

2SP0320V and 2SP0320S Description & Application Manual

Driver solution for PrimePACK™ IGBT modules with fiber-optic interface
for 2-level, 3-level and multilevel converter topologies

Abstract

2SP0320V and 2SP0320S are dual-channel drivers with fiber-optics:

- 2SP0320V is equipped with versatile fiber-optic links (AVAGO HFBR-x522)
- 2SP0320S is equipped with ST fiber-optic links (AVAGO HFBR-x412Z)

The drivers are based on CONCEPT's SCALE-2 chipset, a highly integrated technology for the reliable driving and safe operation of IGBTs.

Perfectly matched driver versions are available for all PrimePACK™ 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.

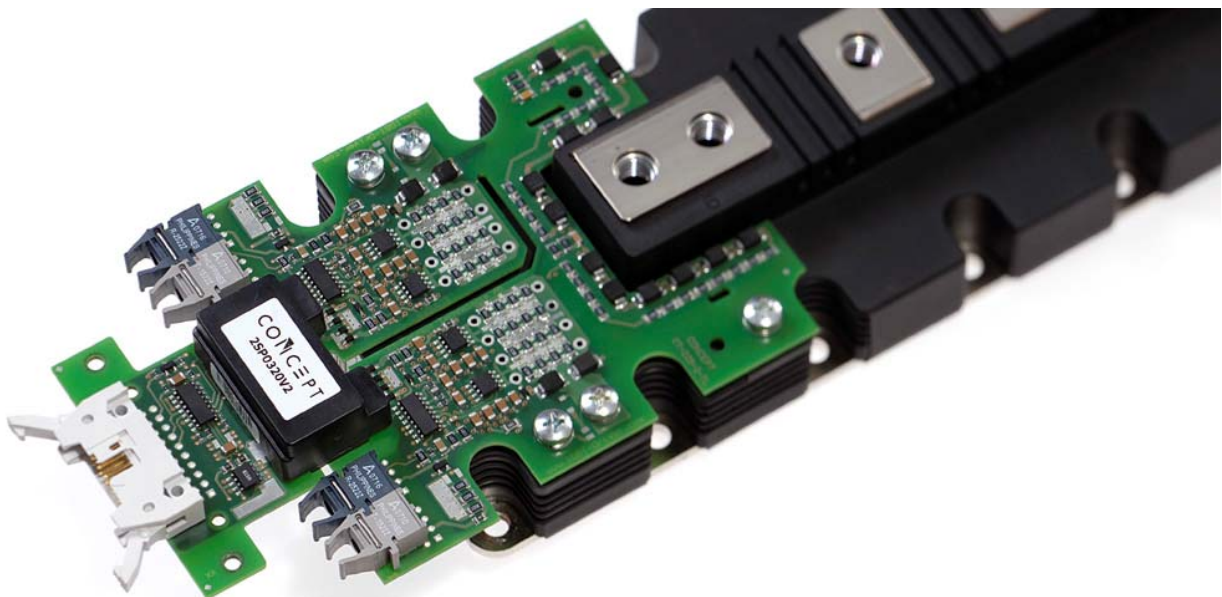


Fig. 1 2SP0320V screwed onto a PrimePACK™ IGBT module

PrimePACK is a trademark of Infineon Technologies AG, Munich

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System Overview

The 2SP0320V and 2SP0320S are plug-and-play drivers based on the highly integrated SCALE-2 chipset developed by CONCEPT /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/.

The basic topology of the 2SP0320V and 2SP0320S drivers is shown in Fig. 2. The values for the gate resistors and other key components can be found in the specific datasheets for a given IGBT module /3/.

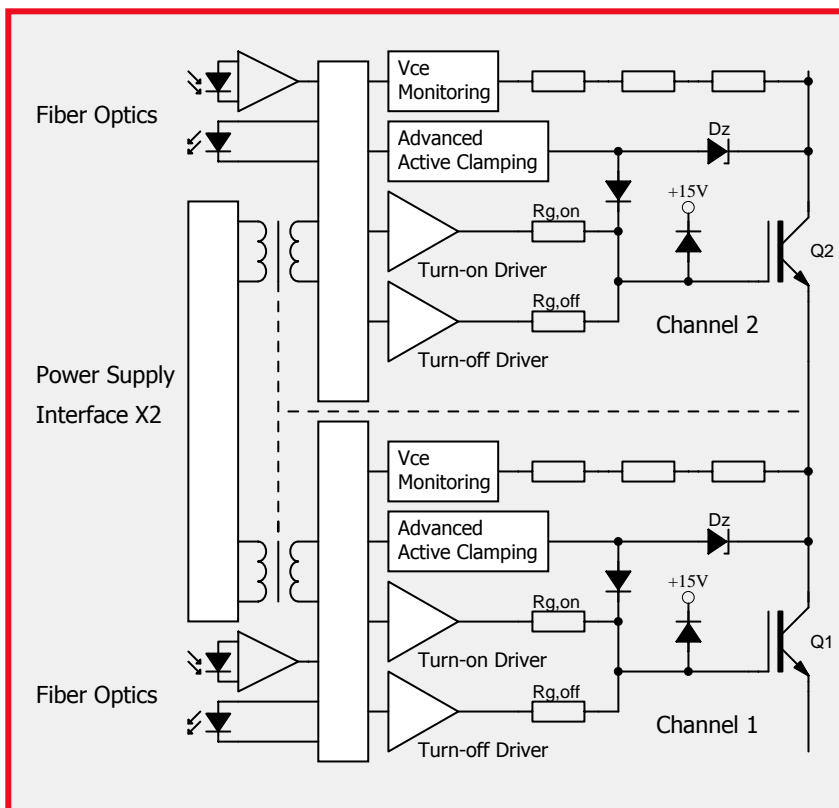


Fig. 2 Basic schematic of the 2SP0320V and 2SP0320S drivers

The driver contains all necessary components for optimal and safe driving of the relevant IGBT module: smallest 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.

The Five Steps to Success

The following steps point out the easy way to use 2SP0320V and 2SP0320S drivers in power converters:

1. Choose a suitable driver

When applying 2SP0320V or 2SP0320S drivers, you should note that they are specifically adapted to a particular type of IGBT module.

The type designation of the driver consequently also includes a number corresponding to a specific IGBT module (see "Ordering Information").

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



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 screwing the corresponding terminals.

3. Connect the driver to the control electronics

Connect the driver plug X2 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 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. CONCEPT specially recommends users to check that the IGBT modules switch inside the RBSOA in the worst case condition, as this strongly depends on the specific converter construction.

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.

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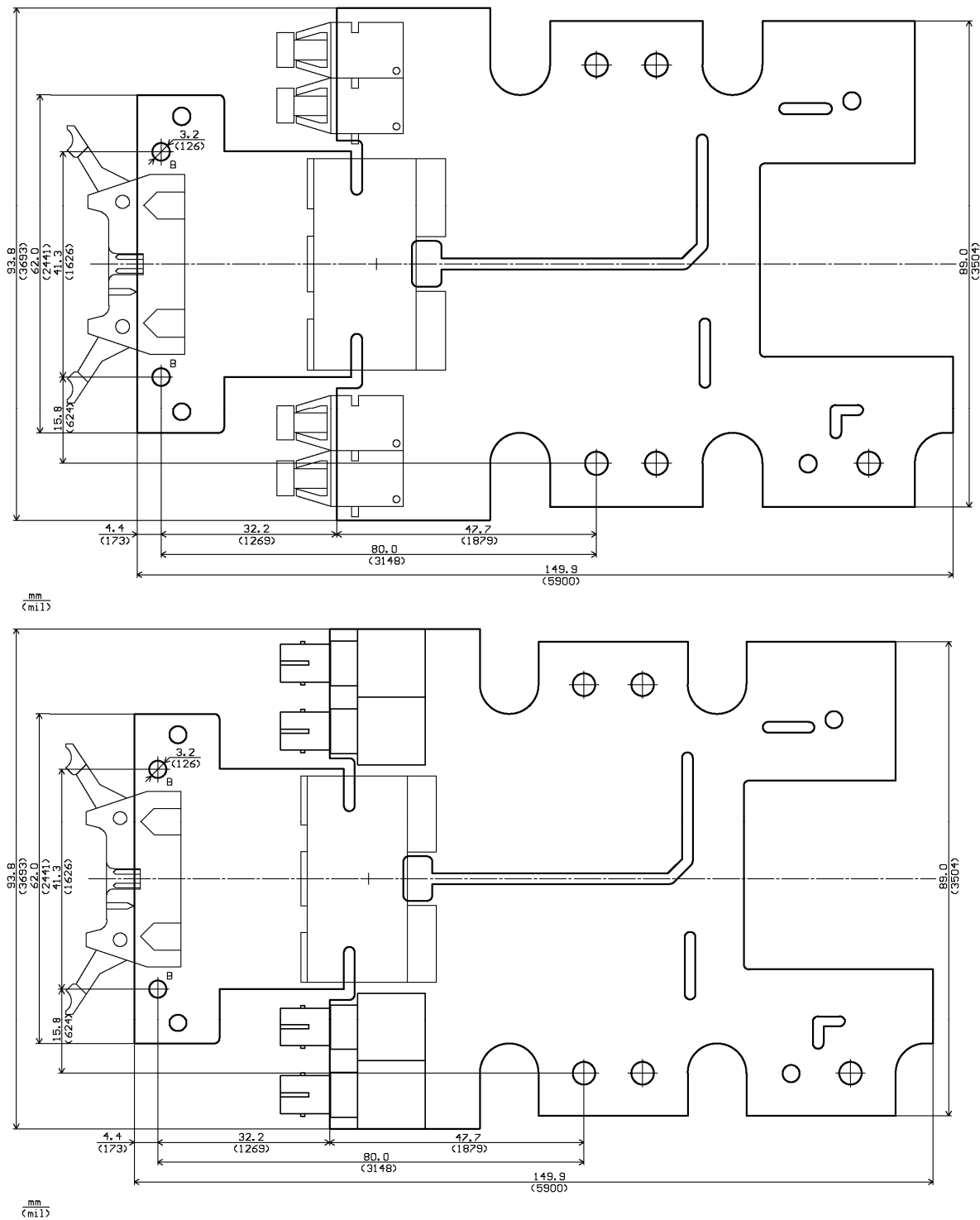
The system is then ready to start under real-world load conditions. This allows the thermal behavior of the whole arrangement to be determined.

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



Max. driver height: 18mm measured from bottom layer

Holes B: fixing holes

Electrical connector on the driver: 71922-110LF from FCI, recom. cable connector: 71600-010LF from FCI

Recommended twisted pair flat cable: 1700/10 or 2100/10 from 3M™

Fig. 3 Mechanical dimensions of 2SP0320V (top picture) and 2SP0320S (bottom picture)

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Pin Designation of Connector X2

| Pin | Des. | Function | Pin | Des. | Function |
|-----|------|-----------------------------------|-----|------|----------|
| 1 | VDC | +15V for DC/DC converter | 2 | GND | Ground |
| 3 | VDC | +15V for DC/DC converter | 4 | GND | Ground |
| 5 | SO | Status output (power supply) | 6 | GND | Ground |
| 7 | VCC | +15V for primary side electronics | 8 | GND | Ground |
| 9 | VCC | +15V for primary side electronics | 10 | GND | Ground |

Recommended Interface Circuitry for Connector X2

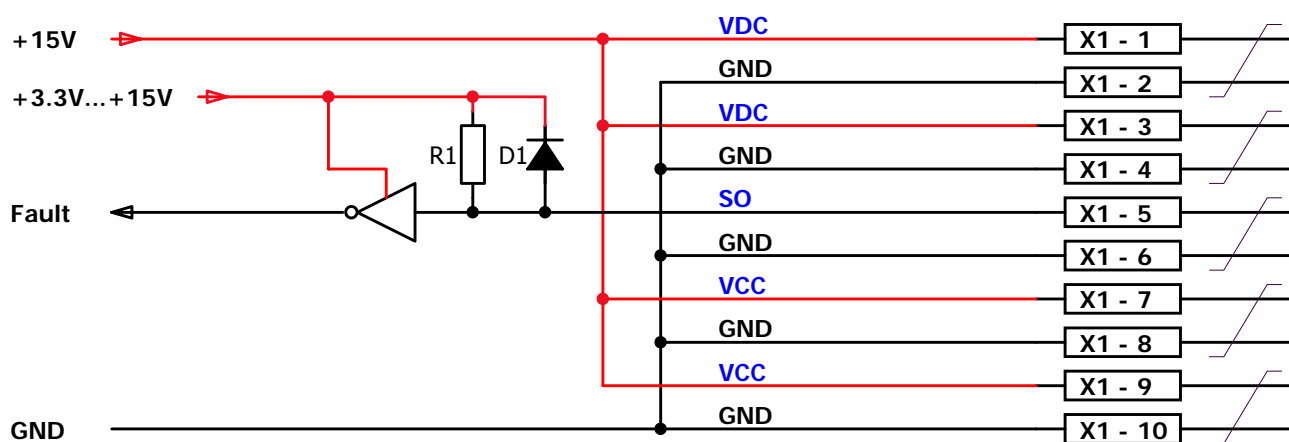


Fig. 4 Recommended user interface of 2SP0320V and 2SP0320S

Description of Interface X2

General

The driver is equipped with a 10-pin interface connector. All even-numbered pins are used as GND connections. The odd-numbered pins 1, 3, 7 and 9 are used for the +15V voltage supply. Pin 5 is used as a status output to monitor the supply voltage VCC.

It is recommended to use a 10-pin twisted flat cable. Pin 5 is then twisted with its own GND wire. All GND pins are connected together on the drivers 2SP0320V and 2SP0320S and should be also connected on the control-board side. This arrangement produces a very low-inductance connection with high immunity against interferences.

VCC terminal

The driver has two VCC terminals on the interface connector to supply the primary side electronics.

VDC terminal

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

As the driver can deliver a total power of $2 \times 3W = 6W$, the maximum input current drawn from the +15V supply is approx. 0.6A (total for terminals VDC and VCC).

All VCC and VDC terminals 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. VDC and VCC terminals are split into separate pins only for testing.

SO (status output power supply)

When no power supply undervoltage of VCC is detected, the output SO has high impedance. An internal current source of 500 μ A pulls it to a voltage of about 4V when leaved open. When a power supply undervoltage of VCC is detected, the status output SO goes to low (connected to GND).

The diode D1 must be a Schottky diode and must only be used when using 3.3V logic. For 5V...15V logic, it can be omitted.

The maximum SO current in a fault condition should not exceed the value specified in the driver data sheets /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 Fiber-Optic Inputs

These are drive inputs. It should be noted that 2SP0320V and 2SP0320S do not feature half-bridge mode.

Description of Fiber-Optic Outputs (status feedback & edge acknowledge)

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

Each edge of the control signal is acknowledged by the driver with a short pulse (light is off for a period of about 700ns). As 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. Figure 5 shows the control and response signals of a gate driver for normal operation.

Figure 6 shows the response of the driver in case of a short-circuit fault. 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 (about 11 μ s). The driver shuts the IGBT off about 1.4 μ s after the response time. This delay allows the user to use 2SP0320V and 2SP0320S drivers in 3-level or multilevel topologies (see "3-level and multilevel topologies" on page 16). The IGBT can be turned on again by applying a positive edge to the corresponding fiber-optic input after the fault status has disappeared.

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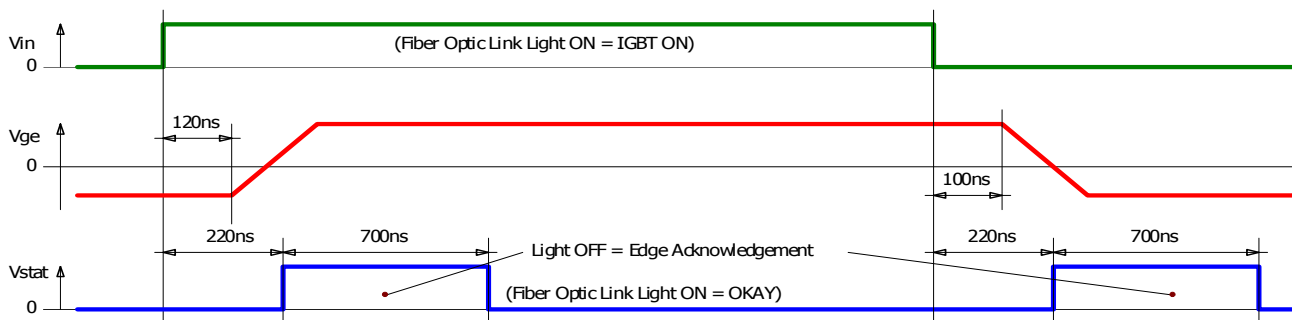


Fig. 5 Driver behavior and status feedback in normal operation

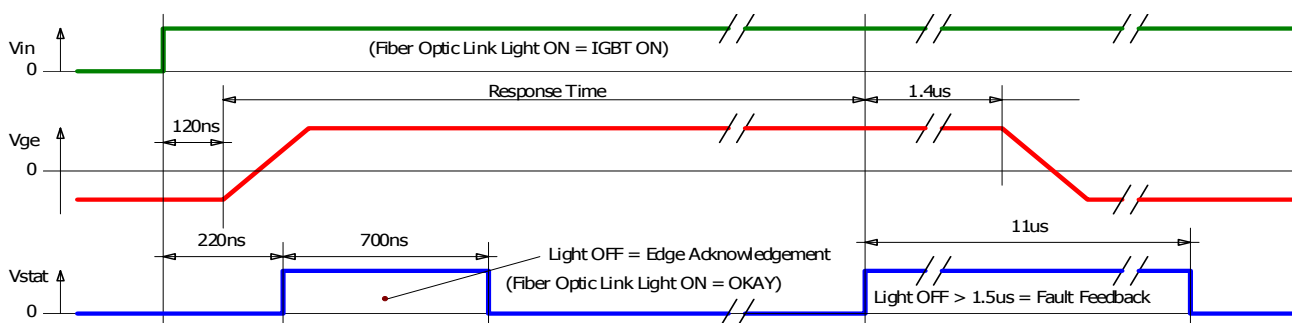


Fig. 6 Driver behavior and status feedback in short-circuit condition

In case of a secondary supply undervoltage fault, the response of the driver is basically the same as in Fig. 6. The fault status keeps active and the driver channel is locked as long as the supply undervoltage remains on the corresponding driver channel.

N.B. During power up, the status feedback will also show a fault condition until the supply undervoltage disappears.

Recommended Interface Circuitry for Fiber Optics

The fiber-optic links are available in two versions (refer to the relevant data sheet /3/): "Versatile" fiber-optic link (2SP0320V) and "ST" fiber-optic link (2SP0320S). See also Fig. 3.

The recommended circuitry for the fiber-optic links is given in Fig. 7 (2SP0320V) and Fig. 8 (2SP0320S).

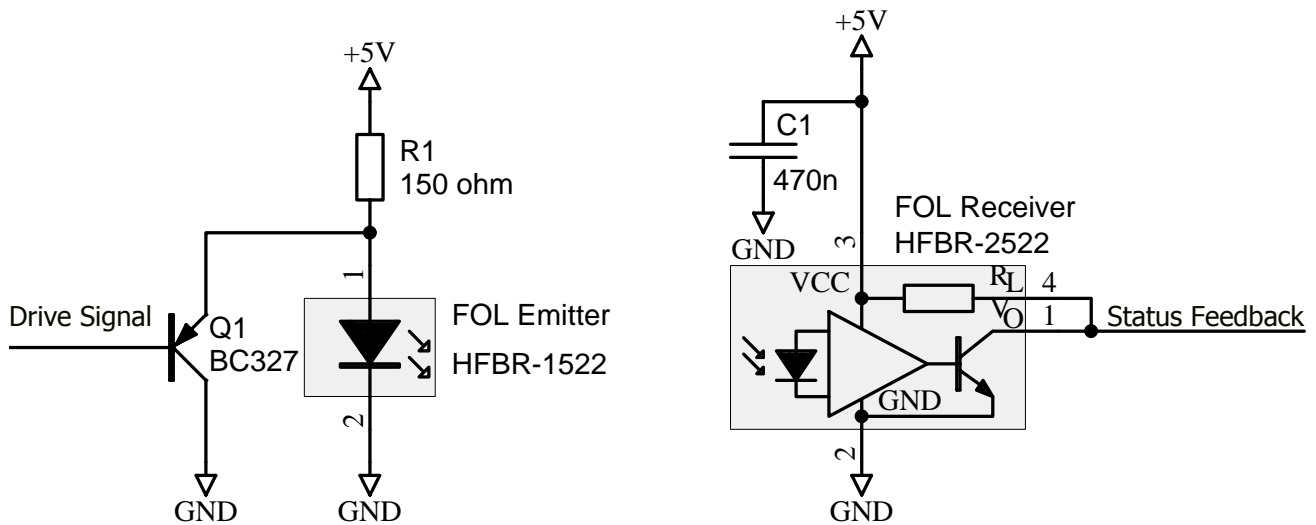


Fig. 7 Recommended circuitry for the "versatile" fiber-optic links (2SP0320V)

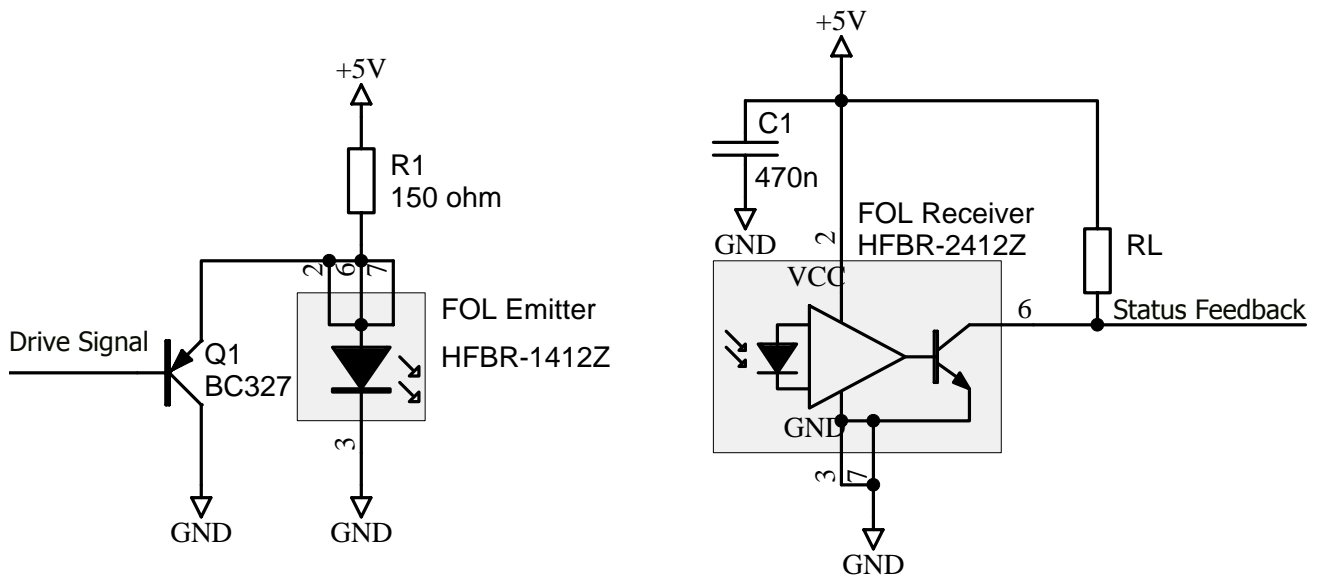


Fig. 8 Recommended circuitry for the "ST" fiber-optic links (2SP0320S)

How Do 2SP0320V and 2SP0320S SCALE-2 Drivers Work in Detail?

Overview

The 2SP0320V and 2SP0320S series of plug-and-play dual-channel drivers are designed for PrimePACK™ IGBT modules from Infineon. All drivers of the SCALE-2 driver family with a fiber-optic interface are equipped with usual protection functions such as V_{ce} monitoring for short-circuit protection, supply-undervoltage shutdown and status feedback.

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Outstanding features of 2SP0320V and 2SP0320S SCALE-2 drivers are: compact size, simple mounting - directly onto the IGBT module, advanced active-clamping function, very low propagation delay time, optional dV/dt feedback to reduce the high dV/dt at turn-off (refer to paragraph "dV/dt feedback" on page 15). 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.

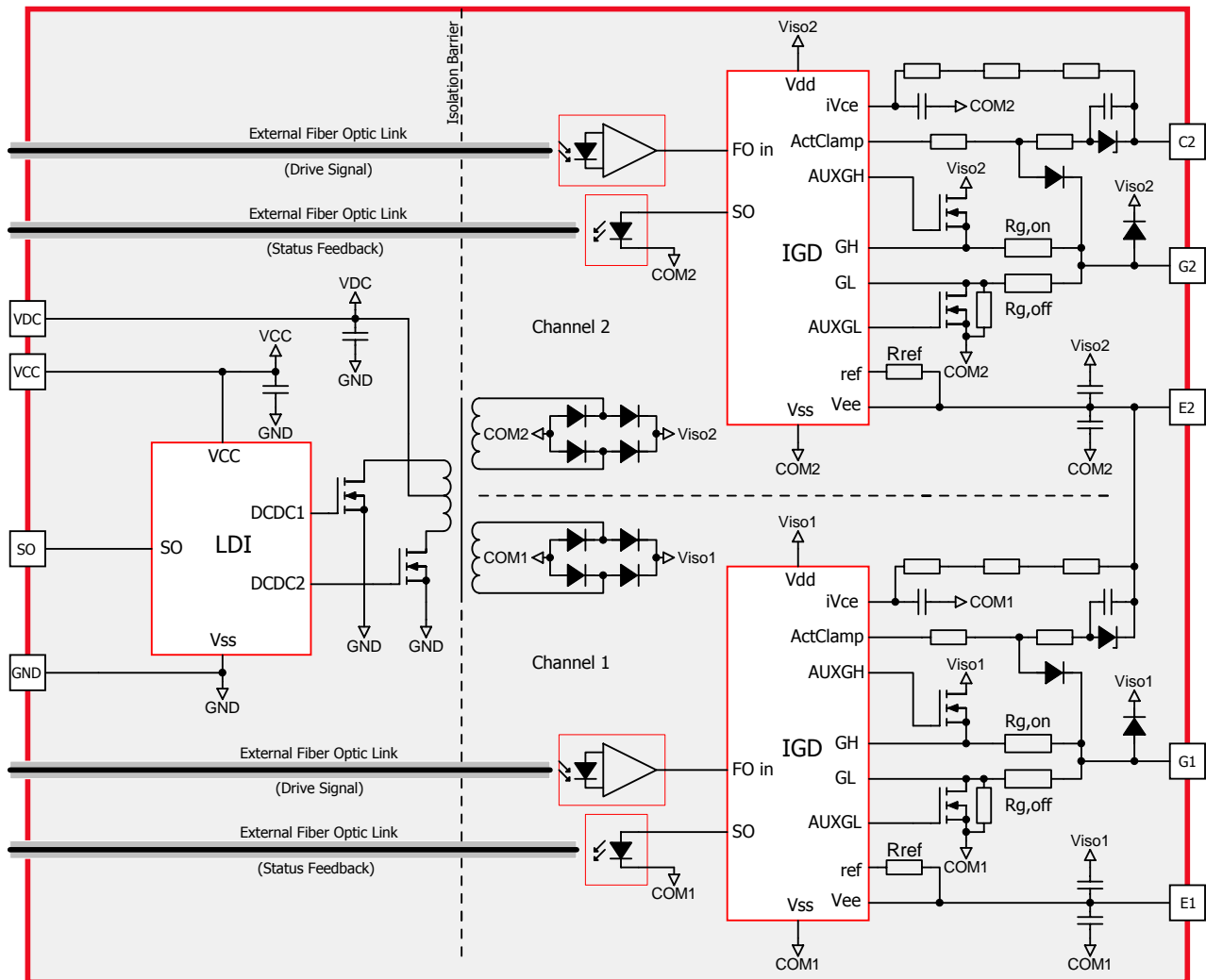


Fig. 9 Block diagram of 2SP0320V and 2SP0320S SCALE-2 drivers

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 transformers feature safe isolation to EN 50178, protection class II between primary side and either secondary side (refer to the data sheets /3/).

Note that the driver needs a stabilized supply voltage.

Power-supply monitoring

The driver's primary side as well as both secondary-side driver channels are equipped with a local undervoltage monitoring circuit.

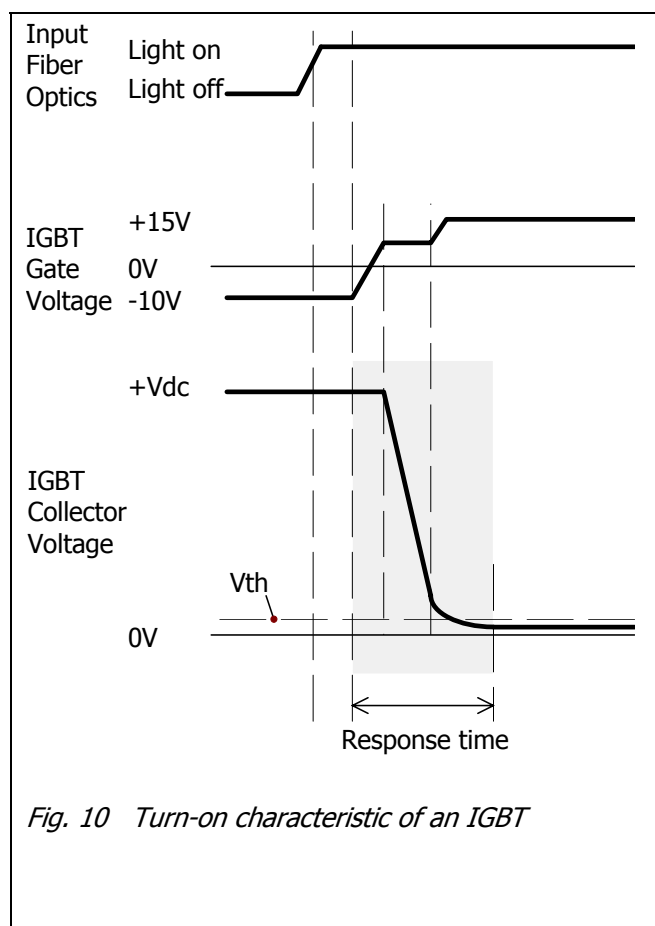
In case of primary-side supply undervoltage, the fault is transmitted to the output SO. However, the IGBTs are not turned off (the channels are not blocked).

In case of secondary-side supply undervoltage, the corresponding IGBT is driven with a negative gate voltage to keep it in the off-state (the channel is blocked) and a fault condition is transmitted to the fiber-optic status feedback.

Even in the case of a low power supply voltage, the driver provides a low-impedance path from the IGBT gate to the emitter.

Within a half-bridge, it is advised not to operate the IGBTs with an IGBT driver in the event of a low supply voltage. Otherwise, a high rate of increase of V_{ce} may cause partial turn-on of these IGBTs.

V_{ce} monitoring / short-circuit protection



The basic V_{ce} monitoring circuit implemented in 2SP0320V and 2SP0320S SCALE-2 drivers is illustrated in Fig. 9. Both IGBT collector-emitter voltages are measured with a resistor network.

V_{ce} is checked after the response time (see Fig. 10) 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 corresponding fiber-optic status feedback. After an additional delay, the corresponding IGBT is switched off. This delay allows the user to use 2SP0320V and 2SP0320S drivers in 3-level or multilevel topologies. 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 corresponding fiber-optic input after the fault status has disappeared.

It should be noted that the response time increases at DC-link voltages lower than about 550V. 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.

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Dynamic behavior of IGBTs

The dynamic behavior of IGBT modules depends on the type and manufacturer due to the particular behavior of the included IGBT and diode chips, the particular module construction and the distribution of internal gate resistances and inductances. Note that different module types from the same manufacturer may also require a specific gate-driver adaptation.

CONCEPT 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.

Turn-on of the IGBT / commutation of diode current

When a driver input goes high, the gate driver turns on the corresponding IGBT. The driver already includes the gate resistors, which are matched to the relevant IGBT module.

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. The gate resistors are determined by CONCEPT 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:

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

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

Most competing drivers are unable to limit the overvoltage in case of overload or short circuit. However, this is essential for high-power or high-voltage IGBTs. To solve this problem, SCALE-2 plug-and-play drivers provide an advanced active-clamping function.

Moreover, 2SP0320V and 2SP0320S drivers feature an optional dV/dt feedback that reduces the high dV/dt at turn-off. Both active clamping and dV/dt feedback are described below.

Advanced active clamping

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. 2SP0320V and 2SP0320S SCALE-2 drivers support CONCEPT's advanced active clamping 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 is mainly integrated in the secondary side ASIC. The circuitry used is shown in Fig. 9.

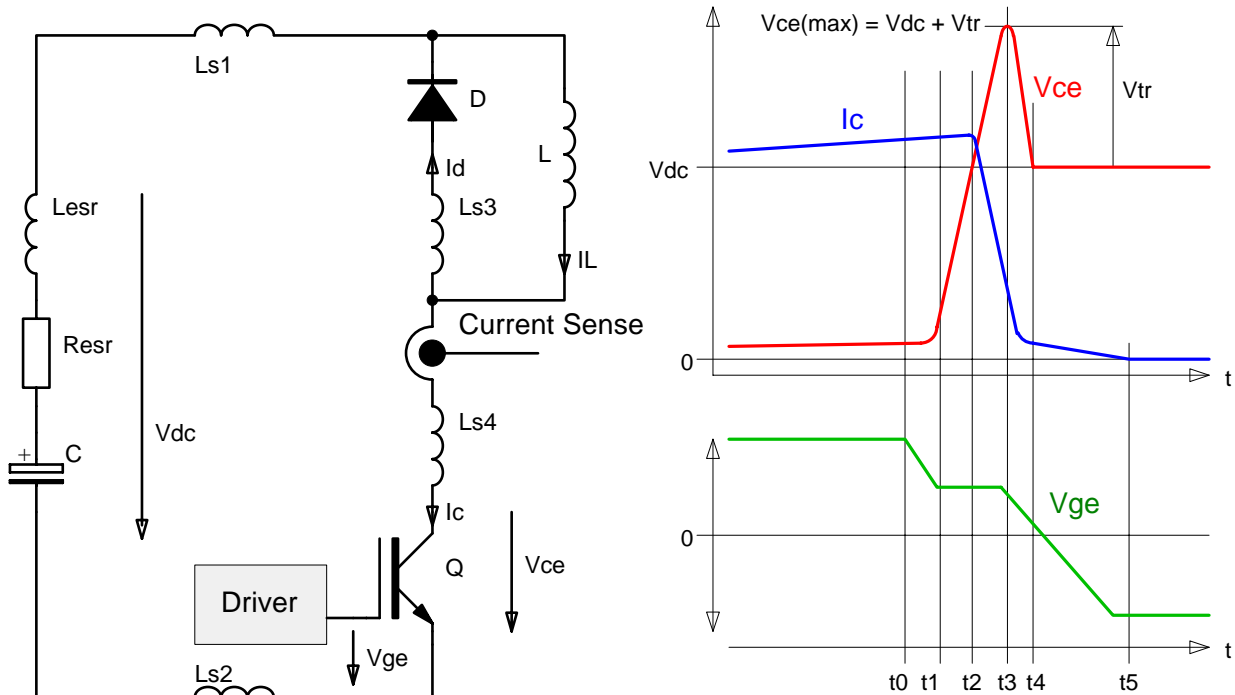


Fig. 11 Test circuit (left) and typical switching behavior (right)

Legend to Fig. 11

- t_0 = Initiation of the turn-off process
- t_1 = Start of turn-off time
- t_2 = Start of collector current fall time
- t_3 = Maximum collector voltage
- t_4 = IGBT is blocking, start of tail current
- t_5 = 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 fault-current turn-off is also managed by active clamping. For the maximum permitted DC-link voltage, refer to the gate driver data sheets /3/.

Figure 12 shows an exemplary turn-off transition of a 1400A/1200V IGBT module controlled with a 2SP0320V or 2SP0320S driver.

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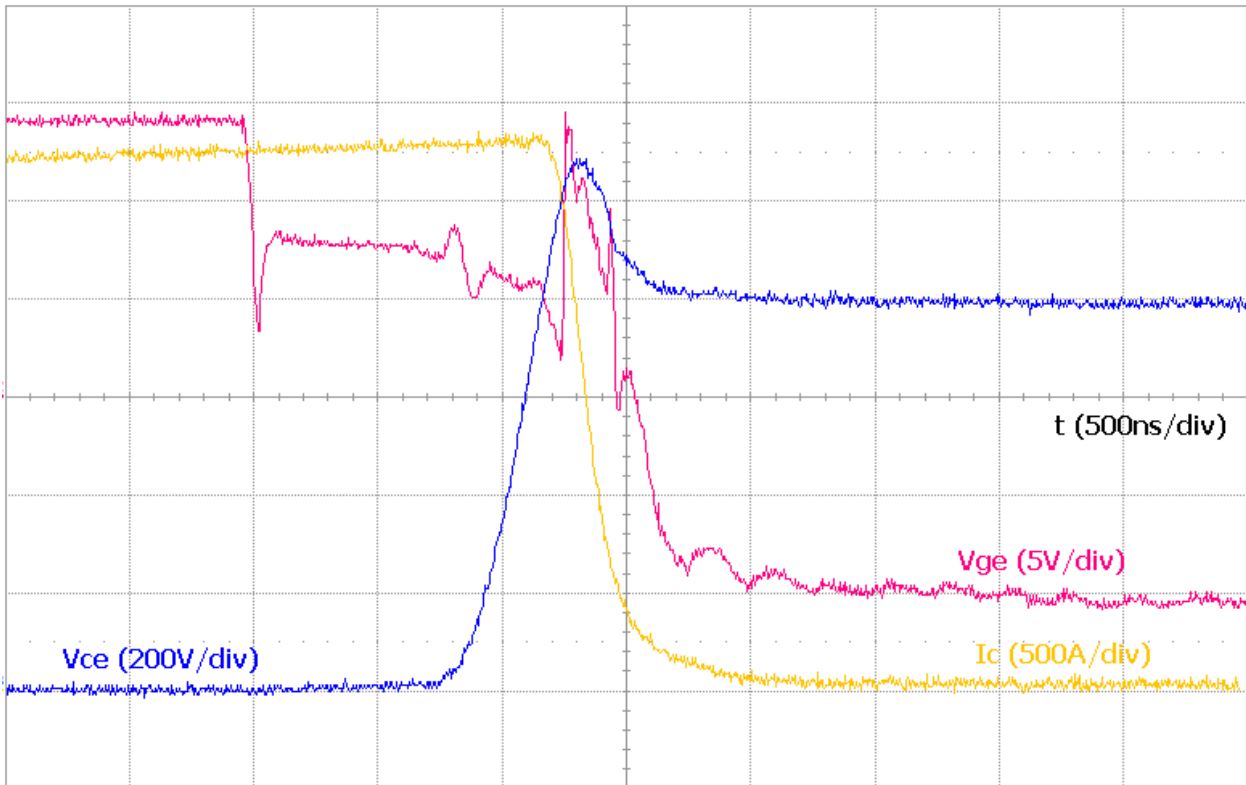


Fig. 12 Behavior of a 1400A/1200V IGBT module turning off at a DC-link voltage of 800V a collector current of 2800A, which is twice the nominal collector current

Parallel connection of 2SP0320V and 2SP0320S

The 2SP0320V and 2SP0320S are unsuitable for parallel connection, as the delay differences between drivers as well as the jitter are too high due to the fiber-optic interface. 2SP0320T2 (transformer interface) can be used to drive parallel-connected IGBT modules.

3-level and multilevel topologies

If 2SP0320V and 2SP0320S drivers are to be used in 3-level or multilevel topologies, please refer to the application note AN-0901 on www.IGBT-Driver.com/go/app-note.

dV/dt feedback

The 2SP0320V and 2SP0320S driver family is optionally equipped with a dV/dt feedback that reduces the high dV/dt during IGBT turn-off. This feature can be used to reduce the turn-off overvoltage and/or to allow higher DC-link voltages. For more information about this feature, please consult CONCEPT's technical support service.

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 40nH...70nH with 2SP0320V and 2SP0320S plug-and-play drivers.

Higher requirements for traction applications or similar

The power-supply interface X2 provides a mechanical interlock.

The vibration withstand capability of 2SP0320V SCALE-2 drivers can be improved by screw-fitting the driver board onto the cooler (see Fig. 13).

Furthermore, an interlocking version of the fiber optic links is also available (see Fig. 13) and ST fiber-optic links may also be supplied (2SP0320S). For available fiber-optic links, refer to the data sheets /3/.

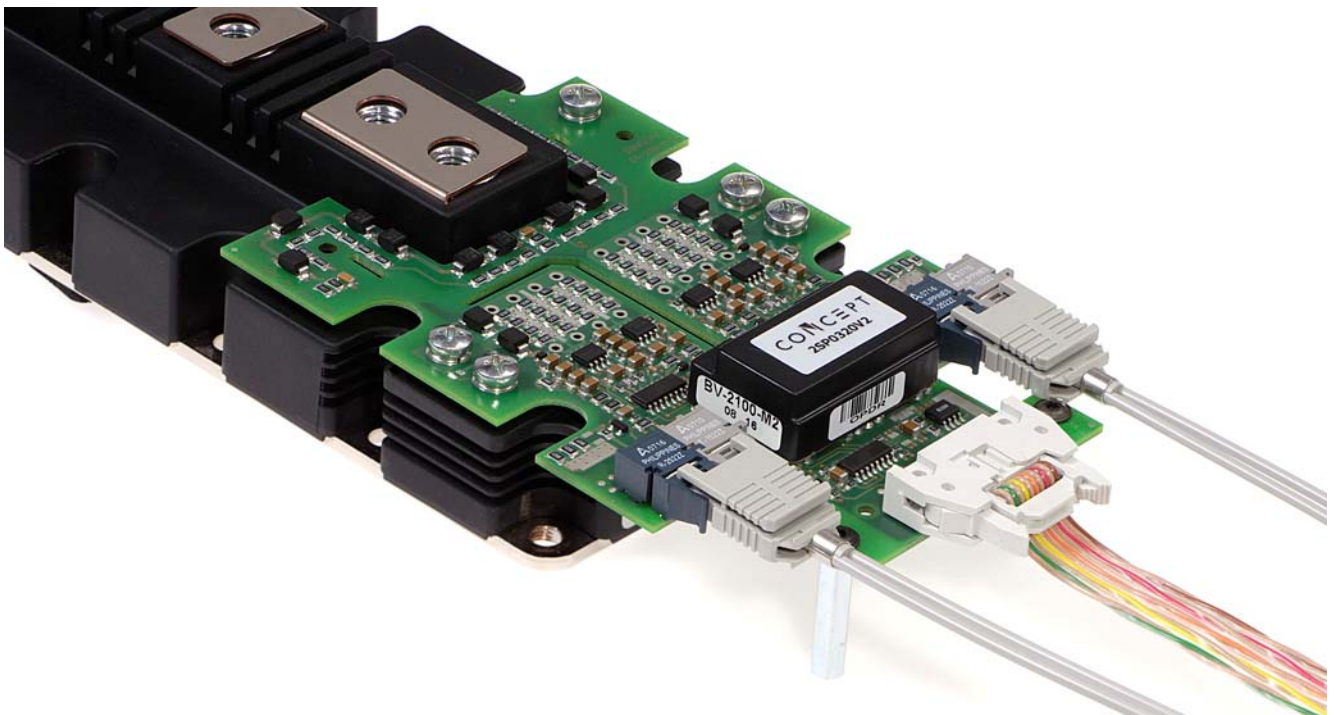


Fig. 13 Additional measures for fixing driver and power-supply cables as well as the relevant version of interlocking fiber-optic links for the 2SP0320V

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Bibliography

- /1/ "Smart Power Chip Tuning", Bodo's Power Systems, May 2007
- /2/ "Description and Application Manual for SCALE Drivers", CONCEPT
- /3/ Data sheets SCALE-2 plug-and-play driver 2SP0320x2xx-xxx, CONCEPT
- /4/ "Driver Solutions for High-Voltage IGBTs", PCIM Europe Magazine, April 2002

Note: These documents are available on the Internet at www.IGBT-Driver.com/go/papers

The Information Source: SCALE-2 Driver Data Sheets

CONCEPT offers the widest selection of gate drivers for power MOSFETs and IGBTs for almost any application needs. The largest website on gate-drive circuitry anywhere contains all data sheets, application notes and manuals, technical information and support sections: www.IGBT-Driver.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 CONCEPT or your CONCEPT sales partner.

CONCEPT has more than 20 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

CONCEPT provides expert help with your questions and problems:

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Quality

The obligation to high quality is one of the central features laid down in the mission statement of CT-Concept Technologie AG. The quality management system covers all stages of product development and production up to delivery. The drivers of the SCALE-2 series are manufactured to the ISO9001:2000 quality standard.

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See the current list on www.IGBT-Driver.com/go/2SP0320

Refer to www.IGBT-Driver.com/go/nomenclature for information on driver nomenclature

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Information about Other Products

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

Direct link: www.IGBT-Driver.com/go/plug-and-play

For other drivers, evaluation systems product documentation and application support

Please click onto: www.IGBT-Driver.com

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