6SP0235T Description & Application Manual

Driver solution for HybridPACK^{TM} 2 IGBT modules with an electrical interface

Abstract

The 6SP0235T is a six-channel driver with an electrical interface. The driver is 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 HybridPACK^{TM} 2 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   6SP0235T soldered onto a HybridPACK^{TM} 2 IGBT module

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System Overview

The 6SP0235T 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 6SP0235T driver 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/.
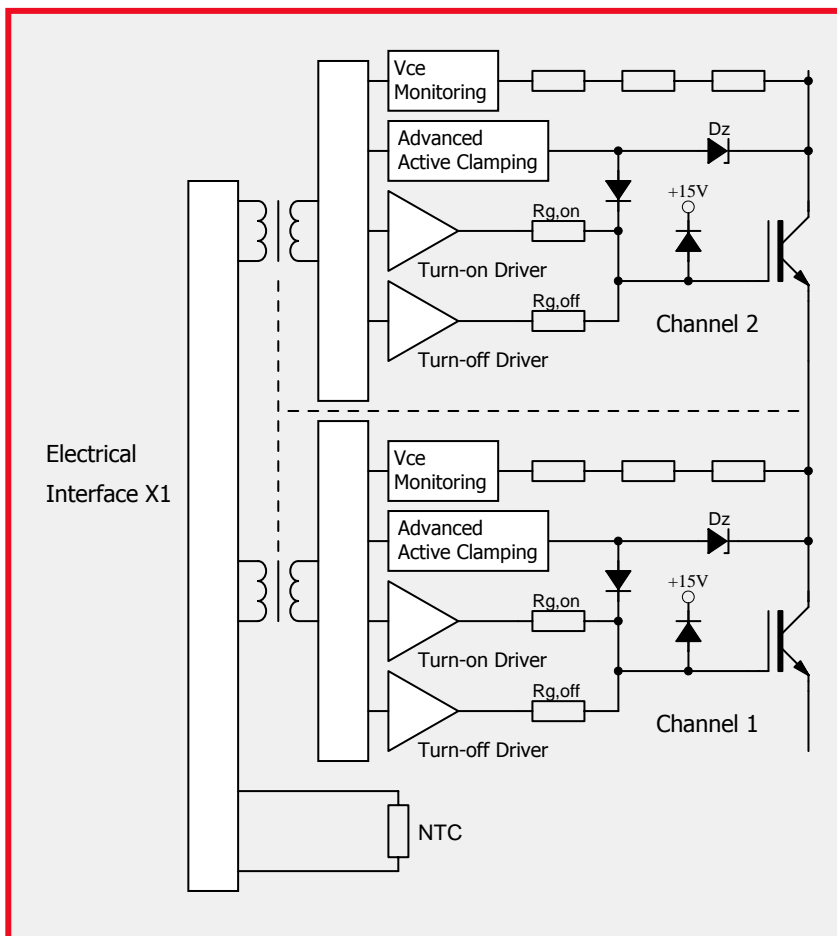
Fig. 2   Basic schematic of the 6SP0235T driver (only one phase with corresponding NTC shown)

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), short-pulse suppression as well as the input electrical connector X1. Moreover, it includes components for setting the turn-off trip level, the response time and the dead time between both channels in half-bridge mode. 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 Six Steps to Success

The following steps point out the easy way to use 6SP0235T drivers in power converters:

1. Choose a suitable driver

When applying 6SP0235T 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 soldering and screwing 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.

4. Select the operating mode

The operating mode can be set with input MOD (interface X1: pin 17). For details, see page 11).

5. 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.
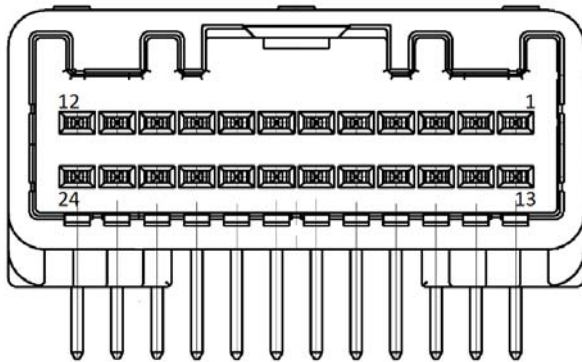
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6. Set up and test the power stack

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 SOA 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.

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

Electrical connector X1: 1318853-3 from TYCO Electronics

Recommended cable connector: 1318917-1 with crimp contacts 1123343-1 from TYCO Electronics

Fig. 3   Mechanical dimensions of 6SP0235T

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Pin Designation of Connector X1

Fig. 4   Front view of connector X1

Pin	Des.	Function Pin	Pin	Des.	Function Pin
1	VDC	+15V for DC/DC converter	13	VCC	+15V for primary side electronics
2	VDC	+15V for DC/DC converter	14	GND	Ground
3	SO1_1	Status output phase 1, low-side	15	INA_1	Signal input phase 1, low-side
4	SO2_1	Status output phase 1, high-side	16	INB_1	Signal input phase 1, high-side
5	GND	Ground	17	MOD	Mode selection (direct/half-bridge)
6	SO1_2	Status output phase 2, low-side	18	INA_2	Signal input phase 2, low-side
7	SO2_2	Status output phase 2, high-side	19	INB_2	Signal input phase 2, high-side
8	GND	Ground	20	TB	Blocking time
9	SO1_3	Status output phase 3, low-side	21	INA_3	Signal input phase 3, low-side
10	SO2_3	Status output phase 3, high-side	22	INB_3	Signal input phase 3, high-side
11	NTC_2	NTC-thermistor phase 2	23	NTC_1	NTC-thermistor phase 1
12	NTC_3	NTC-thermistor phase 3	24	NTC_C	Common pin of NTC-thermistor

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Recommended Interface Circuitry for Connector X1
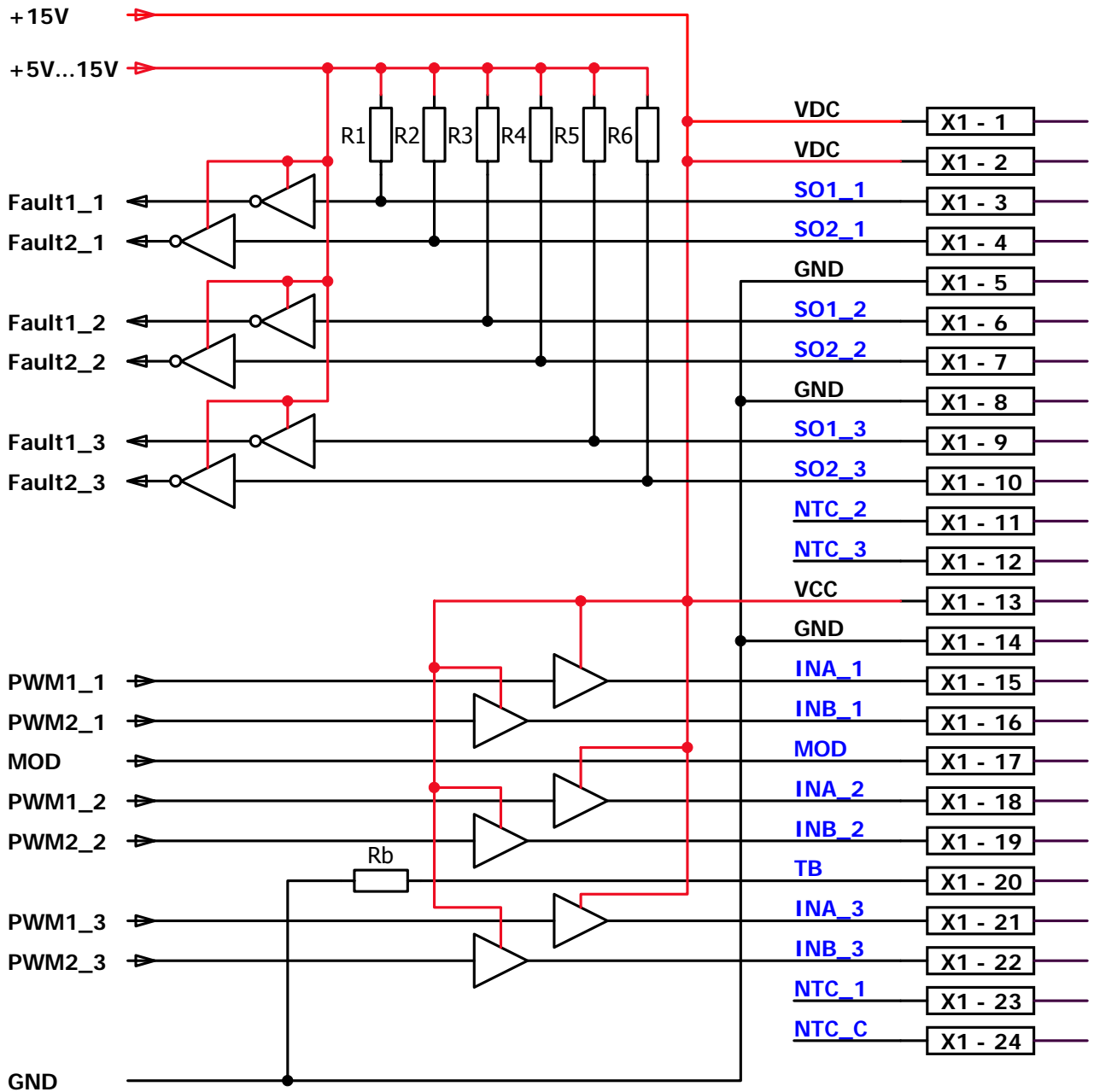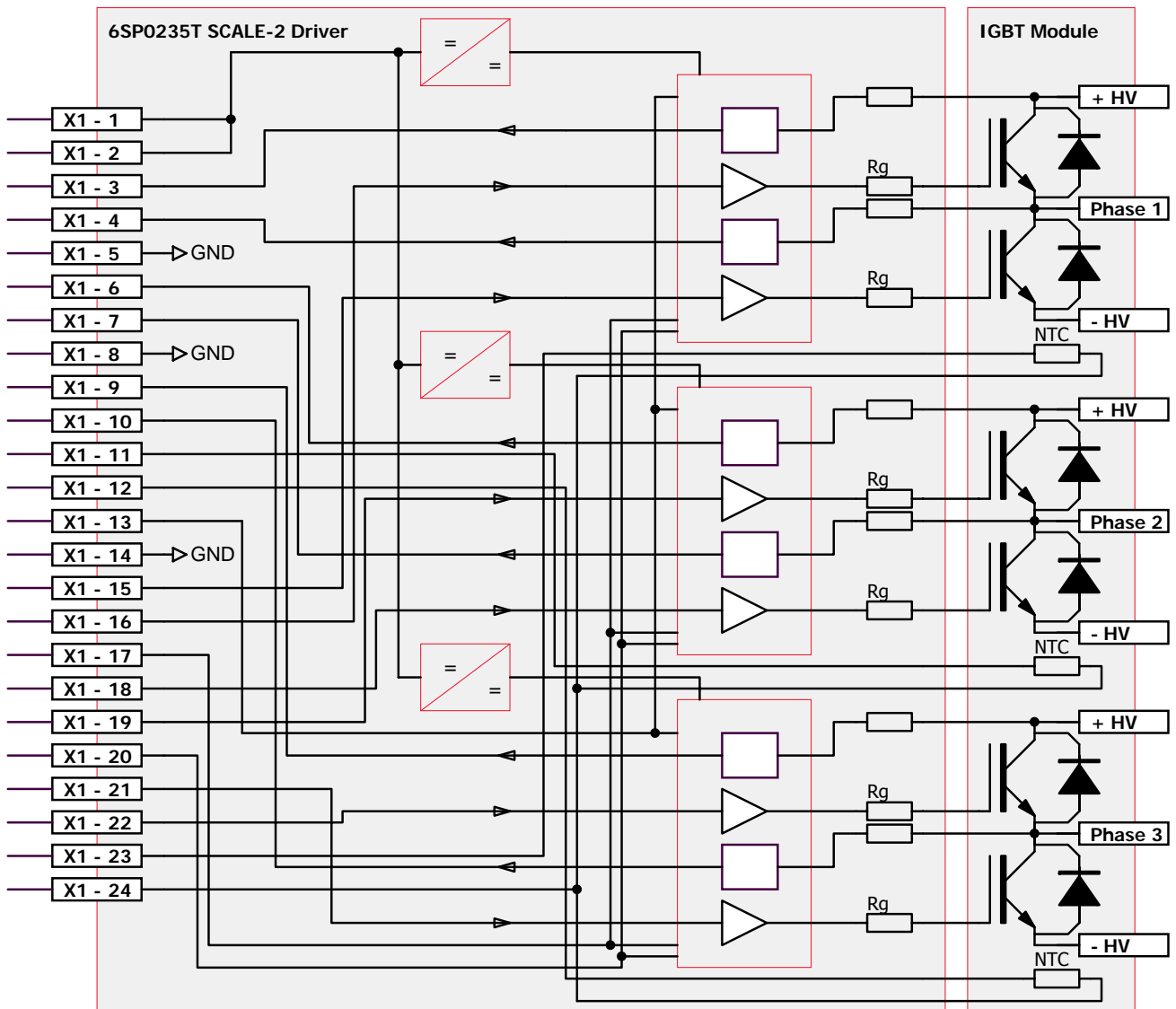

Fig. 5   Recommended user interface of 6SP0235T

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Fig. 6   Block diagram covering SCALE-2 driver 6SP0235T and IGBT module

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Description of Interface X1

General

The interface X1 of the driver 6SP0235T is very simple and easy to use.

The driver has the following terminals:

- 3 x power-supply terminals (but only one 15V power supply is needed)
- 6 x drive signal inputs
- 6 x status outputs (fault returns)
- 1 x mode selection (half-bridge mode / direct mode)
- 1 x input to set the blocking time
- 3 x NTC-thermistor outputs

The driver is equipped with a 24-pin interface connector.

All inputs are ESD-protected. Moreover, all digital inputs have Schmitt-trigger characteristics.

VCC terminal

The driver has one 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 6 x 2W = 12W, the maximum input current drawn from the +15V supply is approx. 1A (total for VDC and VCC terminals).

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.

MOD (mode selection)

The MOD input allows the operating mode to be selected.

Direct mode

If the MOD input is not connected (floating), or connected to VCC, direct mode is selected. In this mode, there is no interdependence between the two channels of one phase. Input INA_x (x is the phase number and can be equal to 1, 2 or 3) directly influences the low-side IGBT while INB_x influences the high-side IGBT of the corresponding phase. High level at an input (INA_x or INB_x) always results in turn-on of the corresponding IGBT. This mode should be selected only when the dead times are generated by the control circuitry so that each IGBT receives its own drive signal.

Caution: Synchronous or overlapping timing of both switches of a half-bridge basically shorts the DC link.

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Half-bridge mode

If the MOD input is low level (connected to GND), half-bridge mode is selected. In this mode, the inputs INA_x and INB_x have the following functions: INA_x is the drive signal input while INB_x acts as the enable input of the corresponding phase (see Fig. 7).

When input INB_x is low level, both channels are blocked. If it goes high, both channels are enabled and follow the signal on the input INA_x. At the transition of INA_x from low to high, high-side IGBT turns off immediately and the low-side IGBT turns on after a dead time. The dead time is set by a resistor on the 6SP0235T.
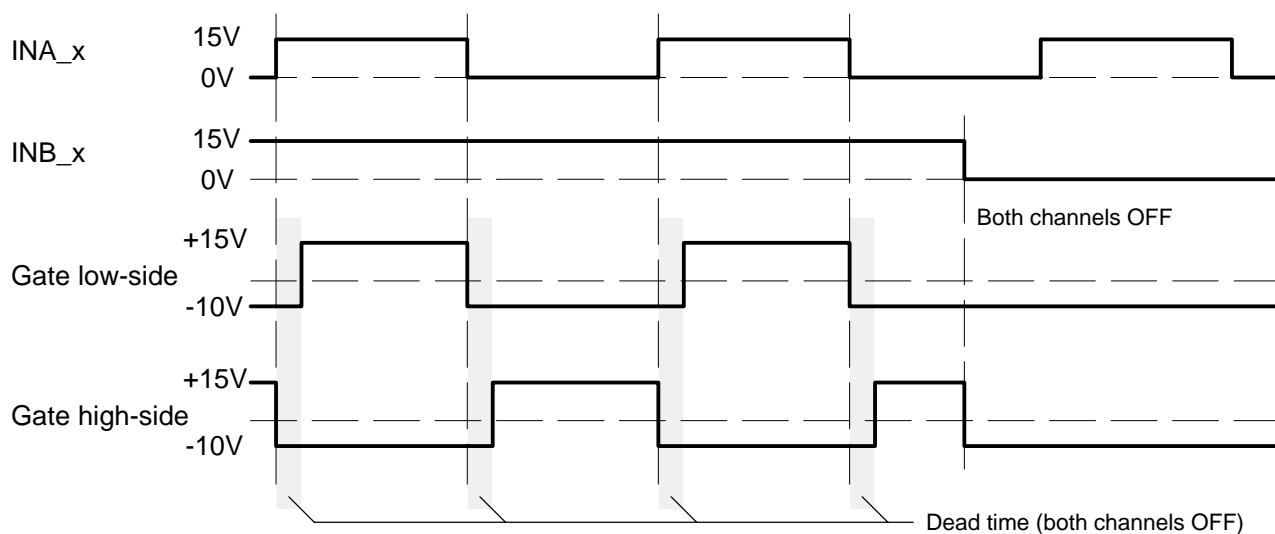

Fig. 7   Signals in half-bridge mode

INA_x, INB_x (channel drive inputs, e.g. PWM)

INA_x and INB_x are basically drive inputs, but their function depends on the MOD input (see above).

15V logic-level signals should be applied at INA_x and INB_x.

SO1_x, SO2_x (status outputs)

The outputs SOx_x have open-drain transistors. When no fault condition is detected, the outputs have high impedance. An internal current source of 500µA pulls the SOx_x outputs to a voltage of about 4V when leaved open. When a fault condition is detected in a channel, the corresponding status output SOx_x goes to low (connected to GND).

All SOx_x outputs can be connected together to provide a common fault signal. However, it is recommended to evaluate the status signals individually to allow fast and precise fault diagnosis.

The maximum SOx_x current in a fault condition should not exceed the value specified in the driver data sheets /3/.

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How the status information is processed

a) A fault on the secondary side (detection of short-circuit of IGBT module or supply undervoltage) is transmitted to the corresponding SOx_x output immediately. The corresponding SOx_x output is automatically reset (returning to the high impedance state) after the blocking time Tb has elapsed (read the relevant data sheet for timing information /3/).

b) A supply undervoltage on the primary side is indicated to both SOx_x outputs of a same phase at the same time. Both SOx_x outputs are automatically reset (returning to a high impedance state) when the undervoltage on the primary side disappears (read the relevant data sheet for timing information /3/).

TB (input for adjusting the blocking time)

The terminal TB allows the factory-set blocking time to be reduced by connecting an external resistor to GND (see Fig. 5). The following equation calculates the necessary resistor R_b connected between pins TB and GND in order to define the desired blocking time Tb (typical value):

$$R_b[k\Omega] = \frac{2574 + 47 \cdot Tb[ms]}{92 - Tb[ms]} - 2.2 \quad \text{where} \quad 20ms < Tb < 90ms$$

The blocking time can also be set to a minimum of 9µs by selecting Rb=0Ω.

If not used, the input TB can be left open.

NTC terminals

The driver has three non-insulated NTC-thermistor outputs on the interface. They are each connected via a series resistor of 20Ω to the NTC thermistors of the IGBT module. Every NTC-thermistor output is protected with a 24V transient voltage suppressor diode according to Fig. 8. NTC_C is the common pin for the three NTC-thermistors.
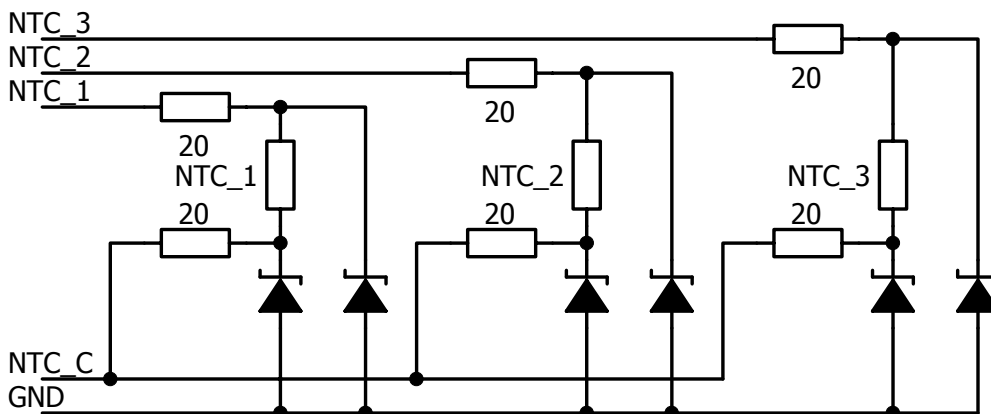

Fig. 8 Connection of the NTC-thermistors to the connector X1

How Do 6SP0235T SCALE-2 Drivers Work in Detail?

Overview

The 6SP0235T series of plug-and-play six-channel drivers are designed for HybridPACK^{TM} 2 modules. All drivers of the SCALE-2 driver family with an electrical interface are equipped with usual protection functions such as Vce monitoring for short-circuit protection, operation inhibit after fault, supply-undervoltage shutdown and status feedback.

Outstanding features of 6SP0235T SCALE-2 drivers are: compact size, simple mounting - directly onto the IGBT module, advanced active-clamping function and short-pulse suppression. 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.
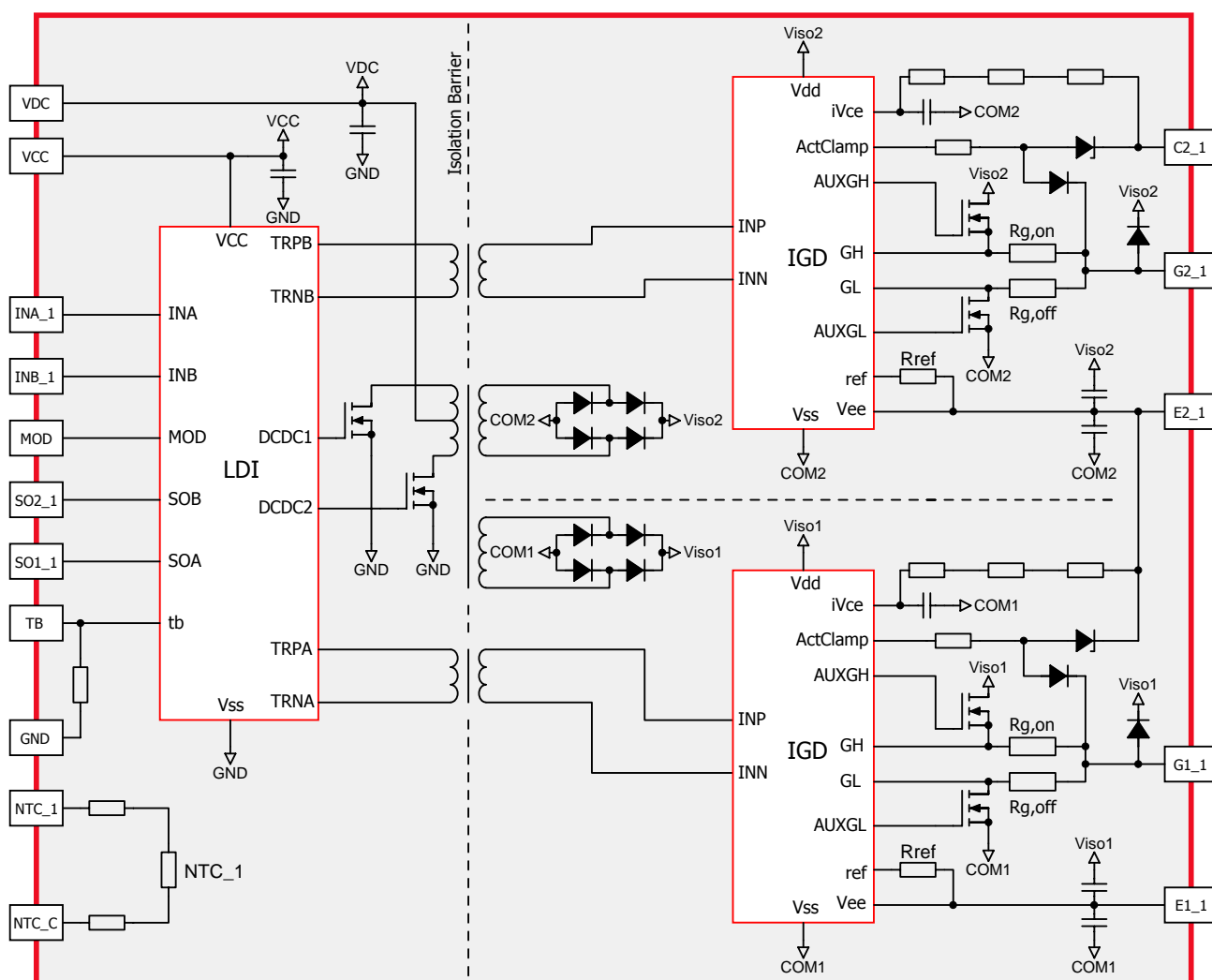

Fig. 9   Block diagram of the 6SP0235T SCALE-2 driver (only phase 1 shown)

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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 signal isolation is realized with transformers. All transformers (DC/DC and signal transformers) feature safe isolation to EN 50178 and IEC 60664-1, 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 all secondary-side driver channels are equipped with a local undervoltage monitoring circuit.

In case of a primary-side supply undervoltage, both IGBTs of a phase are driven with a negative gate voltage to keep them in the off-state (both channels are blocked) and the fault is transmitted to both outputs SO1_x and SO2_x until the fault disappears.

In case of a 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 corresponding SOx_x output. The SOx_x output is automatically reset (returning to a high impedance state) after the blocking time.

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.

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V_{ce} monitoring / short-circuit protection

Fig. 10   Turn-on characteristic of an IGBT
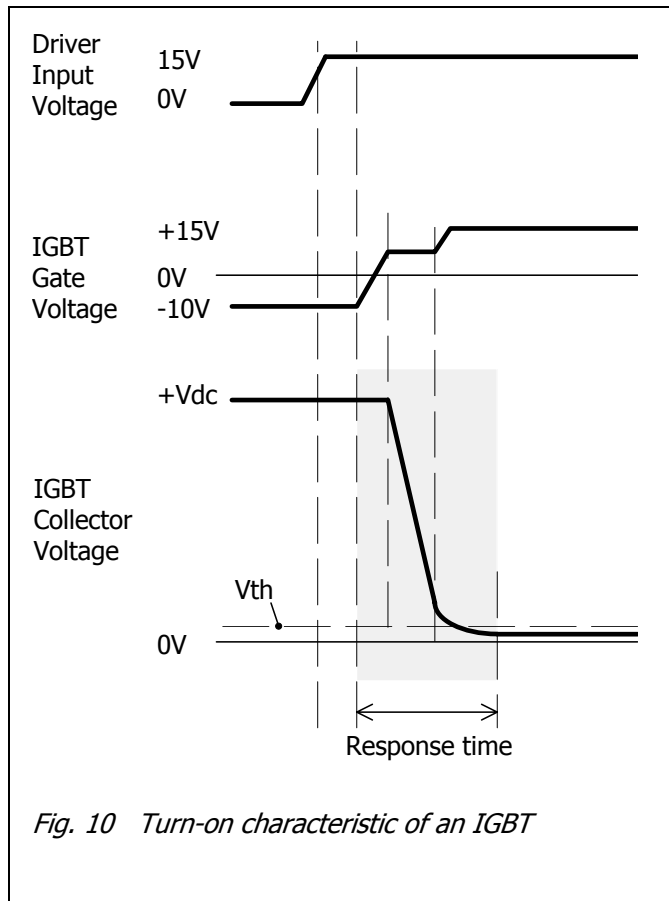
The basic V_{ce} monitoring circuit implemented in 6SP0235T SCALE-2 drivers is illustrated in Fig. 9. The IGBT collector-emitter voltages are measured with a resistor network. V_{ce} is checked after the response time (see Fig. 10) at turn-on to detect a short circuit. If this voltage is higher than the programmed threshold Vth, the driver detects a short circuit at the IGBT and signals it immediately to the corresponding SOx_x output. The corresponding IGBT is switched off. The IGBT is kept off (non-conducting) and the fault is shown at pin SOx_x as long as the blocking time is active.

The blocking time is applied independently to each channel. It starts when V_{ce} exceeds the threshold of the V_{ce} monitoring circuit.

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 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.

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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:

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

where V_{tr} is the turn-off overvoltage and Ls 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.

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. The 6SP0235T 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.
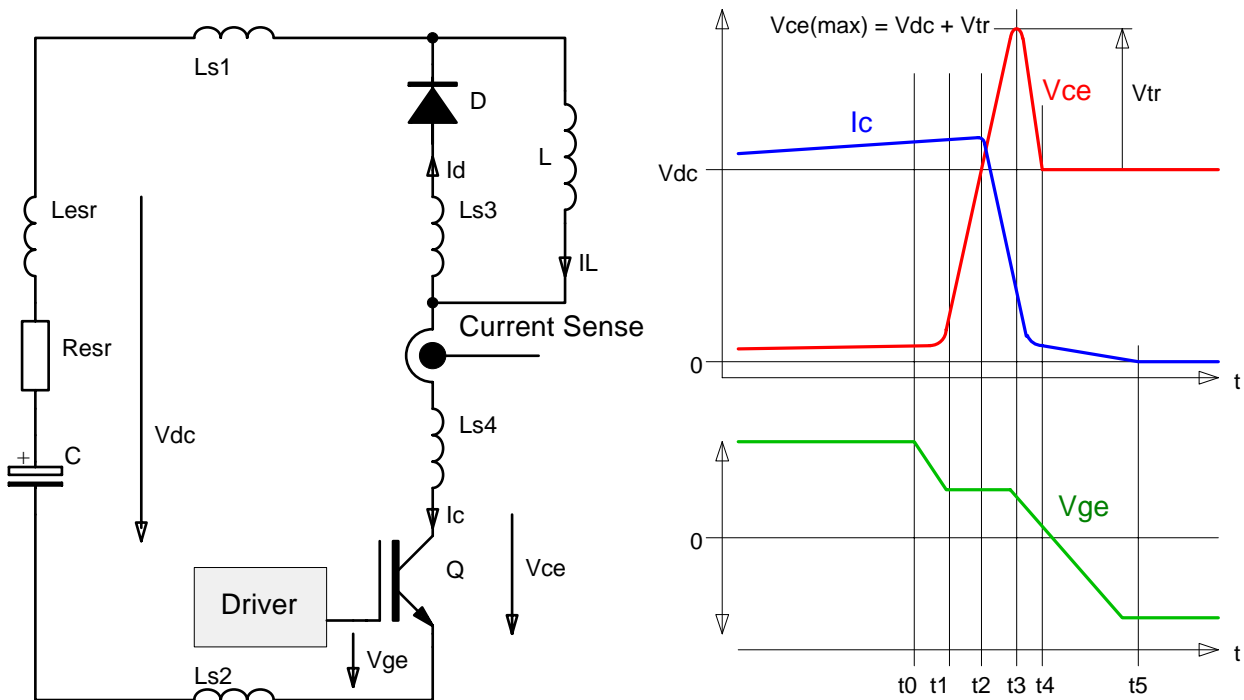

Fig. 11   Test circuit (left) and typical switching behavior (right)

Legend to Fig. 11

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. 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 an 800A/650V IGBT module controlled with a 6SP0235T driver.
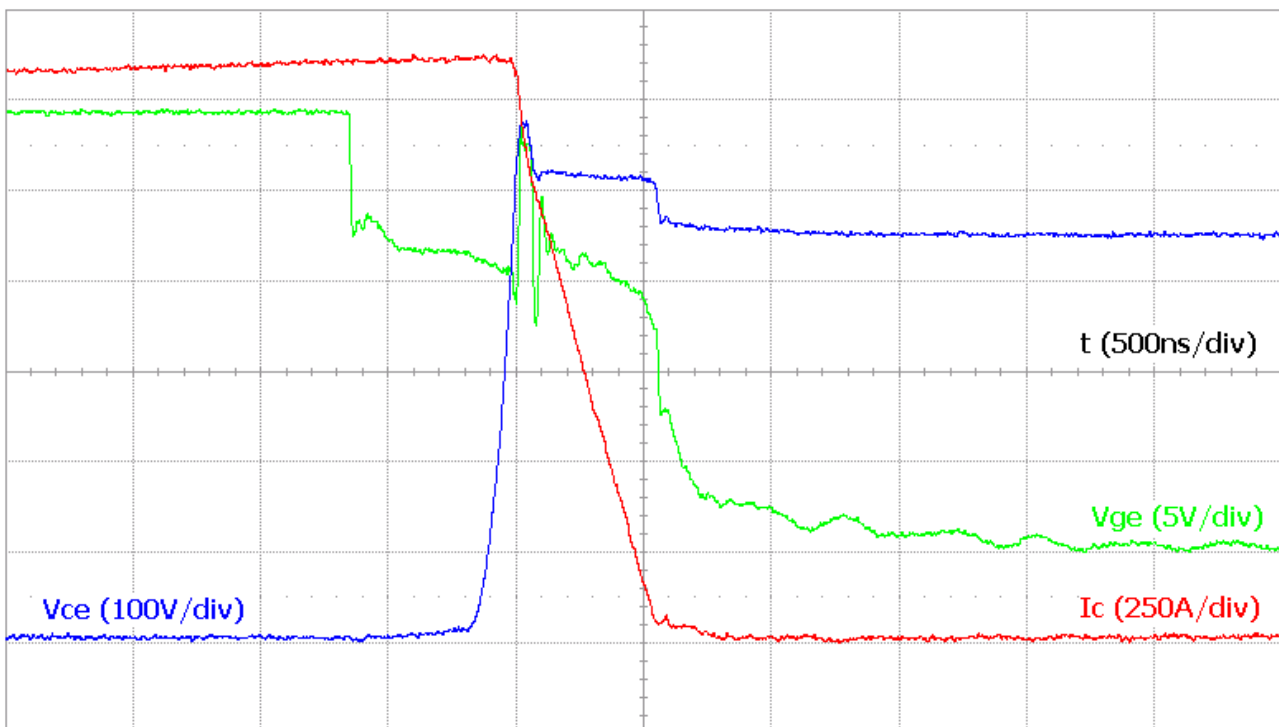

Fig. 12   Behavior of 800A/650V IGBT module turning off at a DC-link voltage of 435V a collector current of 1600A, which is twice the nominal collector current

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Parallel connection of 6SP0235T

The 6SP0235T are unsuitable for direct parallel connection, as the delay differences between drivers as well as the jitter are too high due to the implemented short-pulse suppression.

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 25nH with 6SP0235T plug-and-play drivers.

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 6SP0235Txxx-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

Target

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:

www.IGBT-Driver.com/go/support

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.

Legal Disclaimer

This data sheet specifies devices but cannot promise to deliver any specific characteristics. No warranty or guarantee is given – either expressly or implicitly – regarding delivery, performance or suitability.

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Ordering Information

See the current list on www.IGBT-Driver.com/go/6SP0235T

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

The general terms and conditions of delivery of CT-Concept Technologie AG apply.

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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