SKYPER 52 R

SKYPER®

IGBT Driver Core

SKYPER 52 R

Target Data

Features

- Digital driver core
- 2 output channels with 9W ouput power per channel
- Potential free power supply
- 3,3V and 5V signal interface
- Under voltage lockout
- Interlock logic
- Short circuit detection with intelligent smooth shut-down
- Insulated temperature sensor signal transmission
- Adaptable error processing
- IEC 60068-1 (climate) 40/085/56, no condensation and no dripping water permitted, non-corrosive, climate class 3K3 acc. EN60721
- Coated with varnish
- RoHS compliant

Typical Applications*

- Driver for IGBT modules in bridge circuits in industrial application
- DC bus voltage up to 1200V

Footnotes

1) please refer to maximum limit of switching frequency curves
2) the isolation test is no series test and must be performed by the user
3) according to VDE 0110-20
Isolation coordination in compliance with EN50178 PD2
Degree of protection: IP00

Driver Core

Absolute Maximum Ratings

Symbol	Conditions	Values	Unit
V_s	Supply voltage primary (tp<20ms, repition frequency < 1 Hz)	30	V
V_{iH}	Input signal voltage (HIGH)	Vs + 0.3	V
V_{iL}	Input signal voltage (LOW)	GND - 0.3	V
$Iout_{PEAK}$	Output peak current	50	A
$Iout_{AVmax}$	Output average current	300	mA
f_{max}	Max. switching frequency	100	kHz
V_{CE}	Collector emitter voltage sense across the IGBT	1700	V
dv/dt	Rate of rise and fall of voltage secondary to primary side	100	kV/µs
$V_{isol\ IO}$	Isolation test voltage input - output (AC, rms, 2s)	4000	V
V_{isolPD}	Partial discharge extinction voltage, rms, $Q_{PD} \leq$ 10pC	1500	V
V_{isol12}	Isolation test voltage output 1 - output 2 (AC, rms, 2s)	1500	V
$R_{Gon\ min}$	Minimum rating for external R_{Gon}	0.6	Ω
$R_{Goff\ min}$	Minimum rating for external R_{Goff}	0.6	Ω
$Q_{out/pulse}$	Max. rating for output charge per pulse	100	µC
T_{op}	Operating temperature	-40 ... 85	°C
T_{stg}	Storage temperature	-40 ... 85	°C

Characteristics

Symbol	Conditions	min.	typ.	max.	Unit
V_s	Supply voltage primary side	21.6	24	26.4	V
I_{SO}	Supply current primary (no load)		180		mA
	Supply current primary side (max.)			1800	mA
V_i	Input signal voltage on / off		3.3 / 0		V
V_{IT+}	Input treshold voltage HIGH			2.3	V
V_{IT-}	Input threshold voltage (LOW)	1			V
R_{IN}	Input resistance (switching/HALT signal)		5		kΩ
$V_{G(on)}$	Turn on output voltage		15		V
$V_{G(off)}$	Turn off output voltage		-15		V
f_{ASIC}	Asic system switching frequency		8		MHz
$t_{d(on)IO}$	Input-output turn-on propagation time		1.1		µs
$t_{d(off)IO}$	Input-output turn-off propagation time		1.1		µs
$t_{d(err)}$	Error input-output propagation time				µs
$t_{pERRRESET}$	Error reset time				µs
t_{TD}	Top-Bot interlock dead time	0		4.5	µs
C_{ps}	Coupling capacitance prim sec		35		pF
w	weight		0.16		g
MTBF					10^6h

This is an electrostatic discharge sensitive device (ESDS), international standard IEC 60747-1, Chapter IX

* The specifications of our components may not be considered as an assurance of component characteristics. Components have to be tested for the respective application. Adjustments may be necessary. The use of SEMIKRON products in life support appliances and systems is subject to prior specification and written approval by SEMIKRON. We therefore strongly recommend prior consultation of our staff.

Technical Explanations

Revision 07
Status: *preliminary*
Prepared by: Johannes Krapp

This Technical Explanation is valid for the following parts:

part number: L50450XX (PCB Nr), L610030XX (Article Nr)
date code (YYWW): ≥ 1040

Related Documents:

title: Data Sheet SKYPER® 52 R

SKYPER® 52 R

1. Content

2. Revision History

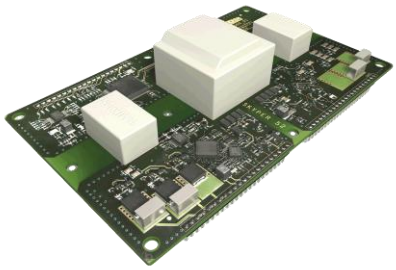
Revision	Date	Changes
00	2008-07-16	Initial target / advanced technical documentation.
01	2008-11-10	Initial target / advanced technical documentation. Additional chapters
02	2009-04-03	Target / specification of product features
03	2009-09-24	Target/ specification of product features/ temperature sensing
04	2010-05-03	Preliminary/Modification Performance Diagramm/ Dimensions+Drill Sizes/ Update Pinning
05	2010-08-20	Update LED
06	2010-09-23	Update structure, changed boot time, changed failure logic, tolerance of power supply
07	2011-02-24	Update LED, Exchange Slot 7 and 8

Please note:
Unless otherwise specified, all values in this technical explanation are typical values. Typical values are the average values expected in large quantities and are provided for information purposes only. These values can and do vary in different applications. All operating parameters should be validated by user's technical experts for each application.

3. Introduction

The SKYPER 52 driver core constitutes an interface between IGBT module and the controller. This driver core is based on fully digital signal processing and provides individual control parameter settings and drives parallel connected.

The differential signal processing ensures a high level of signal integrity and hence high noise rejection. With the digital driver SKYPER 52, switching characteristics, shut down levels, as well as error processing can be set to meet the given application requirements. This means flexibility with the driver circuitry properties and, consequently, the control settings for the power electronics, which can be adapted to meet the individual needs. If an error is detected, this then means that all of the power transistors can be switched off either individually or sequentially. Overvoltages, especially those that occur in short-circuit turn-off conditions, are reduced by the IGBT driver. To do so, the driver switches the power transistor smoothly. This is possible by intelligent turn-off control.

SKYPER® 52	
▪ Two output channels with 9W output per channel ▪ Up to 1700V VCE ▪ Integrated potential free power supply for secondary side ▪ Matched propagation delay for all outputs ▪ UVP (primary & secondary), Interlock logic , Halt logic signal ▪ Intelligent smooth turn off ▪ Failure processing with individual adaptation ▪ DC bus voltage up to 1200V ▪ Coated with varnish	

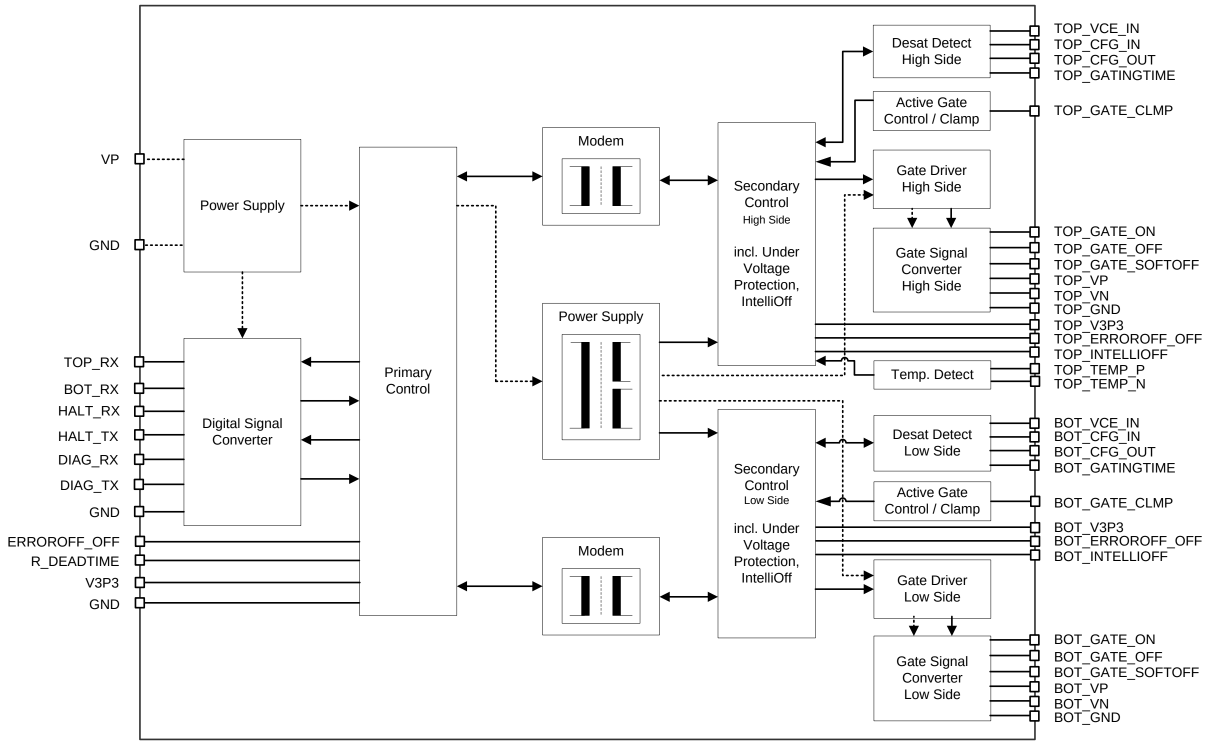
31. Handling Instructions

- Please provide for static discharge protection during handling. As long as the driver board is not completely assembled, the input terminals have to be short-circuited. Persons working with devices have to wear a grounded bracelet. Any synthetic floor coverings must not be statically chargeable. Even during transportation the input terminals have to be short-circuited using, for example, conductive rubber. Worktables have to be grounded. The same safety requirements apply to MOSFET- and IGBT-modules.
- It is important to feed any errors back to the control circuit and to switch off the device immediately in failure events. Repeated turn-on of the IGBT into a short circuit with a high frequency may destroy the device.
- The inputs of the driver boards are sensitive to over-voltage. Voltages higher than specified level +0,3V or below -0,3V may destroy these inputs. Therefore, control signal over-voltages exceeding the above values have to be avoided.

For design support please read the SEMIKRON Application Manual Power Modules and SEMIKRON Application Notes available at www.SEMIKRON.com or consult your responsible sales contact.

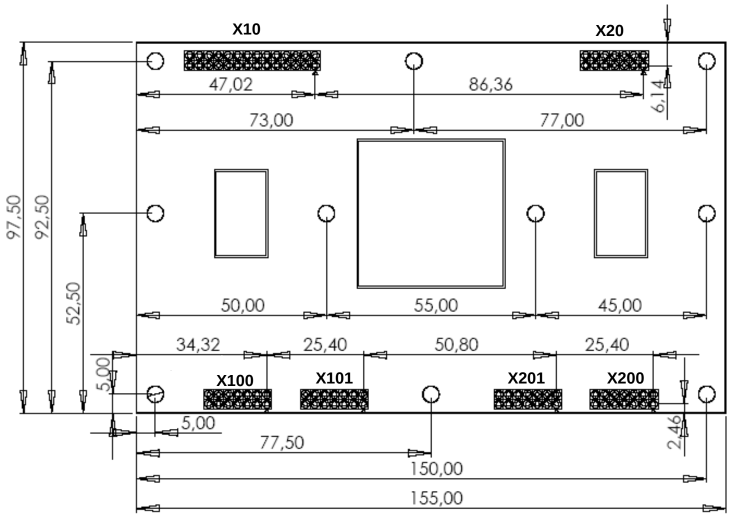
32. Block Diagram

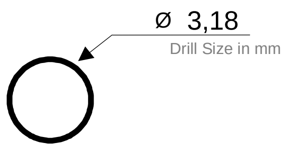
SKYPER 52

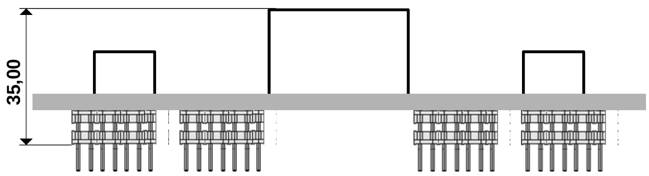


33. Mechanical Data

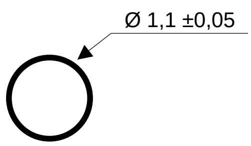
Dimensions in mm (top view)



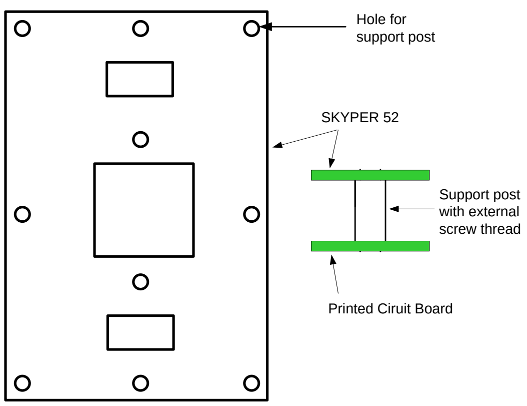




±0,2mm unless otherwise noted

Soldering Hints	Finished Hole & Pad Size in mm
The temperature of the solder must not exceed 260°C, and solder time must not exceed 10 seconds. The ambient temperature must not exceed the specified maximum storage temperature of the driver. The solder joints should be in accordance to IPC A 610 Revision D (or later) - Class 3 (Acceptability of Electronic Assemblies) to ensure an optimal connection between driver core and printed circuit board The driver is not suited for hot air reflow or infrared reflow processes.	 pad size: min. 1,8

Use of Support Posts



The connection between driver core and printed circuit board should be mechanical reinforced by using support posts.

The driver board has got ten holes for supports posts.

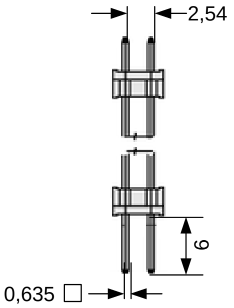
Using support posts with external screw thread improves mechanical assembly.

Product information of suitable support posts and distributor contact information is available at e.g. http://www.richco-inc.com or http://www.ettinger.de.

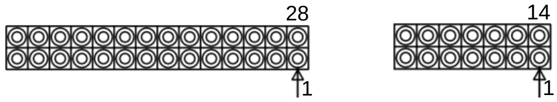
4. Pinning

41. Primary SidePIN Array X10, X20

Connector X10, X20 (Male headers soldering technique)



- Grid: 2,54mm
- Connection type: soldering
- Surface: selective gold-plated
- Male cross-section: square 0,635

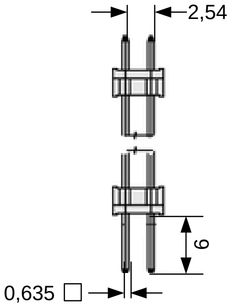


PIN	Signal	Function	Specification
X10:01	ERROROFF_OFF	Disable shut-down output signal	LOW (connection to ground) = enable shut-down output signal HIGH (connection to V3P3) = disable shut-down output signal
X10:02	VP	Driver core power supply. Bypass with low ESR capacitor and place as close to VP pin as possible.	Supply voltage +24V_{DC} (±10%)
X10:03	GND	Ground	
X10:04	V3P3	Reference voltage for ERROROFF_OFF, DEADTIME_OFF	Terminated with 1kΩ
X10:05	GND	Ground	
X10:06	HALT_TX_N	Differential driver core status output. This output pair is the differential status signal output from the core.	Open collector output to GND U_{max}=5,5V; I_{max}=10mA LOW = Ready to operate HIGH = Not ready to operate
X10:07	HALT_TX_P		Open collector output to 3,3V
X10:08	GND	Ground	
X10:09	DIAG_TX_P	Reserved. Do not connect.	
X10:10	HALT_RX_P	Differential driver core status input. This input pair (HALT_RX_P, HALT_RX_N) is the differential status signal input to the core.	Digital 3,3/5V logic LOW = enable driver core HIGH = disable driver core
X10:11	DIAG_RX_P	Reserved. Do not connect.	
X10:12	BOT_RX_P	Differential switching signal input low side. This input pair (BOT_RX_P, BOT_RX_N) is the differential signal input to the core.	Digital 3,3/5V logic LOW = low side transistor off HIGH = low side transistor on
X10:13	TOP_RX_P	Differential switching signal input high side. This input pair (TOP_RX_P, TOP_RX_N) is the differential signal input to the core.	Digital 3,3/5V logic LOW = high side transistor off HIGH = high side transistor on
X10:14	GND	Ground	
X10:15	GND	Ground	
X10:16	TOP_RX_N	Differential switching signal input high side. This input pair (TOP_RX_P, TOP_RX_N) is the differential signal input to the core.	Digital 3,3/5V logic LOW = high side transistor on HIGH = high side transistor off
X10:17	BOT_RX_N	Differential switching signal input low side. This input pair (BOT_RX_P, BOT_RX_N) is the differential signal input to the core.	Digital 3,3/5V logic LOW = low side transistor on HIGH = low side transistor off
X10:18	DIAG_RX_N	Reserved. Do not connect.	
X10:19	HALT_RX_N	Differential driver core status input. This input pair (HALT_RX_P, HALT_RX_N) is the differential status signal input to the core.	Digital 3,3/5V logic LOW = disable driver core HIGH = enable driver core

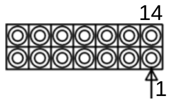
X10:20	DIAG_TX_N	Reserved. Do not connect.	
X10:21	GND	Ground	
X10:22	GND	Ground	
X10:23	R_DEADTIME	Adjustment of locking time.	External resistor to ground.
X10:24	GND	Ground	
X10:25	V3P3	Reference voltage for ERROROFF_OFF, DEADTIME_OFF	Terminated with 1kΩ
X10:26	GND	Ground	
X10:27	VP	Driver core power supply. Bypass with low ESR capacitor and place as close to VP pin as possible.	Supply voltage +24V_{DC} (±10%)
X10:28	DEADTIME_OFF	Disable interlock logic.	LOW (connection to ground) = enable interlock logic HIGH (connection to V3P3) = disable interlock logic
X20:01 ~ X20:14	GND	Ground	

42. Secondary Side PIN Array X100, X101, X200, 201

Connector X100, X101, X200, X201 (Male headers soldering technique)



- Grid: 2,54mm
- Connection type: soldering
- Surface: selective gold-plated
- Male cross-section: square 0,635



PIN	Signal	Function	Specification
X100:01	TOP_GND	Ground for power supply	Connection to emitter (high side)
X100:02	TOP_GATE_SOFTOFF	Control input for smooth shut-down setting (high side)	External resistor to gate (high side)
X100:03	TOP_VN	Output power supply for external boost capacitors (high side)	Typ. -15V; Max. -18V
X100:04	TOP_GATE_OFF	Switch off signal high side transistor	Connection to gate (high side)
X100:05	TOP_VP	Output power supply for external boost capacitors (high side)	Typ. -+15V; Max. +18V
X100:06	TOP_GATE_ON	Switch on signal high side transistor	Connection to gate (high side)
X100:07	TOP_GND	Ground for power supply	Connection to emitter (high side)
X100:08	TOP_GND	Ground for power supply	Connection to emitter (high side)
X100:09	TOP_GATE_ON	Switch on signal high side transistor	Connection to gate (high side)
X100:10	TOP_VP	Output power supply for external boost capacitors (high side)	Typ. +15V; Max. +18V
X100:11	TOP_GATE_OFF	Switch off signal high side transistor	Connection to gate (high side)
X100:12	TOP_VN	Output power supply for external boost capacitors (high side)	Typ. -15V; Max. -18V
X100:13	TOP_GATE_SOFTOFF	Control input for smooth shut-down setting (high side)	External resistor to gate (high side)
X100:14	TOP_GND	Ground for power supply	Connection to emitter (high side)
X101:01	TOP_GATE_CLMP	Gate voltage clamping (high side)	
X101:02	TOP_GND	Ground for power supply	Connection to emitter (high side)
X101:03	TOP_ERROROFF_OFF	Disable shut-down output signal	LOW (connection to ground) = enable shut-down output signal HIGH (connection to TOP_V3P3) = disable shut-down output signal
X101:04	TOP_INTELLIOFF	Intelligent shut-down setting (high side)	External resistor to ground
X101:05	TOP_V3P3	Reference voltage for TOP_ERROROFF_OFF	Terminated with 1kΩ
X101:06	TOP_TEMP_P	Temperature sensor positive input	Temperature dependent resistor between TOP_TEMP_P and TOP_TEMP_N; R_{TEMP}<430Ω
		General error input	Generic failure input. Pull up resistor 511Ω Failure -> over 1,5V No failure -> under 1,5V
X101:07	TOP_GND	Ground for power supply	Connection to emitter (high side)
X101:08	TOP_GND	Ground for power supply	Connection to emitter (high side)

X101:09	TOP_TEMP_N	Temperature sensor negative input	Connected to ground
X101:10	TOP_GATINGTIME	Blanking time setting of short circuit detection (high side)	External resistor to ground
X101:11	TOP_VCE_CFG_IN	Threshold voltage setting of short circuit detection (high side)	Resistor between TOP_VCE_CFG_IN and TOP_VCE_CFG_OUT
X101:12	TOP_VCE_CFG_OUT		
X101:13	TOP_GND	Ground for power supply	Connection to emitter (high side)
X101:14	TOP_VCE_IN	Input short circuit detection (high side)	Connected to auxiliary collector (high side)
X200:01	BOT_GND	Ground for power supply	Connection to emitter (low side)
X200:02	BOT_GATE_ON	Switch on signal low side transistor	Connection to gate (low side)
X200:03	BOT_VP	Output power supply for external boost capacitors (low side)	Typ. +15V; Max. +18V
X200:04	BOT_GATE_OFF	Switch off signal high side transistor	Connection to gate (low side)
X200:05	BOT_VN	Output power supply for external boost capacitors (low side)	Typ. -15V; Max. -18V
X200:06	BOT_GATE_SOFTOFF	Control input for smooth shut-down setting (low side)	External resistor to gate (low side)
X200:07	BOT_GND	Ground for power supply	Connection to emitter (low side)
X200:08	BOT_GND	Ground for power supply	Connection to emitter (low side)
X200:09	BOT_GATE_SOFTOFF	Control input for smooth shut-down setting (low side)	External resistor to gate (low side)
X200:10	BOT_VN	Output power supply for external boost capacitors (low side)	Typ. -15V; Max. -18V
X200:11	BOT_GATE_OFF	Switch off signal high side transistor	Connection to gate (low side)
X200:12	BOT_VP	Output power supply for external boost capacitors (low side)	Typ. +15V; Max. -18V
X200:13	BOT_GATE_ON	Switch on signal low side transistor	Connection to gate (low side)
X200:14	BOT_GND	Ground for power supply	Connection to emitter (low side)
X201:01	BOT_GND	Ground for power supply	Connection to emitter (low side)
X201:02	BOT_GND	Ground for power supply	Connection to emitter (low side)
X201:03	BOT_V3P3	Reference voltage for BOT_ERROROFF_OFF	Terminated with 1kΩ
X201:04	BOT_INTELLIOFF	Intelligent shut-down setting (low side)	External resistor to ground
X201:05	BOT_ERROROFF_OFF	Disable shut-down output signal	LOW (connection to ground) = enable shut-down output signal HIGH (connection to BOT_V3P3) = disable shut-down output signal
X201:06	BOT_GND	Ground for power supply	Connection to emitter (low side)
X201:07	BOT_GATE_CLMP	Gate voltage clamping (low side)	
X201:08	BOT_VCE_IN	Input short circuit detection (low side)	Connected to auxiliary collector (low side)
X201:09	BOT_GND	Ground for power supply	Connection to emitter (low side)
X201:10	BOT_VCE_CFG_OUT	Threshold voltage setting of short circuit detection (high side)	Resistor between BOT_VCE_CFG_IN and BOT_VCE_CFG_OUT
X201:11	BOT_VCE_CFG_IN		
X201:12	BOT_GATINGTIME	Blanking time setting of short circuit detection (low side)	External resistor to ground
X201:13	BOT_GND	Ground for power supply	Connection to emitter (low side)
X201:14	BOT_GND	Ground for power supply	Connection to emitter (low side)

5. Primary Side interface

The ground potentials on the driver board are equal and all physically connected with each other on the printed circuit board. Because of the voltage drop on the power supply cable, the potential of power supply ground at the user side is different to the ground potential on the driver board.

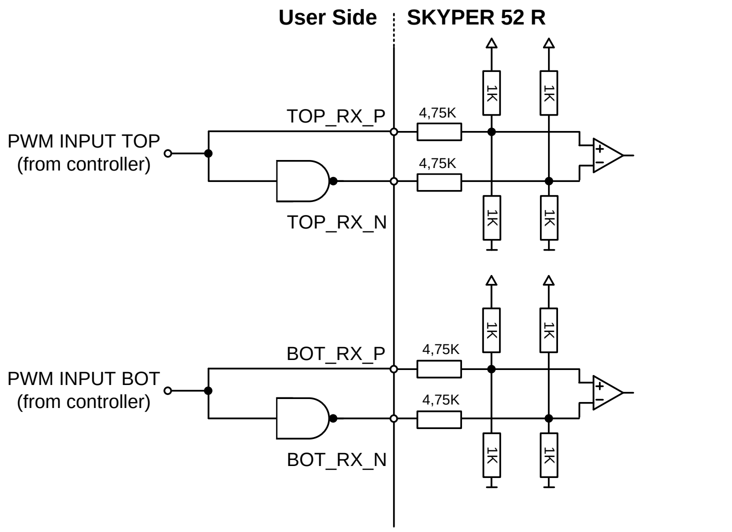
Please note:
Do not remove the plug with applied voltage of the power supply. This can lead to unspecified voltage levels at the output stages of the driver board with the risk of destructions.

51. Digital Input Signals

The signal inputs for high side and low side are compatible with 3.3V and 5V I/O standards. This means that the driver circuit can be directly connected to standard logic outputs of microcontroller or DSP without additional level shifting. To obtain high performance and reliable signal transmission in a power electronic environment, differential signalling is used for the inputs.

Please note:
It is not permitted to apply switching pulses shorter than 2µs.

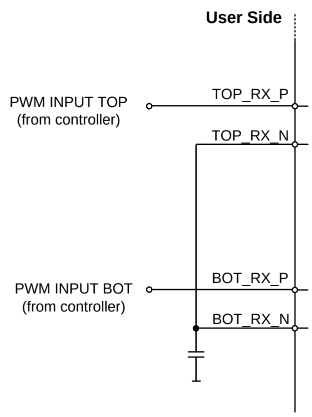
Application Example - Connection µC / DSP with User Interface



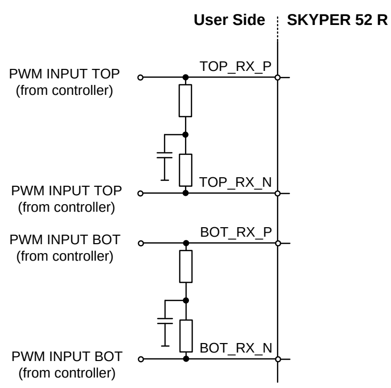
The application example shows a circuit in push-pull configuration for high and lows side input.

The termination resistors are ~5k ohm.

To simplify the interface with less EMC robustness following circuit can be used for standard PWM:



To increase the EMC robustness following circuit with differential signals coming out of the controller can be used:



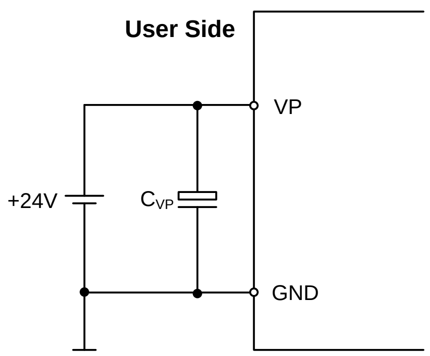
52. Power Supply

A few basic rules should be followed when dimensioning the user side power supply for the driver board. The following table shows the required features of an appropriate power supply.

Requirements of the auxiliary power supply	
Power supply	+24V ±10%
Maximum rise time of auxiliary power supply	50ms
Minimum peak current of auxiliary supply	1,5A
Power on reset completed after (typ.)	3s

Please note:
Do not apply switching signals during power on reset.

The supplying switched mode power supply may not be turned-off for a short time as consequence of its current limitation. Its output characteristic needs to be considered. Switched mode power supplies with fold-back characteristic or hiccup-mode can create problems if no sufficient over current margin is available. The voltage has to rise continuously and without any plateau formation.
If the power supply is able to provide a higher current, a peak current will flow in the first instant to charge up the input capacitances on the driver. Its peak current value will be limited by the power supply and the effective impedances (e.g. distribution lines), only.
It is recommended to avoid the paralleling of several customer side power supply units. Their different set current limitations may lead to dips in the supply voltage.
The driver board is ready for operation typically 3s after turning on the supply voltage. The driver status signal HALT_RX and HALT_TX is operational after this time. Without any error present, the HALT_TX signal will be reset.
To assure a high level of system safety the high and low side, signal inputs should stay in a defined state (OFF state) during driver turn-on time. Only after the end of the power-on-reset, IGBT operation shall be permitted.

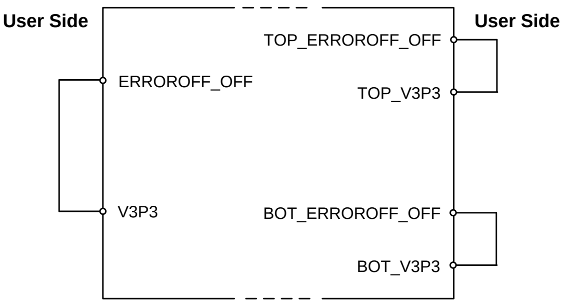
Connection of Stabilizing Capacitor	
	VP should be additionally stabilized by low ESR capacitor C_{VP}. This capacitor has to be placed as close to VP pins as possible. Dimension of CVP: $C_{VP} > 200 \times C_{ies}$ C_{ies} is the input capacitance of connected power semiconductor (see power semiconductor data sheet). C_{VP} should be minimum 220µF/100V.

53. Failure Management

A failure caused by under voltage protection (primary and secondary), critical frequency monitoring, short circuit protection or temperature protection will force HALT_TX into LOW state (not ready to operate) and set the error latch. The IGBTs will be switched off (IGBT driving signals set to LOW) and switching pulses from the controller will be not transferred to the output stage. At the same time an internal timer with a time constant of 20s is started. If no failure is present anymore, a time of minimum 20s after failure detection is passed, the driver board is ready to operate and switching signals are transferred to the output stage again.

The shut-down of all connected IGBTs in case of detected failure event can be disabled by using the ERROROFF_OFF function. If this function is activated, a detected failure is indicated at HALT_TX. The shut-down has to be forced by the user.

Failure management by controller: Enabling ERROROFF_OFF



Failure management by driver

If the shut-down should be forced by the driver, ERROROFF_OFF must be connected to GND, TOP_ERROROFF_OFF must be connected to TOP_GND and BOT_ERROROFF_OFF must be connected to BOT_GND.

Please note:
With activating the ERROROFF_OFF function, the user is responsible for protection shut-down of the IGBTs.

54. System Diagnostic Indication by LED

The system status during system power on, normal operation or failure event are illuminated by three tri-colours LEDs (LED 0 (V12) on primary side, LED 1 (V105) on secondary side for high side switch, LED 2 (V205) on secondary side for low side switch) on the driver board. The LEDs indicate the following conditions.

Diagnostic Code – System Start

LED 0 (V12)	Description
green, flashes	System is starting and checking supply voltages.
red, flashes	Supply voltage < V_s min.
yellow, flashes	Failure during system start. Automatic restart after 10 seconds and V_s > threshold level for reset.

LED 1 (V105), LED 2 (V205)	Description
yellow, flashes	System is starting and waiting for configuration of secondary side.

Diagnostic Code – Normal Operation

LED 0 (V12)	Description
green, steady on	System is working. No system failures occur since last system start.

LED 1 (V105), LED 2 (V205)	Description
green, steady on	System is working. No system failures occur since last system start.

Diagnostic Code – Failure Type Indication after Failure Event on Primary Side

LED 0 (V12) is illuminating ten flashes with a frequency of 1Hz. After no illumination for three seconds, the flashing sequence is repeated. The failure indication is illuminated until the driver is rebooted (turn-off of internal power supply).

Examples for LED 0 (V12):

Flashing sequence										Description
										Failure caused by critical oscillation of input signal is present.
										Failure caused by under voltage supply, but is not present anymore.

LED 0 (V12)

Flash 1	Flash 2	Flash 3	Flash 4	Flash 5
Status HALT signal from customer	Status oscillation failure (>100kHz)	Failure of signal transmission sec to prim	Failure secondary side	Under voltage supply
Flash 6	Flash 7	Flash 8	Flash 9	Flash 10
Status Short circuit or internal supply under voltage	Over current at primary power supply	Overvoltage at generic Analogue input (High Side)	Switching Signal TOP/BOT while system is resetting	Internal Error

LED 0 (V12) (colour of the flash)	**Description**
green	OK. No failure.
yellow	Failure was occurred, but failure is not present anymore.
red	Failure is present.

Diagnostic Code – Failure Type Indication after Failure Event on Secondary Side

LED 1 (V105) and LED 2 (V205) are illuminating five flashes with a frequency of 1Hz. After no illumination for three seconds, the flashing sequence is repeated. The failure indication is illuminated until reconfiguration of the secondary side (turn-off of internal power supply).

Examples for LED 1 (V105), LED 2 (V205):

Flashing sequence					Description
					Failure caused by under voltage +15V is present.
					Failure caused by under voltage -15V happened, but is not present anymore.

LED 1 (V105), LED 2 (V205)

flash 1	flash 2	flash 3	flash 4	flash 5
Short circuit of IGBT	Status failure of power supply	Status under voltage +15V	Status under voltage -15V	Internal Error

LED 1 (V105), LED 2 (V205) (colour of the flash)	**Description**
green	OK. No failure.
yellow	Failure was occurred, but failure is not present anymore.
red	Failure is present.

55. Halt Logic Signal (HLS)

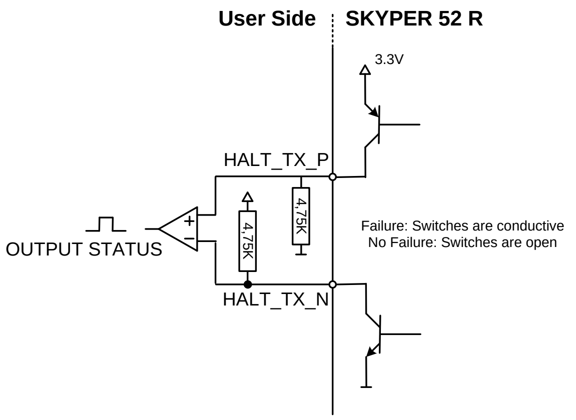
The Halt Logic Signals HALT_RX and HALT_TX show and control the drive core status. The driver core is placed into halt mode by setting HALT_RX_P (reference to HALT_RX_N) into HIGH state (disable driver). This signal can gather disable signals of other hardware components for stopping operation and switching off the IGBT. A HIGH signal will set the driver core into HOLD and switching pulses from the controller will be not transferred to the output stage. The input and output have differential characteristic. Pull up and open collector output stages must not be used.

Halt Logic Signal Table

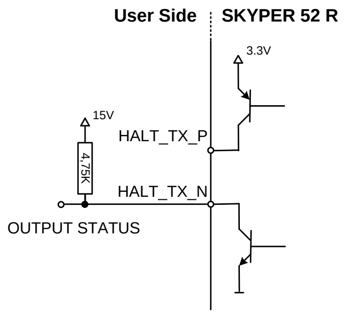
		Ready state	Failure detection by driver	Failure detection by controller
Differential HALT Status Output	HALT_TX_N HALT_TX_P	HALT_TX_N: open HALT_TX_P: open	HALT_TX_N: 0V HALT_TX_P: 3,3V	HALT_TX_N: open HALT_TX_P: open
Differential HALT Enable/Disable Input	Difference of HALT_RX_P and HALT_RX_N	HALT_RX_P higher level than HALT_RX_N -> Enable	xx	HALT_RX_P lower level than HALT_RX_N -> Disable

Please note:
A HIGH signal @ HALT_RX_P (reference to HALT_RX_N) does not generate a HIGH signal @ HALT_TX. After 3s of LOW signal @ HALT_RX_P (reference to HALT_RX_N) the gate driver is enabled to operate.

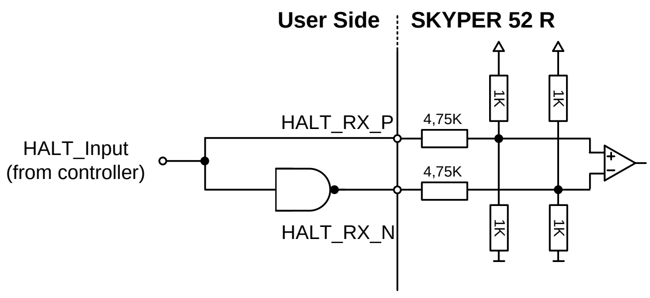
Application example HALT TX -> Failure Output



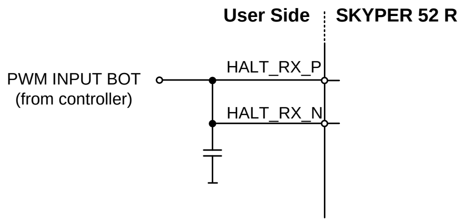
To simplify the error output following interface can be used (15V No FailureError/ 0V Failure):



Application example HALT RX -> Failure Input



To simplify the error output following interface can be used:



56. Under Voltage Protection (UVP) primary

Signal Characteristics	typ.
Under voltage protection trip level	16V
Threshold level for reset after failure event	18V

If the internally detected supply voltage of the driver board falls below this level, the IGBTs will be switched off (IGBT driving signals set to LOW) and the failure signal is present. The system restarts after 20 seconds and, if the supply voltage is higher than threshold level for reset after failure event.

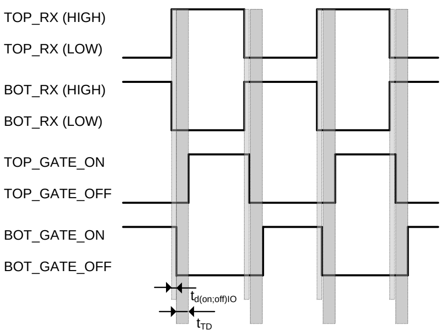
57. Overfrequency Monitoring (OFM)

This circuit monitors oscillation at the digital inputs. If the switching frequency is > 100kHz, the IGBTs will be switched off (IGBT driving signals set to LOW). The system restarts after 20 seconds and, if applied switching frequency is < 100kHz.

58. Dead Time generation (Interlock high / low side) adjustable (DT)

The dead time circuit prevents, that high and low side IGBT of one half bridge are switched on at the same time (shoot through). The dead time is not added to a dead time given by the controller. Thus the total dead time is the maximum of "built in dead time" and "controller dead time". It is possible to control the driver with one switching signal and its inverted signal.

Pulse pattern – DT

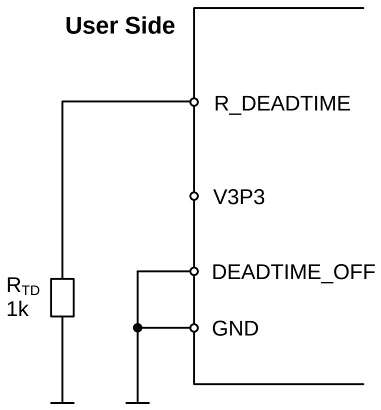


- The total propagation delay of the driver is the sum of interlock dead time (t_{TD}) and driver input output signal propagation delay ($t_{d(on;off)IO}$) as shown in the pulse pattern. Moreover the switching time of the IGBT chip has to be taken into account (not shown in the pulse pattern).
- If only one channel is switching, there will be no interlock dead time.
- No error message will be generated when overlap of switching signals occurs.

Adjustment of Dead time / Neutralizing Locking Functions

Interlock time [µs]	R_DEADTIME	DEADTIME_OFF
1,0	R_{TD} = 0Ω	GND
1,5	R_{TD} = 100Ω	GND
2,0	R_{TD} = 220Ω	GND
2,5	R_{TD} = 470Ω	GND
3,0	R_{TD} = 1kΩ	GND
3,5	R_{TD} = 2,2kΩ	GND
4,0	R_{TD} = 4,7kΩ	GND
4,5	R_{TD} = 10kΩ	GND
no interlock	open	V3P3

Application Example (t_{TD} = 3,0µs)



Please note:

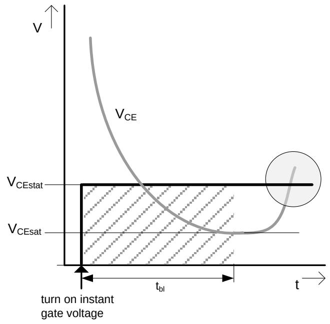
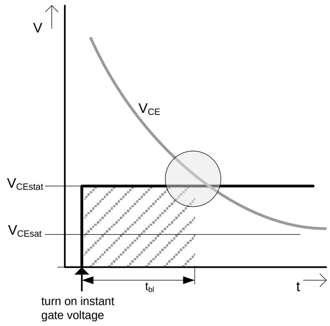
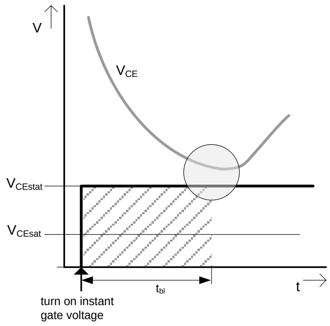
The dead time has to be longer than the turn-off delay time of the IGBT in any case. This is to avoid that one IGBT is turned on before the other one is not completely discharged. If the dead time is too short, the heat generated by the short circuit current may destroy the module in the event of a short circuit in top or bottom arm.

The average output current is available at each output channel. It is not possible to interconnect the output channels to achieve a higher average output current by neutralizing the locking function.

6. Seoncdary Side interface

61. Short Circuit Protection by VCEsat monitoring / de-saturation monitoring (SCP)

The SCP circuit is responsible for short circuit sensing. It monitors the collector-emitter voltage V_{CE} of the IGBT during its on-state. Due to the direct measurement of V_{CEsat} on the IGBT's collector, the SCP circuit switches off the IGBTs and an error is indicated.
After t_{bl} has passed, the de-saturation monitoring will be triggered as soon as $V_{CE} > V_{CEstat}$ and will turn off the IGBT and the failure mode is active. The blanking time (t_{bl}) and the collector-emitter threshold static monitoring voltage (V_{CEstat}) may be controlled by external resistors $R_{GATINGTIME}$ and R_{CE}. Possible failure modes are shows in the following pictures.

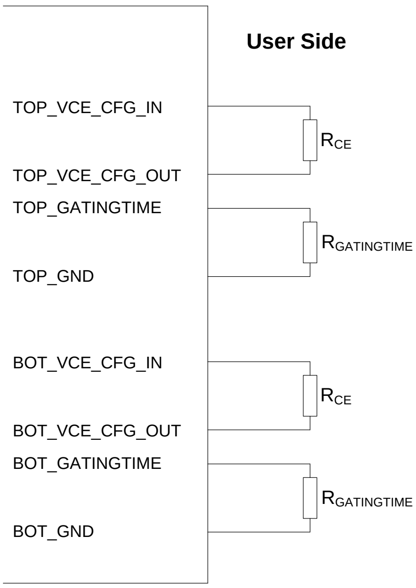
Short circuit during operation	Turn on of IGBT too slow *	Short circuit during turn on
		

* or adjusted blanking time too short

62. Adjustment of DSCP

The external components R_{CE} and $R_{GATINGTIME}$ are applied for adjusting the steady-state threshold the blanking time.

Connection RCE and RGATINGTIME



Dimensioning of RCE and RGATINGTIME

$$R_{CE} = \frac{1000\,\Omega}{V_{CEstat} + 2{,}309\,V} \cdot 21{,}801\,V - 1221\,\Omega$$

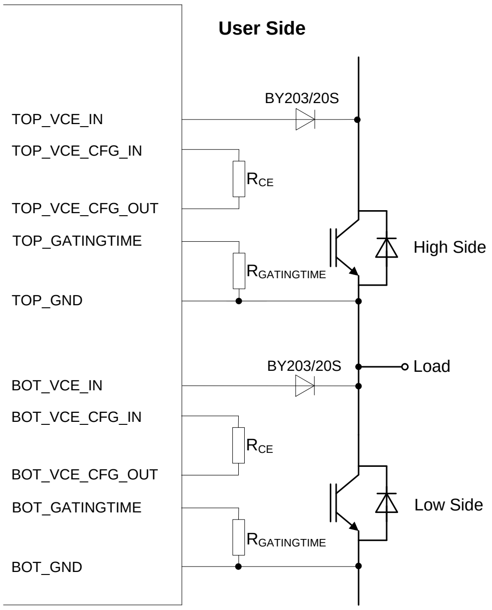
Blanking time [µs]	$R_{GATINGTIME}$ [Ω]
3	10k
4	4,7k
5	2,2k
6	1k
7	470
8	220
9	100
10	0

V_{CEstat}: Collector-emitter threshold static monitoring voltage
t_{bl}: Blanking time
$V_{CEstat\_max} = 10{,}5V$

Please Note:
The equations are calculated not considering the forward voltage of the high voltage diode (~1,5V). The calculated values V_{CEstat} and t_{bl} are typical values at room temperature can and do vary in the application (e.g. tolerances of used high voltage diode, resistor R_{CE}, $R_{GATINGTIME}$). The DSCP function is not recommended for over current protection.

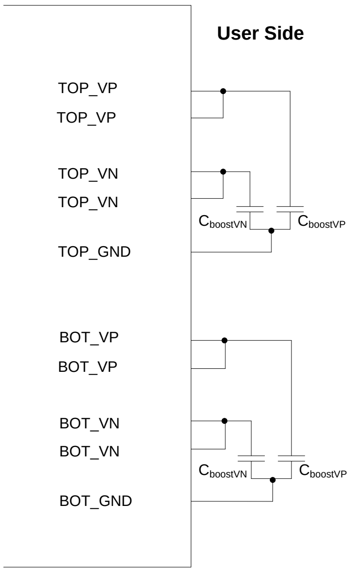
If the SCP function is not used, for example during the experimental phase, TOP_VCE_IN must be connected with TOP_GND for disabling SCP @ high side and BOT_VCE_IN must be connected with BOT_GND for disabling SCP @ low side. Please consider that no protection will be anymore available

The high voltage diode blocks the high voltage during IGBT off state. The connection of this diode between driver and IGBT is shown in the following schematic.

Connection High Voltage Diode	Characteristics
	▪ Reverse blocking voltage of the diode shall be higher than the blocking voltage of the used IGBT. ▪ Reverse recovery time of the fast diode shall be lower than $t_{d(off)}$ of the used IGBT. ▪ Forward voltage of the diode: 1,5V @ 2mA forward current (T_j=25°C).

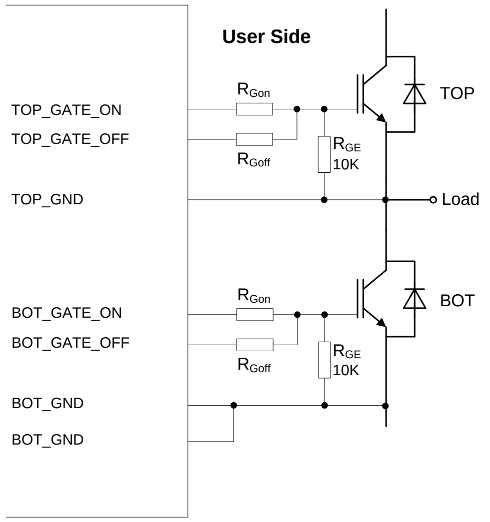
63. External Boost Capacitors (BC)

The gate charge of the driver may be increased by additional boost capacitors to drive IGBT with large gate capacitance.

Connection External Boost Capacitors	Dimensioning of C_{boost}
	If the required gate charge is > 5µC, additional boost capacitor has to be used. ▪ $C_{boostVP}$ = 5 × C_{ies} ▪ $C_{boostVN}$ = 5 × C_{ies} ▪ C_{ies} is the input capacitance of connected power semiconductor ▪ Minimum rated voltage $C_{boostVP}$: 25V ▪ Minimum rated voltage $C_{boostVN}$: 25V ▪ Type of capacitor: ceramic capacitor **Please consider the maximum rating four output charge per pulse of the gate driver.** **Application Hints** The external boost capacitors should be connected as close as possible to the gate driver and to have low inductance.

64. Gate Resistors

The output transistors of the driver are MOSFETs. The drains of the MOSFETs are separately connected to external terminals in order to provide setting of the turn-on and turn-off speed of each IGBT by the external resistors R_{Gon} and R_{Goff}. As an IGBT has input capacitance (varying during switching time) which must be charged and discharged, both resistors will dictate what time must be taken to do this. The final value of the resistance is difficult to predict, because it depends on many parameters as DC link voltage, stray inductance of the circuit, switching frequency and type of IGBT.

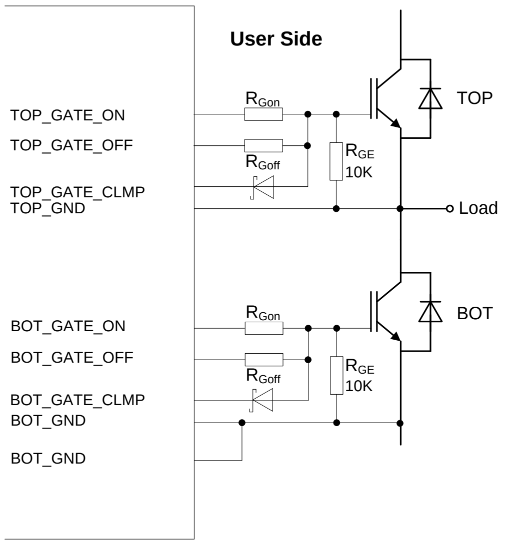
Connection R_{Gon}, R_{Goff}	Application Hints
	The gate resistor influences the switching time, switching losses, dv/dt behaviour, etc. and has to be selected very carefully. Due to this influence a general value for the gate resistors cannot be recommended. The gate resistor has to be optimized according to switching behaviour and over voltage peaks within the specific circuitry. By increasing R_{Gon} the turn-on speed will decrease. The reverse peak current of the free-wheeling diode will diminish. By increasing R_{Goff} the turn-off speed of the IGBT will decrease. The inductive peak over voltage during turn-off will diminish. In order to ensure locking of the IGBT even when the driver supply voltage is turned off, a resistance (R_{GE}) has to be integrated.

Please note:
Do not connect the terminals TOP_GATE_ON with TOP_GATE_OFF and BOT_GATE_ON with BOT_GATE_OFF, respectively.

Application hint:
For futher design support, please read the Application Note AN-7003 "Gate Resistior – Principles and Applications". The application note is available on Driver Electronics product page at www.SEMIKRON.com.

65. Gate Clamping

By using an external Schottky diode, the voltage at the gate can be limited in case of turned off driver.

Connection Clamping Diode	
	**Application hint:** For futher design support, please read the Application Note AN-7002 "Connection of Gate Drivers to IGBT and Controller". The application note is available on Driver Electronics product page at www.SEMIKRON.com.

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66. Under Voltage Protection secondary

This function monitors the rectified voltage on the secondary side. The table below gives an overview of the trip level.

Signal Characteristics	typ.
Under voltage protection trip level +15V	11V
Threshold level for reset after failure event +15V	13V
Under voltage protection trip level -15V	-11V
Threshold level for reset after failure event -15V	-13V

67. Temperature Sensing

TOP_TEMP_P can be used for external fault signals from e. g. over current protection circuit or over temperature protection circuit to place the gate driver into halt mode. Failure is detected when voltage gets over 1,5V. TOP_TEMP_P has to be connected with ground.

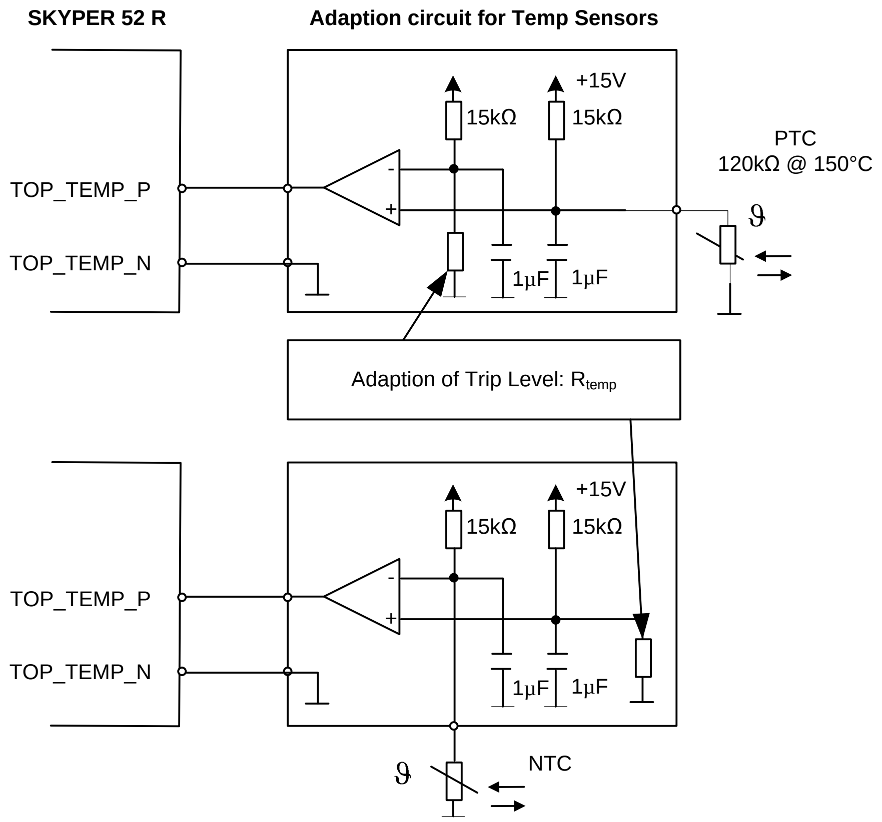
Trip level	
Failure	>1,5V
No failure	<1,5V

Application Example for Temperature Sensor

To realise temperature sensing a temperature dependent resistor can be connected to TOP_TEMP_P. Trip level is set at 430Ω. To adapt temperature range to customer's temperature sensor following circuit can be used.

Disabling of this function can be achieved by connection to Ground.

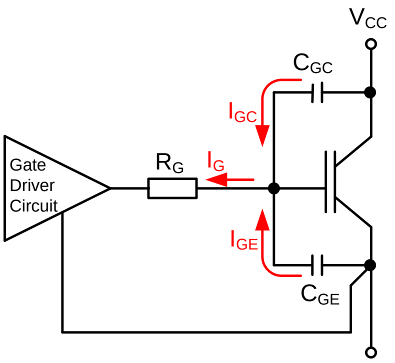
You can find an application example for NTC and PTC sensors.



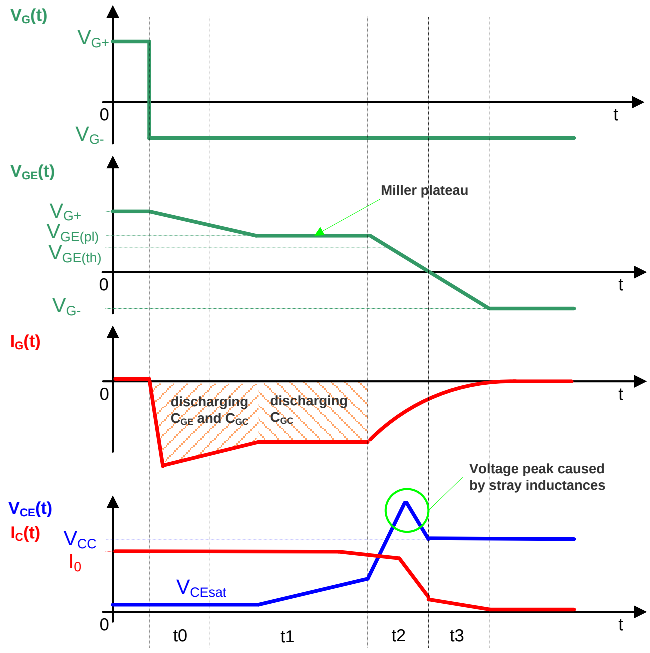
68. IntelliOFF

An intelligent turn-off feature has been implemented in order to avoid critical voltage spikes at the IGBT pins during turn-off procedure. This feature can turn-off the IGBT in a shorter time without generating dangerous voltage spikes, if used appropriately. Following diagrams demonstrate gate capacitor discharging and time dependant voltage and current traces.

Gate Turn-Off Current

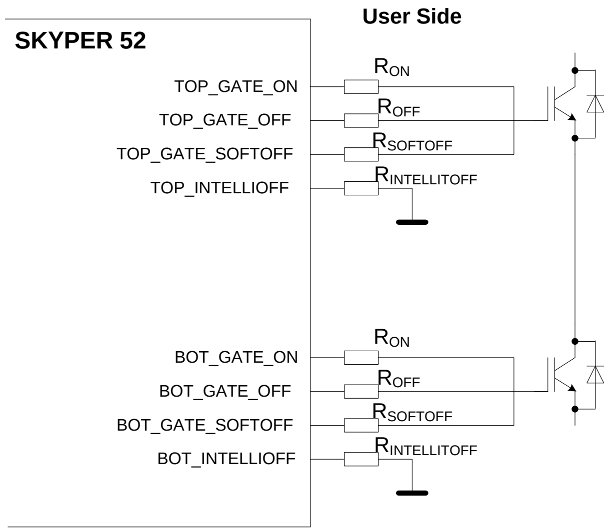


Gate Turn-Off Voltage and Current Diagrams



After initiating the turn-off procedure the driver switches gate voltage to -15V. The discharging procedure of the gate-collector capacitor C_{GC} and gate-emitter capacitor C_{GE} starts immediately and the gate current rises to its negative maximum (period t0). Because of the miller effect the V_{GE} remains at higher level for a while. IntelliOFF functionality of SKYPER 52 shortens the time frame until end of t1 switching the R_{OFF} resistor and $R_{SOFTOFF}$ resistor parallel to accelerate the discharging of C_{GE} and C_{GC} without having a significant effect on the level of V_{CE} (period t0 and t1). During the period t2 SKYPER 52 switches back to $R_{SOFTOFF}$ resistor only and discharging continues without parallel connection of R_{OFF} resistor to reduce the discharging speed. This avoids voltage spikes at IGBT pins because of the high response capability of V_{CE} and I_C to V_{GE} decrease. After passing the critical time frame t2 SKYPER 52 again establishes the parallel connection of R_{OFF} resistor and $R_{SOFTOFF}$ resistor to achieve the secure OFF state of the IGBT (period t3). The length of the time period will be determined by the $R_{INTELLIOFF}$ connected between SKYPER 52 pin and ground.

R_{ON}, R_{OFF}, $R_{SOFTOFF}$ and $R_{INTELLIOFF}$ Connections



Resistor $R_{INTELLIOFF}$ Characteristics

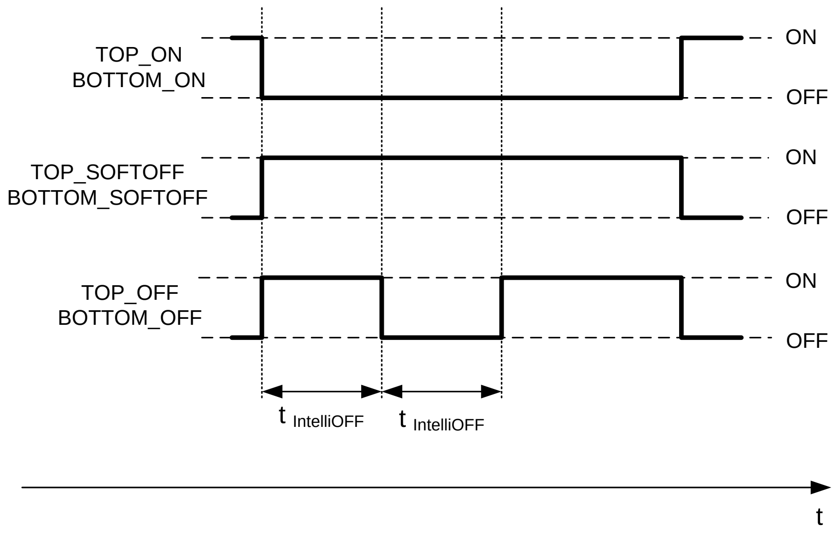
The resistor $R_{INTELLIOFF}$ connected to ground determines the time constant for connection of the regular R_{OFF} resistor parallel to $R_{SOFTOFF}$ resistor.

Possible values are:

Resistor $R_{INTELLIOFF}$ [Ω]	$t_{IntelliOFF}$ [μs]
0	2.33
100	2.00
220	1.67
470	1.33
1000	0.67
2200	0.67
4700	0.33
10,000	no IntelliOff
∞	error

For timings see diagram below

R_{ON}, R_{OFF}, $R_{SOFTOFF}$ and $R_{INTELLIOFF}$ Timings



7. Driver Performance

The driver is designed for application with half bridges or single modules and a maximum gate charge per pulse < 100µC. The charge necessary to switch the IGBT is mainly depending on the IGBT's chip size, the DC-link voltage and the gate voltage. This correlation is shown in module datasheets. It should, however, be considered that the driver is turned on at +15V and turned off at -15V. Therefore, the gate voltage will change by 30V during each switching procedure. Unfortunately, many datasheets do not show negative gate voltages. In order to determine the required charge, the upper leg of the charge curve may be prolonged to +30V for determination of approximate charge per switch.
The medium output current of the driver is determined by the switching frequency and the gate charge. The maximum switching frequency may be calculated with the shown equations and is limited by the average current of the driver power supply and the power dissipation of driver components.

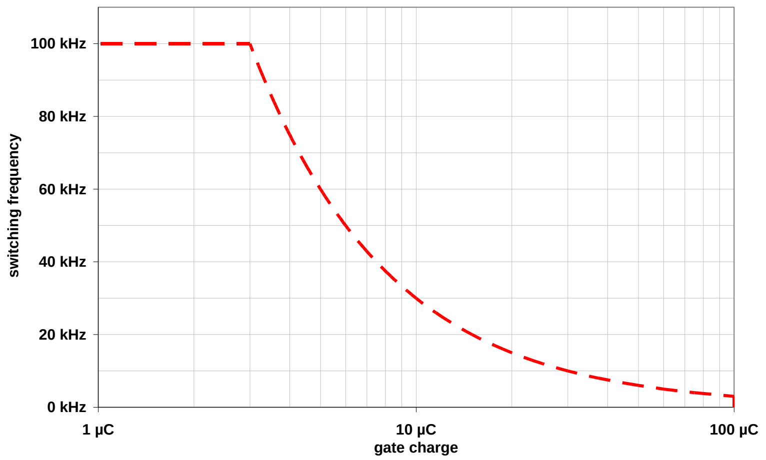
Calculation Switching Frequency

$$f_{max} = \frac{Iout_{AVmax}}{Q_{GE}}$$

f_{max}: Maximum switching frequency *
$Iout_{AVmax}$: Maximum output average current
Q_{GE}: Gate charge of the driven IGBT

*@ T_{amb}=25°C

Maximum Switching Frequency @ different Gate Charges @ T_{amb}=25°C

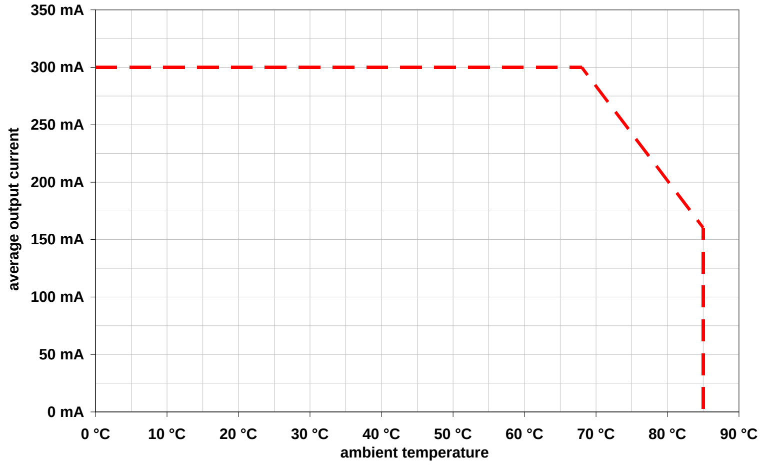


Calculation Average Output Current

$$Iout_{AV} = f_{sw} \times Q_{GE}$$

$Iout_{AV}$: Average output current
f_{sw}: Switching frequency
Q_{GE}: Gate charge of the driven IGBT

Total Average Output Current as a Function of the Ambient Temperature



Please note:
The average output current per output channel is 300mA. The maximum value of the switching frequency is limited to 100kHz due to switching reasons.

Application hint:
For futher design support, please read the Application Note AN-7004 "IGBT Driver Calculation". The application note is available on Driver Electronics product page at www.SEMIKRON.com.

71. Insulation

Magnetic transformers are used for insulation between gate driver primary and secondary side. The transformer set consists of pulse transformers which are used for turn-on and turn-off signals of the IGBT and the signal feedback between secondary and primary side, and a DC/DC converter. This converter provides a potential separation (galvanic separation) and power supply for the two secondary (high and low) sides of the driver. Thus, external transformers for power supply are not required.

Creepage and Clearance Distance in mm	
Secondary to secondary	Min. 7,2
Primary to secondary	Min. 18,0

72. Isolation Test Voltage

The isolation test voltage represents a measure of immunity to transient voltages. The maximum test voltage and time applied once between input and output, and once between output 1 and output 2 are indicated in the absolute maximum ratings. The high-voltage isolation tests and repeated tests of an isolation barrier can degrade isolation capability due to partial discharge. Repeated isolation voltage tests should be performed with reduced voltage. The test voltage must be reduced by 20% for each repeated test.
The isolation will be ensured by the isolation barrier (transformer) that is checked in the part. An isolation test is not performed as a series test. Therefore, the user can perform once the isolation test with voltage and time indicated in the absolute maximum ratings.

73. Environmental Conditions

The driver board is type tested under the environmental conditions below.

Conditions	Values (max.)
Thermal Cycling	- 100 cycle, $T_{stg(max)}$ - $T_{stg(min)}$, without operation - Tested acc. IEC 60068-2-14 Test Na
Vibration	Sinusoidal sweep 20Hz … 500Hz, 5g, 26 sweeps per axis (x, y, z) - Tested acc. IEC 68-2-6 - Connection between driver core and printed circuit board mechanical reinforced by using support posts.
Shock	Half-sinusoidal pulse 15g, shock width 18ms, 3 shocks in each direction (±x, ±y, ±z), 18 shocks in total - Tested acc. IEC 68-2-27 - Connection between driver core and printed circuit board mechanical reinforced by using support posts.
Temperature humidity	- 40/085/56 (+40°C, 85% RH, 56h) - Tested acc. IEC 60068-1 (climate) - Climate class 3K3
Fast transients (Burst)	- Power terminals: 4kV / 5kHz - Control terminals: 4kV / 5kHz - Tested acc. EN 61000-4-4
Electrostatic discharge (ESD)	- Contact discharge: 6kV - Air discharge: 8kV - Tested acc. EN 61000-4-2
Radio Frequency Fields	- Electrical field: 7,5V/m - Polarisation: vertical + horizontal - Frequency: 80 MHz - 1000 MHz - Modulation: 80% AM, 1kHz - Tested acc. EN 61000-4-3
RF Conducted Disturbance	- Voltage: 10V EMF - Frequency: 150 kHz - 80 MHz - Modulation: 80 % AM, 1kHz - Tested acc. EN 61000-4-6

8. Marking

Every driver board is marked. The marking contains the following items.

Part marking information

❶ 2D data matrix code

- Type: EEC 200
- Standard: ICO / IEC 16022
- Cell size: 0.254 – 0.3 mm
- Dimension: 5 x 5 mm

❷ Data in plain text

- XXXXXXXX 8 digits part number (e.g. L5022001)
- YY 2 digits version number (e. g. NF)
- ZZZZ 4 digits date code (e.g. 0440 = year + week)
- VVVV 4 digits continuous lot number
- U 1 digit country code
- TTTTT 5 digits account number (e.g. 54229)

9. Status Definition

Data Sheet Status	Product Status	Definition
Target	Formative or in design	The data sheet and technical explanations contain advanced information or the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First production	The data sheet and technical explanations contain preliminary data, and supplementary data might be published at a later date. SEMIKRON reserves the rights to make changes at any time without notice in order to improve design.
No identification	Full production	The data sheet and technical explanations contain final specification. SEMIKRON reserves the rights to make changes at any time without notice in order to improve design.