

# Description and Application Manual for SCALE Drivers

The drive circuit for IGBTs that's a prizewinner

**The SCALE driver is a winning project of the competition organized by "Technology Center Switzerland 1998". And ABB Switzerland AG honored the development of the SCALE driver by distinguishing it as the "best project in power electronics 1998".**

The SCALE drivers from CONCEPT are based on a chip set that was developed specifically for the reliable driving and safe operation of IGBTs and power MOSFETs.

The name "SCALE" is an acronym for the most outstanding properties of the SCALE series of drivers:

**SCALE** = **S**caleable, **C**ompact, **A**ll purpose, **L**ow cost and **E**asy to use.

## Product Highlights

- ✓ Suitable for IGBTs and power MOSFETs
- ✓ Short circuit and overcurrent protection
- ✓ Extremely reliable, long service life
- ✓ High gate current from  $\pm 6A$  to  $\pm 30A$
- ✓ Electrical isolation from 500V to over 10kV
- ✓ Electrically isolated status acknowledgement
- ✓ Monitoring of power supply and self-monitoring
- ✓ Switching frequency DC to >100kHz
- ✓ Duty cycle: 0... 100%
- ✓ High dv/dt immunity, guaranteed >100,000V/ $\mu s$
- ✓ Complete with DC/DC converter

## Applications

- ✓ Inverters
- ✓ Motor drive technology
- ✓ Traction
- ✓ Railroad power supplies
- ✓ Converters
- ✓ Power engineering
- ✓ Switched-mode power supplies
- ✓ Radiology and laser technology
- ✓ DC/DC converter
- ✓ Research
- ✓ RF generators and converters

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### **SCALE driver application – it's never been so simple**

**As soon as you've read the following eleven and a half pages, you'll be able to use a SCALE driver.**

**Power electronics really has become that easy!**

**And you will learn directly from each paragraph where to access all the details you need to obtain more detailed information. For you will certainly want to know more about some of the topics covered.**

**Everything is described in full detail in the section "How exactly do they work? The SCALE drivers in detail" from page 11 onwards, so that you can find all the information that you need.**

**At the end of the brief introduction you will see from an example how easily a current inverter can be put together with a SCALE driver.**

### **A brief introduction**

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## **Mode selection and dead times**

First of all select the mode in which you wish to operate the SCALE driver. There are two modes: direct mode and half-bridge mode.

In direct mode, there are no links between the individual channels of a multiple driver. And that's how it works: the MOD input is connected to VCC and the inputs RC1 through RCn (depending on how many channels the driver has) are connected to GND. In half-bridge mode, the chip set can directly generate the required dead times. For half-bridge operation, the MOD input is connected to GND and an RC network is connected to inputs RC1 through RCn for each channel to generate the dead time. See page 26 for the dimensioning of the RC networks.

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## **Voltage supply and logic level**

The GND terminals (some SCALE drivers have several GND and several voltage supply terminals) are connected to the ground terminal of the voltage supply unit. The VDD and VDC terminals should be connected to a stabilized 15V supply source.

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The VL/Reset pin is used to define the logic level and to erase the error memory. The circuits for 5V and 15V logic levels are shown in Fig. 11. There's more on this topic from page 23 onwards.

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### Signal inputs and status outputs

The PWM signals of the control electronics are applied to inputs A and B. Depending on the selected mode, these inputs have a different function: in direct mode, input A is assigned directly to channel 1, whereas input B controls channel 2.

In half-bridge mode, the PWM signal is applied to input A whereas input B carries the release signal for both channels. There's more on this topic on page 25.

The status outputs are "open collector" outputs and can thus be simply matched to all logic levels and families. The outputs lead simply to the logic and are connected to the logic supply via a pull-up resistor. There's more on this topic on page 25.

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### Connecting the IGBTs

The auxiliary emitter (emitter control terminal) is connected to output "Ex" (where "x" stands for the number of the drive channel in multi-channel drivers). In the same way, the gate is connected to output "Gx"; but via a gate resistor or a gate resistor network. There's more on this topic from page 27 onwards.

The collector sense terminal "Cx" is connected via a diode to the collector of the IGBT. On this point, read the hints from page 28 onwards and any additional hints in the data sheet of the SCALE driver used.

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### Defining the turn-off threshold

The turn-off threshold and the response time are defined by a resistor connected between the terminal "Rthx" and the emitter terminal "Ex". An explanation of these terms is found from page 17 onwards. A table or a diagram of the turn-off threshold and the response time can be obtained from the data sheet of the relevant SCALE driver.

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### Application example: 30kW inverter with six-pack driver

The drawing in Fig. 1 shows all the required components of the current inverter circuit. The circuit diagram clearly illustrates the level of integration of the driver solution and its simplicity in application.

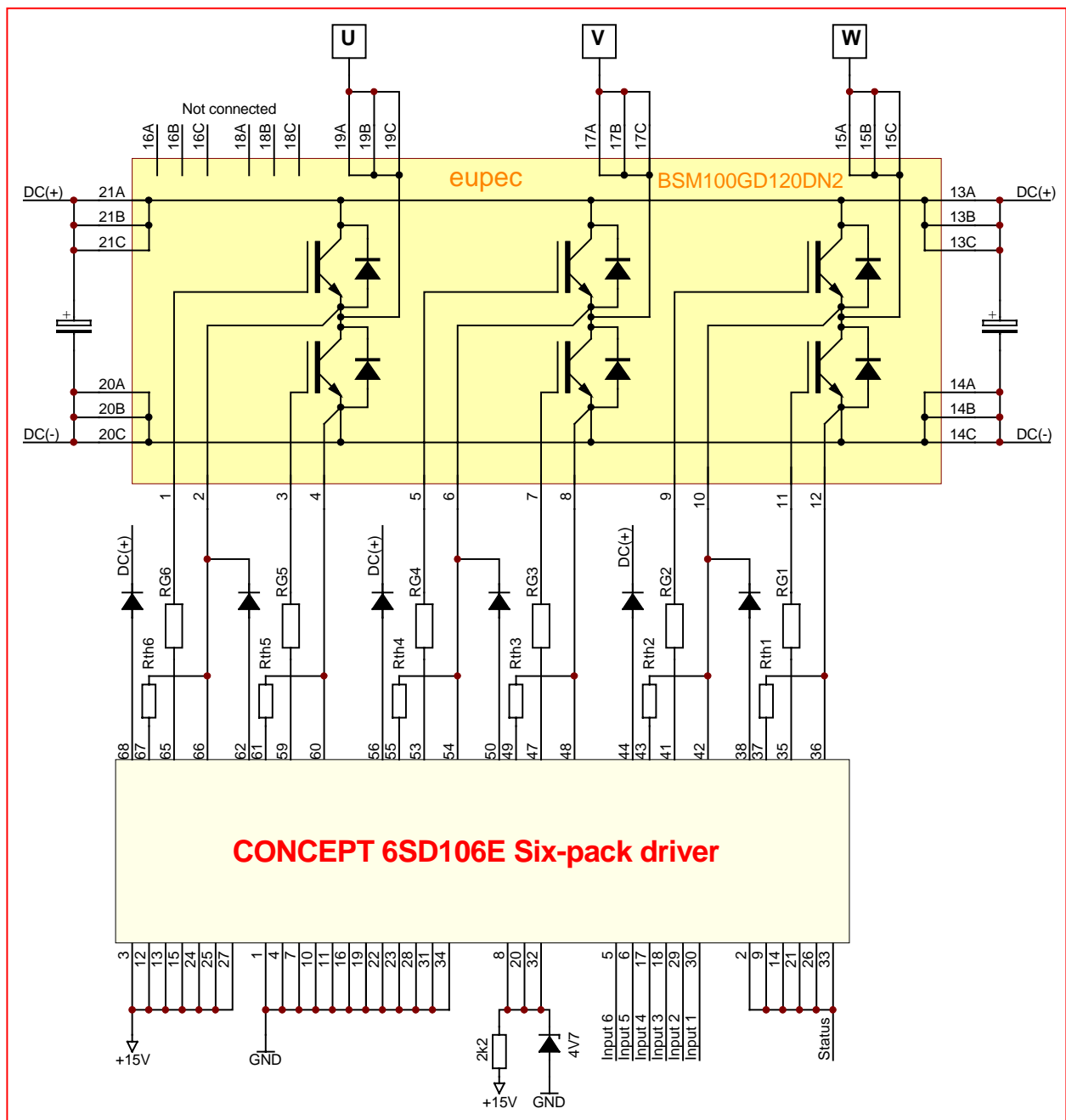


Fig. 1 Complete circuit diagram of the 30kW inverter

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The circuit diagram in Fig. 1 shows all the components required for the inverter circuit. The diagram thus illustrates clearly the level of integration of the driver solution and its simplicity of application.

Compared with IPM solutions, which require more external components but offer no additional flexibility in the selection of the switching properties, the SCALE driver solution has the advantage of allowing the switching characteristic to be defined in any way required with the few components that are still located externally. In addition, the level of the protection cut-out (V<sub>ce</sub> monitoring circuit) can be freely selected.

For this example, we assume that the drive controller already generates the dead times internally. It thus supplies six drive signals. The controller operates with TTL levels, so that we set the input VL (pins 8, 20, 32) to 4.7V. The PWM inputs are marked with "Input 1"..."Input 6".

However, the controller still has only one error input: so we must combine our six status acknowledgements into a single signal "status".

The other inputs and outputs are now quickly connected in the correct way in accordance with the description given on the preceding pages: the result is the completed circuit diagram shown in Fig. 1.

And now you can switch on...

### What is a "SCALE" driver?

"**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.

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### Scaleable

One of the most important properties of the SCALE driver chip set is its scaleability. In this context, the term scaleable means that the chip set — in contrast to all previous approaches to integrated drive circuits — can be used for a very large range of applications. The SCALE driver chip set can be used to implement solutions for diverse drive currents (gate currents) and various drive powers. SCALE drivers are well suited

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for almost any switching frequency, any modulation mode and not least for isolation voltages of practically any magnitude.

SCALE drivers can be used to construct power sections from the kilowatt to the megawatt range.

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### **Compact**

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SCALE drivers accommodate all the necessary components on a minimum surface area. They cover the following functions: driving, monitoring, status acknowledgement, isolated voltage supply (DC/DC converters) and electrical isolation of all signals between the control electronics and the power section.

SCALE drivers are currently the most compact driver solutions on the market with this range of functions.

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### **All purpose**

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The SCALE driver chip set offers maximum flexibility of operation: by switching the mode accordingly, a choice can be made between half-bridge or direct-mode operation.

In half-bridge operation, the chip set can generate the required dead times directly. In direct mode, there are no links between the individual channels of a multiple driver.

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### **Low cost**

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SCALE drivers are high-quality driver circuits for IGBTs and power MOSFETs with an outstanding price/performance ratio. A SCALE driver contains all the components that can possibly be integrated. It encompasses the driver function itself, plus monitoring, acknowledgement, power supply (DC/DC converter) and electrical isolation of all signals.

SCALE drivers are the most inexpensive drivers on the market offering this performance.

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### **Easy to use**

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The interface to the electronics is very simple: the SCALE driver chip set can handle all standard logic levels between 5V and 15V. The inputs have a Schmitt trigger characteristic and make no special demands on the input signals. The status acknowledgements are designed as open-collector outputs and are thus compatible with all the usual logic levels.

Application is extremely simple because a SCALE driver contains all the functions of an intelligent driver, and the drive signals, the status acknowledgement and the power supply are completely isolated from the power section.

Application of SCALE drivers with standard IGBT modules is in most cases simpler than an IPM, but without any loss in flexibility.

**Your benefit:  
the application advantages of SCALE drivers**

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### **Reliable operation**

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Gate driving with a bipolar control voltage (typically  $\pm 15V$ ) allows the reliable operation of IGBT modules of any size from any manufacturer. Thanks to the high interference immunity attained by using a negative gate voltage, a number of power MOSFET or IGBT modules can be connected in parallel.

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### **Genuine electrical isolation**

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SCALE drivers contain miniaturized transformers for the isolation of all channels. These offer outstanding isolation properties and low coupling capacitances.

The SCALE driver can be used to obtain isolation voltages of practically any magnitude. The product-specific isolation data relating to the individual versions can be found in the data sheets dealing with the individual types.

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### **Reliable transformer principle**

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Pulse transformers were selected because they offer the following advantages over all other designs: minimum delay times, no degradation effects, maximum service life and the ability to obtain isolation voltages of any desired magnitude.

The MTBF (failure probability) of a pulse transformer of the kind used in the SCALE drivers is better by a factor of 20 than that of a high-quality optical coupler, for instance, and about 200 times better than that of a good fiber-optic link.

The extremely high interference immunity of at least 100kV per microsecond predestines the SCALE driver to applications in which large potential differences and large potential jumps occur between the power section and the control electronics.

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### **Delay times**

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The delay times through the complete driver circuit are around 300...350ns. The delays for the positive and the negative edges are symmetrical.

There are almost no differences in delay time between the different drivers, an important factor for ensuring operation without offset problems as well as for parallel circuits. Signal transfer is practically jitter-free.

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### **Status acknowledgements**

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The pulse transformer is operated bi-directionally - for transferring both the drive information and the status acknowledgement.

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### **Ideal layout of the terminals**

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The terminal pins of the drivers are arranged so that the layout can be kept very simple and the logic signal flow (input signal  $\Rightarrow$  drive circuit  $\Rightarrow$  power transistors) is maintained.

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**How exactly do they work? The SCALE drivers in detail****Overview**

SCALE drivers are available in various versions in order to satisfy the different requirements in terms of driver performance, number of drive channels, isolation requirements and to cover the diversity of applications and standards.

The information given in this description is identical or practically so for all versions. The product-specific data relating to the individual versions can be found in the data sheets dealing with the individual types.

**The concept of the SCALE driver circuit**

The interface to the control electronics forms the first building block of the SCALE chip set: the LDI (LDI = **L**ogic to **D**river **I**nterface). An LDI drives two channels. The PWM signals applied to inputs A and B are processed so that the drive information can be fed to a pulse transformer for each channel.

The pulse transformers are responsible for the electrical separation of the drive information. At the same time, they are also used in the reverse direction in order to return the status information of each channel to the LDI.

The second building block of the SCALE driver chip set is used once for each drive channel. This is the IGD (IGD = **I**ntelligent **G**ate **D**river). It receives the pulse-coded information from the transformers and reconstructs the original PWM signal from it. This is then amplified, making a gate current of several amps available to drive the power semiconductor. Furthermore, the IGD contains protection functions that safeguard the power semiconductor from harmful operating conditions.

The DC/DC converter makes the electrically separated power supply available to the individual driver channels. The SCALE drivers require a simple stabilized 15V DC supply.

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### Block diagram of the "Logic-to-Driver-Interface" LDI 001

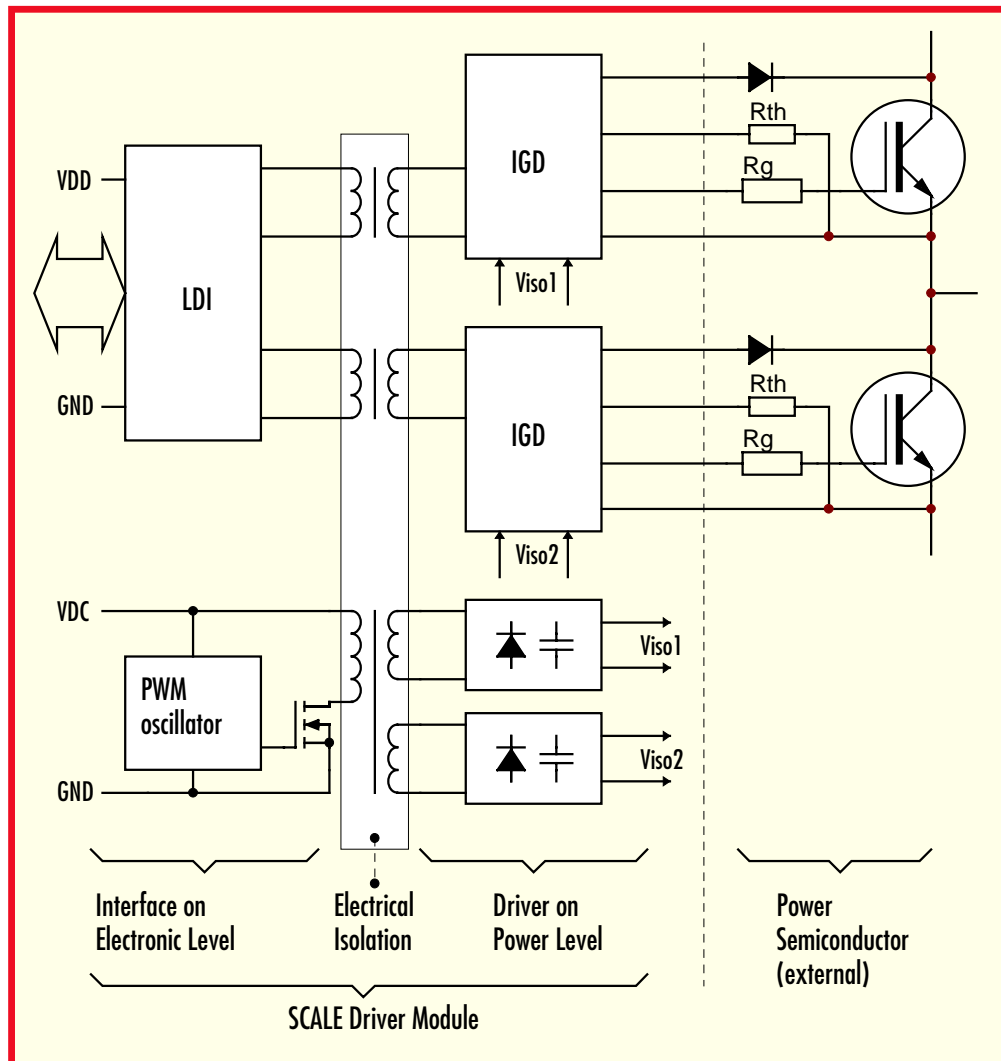


Fig. 2 Block diagram of a two-channel SCALE driver

The block diagram shows a two-channel driver based on the SCALE chip set. For a three-phase version, there is only one PWM oscillator, all other components are present in triplicate.

For each channel, the SCALE drivers contain the electrical separation between the control and power sides, an over-current and short-circuit protection circuit for the power transistors, a feed monitoring circuit, a status acknowledgement circuit as well as an electrically separated power supply for the drive electronics via an integrated DC/DC converter.

## The power supply: the integrated DC/DC converter

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All standard SCALE drivers contain a DC/DC converter. This is used for the power supply of the individual driver channels. The electrical separation of the DC/DC converters allows the SCALE drivers to be supplied from the electronic power unit which is in most cases present in any case.

Drive energies of different magnitudes are required depending on the application – and especially on the clock frequency and gate charge of the used power semiconductors. SCALE drivers are therefore offered with differently dimensioned DC/DC converters. The exact data of the relevant DC/DC converter can be obtained from the data sheets of the individual SCALE drivers.

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## The electronic interface: LDI 001

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PWM signals of the kind generated by the control electronics cannot simply be transferred via transformers. This is particularly difficult when a large frequency range and various duty cycle ratios are to be transmitted.

The LDI 001 logic-to-driver interface was developed for this reason. This IC has the following main functions:

- 1) Creation of a simple interface for the user. Both signal inputs have a Schmitt trigger characteristic
- 2) Simple matching to the logic level used in the electronics (5V...15V)
- 3) Forming the dead times in a half bridge, where required. This function can also be deactivated
- 4) Coding of the PWM signals so that they can be transmitted via a pulse transformer
- 5) Evaluation of the status acknowledgement transmitted in coded form and its subsequent buffering so that a quasi-static acknowledgement signal is available to the user

A SCALE driver can be connected directly and with no additional components to any logic circuit. In the same way, however, driving is also possible via longer cables: with a 15V level, acceptable signal-to-noise ratios are obtained in such applications.

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The possibility of generating the dead times directly with the SCALE driver obviates the external circuits that are usually required.

These functions make SCALE drivers directly compatible with practically all available interfaces and levels. As a rule, therefore, the interfaces usually required for other driver solutions are obviated.

### Block diagram of the "Logic-to-Driver-Interface" LDI 001

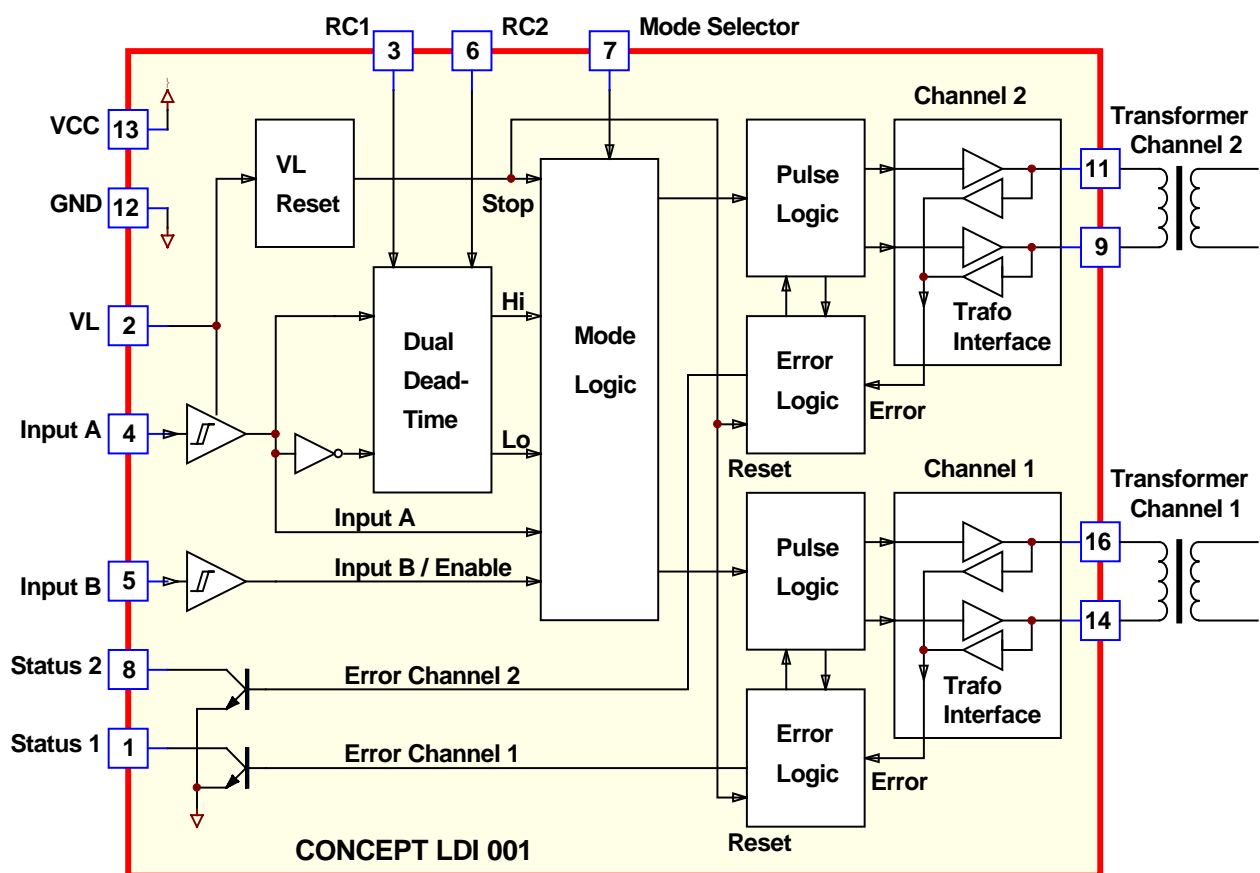


Fig. 3 Block diagram of the LDI 001

All necessary functions of an intelligent gate driver are integrated in the IGD 001: the transformer interface, overload and short-circuit protection, blocking time logic, status acknowledgement, monitoring of the supply voltage and the output stage.

## The Intelligent Gate Driver: IGD 001

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All necessary functions of an intelligent gate driver are integrated in the IGD 001: the transformer interface, overload and short-circuit protection, blocking time logic, status acknowledgement, monitoring of the supply voltage and the output stage.

An IGD 001 intelligent gate driver is used for each drive channel. This IC has the following functions:

- 1) Decoding the PWM signals transferred via the pulse transformer
- 2) Amplifying the PWM signals to drive the final stage
- 3) Power Semiconductor desaturation monitoring (short circuit & overcurrent protection)
- 4) Under-voltage monitoring
- 5) Generating response and blocking times
- 6) Status acknowledgement to the controller (LDI 001)

All necessary protection functions that safeguard the semiconductor from over-current and short circuit are present locally in every driver (and thus every power semiconductor).

In the same way, the local under-voltage monitoring circuit ensures for each channel that the driver is released only when the supply voltage is sufficiently high. This reliably avoids the critical condition of "half" driving of power semiconductors.

Every time an error is detected, a blocking time is applied locally on the driver. In particular after a short circuit, power semiconductors require a "pause" in order to cool down again before the next drive pulse is released.

The status (error or normal) can be queried at any time from the pre-connected LDI 001.

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### Block diagram of the "Intelligent Gate Driver" IGD 001

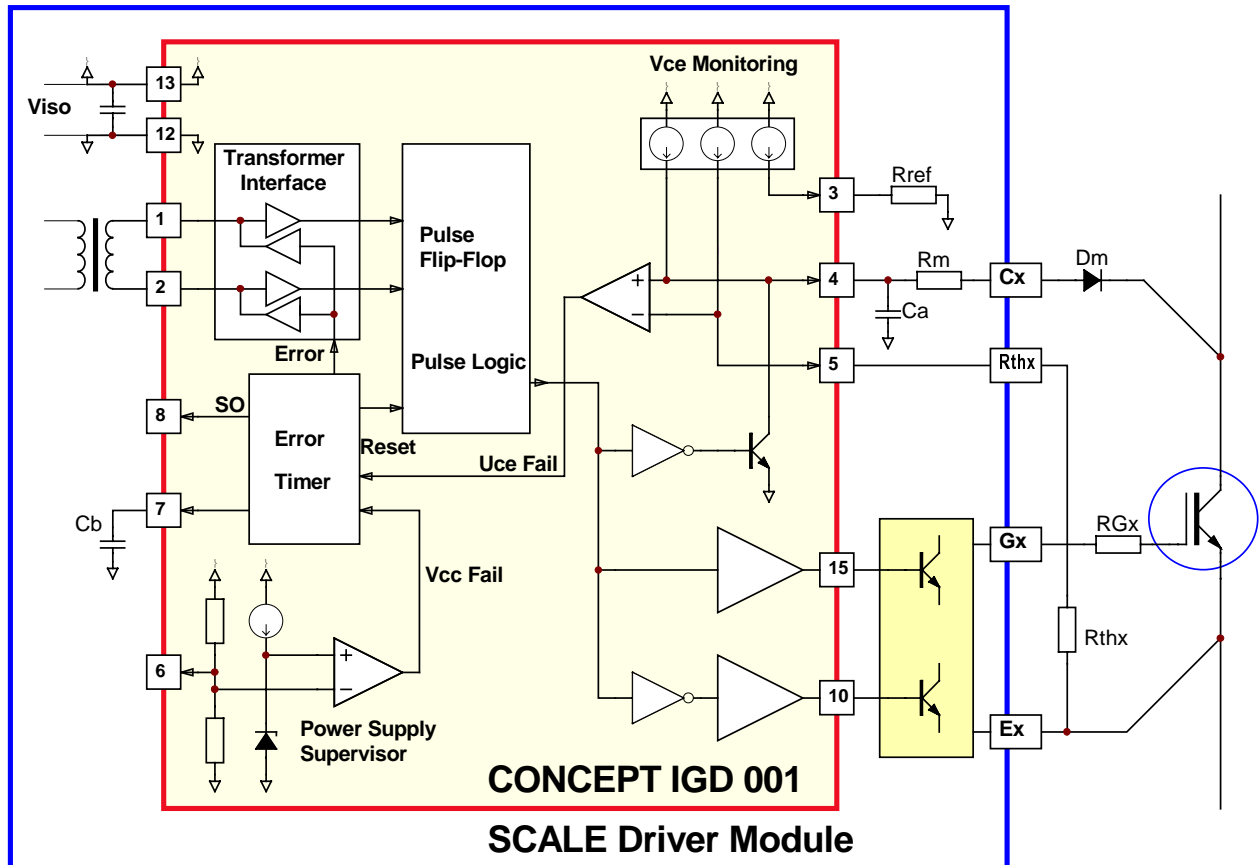


Fig. 4 Block diagram of IGD 001 intelligent gate driver with external wiring

All the functions shown in the inner block of Fig. 4 are integrated on the chip. The components shown in the outer block are contained in the SCALE driver modules. This means that practically no external components are required.



**Absolute safety: the protection concept**

**Short circuit and over-current protection**

Every channel of a SCALE driver is equipped with a Vce monitoring circuit. A resistor (Rth in Fig. 4) is used as the reference element for defining the turn-off threshold.

During the response time, the Vce monitoring circuit is inactive. The response time is the time that elapses after turn-on of the power semiconductor until the transistor is saturated.

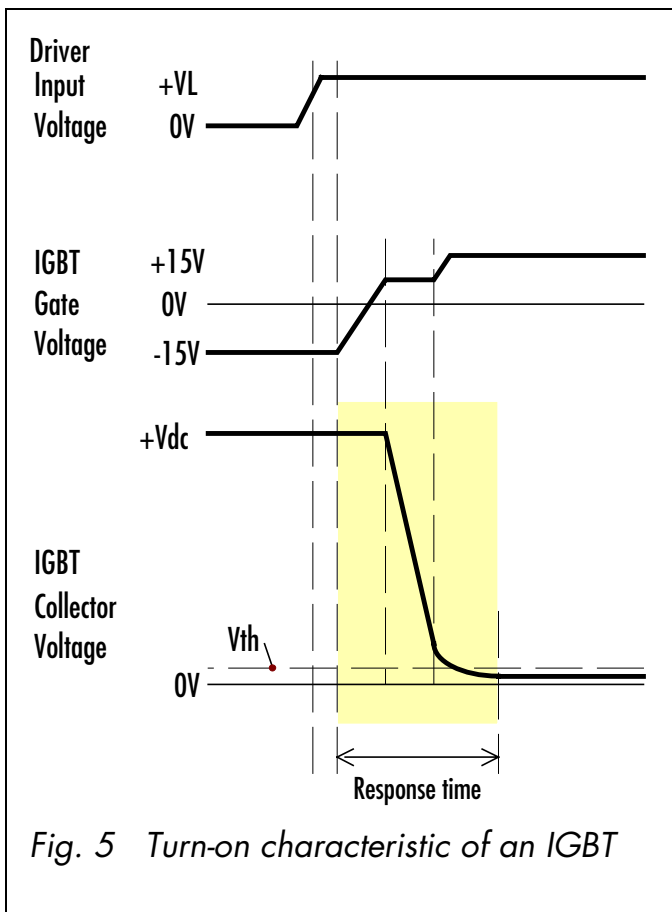


Fig. 5 Turn-on characteristic of an IGBT

The characteristic described below is shown graphically in Fig. 6.

After a Vce or under-voltage error, the blocking time is initiated. During this period, the driver blocks the power semiconductor and accepts no drive signals. The blocking time is a function that runs locally on every driver channel and is implemented within the IGD 001. It starts immediately after the threshold of the VCE monitoring circuit set (with reference resistor Rth) has been exceeded. With the consequent edge change of the drive signal, the "error" information is transferred for storage to the LDI 001, whose status output SOx for the corresponding channel now becomes active (Lo level). The driver then ignores any drive signals that may be subsequently applied until the blocking time has elapsed.

If no further drive signals are applied, the error information continues to be stored in the LDI 001 even after the blocking time. The error memories can be erased by briefly pulling the input VL/Reset to GND. However, these memories are also

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erased automatically at the next edge change of the drive signal following the elapse of the blocking time. The latter way of deleting the error memories is shown in Fig. 6.

The values of response and blocking times can be obtained from the data sheet of the SCALE driver.

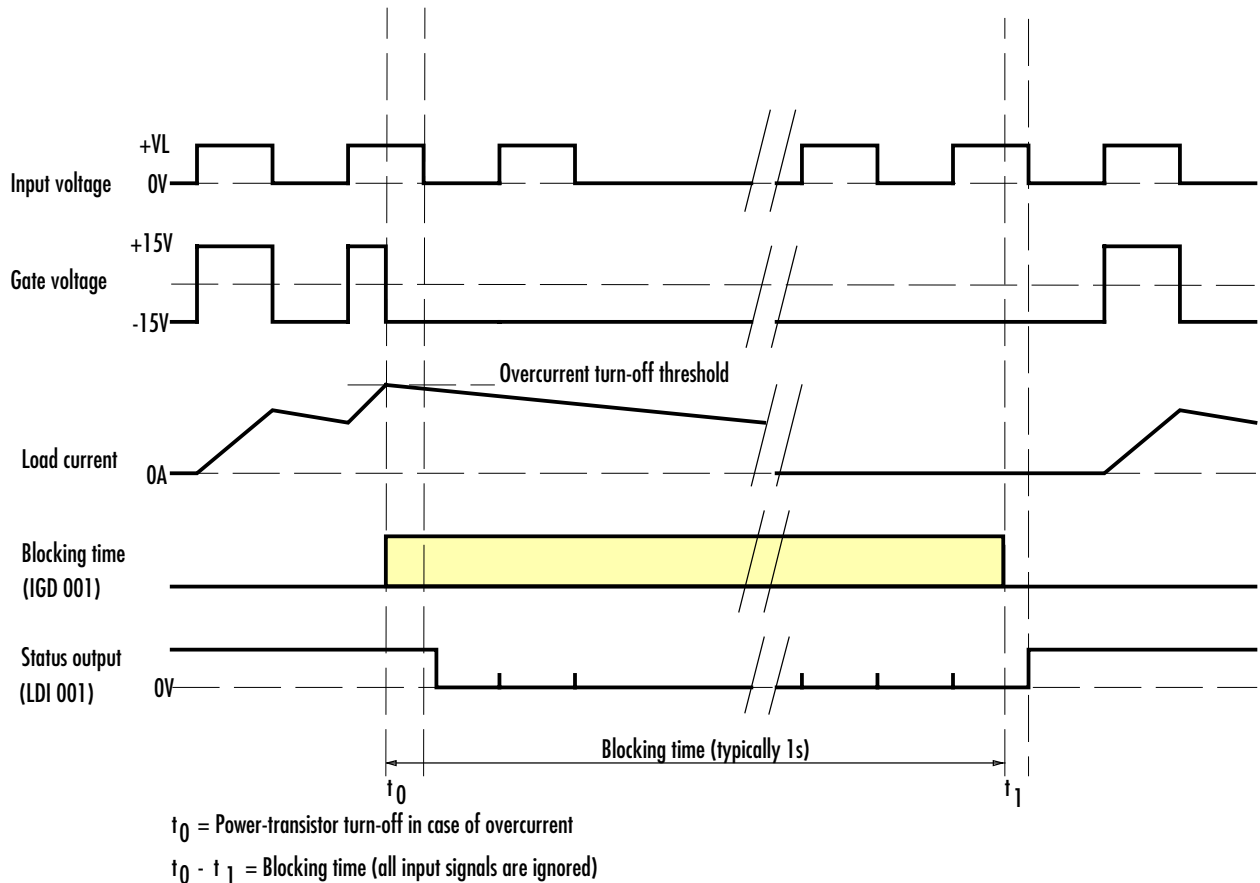


Fig. 6 Short circuit & overcurrent protection / Function of the blocking time

## Power supply monitoring

An under-voltage monitoring circuit blocks the driver if the supply voltage drops to below about 10...11V. In the case of under-voltage, the power semiconductor is driven with a negative gate voltage and an error is reported.

The monitoring is performed locally on each gate driver (integrated in the IGD 001).

Selecting the operating mode

Direct mode

In direct mode, there is no locking between the various drive channels. This allows the use of regulators that already generate a dead time, for example. However, several channels may also switch on concurrently, as is shown in the following example of an asymmetrical half bridge.

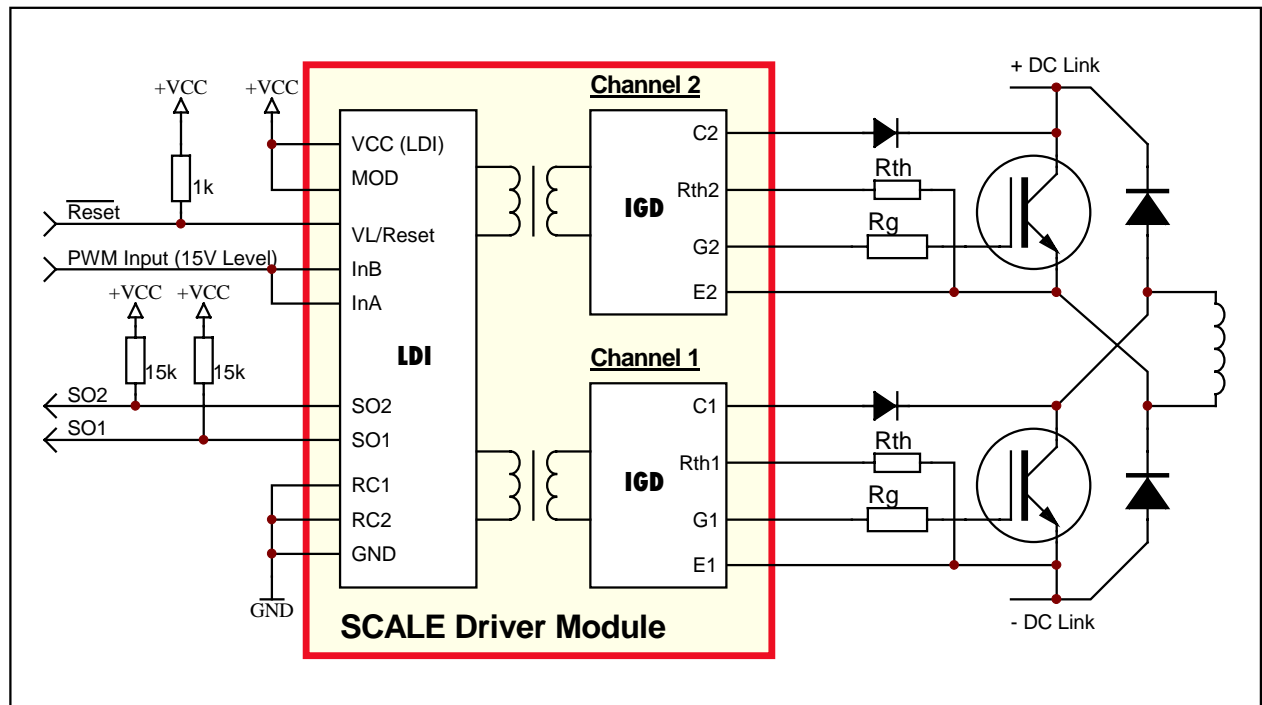


Fig. 7 Application example for direct mode: An asymmetrical half bridge

Legend to Fig. 7

Both channels are always driven simultaneously. For this reason, InA and InB are also connected together. The input VL/Reset is connected to VCC via a pull-up resistor. Inputs InA and InB are then programmed for a 15V level.

The MOD input is on VCC, so that direct mode is selected. RC1 and RC2 are connected to GND. This is necessary in direct mode.

Both status outputs SO1 and SO2 are run back separately. In this way, the control electronics can detect which channel shows an error status in any given case.

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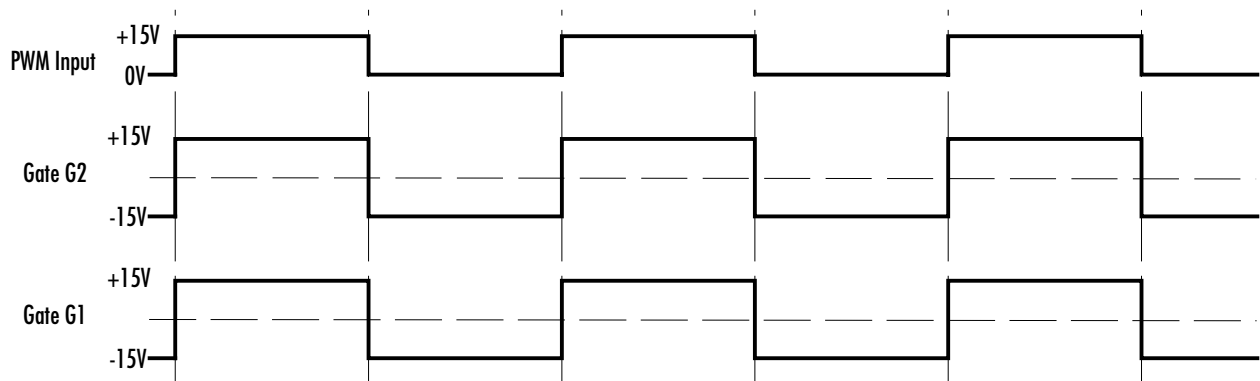


Fig. 8 Signals curves of the circuit as per Fig. 7

### Half-bridge mode with dead time

In half-bridge mode, two channels are always operated as a half bridge. In this mode, the SCALE driver can generate the required dead times directly in a range from about 100ns up to several microseconds. Only two external RC networks are required (see page 26 for dimensioning). All power semiconductors can be turned off by switching the release input (InB) to low.

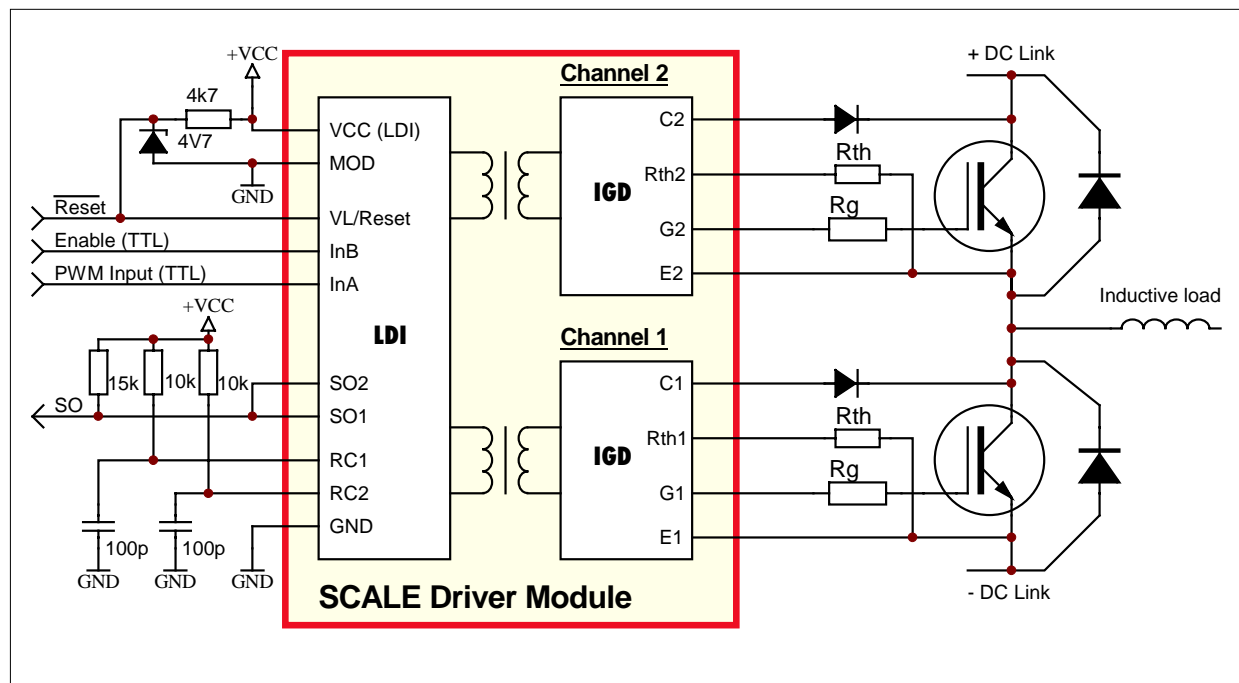


Fig. 9 Application example for half-bridge mode with dead time generation

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### Legend to Fig. 9

The power section represents the typical half-bridge circuit of a voltage link-circuit inverter. Both IGBTs must never be driven simultaneously in this application.

Input MOD is on GND, which means that half-bridge mode has been selected.

Input InA is the PWM input, InB is the release input.

With the 4V7 zener diode at the VL/Reset input, the Schmitt triggers of inputs InA and InB are programmed for TTL level.

The two status outputs SO1 and SO2 are connected together: there is a common error acknowledgement for both drive channels.

RC1 and RC2 are each connected to an RC network 10kΩ/100 pF. This results in dead times of about 500ns.

The circuit characteristics are shown in Fig. 10

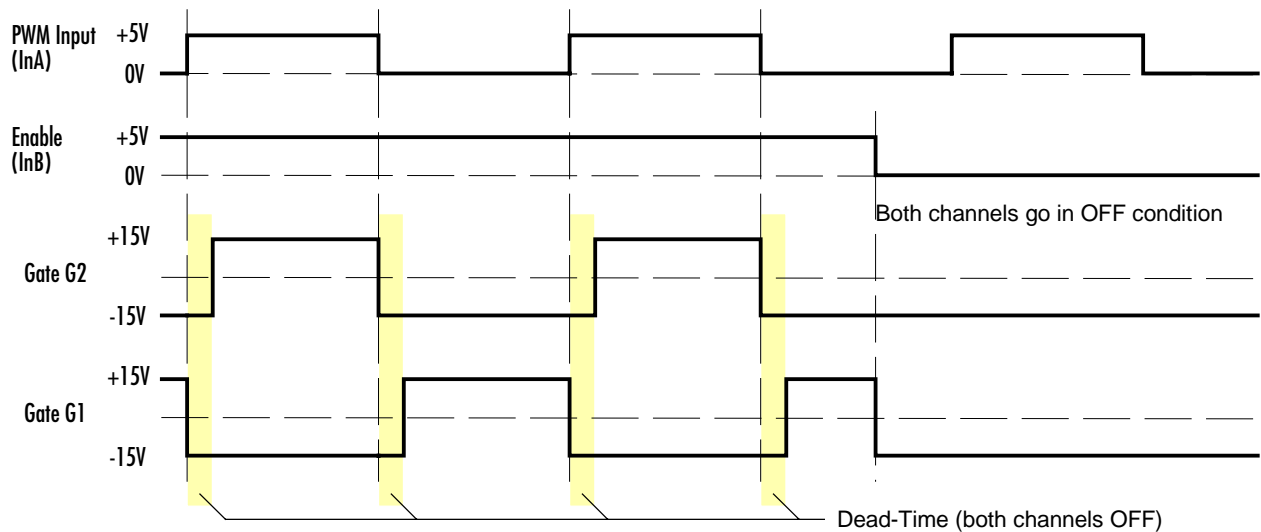


Fig. 10 Signals curves of the circuit as per Fig. 9

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### **Practical Part 1: the input side**

The following terminal pins are normally led to the outside in the SCALE drivers:

<b>Label</b>	<b>Description</b>
GND	Power supply GND
VDC	Power supply +15V terminal for the DC/DC converter
VDD	Power supply +15V terminal for the interface electronic (LDI 001)
VL/Reset	Define logic level/acknowledge error
MOD	Mode selection input
InA	Input A, PWM 1 / PWM
InB	Input B, PMW 2 / Enable
SO1	Status output channel 1
SO2	Status output channel 2
RC1	RC networks for dead time channel 1
RC2	RC networks for dead time channel 2

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### **Pin GND**

Pin GND is connected to the ground of the electronic power supply. If several GNDs are present, all GNDs should be connected to ground.

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### **Pin VDC (voltage supply DC/DC converter)**

A stabilized voltage supply of +15V with respect to GND is connected to terminal VDC. This input supplies the internal DC/DC converter(s). The current consumption and other data can be obtained from the data sheet of the relevant driver. It is recommended that a blocking capacitor is inserted between VDC and GND.

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### **Pin VDD (voltage supply electronics input side)**

A stabilized voltage supply of +15V with respect to GND is connected to terminal VDD. Additional data may be obtained from the data sheet of the relevant driver.

**Pin VL / Reset (define logic level/acknowledge error)**

This terminal is used for programming the switching thresholds of Schmitt trigger inputs InA and InB. These inputs switch on at 2/3 of the voltage applied to VL. A level of 1/3 of this voltage acts as a turn-off signal.

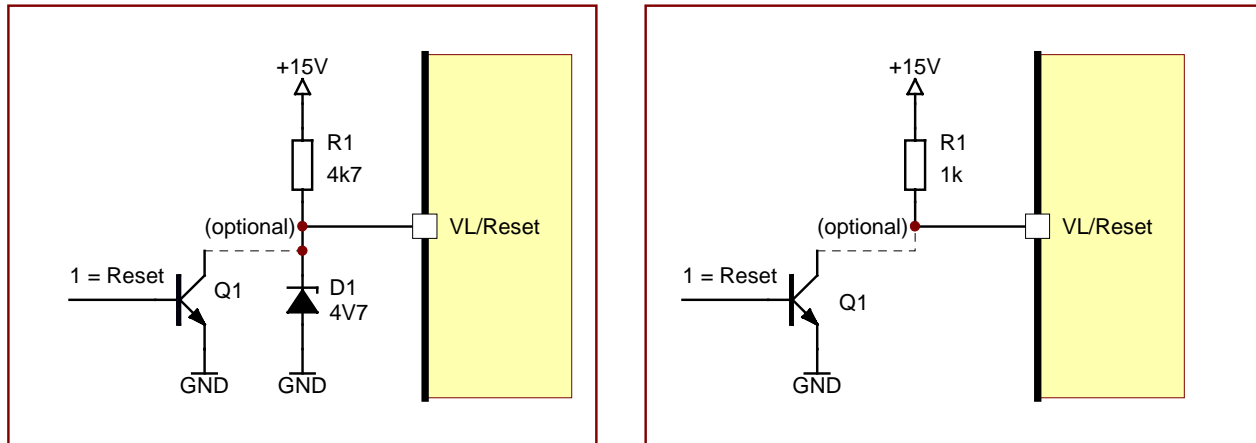


Fig. 11 Circuit for input VL/Reset for 5V logic (left) and 15V logic level

When the PWM signals have TTL level, pin VL is connected as shown in Fig. 11 (left). When the signals at inputs InA and InB have 15V level, then pin VL should be connected via a resistor of about 1kΩ to +15V (see Fig. 11 (right)). The switching thresholds of Schmitt trigger inputs InA and InB are then 5V and 10V respectively. This variant is recommended especially in the case of longer connecting cables between the control electronics and the driver; this produces higher signal-to-noise ratios.

In addition, the input VL has a double function: if it is pulled to GND (see Transistor Q1 in Fig. 11), the error memories of the LDI 001 are erased when they were previously set.

The current consumption of the inputs VL is (depending on the switching status and per LDI 001):

typ. 0.14...0.5mA @ 5V

typ. 0.4...1.4 mA @ 15V

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**Note:**

When a SCALE driver is turned on, the error memories are usually set. They can be erased by pulling pin VL to GND after turn-on or during the entire turn-on process (for example by a power-up reset signal). However, the error memories are also erased automatically at the first edge of a drive signal after the blocking time has elapsed (see also Fig. 6).

**Important notes:**

The VL/Reset input has no Schmitt trigger characteristic like signal inputs InA and InB. For this reason, only “clean” digital levels are permissible. Voltages smaller than 1V are regarded as a reliable level indicator for the error reset function. Voltages between 4V and 15V are regarded as safe logic levels. Levels between 1V and 4V must be avoided.

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### Pin MOD (mode selection)

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The input mode selection “MOD” can be used to select the operating mode of the LDI 001.

If the MOD pin is connected to GND, half-bridge mode is selected. In this operating mode, inputs RC1 and RC2 must be connected to RC networks. For the dimensioning, see Section “Pin RCx (RC networks for the dead times)” from page 26 onwards.

In half-bridge mode, inputs InA and InB have the following functions: InA is the PWM input and InB has the release function.

If the level on InB is “Lo”, then both channels are blocked. With a Hi level on InB, the outputs are released, depending on InA. In the event of an edge change from Lo to Hi at InA, channel 1 switches off immediately and channel 2 switches on when the dead time has elapsed. In the event of an edge change from Hi to Lo at InA, channel 2 is immediately switched off and channel 1 is switched on when the dead time has elapsed. The characteristic is shown in Fig. 10.

If the MOD pin is connected to VCC, direct mode is selected. In this operating mode, there is no mutual influence between the two drive channels. InA affects channel 1 and InB affects channel 2. In each case, a high level at the input leads to switch-on of the corresponding IGBT. This operating mode should be selected when the control electronics has already generated the dead times and a control signal is thus present



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for each power semiconductor. Moreover, in this operating mode both channels can also be driven either simultaneously or in overlapping mode.

### **Note:**

In direct mode, the two pins RC1 and RC2 are connected to GND. If this is not done, unexpected switching processes will result.

---

### **Pin InA (signal input A)**

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In direct mode, terminal InA drives channel 1 directly. The input has a Schmitt trigger characteristic and corresponds to positive logic: a Hi level switches the power semiconductor on, a Lo level means a switch-off state.

In half-bridge mode, the PWM signal for the phase branch is connected to InA (see also "Pin MOD" from page 24 onwards).

Inputs InA and InB can be operated with 5V...15V levels (see also "Pin VL/Reset" from page 23 onwards).

During the build-up of the supply voltage, both inputs InA and InB or input VL/Reset should be on GND, so that no uncontrolled drive signals are generated.

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### **Pin InB (signal input B)**

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In direct mode, terminal InB controls channel 2 directly. The input has a Schmitt trigger characteristic and corresponds to positive logic (like InA).

In half-bridge mode, the release signal for the phase branch is connected to InB. Hi level means release, Lo level means that all channels are blocked (see also "Pin MOD" from page 24 onwards).

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### **Pin SOx (status outputs)**

---

The "x" in "SOx" stands for the number of the drive channel in multi-channel drivers.

The output stage SOx consists of an open-collector transistor (see Fig. 3). The output is pulled to GND if an error has been detected in channel x. The transistor goes high when no error is present.

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Any number of status outputs can be connected together directly if a common error signal is required for each phase or current inverter (see the examples in Fig. 1 and Fig. 9).

The status outputs can be pulled to +5V...+15V via a pull-up resistor. A current of 1.5mA can be applied to the outputs SOx.

### How the status information is determined

Every time that an edge of a drive signal changes:

- a) the error memory in the LDI 001 is erased (for each channel),
- b) the status information of the IGD 001 is transferred to the LDI 001,
- c) if an error was detected in the IGD 001 (and the blocking time is still running), then the error memory in the LDI 001 is set (and the output is pulled to GND).

### Note:

The error memory can also be erased when VL is pulled to GND (see "Pin VL"). The error memory is then reset at the next edge change as long as there is still an error in this channel.

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## Pin RCx (RC networks for the dead times)

---

The "x" in "RCx" stands for the number of the drive channel in multi-channel drivers

In half-bridge mode, an RC network is connected to each RCx terminal. It determines the dead time of the corresponding channel.

### Table for values of the dead times of RC networks:

<b>R</b>	<b>C</b>	<b>typ. dead time</b>
10k	47pF	≈ 200ns
10k	100pF	≈ 500ns
15k	120pF	≈ 1.1μs
22k	150pF	≈ 2.1μs
33k	220pF	≈ 4.6μs

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These values produce the smallest scatter of dead times over the whole temperature range. Resistance values below 5kΩ are not permissible.

The RC networks must be connected as shown in Fig. 9: the resistor is connected to VCC, the capacitor to GND.

In direct mode, all RC inputs must be connected to GND.

### Practical Part 2: the power side

In the SCALE drivers, the terminal pins described below are usually accessible from the outside:

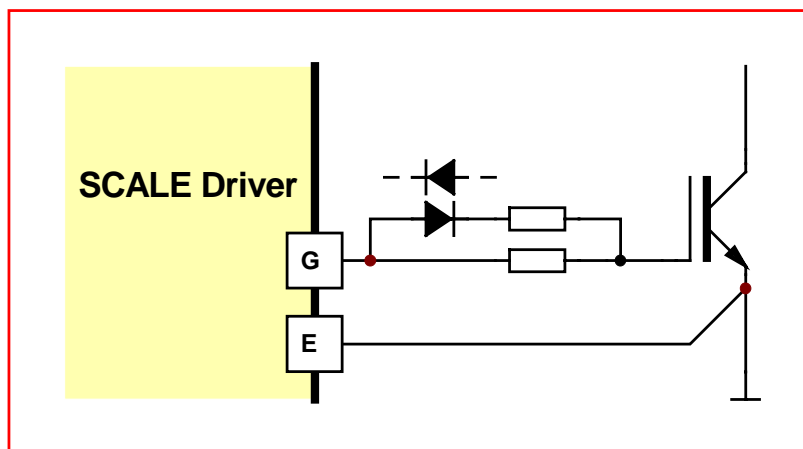
#### Pin Gx (gate terminal)

The "x" in "Gx" stands for the number of the drive channel in multi-channel drivers.

The output Gx is the output for the gate drive. When the SCALE driver is supplied with 15V, the gate is driven with ±15V. The negative gate voltage is generated internally.

A sufficiently low-resistance termination of the gate is ensured by the SCALE driver even if it is not supplied with the operating voltage.

The maximum permissible gate current can be obtained from the data sheet of the SCALE driver used. For the correct selection and calculation of drivers, reference is made to Application Document AN-9701 from CONCEPT "IGBT drivers correctly calculated".



In order to allow the switching speed to be set independently during both turn-on and turn-off, a gate circuit can be used with two gate resistors and a diode (see Fig. 12).

Fig. 12 Asymmetrical gate resistors

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### Pin Ex (emitter terminal)

The "x" in "Ex" stands for the number of the drive channels in multi-channel drivers.

This terminal should be connected to the emitter or source terminal of the power transistor. The connection must be as short as possible and be run directly to the emitter or source terminal of the power element. This terminal should be used in modules with auxiliary emitters or an auxiliary source. This terminal is also used as the low end of the reference resistor Rthx. Where possible, this should be connected directly to the terminal Ex of the driver.

### Pin Cx (collector sense)

The "x" in "Cx" stands for the number of the drive channels in multi-channel drivers.

This terminal is used to measure the voltage drop across the turned-on power transistor in order to ensure protection from short circuit and overload. It should be noted that it

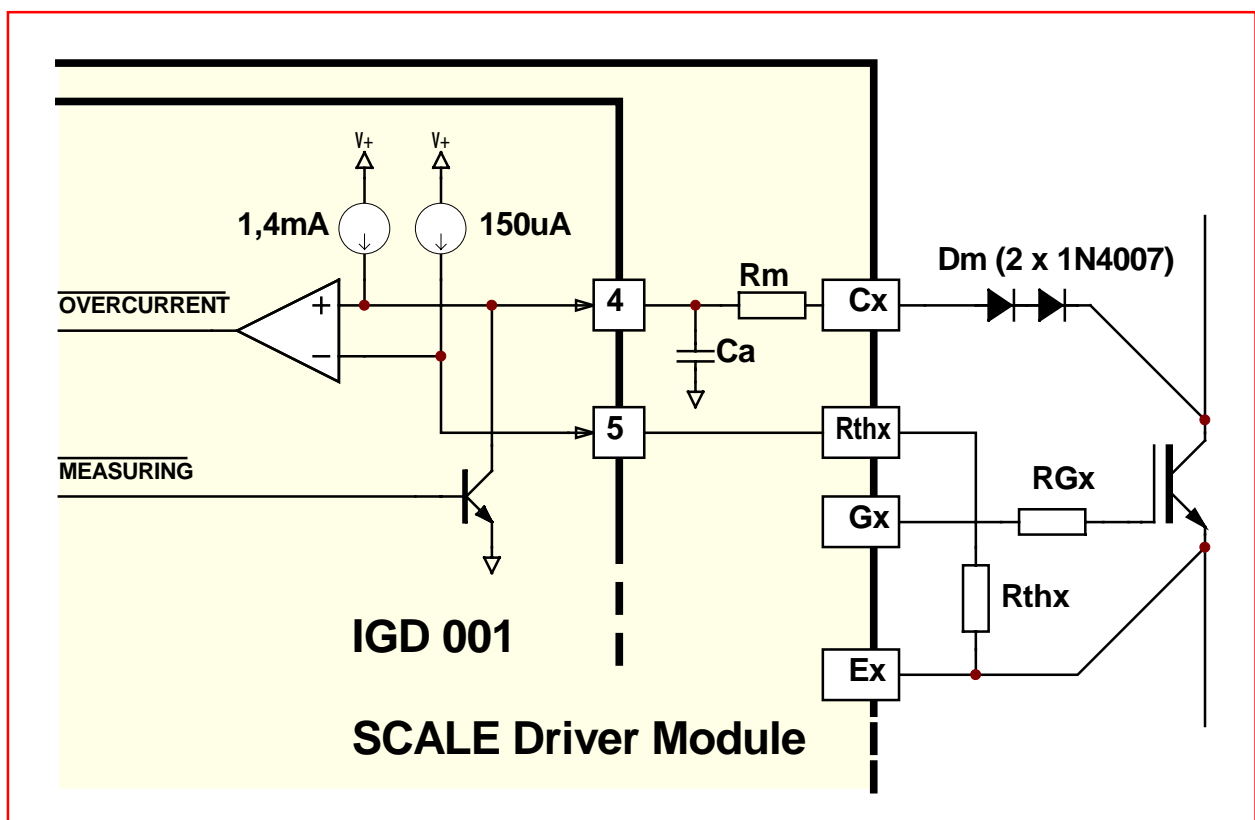


Fig. 13 Principle of the collector sense circuit

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must never be connected directly to the drain or collector of the power transistor. A circuit with a high-blocking diode ( $D_m$ ) must be included to protect the measuring terminal from the high drain or collector voltage of the turned-off power element. For 1200V and 1700V modules, a circuit made up of two or three diodes of type 1N4007 connected in series has proved its worth in place of exotic higher-blocking elements (see Fig. 13). It is recommended that the voltage of these diodes be over-dimensioned by at least 40%. Fast diodes are not required here. Standard line diodes are quite sufficient.

A current source integrated in the IGD 001 ensures that a current flows through the diode(s) in the power semiconductors when the power transistor is turned on. A voltage is thus applied at the comparator that corresponds to the forward voltage of the turned-on transistor plus the diode forward voltage and the voltage drop across  $R_m$  (about 250 mV).

It should be noted that power transistors take a finite time to turn on, especially in the case of IGBTs, that can take several microseconds to completely switch through. The current source and the capacitor ( $C_a$ ) cause a delay in the measurement after the power transistor has been turned on. This delay is known as the response time. Its magnitude as a function of the turn-off threshold can be obtained from the data sheet of the selected SCALE driver.

Negative voltages are impermissible at the input  $C_x$ .

---

### Pin $R_{thx}$ (reference resistor)

The "x" in " $R_{thx}$ " stands for the number of the drive channels in multi-channel drivers.

A resistor is connected to this pin as a reference. It defines the maximum voltage drop across the turned-on power transistor at which the protection function of the drive circuit is activated and thus the power transistor is turned off.

The protection function is always active when the voltage at  $C_x$  (measurement drain/collector) exceeds the voltage at  $R_{thx}$ .  $E_x$  is the reference potential. The reference resistor must be placed as close as possible to the driver module.

The current source in the SCALE driver supplies a current of 150 $\mu$ A.

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The reference resistor can be calculated as follows:

$$R_{th} = \frac{V_{th}}{150\mu A}$$

$V_{th}$  = turn-off threshold

Example: required turn-off threshold  $V_{th} = 5.85V$

$$R_{th} = \frac{V_{th}}{150\mu A} = \frac{5.85V}{150\mu A} = 39k\Omega$$

### Note:

Because of the voltage drops across the diode  $D_m$  (approx. 0.6 V per diode) and the resistor  $R_m$  (approx. 250 mV) in the collector sense circuit, the voltage at the power semiconductor – at which the protection function cuts in – is lower than the threshold calculated above by about 850mV with a diode (or 1.45V if two diodes are connected in series). In this example with two diodes connected in series, the protection function thus reacts when the collector voltage exceeds a value of 4.4V (5.85V-1.45V).

## Layout and wiring

Drivers should as a rule be placed as close as possible to the power semiconductors so that the leads from the driver to the transistors are as short as possible. Lead lengths of more than 10 cm must be avoided. When the power semiconductors are connected by stranded wires, it is recommended always to twist the three associated leads  $G_x$ ,  $E_x$ , and  $C_x$  (see Fig. 14).

It is also recommended to place two 15V zener diodes

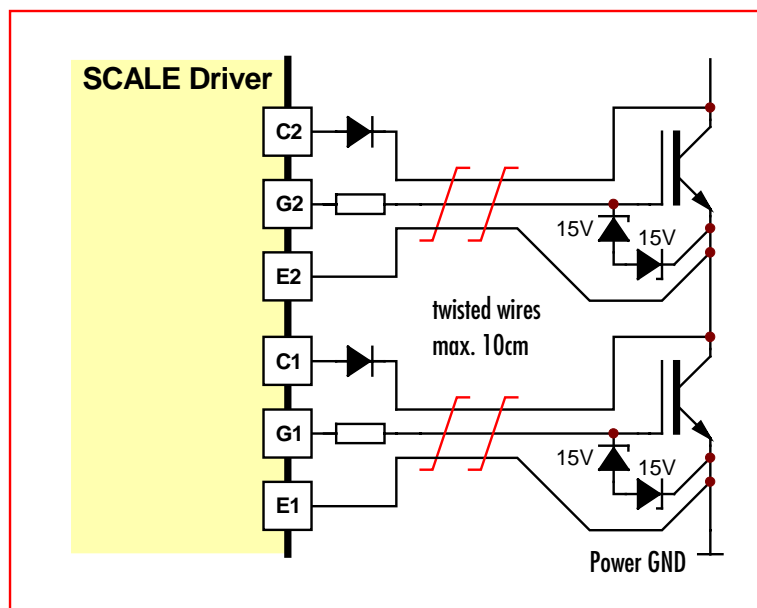


Fig. 14 Wiring driver → IGBT

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connected in counter-series immediately between the gate and emitter of the IGBTs (see Fig. 14). This prevents the gate voltage from increasing to an impermissible level due to parasitic effects (such as the Miller effect). An excessive gate voltage increases the short-circuit current to an over-proportional extent and can lead to destruction of the power semiconductor.

### **The really fast variant: evaluation boards**

CONCEPT offers a wide range of evaluation boards to introduce users quickly to the sector of IGBT technology and to the protection concept used with SCALE drivers. These boards represent completely built up and tested current-inverter circuits in the power range from 10 kW to over 1000 kW and contain the power semiconductors (IGBTs), a driver card with correctly matched drivers and the link-circuit capacitors. The power sections are designed with very low inductance.

Together with the documentation supplied, these evaluation boards can be used to create prototype equipment that is ready to use within a matter of hours. You are invited to request an overview of the available evaluation boards.

### **If you need any help, simply call our technical support**

CONCEPT offers you expert help for your questions and problems:

E-Mail: [support@ct-concept.com](mailto:support@ct-concept.com) or on the Internet: [www.CT-CONCEPT.com](http://www.CT-CONCEPT.com)

Fax international ++41 32 / 322 22 51 (in Switzerland: 032 / 322 22 51)

Tel international ++41 32 / 322 42 36 (in Switzerland: 032 / 322 42 36)

## Description and Application Manual

### **Important information: the SCALE driver data sheets**

A data sheet is available for every SCALE driver.

Please request our overview of SCALE drivers.

### **Quite special: customized SCALE drivers**

If you need a power MOSFET or 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 drivers for power MOSFETs and IGBTs and have already implemented a large number of customized solutions.

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