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Technical Description

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SEMIDRIVER™ – SEMIKRON IGBT Driver Electronics

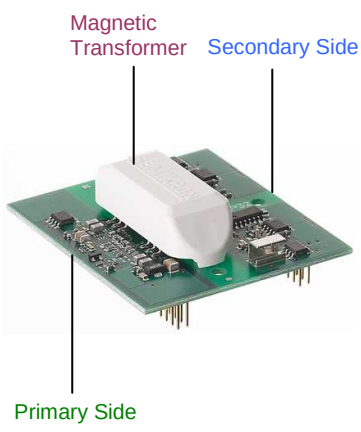
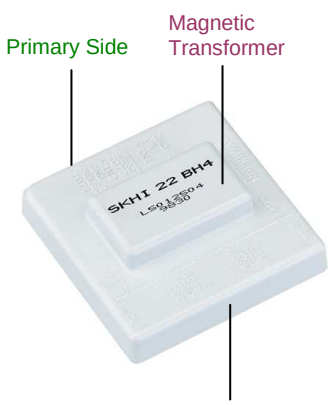
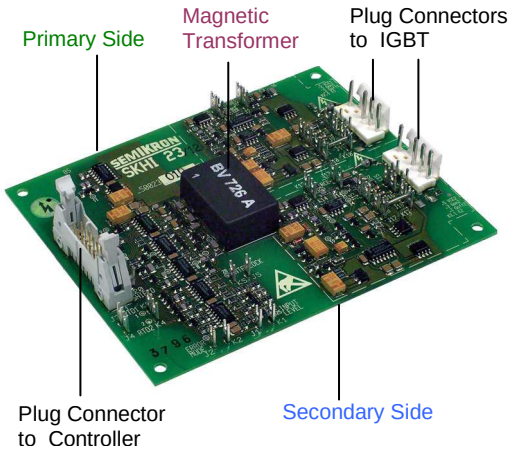
Leading Driver Electronics Technology

Drivers form the vital interface between power transistors and controller. It cannot be emphasized enough that it is the choice and design of the electronic drive circuit that ultimately determine the performance of an IGBT. For this reason, the performance of the driver is closely linked with the degree of reliability of a converter solution. Inadequate driver power or the wrong choice of or poorly designed drive circuits can cause both modules and the driver - and ultimately an entire system - to malfunction.

In driver electronics the focus lies on ensuring that the capabilities of the IGBT technology are fully utilized. To achieve this, SEMIKRON reduced the interdependent characteristics of driver solutions to enable each individual parameter to be optimally tuned. In this way a high level of flexible standardisation is achieved and the drivers can be used for any brand and IGBT package in a variety of applications. The characteristics of the electronic drive circuit are instrumental in utilizing the full scope and performance of the IGBT characteristics. And this IGBT performance can be greatly enhanced by SEMIKRON's substantial experience in the field of electronics and production of IGBT modules. In fact, SEMIKRON driver electronics stand for continued innovation, uncomplicated engineering and increased efficiency. And this accounts for SEMIKRON's presence and success in the area of driver electronics, with millions of SEMIKRON drivers in use.

The SEMIDRIVER™ range of IGBT driver electronics comprises driver components for IGBT power modules (single switches, bridge arms or three-phase inverters) and are available in a variety of designs, with different output performances, integration levels and connection technologies:

- SKYPER® Driver Core ⇨ core technology
- SKHI-DRIVER PCB-mountable ⇨ hybrid technology
- SKHI-DRIVER Plug-and-Play ⇨ SMT technology

SKYPER® Driver Core	SKHI-DRIVER PCB-mountable	SKHI-DRIVER Plug-and-Play
		
▪ Core technology ▪ PCB mountable driver ▪ Pins for PCB soldering & plug connection	▪ Hybrid technology ▪ PCB mountable driver ▪ Pins for PCB soldering ▪ Capsule housing	▪ SMT technology ▪ Complete driver solution ▪ Connectors for controller and IGBT connection ▪ Integrated turn-on and turn-off gate resistors

Note: The primary side is connected to the controller, i.e. signal processing component. The secondary side is connected to the power transistors.

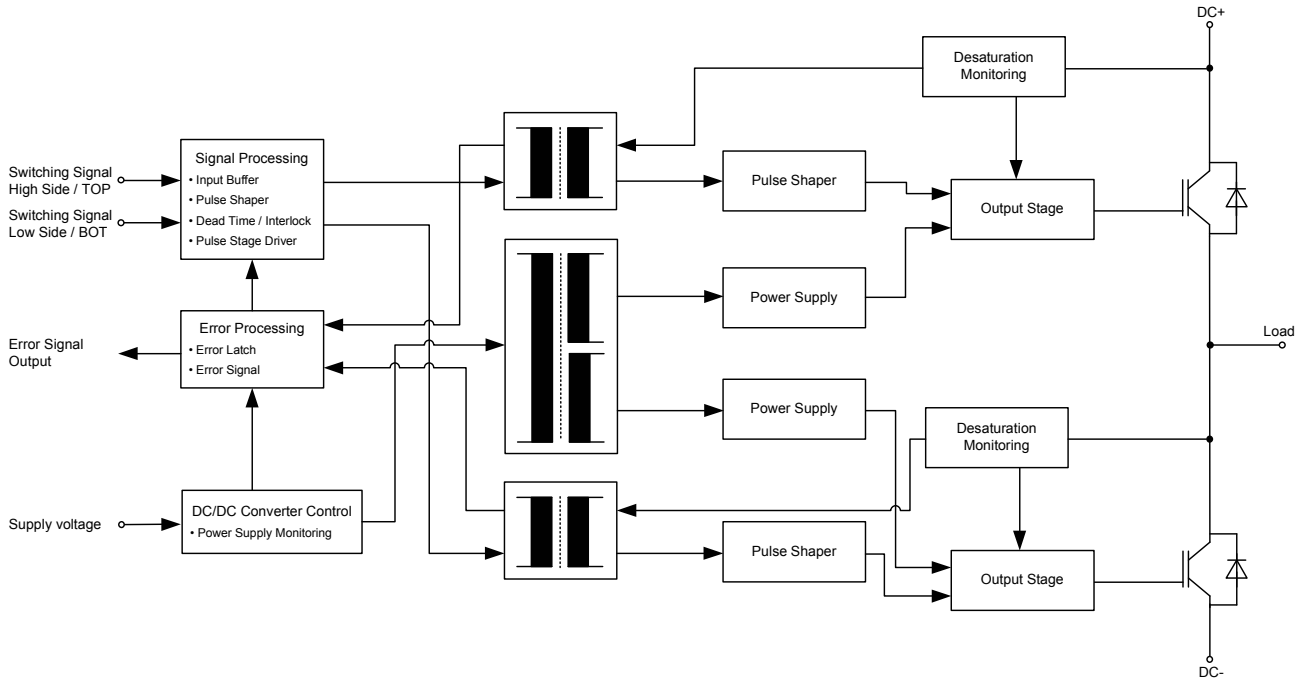
Flexible SEMIKRON IGBT Driver Electronics

All SEMIKRON driver circuits incorporate control and basic protection functions to drive IGBT modules in high-power applications and offer a maximum in system flexibility and user-friendliness. The driver circuits differ in their output performance and mechanical design and comprise the following features:

- Integrated potential-free power supply ⇨ only one non-insulated power supply needed, even if three drivers are used in a three-phase system
- High dv/dt capability by magnetic transformers (up to 75kV/µs)
- Full insulation between controller, i.e. logic level input signals and IGBT (insulation voltage up to 4kV$_{AC}$)
- Switching frequency of up to 100kHz and duty cycle 0…1
- Gate resistor for turn-on and turn-off separately adjustable ⇨ optimisation of IGBT performance in various applications
- Variable interlock mode and desaturation monitoring ⇨ adjustable to user's specific application
- Undervoltage control ⇨ ensures operating in saturated region
- Fault memory and fault feedback to the control system
- Simple interface to controller
- High EMI immunity
- Lead-free in accordance with RoHS directives
- 100% tested quality

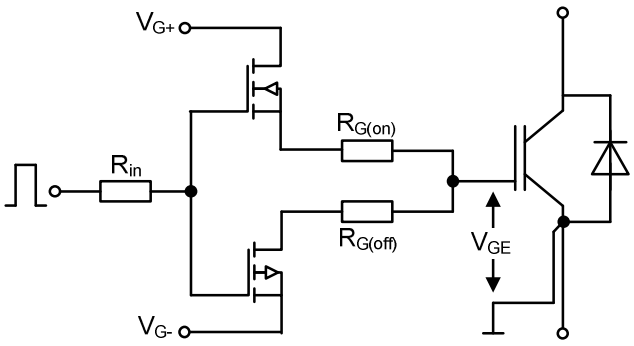
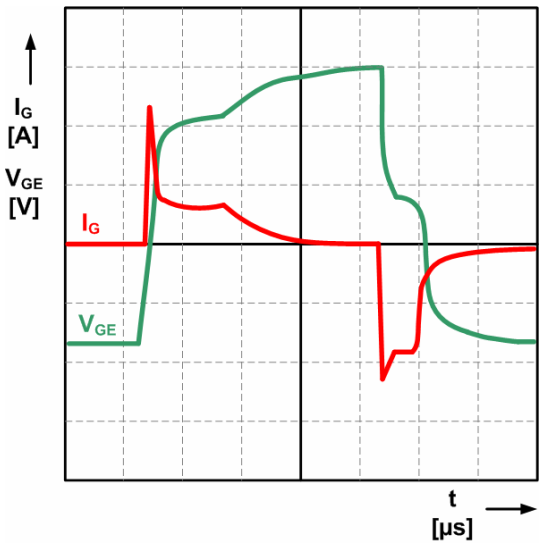
The following table shows a typical block diagram of SEMIKRON driver electronics with potential insulation, output stage and basic protection functions:

Typical Block Diagram



Driver Output Stage

The primary purpose of an electronic drive circuit is to drive power transistors. Under static operating conditions the IGBT needs no gate drive current because it is voltage-controlled, but since the gate input has a large capacitance, a gate drive current of short-duration pulses at turn-on and turn-off has to be generated. The following table shows the basic circuit drive of an IGBT and details of the gate-emitter voltage (V_{GE}) and gate current (I_G) behaviour.

Output Stage	Gate Voltage and Gate Current
	

The gate current reaches a peak value during the turn-on time and still has to charge the input capacitance of the IGBT without reducing V_{GE}, something which can only be achieved with a special output buffer rather than an opto-coupler.

Another important point is how fast the IGBT can be switched. With gate charge Q_G, the total power needed to drive the IGBT may be calculated using the following simple equation:

Calculation of Driver Output Power per Channel

$$P_{GD(out)} = Q_G \times (V_{G(on)} - V_{G(off)}) \times f_{sw}$$

The maximum possible switching frequency f_{sw} and gate current can be calculated from this equation.

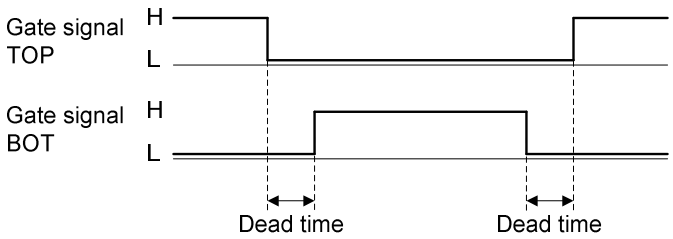
Calculation of Average Gate Current per Channel

$$I_G = Q_G \times f_{sw}$$

The voltage of the driver output stage has to be kept stable at all times in order to achieve the lowest possible V_{CEsat}-related losses. A further important factor is the gate resistor R_G, which limits the amplitude of the gate current pulses during turn-on and turn-off. By varying R_G it is possible to control the switching losses. See Application Note AN-7004 "IGBT Driver Calculation" for additional information. This application note is available on the Driver Electronics product page at www.SEMIKRON.com.

In voltage source inverter applications and the likes, it is necessary to set a dead time in order to prevent the high (TOP) and low-side (BOT) power transistor of one half-bridge from being switched on at the same time (shoot-through). By the integrated interlock / dead time circuit, a bridge-arm short circuit is avoided.

Dead Time Pulse Pattern

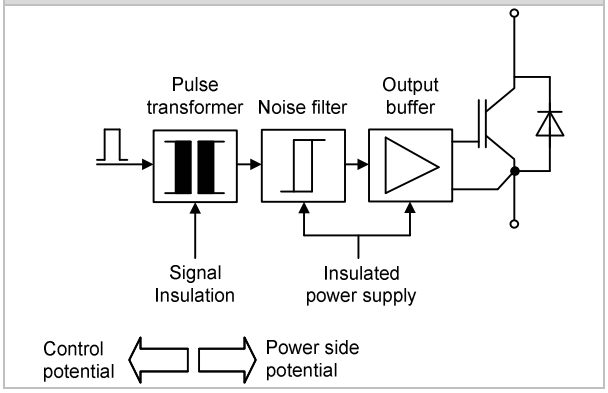


Technical Advantages of SEMIKRON Driver Electronics	User Benefits
MOSFET output transistor pair, with reduced ohmic contact.	Improves speed and optimisation of turn-on and turn-off with reduced driver losses.
Separated gate resistor for turn-on and turn-off.	Separate optimisation of turn-on and turn-off with regard to turn-on overcurrent, turn-off overvoltage spikes and short-circuit and EMI behaviour.
Integrated voltage source	Increased reliability
Regulated power supply	Provision of full-power output pulses without V_{GE} degradation.
Interlock mode	Prevents bridge-arm short-circuit

Potential Signal Insulation

The elements of the control system (µC, DSP, etc.) always operate at a low voltage level of between 3.3V to 15V. Owing to high power, high voltages and high currents that occur in the power system (secondary side), users of the power system and low power electronics (primary side) have to be properly protected by potential separation.
In the case of, for example, two-pulse or six-pulse inverter bridge circuits, the relatively fast turn-on and turn-off of the IGBTs cause steep voltage steps (high dv/dt values). It therefore has to be taken into account that even if the interface is located favourably, interference may still occur. Noise signals may reach the control system via the internal capacitive coupling of the device used for electrical isolation, leading to interference in the control system.

Potential Separation with Signal Transformer



Furthermore, in the forward direction the same noise signals cause unwanted oscillations, particularly in the case of commercial opto-couplers, due to the high coupling capacitance and relatively high-resistive termination. Signal transformers are therefore best suited to transmit the information to the respective driver stages. Compared with opto-couplers, signal transformers are far less sensitive to noise. Moreover, they offer better performance as regards achieving a higher isolation voltage.

Technical Advantages of SEMIKRON Driver Electronics	User Benefits
The use of coated toroid ferrite transformers	Provides high insulation between input (controller, primary side) and output (power transistor, secondary side). Insulation up to $4kV_{AC}$ (drives IGBTs up to 1700V).
High dv/dt capability by using insulated transformers with low coupling capacitance instead of opto-couplers	High dv/dt immunity between primary and secondary side (up to 75kV/µs).

Insulated Power Supply

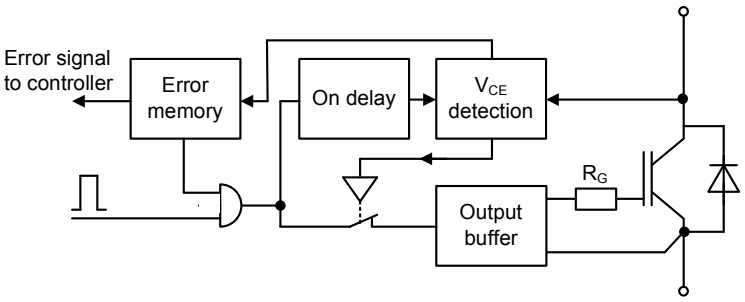
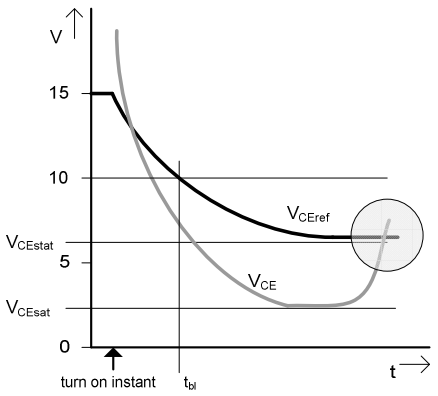
The use of large mains transformers (50/60Hz) would always require secondary connected stabilisation networks with voltage regulators and large capacitors to compensate for the voltage fluctuations. Since the voltage supply is often needed for several driving sections (e.g. three-phase bridge), this design can be very impractical. The use of a central DC/DC converter with f > 50kHz with a constant alternating output voltage eliminates the above-mentioned problems and leads to transformers with relatively low capacitive coupling.

In combination with the integrated potential-free power supply (DC/DC converter), an integrated undervoltage monitoring circuit is also included. If the driver supply voltage drops substantially, the gate-drive and protection functions may fail. Moreover, the power transistors can no longer be fully controlled or blocked and the IGBT will operate in the linear area due to a too low gate voltage. If the IGBT operates in the linear area, there will be higher losses, and thermal overloading of the IGBT may occur. To ensure that any drops in driver supply voltage are detected, the supply voltage is monitored and, in the event of a failure, switching pulses to the output stage are blocked and the IGBT is forced into the off-state.

Technical Advantages of SEMIKRON Driver Electronics	User Benefits
Internal DC/DC converter with insulated ferrite transformers	Saves external transformers and allows compact design.
Undervoltage monitoring on the primary side	Ensures a safe and powerful pulse trigger at the IGBT gate.
Independent power supply per IGBT with very low coupling capacitance	Improves the immunity between switching signals

Short-Circuit Detection

When using an IGBT in an inverter circuit, short-circuit breakdown of a device becomes an important protection parameter. Short currents are mainly caused by short-circuited output, the simultaneous switch-on of a pair of transistors from the same leg, or an earth fault in the load circuit
The detection of short-circuits as well as response signal processing in the electronic monitoring stage takes time. To prevent electrical components from being subjected to unwanted stresses and to achieve a high degree of reliability, it is always an advantage to terminate the short-circuit current as quickly as possible. To this end, the turn-off signal should be applied to the driver stage of the IGBT with the shortest possible delay. The detection of the short-circuit current is done via desaturation monitoring. For detection of a short-circuit current, the collector-emitter voltage (V_{CE}) of an IGBT can be utilized because it rapidly increases as a result of desaturation.

Processing of Desaturation Monitoring	Short-Circuit during Operation
	

Technical Advantages of SEMIKRON Driver Electronics	User Benefits
V_{CE} trip level varied to suit the IGBT in use	Adaptable to various IGBT technologies and applications.
Adjustable delay time for the V_{CE} signal.	Prevents false short-circuit signal to the V_{CE} monitoring circuit.

Soft Turn-Off

In short-circuit conditions the IGBT's peak current can increase to extreme values and lead to the generation of a high di/dt during turn-off. Due to stray inductances that are always present in power circuits, a high voltage spike is produced. This surge voltage can be estimated using the following equation.

Equation for Voltage Spike
$V_{stray} = L_\sigma \times \frac{di}{dt}$

The high voltage spike can be reduced by soft-turn-off. In the event of a short-circuit, the soft turn-off circuit automatically increases the IGBT turn-off time. This reduces the di/dt and, consequently, the voltage spike across the collector and emitter of the IGBT, enabling the use of higher DC-bus voltages. This in turn means an increase in the final output power.

Technical Advantages of SEMIKRON Driver Electronics	User Benefits
Soft turn-off	Reduction of dangerous overvoltages across the IGBT.

Error Processing

Failures in power transistors may be detected at various points and the reaction to detected errors may be differently. In case of failure detection within the switched device itself or within the driver circuit, the power transistors are turned-off directly by the electronic drive circuit. A failure signal is transmitted to a central error processing unit in the gate drive circuit as well to the connected controller. To prevent the turn-on on a short-circuit, the signal path for subsequent turn-on signals remains blocked until resetting is carried out via a reset pulse.

Technical Advantages of SEMIKRON Driver Electronics	User Benefits
Error fault memory	Avoids repeated high current peaks.
Error signal output	Informs the controller of the status of the power stage.

Product Overview

SEMIKRON offers a broad range of driver electronics that can be used to control and protect power semiconductors. The following table shows an overview of the driver types and their main characteristics:

Driver Type	Collector-Emitter Voltage	Gate Current / Peak Current	Switching Frequency	Signal Voltage	Channels	Features	Tech-nology	RoHS
SKYPER 32 R	1700V	50mA / 15A	50kHz	15V	2	1,2,3,4	core	✓
SKYPER 32PRO R	1700V	50mA / 15A	50kHz	15V	2	1,2,3,4,5	core	✓
SKHI 21A R *)	1200V	40mA / 8A	50kHz	15V	2	1,2,3,4	hybrid	✓
SKHI 22A R	1200V	40mA / 8A	50kHz	15V	2	1,2,3,4	hybrid	✓
SKHI 22A H4 R	1700V	40mA / 8A	50kHz	15V	2	1,2,3,4	hybrid	✓
SKHI 22B R	1200V	40mA / 8A	50kHz	5V	2	1,2,3,4	hybrid	✓
SKHI 22B H4 R	1700V	40mA / 8A	50kHz	5V	2	1,2,3,4	hybrid	✓
SKHI 24 R	1700V	80mA / 15A	50kHz	5V	2	1,2,3,4	hybrid	✓
SKHI 61 R **)	900V	20mA / 2A	50kHz	5V / 15V	6	1,2,3,4	hybrid	✓
SKHI 71 R **)	900V	20mA / 2A	50kHz	5V / 15V	7	1,2,3,4	hybrid	✓
SKHI 10/12 R	1200V	100mA / 8A	100kHz	5V / 15V	1	1,3,4,5	SMT	✓
SKHI 10/17 R	1700V	100mA / 8A	100kHz	5V / 15V	1	1,3,4,5	SMT	✓
SKHI 23/12 R	1200V	50mA / 8A	100kHz	5V / 15V	2	1,2,3,4,5	SMT	✓
SKHI 23/17 R	1700V	50mA / 8A	100kHz	5V / 15V	2	1,2,3,4,5	SMT	✓

Note: *) Driver for MOSFETs, **) Potential signal insulation using opto-coupler

Features: 1. Undervoltage control, 2. Interlock mode, 3. Short-circuit detection, 4. Error processing, 5. Soft turn-off

Driver Applications

SEMIKRON driver electronics can be used in a wealth of applications, ranging from motor drives and power supplies to welding and power generation. The following table contains an overview of the typical applications:

Motor Drives	Power Supplies	Wind & Solar	Process Control	Communication	Others
▪ AC Drive ▪ DC Drive ▪ Servo Drive ▪ Soft-Starter ▪ Elevator ▪ Escalator ▪ People Mover	▪ SMPS ▪ Voltage deregulator ▪ AC-DC charger ▪ Uninterrupted Power Supplies	▪ Wind generator ▪ Drive for pitch control ▪ Solar inverter	▪ Heating ▪ Welding ▪ Induction ▪ Galvanisation	▪ Air conditioning ▪ Washing machines ▪ Telecoms ▪ Distributed power systems	▪ Medical (e.g. X-Ray) ▪ Laser ▪ Power generation ▪ Industrial washing machines

Technical Application Service

As a supplier of a broad line of power modules and driver electronics, SEMIKRON is able to provide valuable support for your power application. For technical / engineering support and assistance with your power system designs go to SEMIKRON's driver electronics product page at www.SEMIKRON.com. Our support service includes the following features:

- Detailed technical explanations
- Evaluation boards with open source design (e.g. schematic, layout, parts list)
- Application notes
- Calculation tools

Type Designation System

SKYPER®

❶	❷	❸	❹	❺
SKYPER	3	2	PRO	R

❶ SEMIKRON Driver Core
❷ Driver type
❸ Driver channels
1 = single driver
2 = half-bridge driver
6 = six-pack driver
❹ Driver version
PRO = Premium version
❺ Type in acc. with RoHS

Evaluation Board

❶	❷	❸	❹
Board	1	SKYPER 32	R

❶ Evaluation board
❷ Board type
1 = Generic Board
2s = Adapter Board SEMiX 2s (spring contact version)
3s = Adapter Board SEMiX 3s (spring contact version)
4s = Adapter Board SEMiX 4s (spring contact version)
❸ Driver type: e.g.: SKYPER 32 = Board for SKYPER 32
❹ Type in acc. with RoHS

SKHI-DRIVER

❶	❷	❸	❹	❺	❻
SKHI	2	2	A	H4	R

❶ SEMIKRON Hybrid Driver Circuit
❷ Driver channels
1 = single driver
2 = half-bridge driver
6 = six-pack driver
7 = seven-pack driver
❸ Driver type
❹ Driver version
❺ Special type: H4 = $4kV_{rms}$ isolation voltage
❻ Type in acc. with RoHS

References

[1] http://www.SEMIKRON.com

[2] Application Manual Power Modules, SEMIKRON International

[3] M. Hermwille, "Plug and Play IGBT Driver Cores for Converters", Power Electronics Europe Issue 2, pp. 10-12, 2006

[4] M. Hermwille, "IGBT Driver Calculation", Application Note AN-7004, SEMIKRON

[5] M. Hermwille, "IGBT Gate Resistor – Principle and Application", Application Note AN-7003, SEMIKRON

[6] P. Bhosale, M. Hermwille, "Connection of Gate Drivers to IGBT and Controller", Application Note AN-7002, SEMIKRON

DISCLAIMER

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