload, the fault is immediately reported by the optical status feedback output. The fault signal applies – depending on the short circuit/overload condition – permanently or repeatedly for about 1ms. The primary-side supply VDC has to be switched off within the time frame given in the driver data sheet /3/ to prevent driver damage.

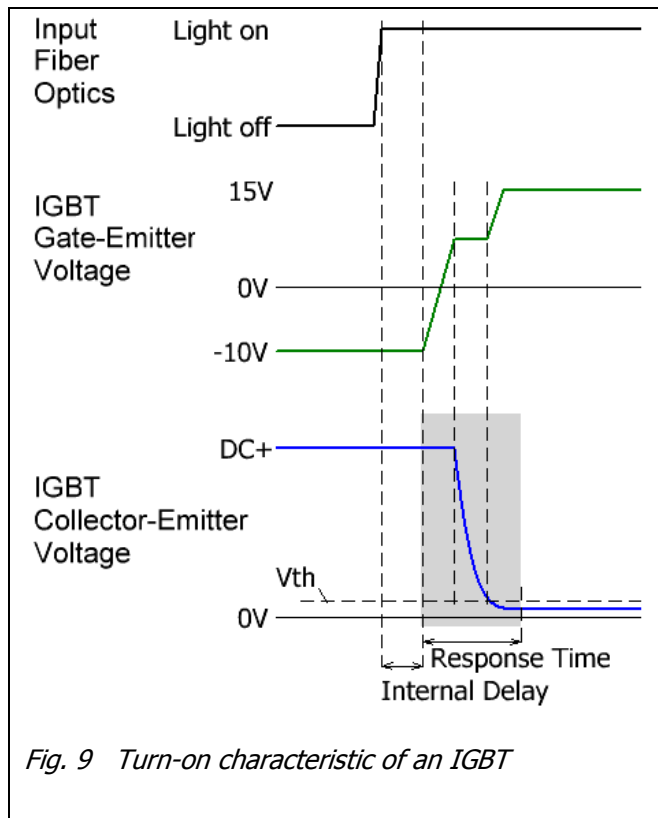
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3-level or multilevel topologies

In applications with multi-level topologies, the turn-off sequence of the individual power semiconductors usually needs to be controlled by the host controller in case of a detected fault condition (e.g. short circuit, over-current).

By setting Jumper J1 (refer to Fig. 12), the driver will only report a fault over the fiber-optic interface, but not turn-off the IGBT in fault condition (IGBT short-circuit, undervoltage lockout, overload protection). The user can therefore turn off the IGBT in the required sequence. Note that in that case, the user is responsible to turn off an IGBT short circuit within the maximum allowed short-circuit time (e.g. 10 μ s).

V_{CE} monitoring / short-circuit protection



A V_{CE} monitoring circuit is implemented in 1SP0350V gate drivers. The IGBT collector-emitter voltage is measured with a resistor network.

V_{CE} is checked after the response time (Fig. 9) at turn-on to detect a short circuit. If this voltage is higher than the programmed threshold V_{th}, the driver detects a short circuit at the IGBT and signals it immediately to the fiber-optic status feedback. After an additional delay, the corresponding IGBT is switched off (Jumper J1 not set). The fault feedback is automatically reset after the delay to clear the fault state. The IGBT is turned on again as soon as the next positive edge is applied to the fiber-optic input after the fault status has disappeared.

The dynamic V_{CE} monitoring circuit allows the V_{CE} curve form to be given a better fit.

It should be noted that the response time is dependent on the DC-link voltage. It remains constant between about 50% to 100% of the maximum DC-link voltage and increases at lower DC-link voltages. Please read the relevant driver data sheet for timing information /3/.

Note: The desaturation function is for short-circuit detection only and cannot provide overcurrent protection. However, overcurrent detection has a lower time priority and can be easily provided by the application.

Dynamic behavior of IGBTs

The dynamic behavior of IGBT modules depends on their type and manufacturer due to the specific behavior of the included IGBT and diode chips, the particular module construction and the distribution of the internal gate resistances and inductances. 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 the particular IGBT module. These drivers must not be used with IGBT modules other than those for which they were specified.

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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 is optimized to achieve minimum switching losses for the case of relatively low inductances within the power stack. It is recommended to check the commutation behavior within the final system assembly.

Turn-off of the IGBT

The IGBT is turned off when the corresponding input turns low (light off). The gate resistors are recommended by Power Integrations and must 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 can be approximated by:

$$V_{tr} = -L_s * di_c/dt$$

where V_{tr} is the turn-off overvoltage, i_c the collector current and L_s the stray inductance.

Overvoltage limitation at turn-off is essential for high-power or high-voltage IGBTs. To solve this problem, SCALE-2 plug-and-play drivers provide a Dynamic Advanced Active Clamping function DA²C which is described below.

Dynamic Advanced Active Clamping DA²C

Active clamping is a technique designed to partially turn on the IGBT in case the collector-emitter voltage exceeds a predefined threshold. The IGBT is then kept in linear operation. The basic circuit for active clamping can be found in /4/.

Basic active-clamping topologies implement a single feedback path from the IGBT's collector through transient voltage suppressor devices (TVS) to the IGBT gate. 1SP0350V SCALE-2 drivers support Power Integrations' Dynamic Advanced Active Clamping (DA²C) based on this principle:

- When active clamping is activated, the turn-off MOSFET of the driver is switched off in order to improve the effectiveness of the active clamping and to reduce the losses in the TVS. This feature – called Advanced Active Clamping – is mainly integrated in the secondary-side ASIC.
- Additional transient voltage suppressors (TVS) have been added in series to the TVS required to withstand the maximum DC-link voltage under switching operation. These TVS are short-circuited during the IGBT on state as well as during about 15-20µs after the turn-off command to guarantee efficient active clamping. After this delay, these additional TVS are activated and allow the DC-link voltage to be increased to a higher value during the IGBT off-state (e.g. after emergency shut-down). This feature – together with Advanced Active Clamping – is called Dynamic Advanced Active Clamping DA²C. Note that the time during which the voltage can be applied above the value for switching operation should be limited to short periods (< 60 seconds).

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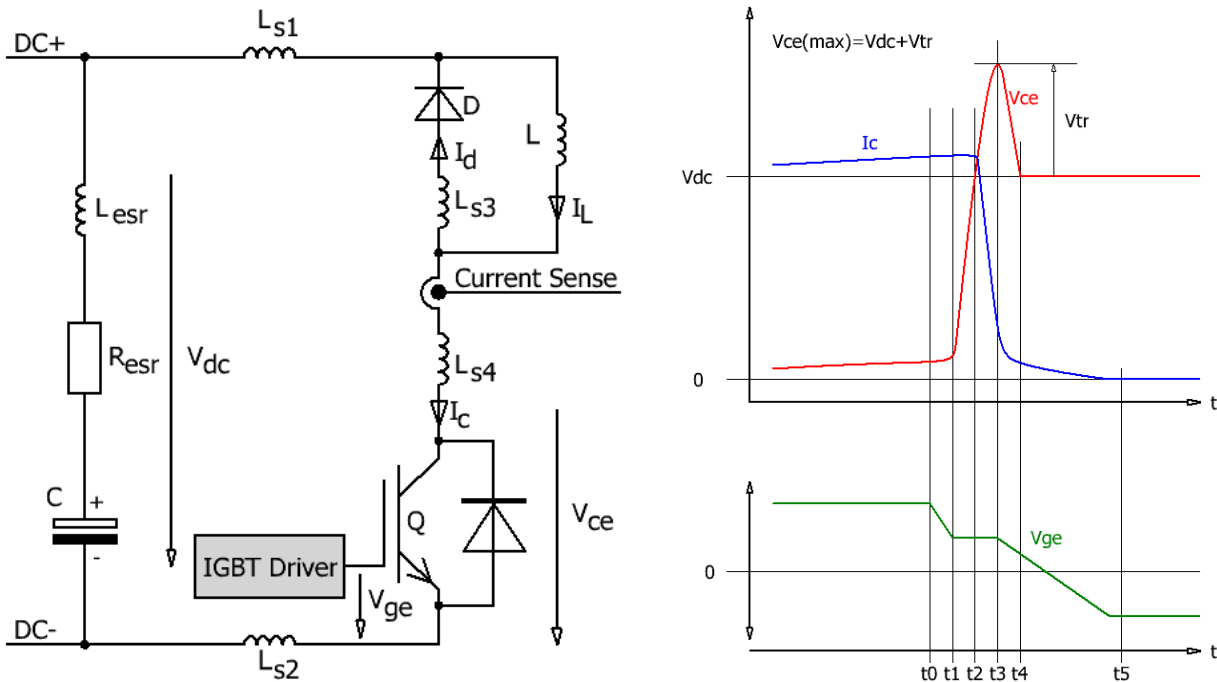


Fig. 10 Test circuit (left) and typical switching behavior (right)

Legend to Fig. 10

- t0 = Initiation of the turn-off process
- t1 = Start of turn-off time
- t2 = Start of collector current fall time
- t3 = Maximum collector to emitter voltage
- t4 = IGBT is blocking, start of tail current
- t5 = End of tail current

In comparison with other driving methods, active clamping allows enhanced utilization of the IGBT modules during normal operation by increasing the switching speed and therefore reducing switching losses. The overvoltage at turning off an overcurrent is also managed by active clamping.

The value of the maximum DC-link voltage under switching operation and in IGBT off state can be found in the corresponding driver data sheet /3/.

Fig. 11 shows an exemplary turn-off transition of a 3000A/4500V IGBT module controlled with a 1SP0350V driver.

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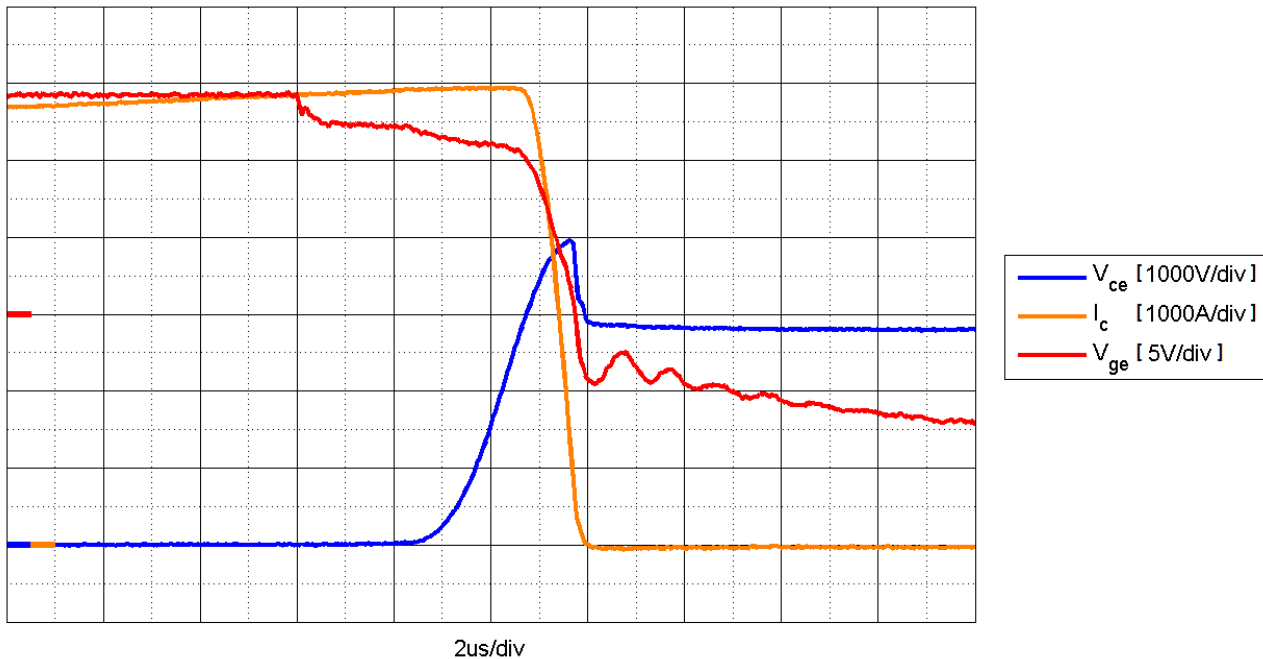


Fig. 11 Behavior of a 3000A/4500V IGBT module turning off at a DC-link voltage of 2800V a collector current of 6000A, which is twice the nominal collector current

Low-inductance layout

The active-clamping function should not lead anyone to forget about the inductances of the power stack. For several reasons, it is still necessary to reduce the DC-link stray inductance to about 50nH...200nH with 1SP0350V plug-and-play drivers.

Higher requirements for traction applications or similar

The power-supply interface X1 as well as the IGBT-module steering connector X2GE provide a mechanical interlock and are suitable for traction applications.

For sufficient vibration withstand capability the 1SP0350V SCALE-2 driver must be screw fitted onto a mounting plate (see red marked mounting holes in Fig. 12). **However, it should be noted that these connections must be electrically insulated to comply with the particular clearance and creepage distance requirements (e.g. use of plastic distance bolts).**

Furthermore, an interlocking version of the fiber optic links is available.

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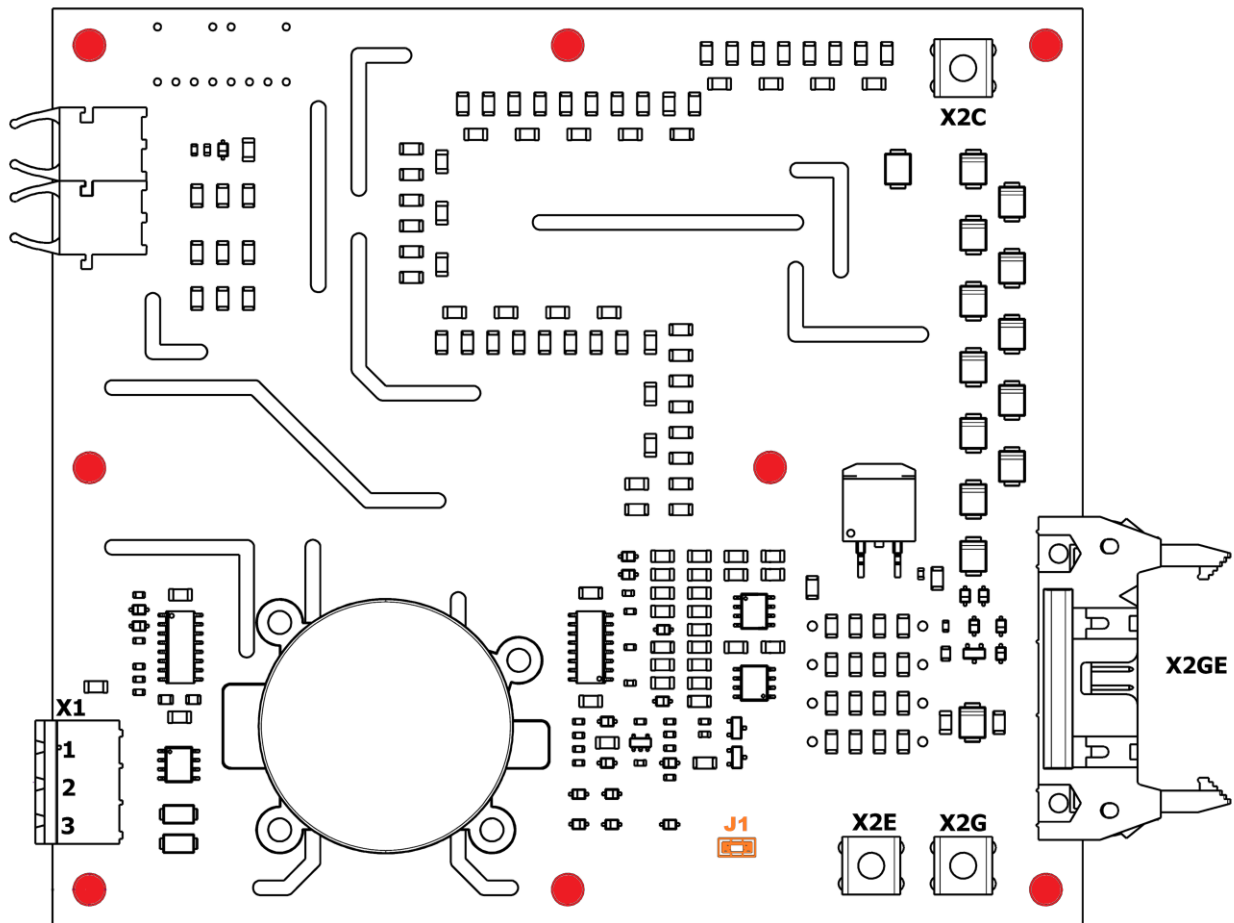


Fig. 12 Measures for fixing the driver (red). Position of jumper J1 (orange).

References

- /1/ Paper: Smart Power Chip Tuning, Bodo's Power Systems, May 2007
- /2/ Description and Application Manual for SCALE™ Drivers, Power Integrations
- /3/ Data sheets of SCALE™-2 plug-and-play driver 1SP0350V2A0-45, Power Integrations
- /4/ Paper: Advantages of Advanced Active Clamping, Power Electronics Europe, Nov/Dec 2009

Note: The papers are available on the Internet at www.power.com/igbt-driver/go/papers.

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The Information Source: SCALE-2 Driver Data Sheets

Power Integrations offers the widest selection of gate drivers for power MOSFETs and IGBTs for almost any application requirements. The largest website on gate-drive circuitry anywhere contains all data sheets, application notes and manuals, technical information and support sections: www.power.com.

Quite Special: Customized SCALE-2 Drivers

If you need an IGBT driver that is not included in the delivery range, please don't hesitate to contact Power Integrations or your Power Integrations' sales partners.

Power Integrations has more than 25 years experience in the development and manufacture of intelligent gate drivers for power MOSFETs and IGBTs and has already implemented a large number of customized solutions.

Technical Support

Power Integrations provides expert help with your questions and problems:

www.power.com/igbt-driver/go/support

Quality

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Ordering Information

Our international terms and conditions of sale apply.

See the current list on www.power.com/igbt-driver/go/1SP0350V.

Refer to www.power.com/igbt-driver/go/nomenclature for information on driver nomenclature.

Information about Other Products

For drivers adapted to other high-voltage or high-power IGBT modules

Direct link: www.power.com/igbt-driver/go/Plug-and-Play

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