Description and Application Manual for 1SD418FI SCALE High Voltage IGBT Drivers

Ultra compact, high performance, single channel driver for high-voltage and high-power IGBT modules

Description

The intelligent gate drivers of the 1SD418FI SCALE HVI driver series are advanced, ultra compact, high performance, single-channel drive components. They were designed specifically for the precise and reliable driving and the perfect protection of high-power, high-voltage modules.

Product Highlights

- ✔ Perfect driver solution for high-power IGBTs
- ✔ Protects the IGBTs against short-circuit
- ✔ Reliable, long service life
- ✔ High gate current of ±18A
- ✔ Dielectric test voltage 6000 V_{AC}
- ✔ Monitoring of power supply and self-monitoring
- ✔ Switching frequency DC to typ. 5kHz
- ✔ Duty cycle: 0... 100%
- ✔ Fiber-optic links make long drive cables possible
- ✔ Complete with integrated DC/DC converter
- ✔ Shorten development time

Applications

- ✔ Inverters
- ✔ Motor drive technology
- ✔ Traction
- ✔ Railroad power supplies
- ✔ High-voltage converters
- ✔ Power engineering
- ✔ Switch-mode power supplies
- ✔ Radiology and laser technology
- ✔ Wind-power converter
- ✔ Research
- ✔ Medium voltage applications

Description and Application Manual

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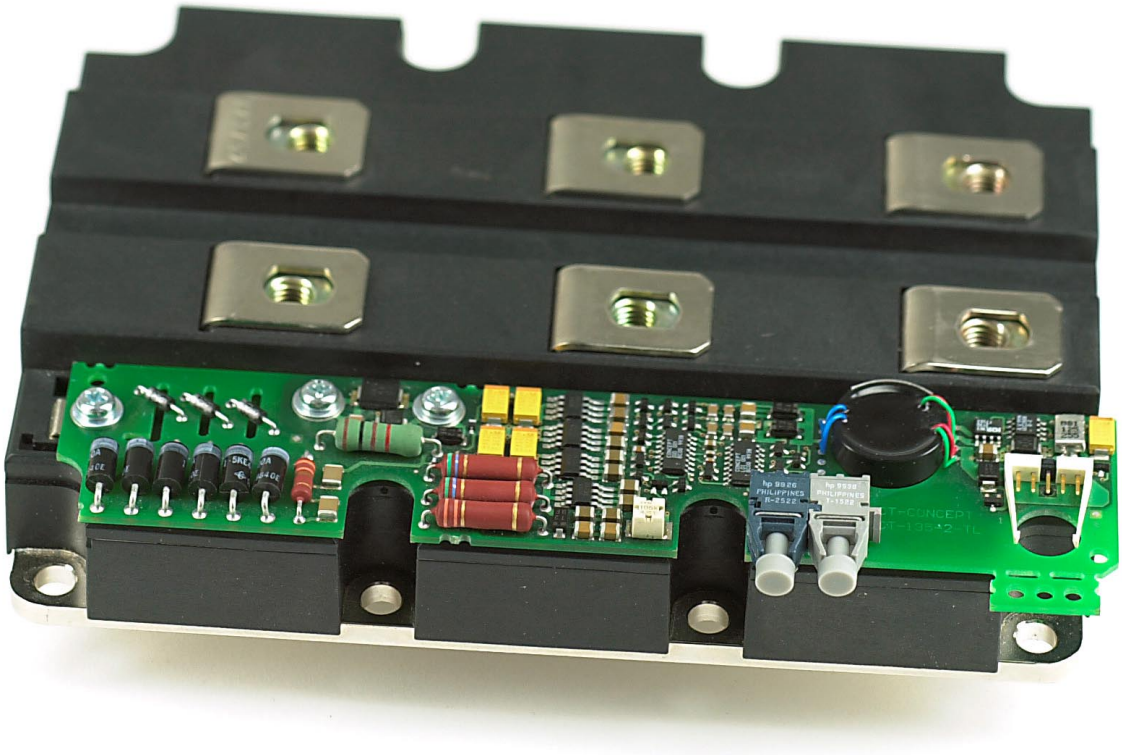

Fig. 1 SCALE HVI driver 1SD418FI screwed onto a IGBT 1200A/3300V

Important Note on Technical Information

SCALE HVI drivers are available in several versions in order to satisfy the particular requirements of different IGBT technologies from various manufacturers.

This brief paper covers the general functionality of SCALE HVI drivers. For detailed technical data of a specific driver, please refer to the corresponding data sheet.

A list of available SCALE HVI drivers, detailed technical data, and application notes can be found on the Internet at: www.IGBT-Driver.com/HVI

SCALE HVI Drivers – the Easiest Way to Build Megawatt Converters

The following abstract points out the easy way to design megawatt-converters by using superior SCALE HVI technology.

Furthermore, from page 7 you could gain a closer insight to SCALE HVI drivers and you'll find must-read application notes.

Six Steps to Success

Guide to design a reliable megawatt-converter:

1. Calculate the power dissipation of the IGBT Modules

First choose the IGBT module suited for your application and determine its particular on-state and switching losses. This is used to approximate the size of heatsink required.

Since high-voltage IGBTs have relatively high switching losses, the switching frequency should be limited as much as possible.

2. Choose a suitable SCALE HVI driver

When applying SCALE HVI drivers, kindly note that these drivers are highly adapted to a particular type of IGBT modules.

Therefore, the type designation of SCALE HVI drivers also include an appendix of the type designation of the corresponding IGBT module. **These drivers are not valid for other than specified IGBT modules. Doing otherwise may cause failure.**

3. Design the power stack

When designing a power stack, minimize the parasitic inductances. As a rule, a total (DC link) inductance of about 50nH...100nH shall be achievable with reasonable effort.

SCALE HVI drivers are specified and optimized to work under such conditions resulting in a dynamic behavior of the IGBTs being superior to straightforward gate driving.

To speed-up your startup with SCALE-HVI drivers, CONCEPT offers ready-to-use evaluation boards; see page 18

4. Attach the drivers to the IGBT modules

Mounting the driver onto an IGBT module is quite simple by using the 3 screws enclosed.

Fig. 2 SCALE HVI driver and the needing tool

Any handling with IGBT modules or drivers is subject to the general requirements for protecting electrostatic sensitive devices according to the standard DIN/EN 100015 (i.e. workplace, tools, etc. must comply with that standard).

Otherwise, both IGBTs and drivers may be damaged.

5. Perform the functional tests of the drivers

Attach the driver to the fiber-optic links and to the power supply. Check the gate voltage. For the off-state, the nominal gate voltage is –15V. For the on-state, i.e. with light into the fiber-optic receiver, the nominal gate voltage is +15V. Furthermore, check the current consumption of the driver (from the power supply) at a frequency (of the command signal) of about 1kHz to 3kHz.

It is proposed to perform these tests before installation, since otherwise the gate terminals might not be accessible.

6. Setting up and testing the power stack

Before starting-up the system, it is proposed to check each IGBT module separately under power-cycling conditions. Commonly, it is sufficient to apply the single- or double-pulse technique.

Even if only testing single IGBTs, all the system's gate drivers shall be supplied with energy. Thereby, all other IGBTs can be kept in off-state by applying negative gate voltages, which is particularly important during the switching of the IGBTs under test.

Furthermore, the short-circuit behavior can be verified now.

Hereafter, the system is ready to start under real-world load conditions. This allows to determine the thermal behavior of the whole arrangement.

Qualification of the system has to be reapplied over the entire specified range of temperature and load conditions.

CAUTION: All handling with high voltage is at the risk of one's life.

Definitely comply with the respective safety regulations!

What's a "SCALE HVI" Driver?

SCALE HVI drivers are based on the sophisticated SCALE driver chipset. This is a set of application-specific integrated circuits (ASICs), which are covering the main functionality needed to design intelligent gate drivers.

"**SCALE**" stands for **S**caleable, **C**ompact, **A**ll-purpose, **L**ow-cost and **E**asy-to-use

This is a concise enumeration of the most outstanding properties of SCALE drivers.

"HVI" stands for **H**igh **V**oltage **I**GBT

For further information about the SCALE driver chipset refer to: „Description and Application Manual for SCALE Drivers" /4/

Description and Application Manual

Your Benefit:
The Application Advantages of SCALE Drivers

Reliable operation

SCALE HVI drivers were developed specifically for the precise and reliable driving and protection of high-power, high-voltage IGBT modules.

Gate driving with a bipolar control voltage (typically ±15V) allows the reliable operation of IGBT modules with high interference immunity.

SCALE HVI drivers are featuring an "Active Clamping" function, which is the most reliable and best-performance way to protect the costly IGBTs against overvoltage at turn-off, particularly during conditions of overload and short circuit.

Electrical insulation

SCALE HVI drivers are equipped with DC/DC converters, which provide an insulated power supply for the driver circuitry.

Control signals are applied via external fiber optic cables. By this means, in addition to electrical insulation, superior noise immunity is achieved even for long signal cables.

Status feedback

A status feedback is transmitted via the fiber optic interface. This feedback enables the host controller to monitor both gate driver and IGBT. Since each edge of the control signal is acknowledged by that interface, a malfunction of the fiber optic links is also observable by the host controller.

How Do SCALE HVI Drivers Work in Detail

Overview

SCALE HVI drivers are one-channel drivers for high-voltage IGBTs. The drivers are equipped with common protection functions such as Vce-monitoring for short-circuit protection, operation inhibit after fault, supply-undervoltage shut-down, status feedback, as applied to all drivers of the SCALE driver family /3/, /4/.

Outstanding features of SCALE-HVI drivers are: ultra-compact size, simple mounting - directly onto the IGBT module, advanced „Active Clamping"-function. „Active Clamping" is a term for an active scheme to protect the IGBTs against overvoltage during turn-off. This is particularly relevant when turning-off an IGBT in cases of high collector current or short-circuit.

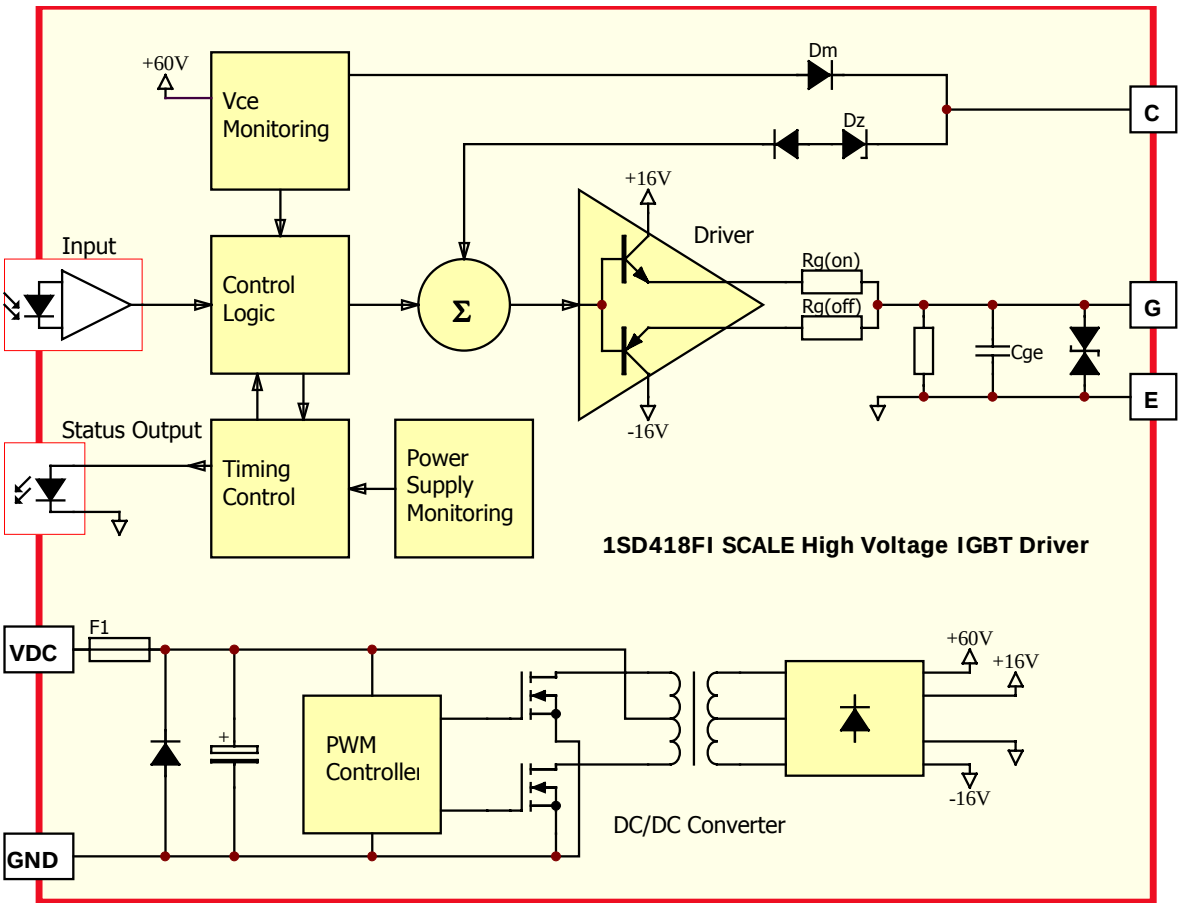

Fig. 3 Block diagram SCALE HVI driver

Power supply and electrical insulation

The driver is equipped with a DC/DC-converter to provide electrically insulated power supply of the gate driver circuitry. SCALE HVI driver are designed for the same insulation- and test-voltages as the corresponding IGBT module. (Refer to the data sheets /1/.) Note that the driver needs a stabilized supply voltage.

An automatic-reset thermal fuse protects power supply, wiring, and driver PCB in case of wrong polarity or driver defects.

Undervoltage protection

The driver circuitry includes an undervoltage protection, which inhibits the turn-on of an IGBT in case of too low power supply voltage.

Even for the case of low power-supply voltage, the driver provides a low impedance path between the IGBT's gate to the emitter.

Within a half-bridge, it is kindly advised not to operate the IGBTs in case of low supply voltage at any IGBT driver. Otherwise, high rate of increase of Vce might cause a partial turn-on of that IGBTs.

Vce-monitoring / short-circuit protection

The SCALE HVI driver performs short-circuit protection based on Vce-monitoring, i.e. the collector-emitter voltage is monitored at turn-on and on-state.

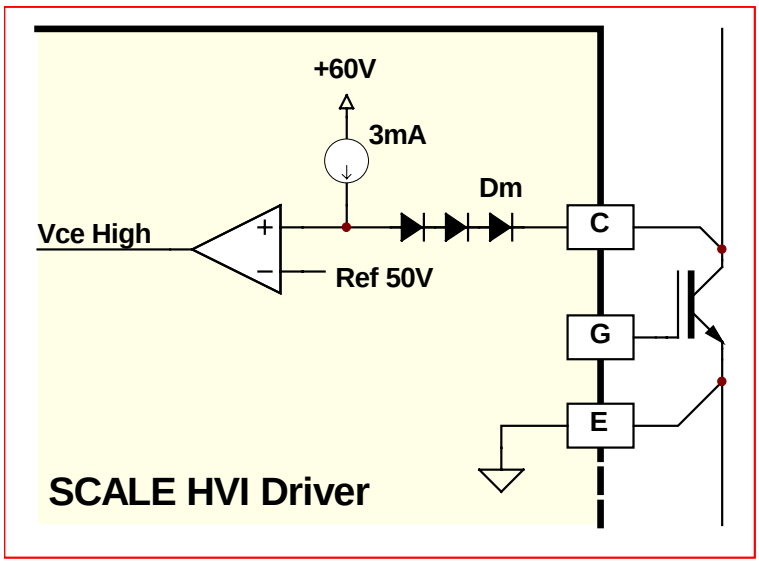

Fig. 4 Vce-desaturation monitoring

Fig. 4 shows the basic circuit of Vce-monitoring implemented in SCALE HVI drivers. From the limit of a 60V voltage source, a constant current of 3mA drives the IGBT's collector via high-voltage diodes (for the case of Vce < 60V). To detect a short-circuit, Vce is checked at a time of 8,5us after the turn-on command. If this voltage is higher than 55V, the driver detects a short-circuit at the IGBT. In this case, the IGBT is immediately turned-off. This state is locked for a period of 1 second. This state is fed back to the optical link. (Light is off for 1 second.) The threshold of Vce monitoring is not changeable by application.

This relatively high threshold voltage is required as high-voltage IGBTs, particularly for the case of higher load currents, do not approach the specified saturation voltage within a period of 10µs, which defines the maximum operation time during short circuit to avoid a thermal breakdown of the IGBT.

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

Note: The above-mentioned current source is permanently operating as long as the gate driver is supplied with energy. So, the DC-link capacitors of the power converter may be charged to about 120V.

Note for traction application or similar

The vibration withstand capability of SCALE HVI drivers can be improved as follows. In addition to screw-mounting onto the IGBT module provide:

a) Screw fitting of the driver board to the cooler (see Fig. 12)

b) Bonding the driver board (bottom side) to the IGBT module.

Dynamic behavior of IGBTs

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

CONCEPT therefore delivers specific versions of SCALE HVI drivers adapted to the particular IGBT module. These drivers must not be used with other IGBT modules than specified for.

Turn-on of the IGBT / commutation of diode current

When there is light into the fiber optic receiver, the gate driver commands the IGBT to turn-on. The driver already includes the gate resistors which are matched to the particular IGBT module.

The driver is optimized to achieve minimum switching losses for the case of relatively low inductances within the power stack. It is proposed to verify the commutation behavior within the final system assembly against the data provided from the IGBT module manufacturer.

Turn-off of the IGBT

The IGBT is turned-off when there is no light into the fiber optic receiver. The gate resistors are determined by CONCEPT and must not be altered.

Fast turn-off of the IGBT may cause overvoltage, which increases with increasing DC-link voltage or increasing load current. The turn-off overvoltage can be approximated by:

Vtr = -Ls * di/dt

where Vtr is the turn-off over-voltage and Ls the stray inductance.

Most drivers are not able to limit the overvoltage in case of overload and short-circuit which, however, is essential for high-power IGBTs. To solve this problem, SCALE HVI driver provide an „Active Clamping"-function, which is described now.

Active Clamping

„Active Clamping" is a technique to partially turn-on the IGBT in case that the collector-emitter voltage exceeds a predefined threshold. Thereby, the IGBT is kept in linear operation. The basic circuitry is shown in Fig. 5.

The SCALE HVI driver applies an advanced scheme based on this principle (see the circuit Fig. 6). For further details refer to /2/ and /5/.

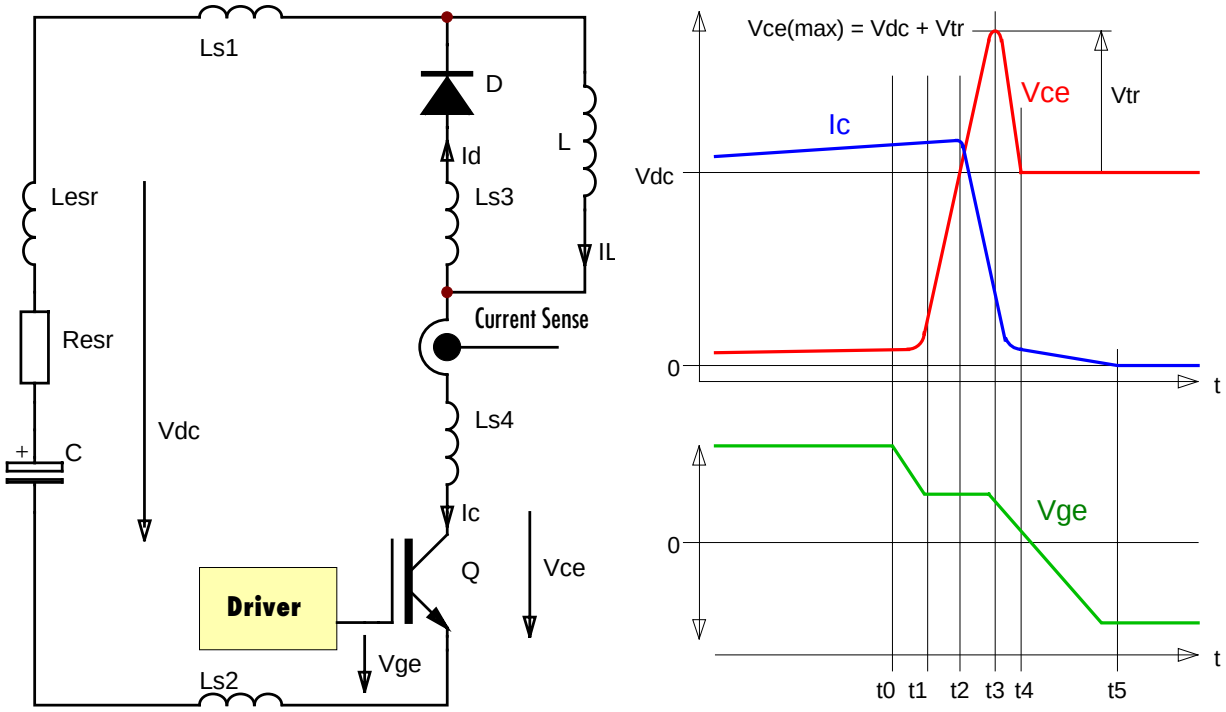

Fig 5 Test circuit (left) and typical switching behavior (right)

Legend to Fig. 4

t0 = Initiation of the turn-off process
t1 = Start of turn-off time
t2 = Start of collector current fall time
t3 = Maximum collector 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. Even so, the overvoltage at fault-current turn-off is managed by „Active clamping". For the maximum permitted DC-link voltage refer to the gate driver data sheets /1/.

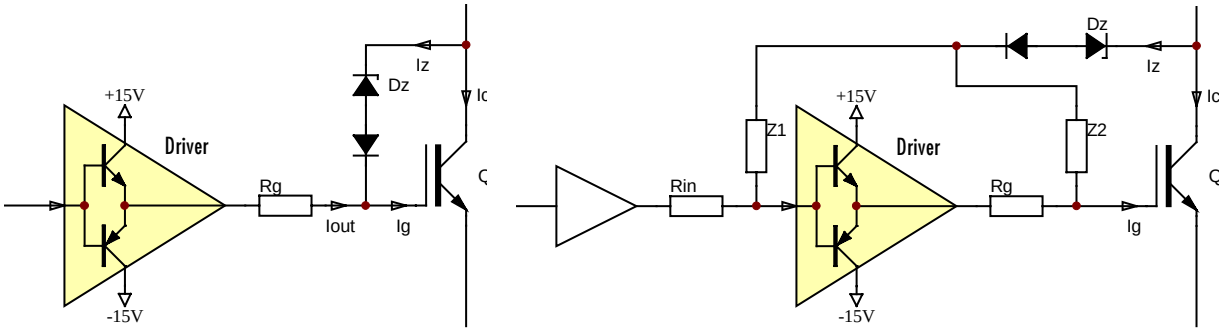

Fig. 6 Basic Active Clamping circuitry (left) and advanced circuitry used in SCALE HVI drivers (right)

In Fig. 7 shows an exemplary turn-off transition of a 1200A/3300V IGBT controlled with a SCALE HVI driver.

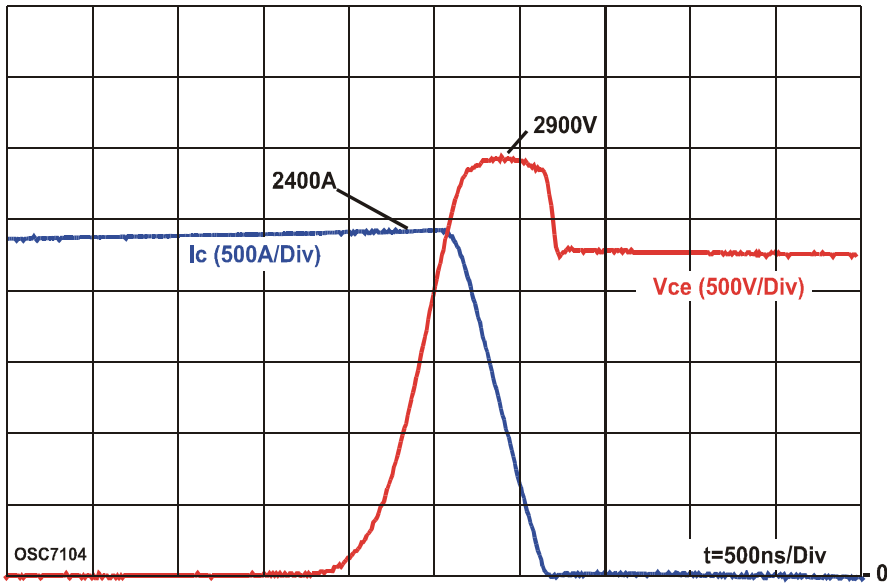

Fig. 7 Behavior of a 1200A/3300V-IGBT for turning-off a collector current of 2400A, which is twice the nominal collector current

Low-inductance layout

The „Active Clamping" function shall not entice someone to forget about inductances of the power stack. For several reasons it is still proposed to reduce the stray inductance to about 50nH to 100nH. Commonly, it is not advantageous to further reduce this inductance. The driver, nevertheless, manages the overvoltages in any case.

Interfaces

Fiber optics are used for electrical insulation of command and status-feedback signals. For the type refer to the data sheets /1/.

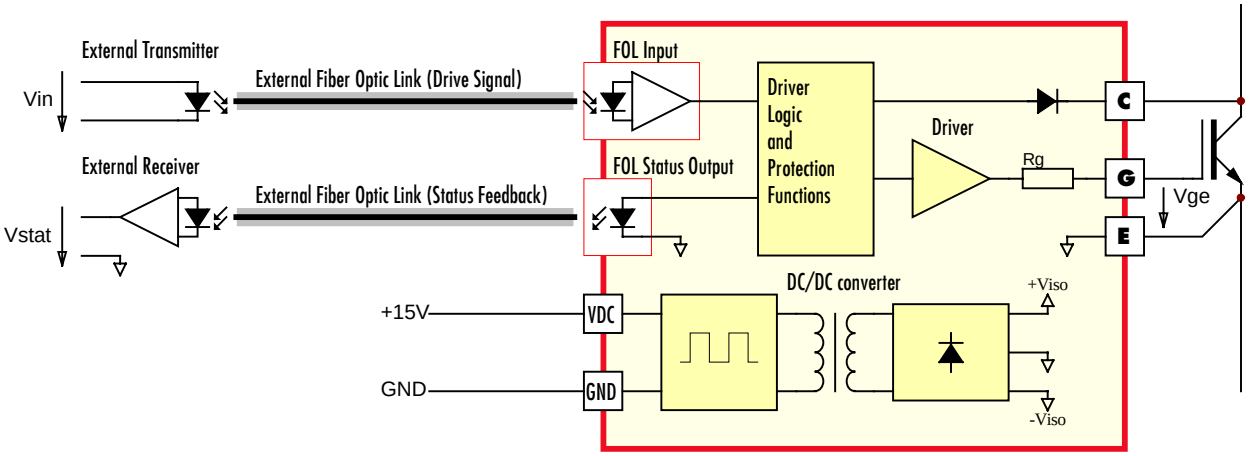

Fig. 8 Test circuit for signal slopes and delay time

The signal delay of a driver including the external fiber optic links are according to the test environment of Fig. 8. For the data see Fig. 9 and Fig. 10.

Status-feedback & edge-acknowledge

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

Each edge of the control signal is acknowledged by the driver by a short pulse (light is off for a period of about 900ns). As this is observable by the host-controller, this method allows a simple and continuous monitoring of all drivers and fiber optic links of the system.

Fig. 9 shows the control and response signals of a gate driver for normal operation. Fig. 10 shows the response of the driver in case of a (short-circuit) failure. The IGBT shuts the IGBT off within a maximum delay of 10µs (typically 8,5µs). The failure status is transferred to the status feedback terminal, which is driven to „light off" for approx. 1 second.

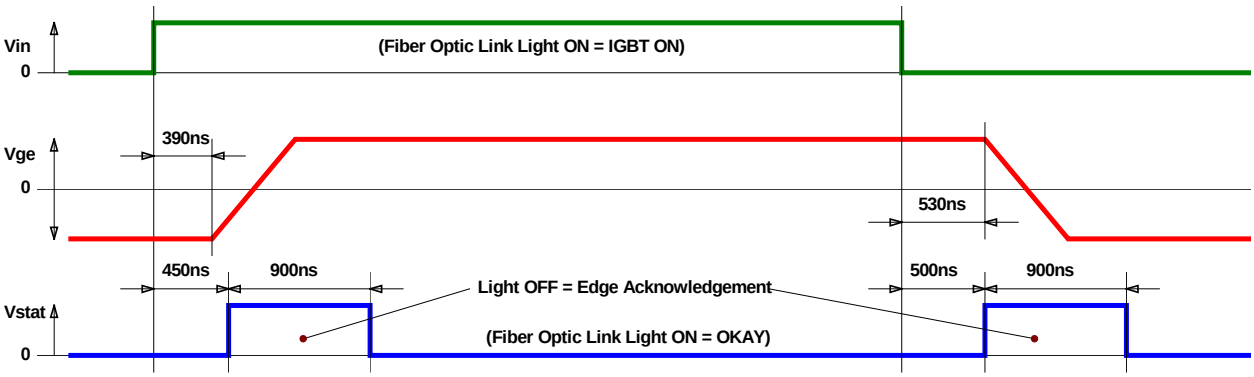

Fig. 9 Failure status feedback; signals for normal operation

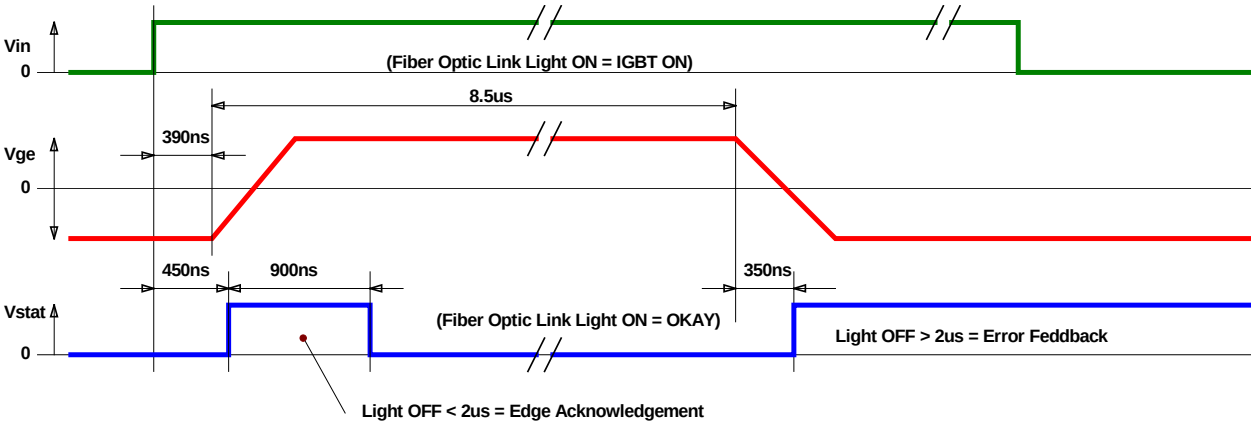

Fig. 10 Failure status feedback; signals under short circuit conditions

It is strongly recommended to check this status signal by the host controller. Note, that this signal also identifies a malfunction of the fiber optic links, which otherwise may cause a defect of gate drivers or IGBTs or a malfunction of the system.

Suggested application-level circuitry for fiber optic links

The recommended circuitry for the fiber optic links is given in Fig. 11. For a typical application (a few meter plastic optical fiber), the best noise immunity is achieved by a transmitter current of 30mA.

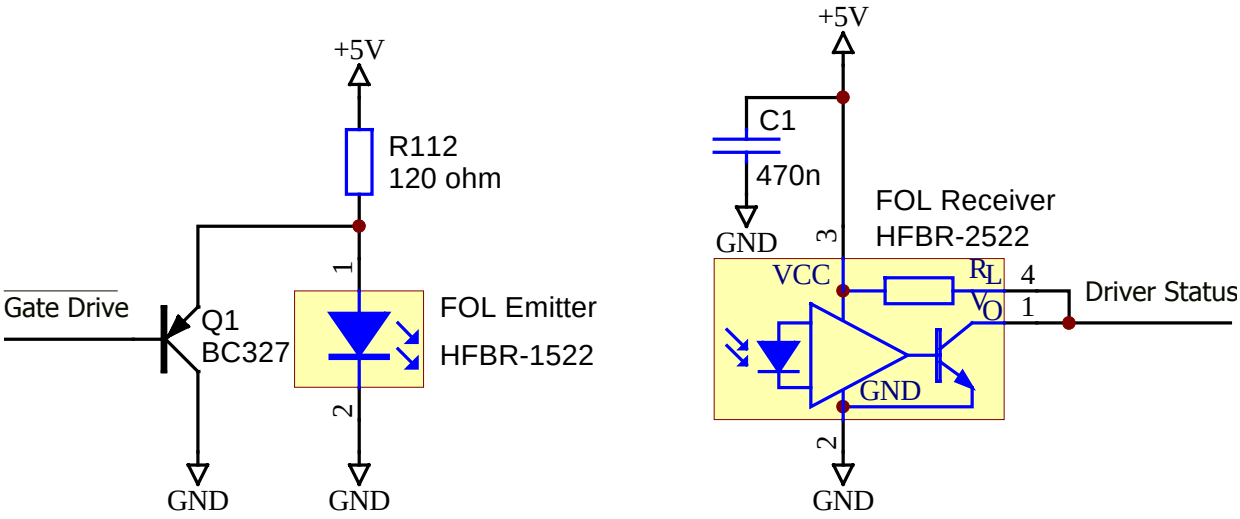

Fig. 11 Recommended circuitry for the fiber optic links

Higher requirements for traction applications or similar

Basically, the power-supply plug provides a mechanical interlock. If desired, the supply cables could also be fixed at the driver board (see Fig. 12). Furthermore, an interlocking version of the fiber optic links is also deliverable, see Fig. 12.

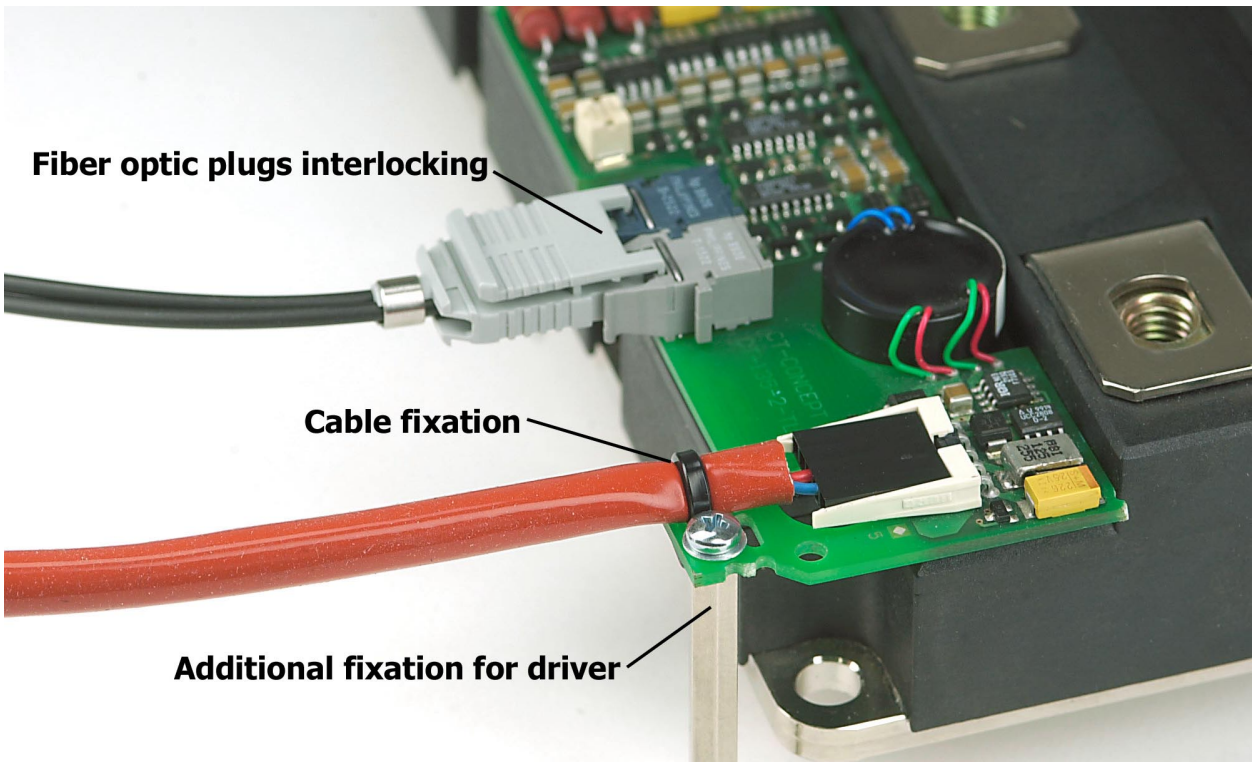

Fig. 12 Additional measures for fixing driver and power supply cables , and version of interlocking fiber optic links

Bibliography

/1/ Data sheets SCALE HVI driver 1SD418FI-xxx, CONCEPT

/2/ "SCALE Driver for High Voltage IGBTs", PCIM 1999 Proceedings

/3/ "New IGBT Drivers features Active clamping", Power Electronics Europe Magazine 2000 / Issue 1

/4/ „Description and Application Manual for SCALE Drivers", CONCEPT

/5/ "Driver Solutions for High-voltage IGBTs", PCIM Europe Magazine, April 2002

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

Evaluation systems

Particularly for development, verification, qualification, and test, an evaluation half-bridge system with 1200A/3300V IGBTs is deliverable, which is fully equipped with high-voltage IGBTs, SCALE HVI drivers, a load-side high-quality current sensor, safety case and interfaces; 100% tested.

For details see: www.IGBT-Driver.com/HVI

Customer-Specific Systems

CONCEPT develops and produces complete power equipment and systems according to the customer's specifications.

Consulting and Training

CONCEPT provides consulting and training services to customers on optimal procedures in power control, ideal circuit topologies, and general do's and don'ts in development of power electronics.

Technical Support

CONCEPT provides expert help for your questions and problems:

Internet: www.IGBT-Driver.com/support

E-Mail: Support@IGBT-Driver.com

Exclusion Clause

CONCEPT reserves the right to make modifications to its technical data and product specifications at any time without prior notice. The general terms and conditions of delivery of CT-Concept Technology Ltd. apply.

Quality

The obligation to high quality is one of the central features laid down in the mission statement of CT-Concept Technology Ltd. Total Quality Management (TQM) covers all stages of product development and production up to delivery. The drivers of the SCALE HVI series are manufactured according to the ISO9001 quality standard.

The Information Source: SCALE HVI Driver Data Sheets, Other Drivers, Evaluation Boards and Systems

CONCEPT offers the widest selection of gate drivers for power-MOSFETs and IGBTs for almost any application needs. At the largest Web site on gate drive circuitry you will find all data sheets, application notes and manuals, technical information and support sections.

Internet: www.IGBT-Driver.com

Quite Special: Customized SCALE HVI Drivers

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

CONCEPT engineers have more than 15 years experience in the development and manufacture of intelligent gate drivers for power MOSFETs and IGBTs and have already implemented a large number of customized solutions.

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