Technical Explanation SKYPER® 32 2^{nd} edition

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Prepared by:	Niklas Hofstötter
Reviewed by:	Daniel Obernöder
Approved by:	Marco Honsberg

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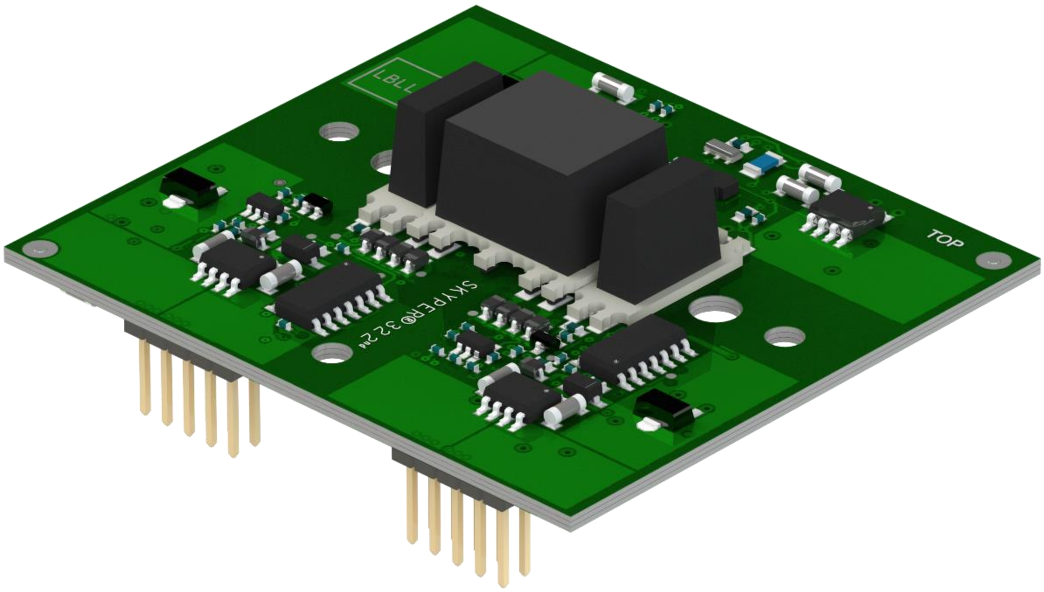
1. Introduction

The SKYPER® 32 2nd edition is a two-channel driver core serving as 1:1 replacement of the industry standard SKYPER® 32. Designed to master the challenging requirements of today's driver electronics the SKYPER® 32 2nd edition drivers provides an increased output power, a higher peak output current capability and an increased MTBF rate in comparison to its predecessor. These upgrades combined with its high EMC ruggedness enable the driver to reliably control standard semiconductor power modules.

Figure 1: SKYPER® 32 2nd edition



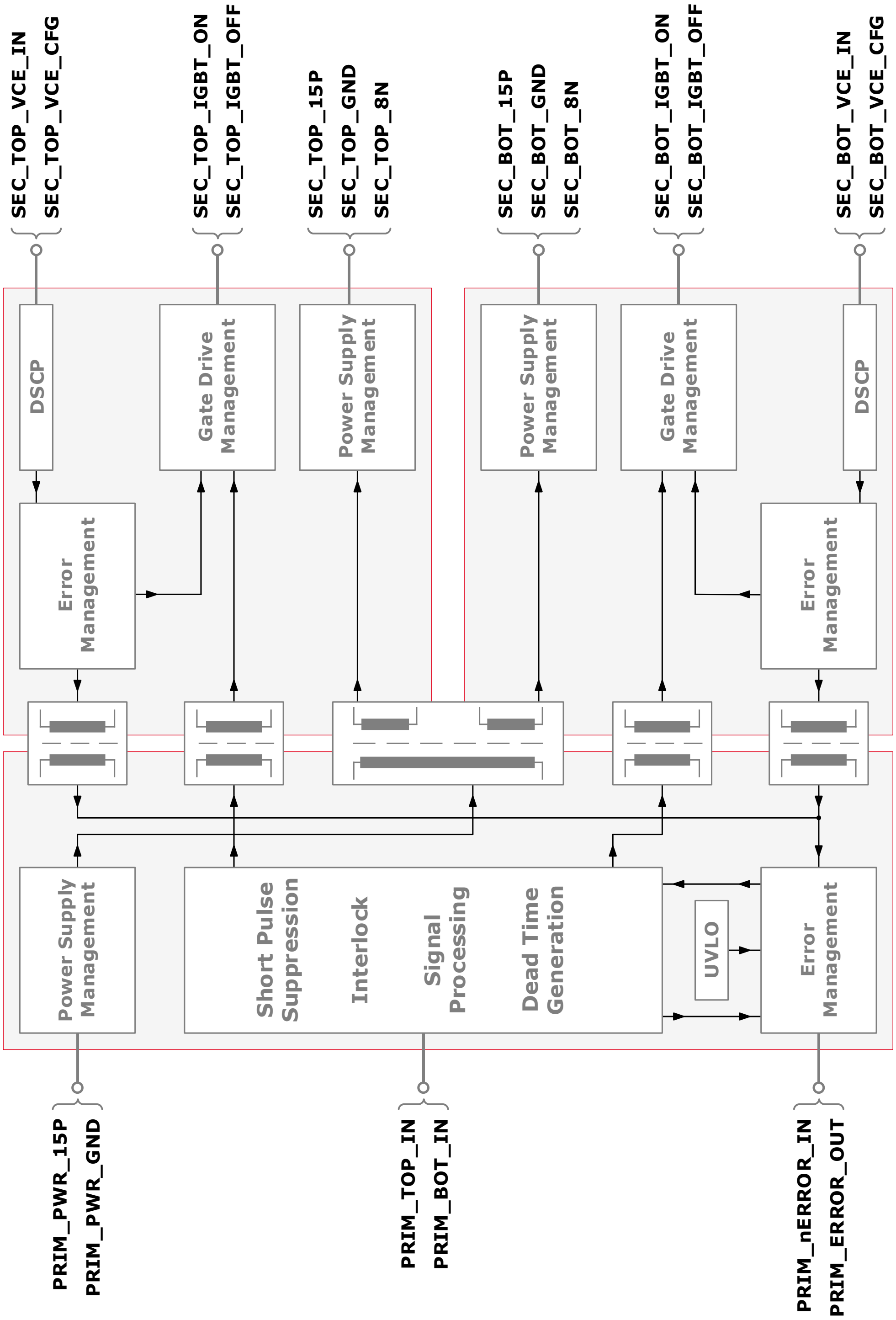
KEY FEATURES

- Two output channels
- 1.6 W output power per channel
- Two output channels
- Integrated potential free power supply for the secondary side
- Short Pulse Suppression (SPS)
- Under Voltage Protection (UVP)
- Under Voltage Lockout on primary side (UVLO)
- Dynamic short circuit protection (DSCP)
- Drive interlock (dead time) top / bottom (DT)
- Shut Down Input (SDI)
- MTBF rate > 4.2 Million hours at full load

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.

2. Block Diagram

Figure 2: SKYPER® 32 2nd edition | Block diagram



3. Handling Instruction and UL Specified Remarks

3.1 Handling instruction

Please ensure electric static discharge protection during handling. The driver should only be removed from its original packaging just before mounting. When mounting the driver it has to be ensured that the work is done in an ESD-protected workplace environment. Persons working with the IGBT driver have to wear ESD wristbands, overalls and shoes. If tools are used for mounting, those must comply with ESD standards.

When handling the driver, do not pick up the driver at the transformers. The driver MUST be handled at the PCB sides as shown in figure 3.

Figure 3: SKYPER® 32 2nd edition | Handling instruction

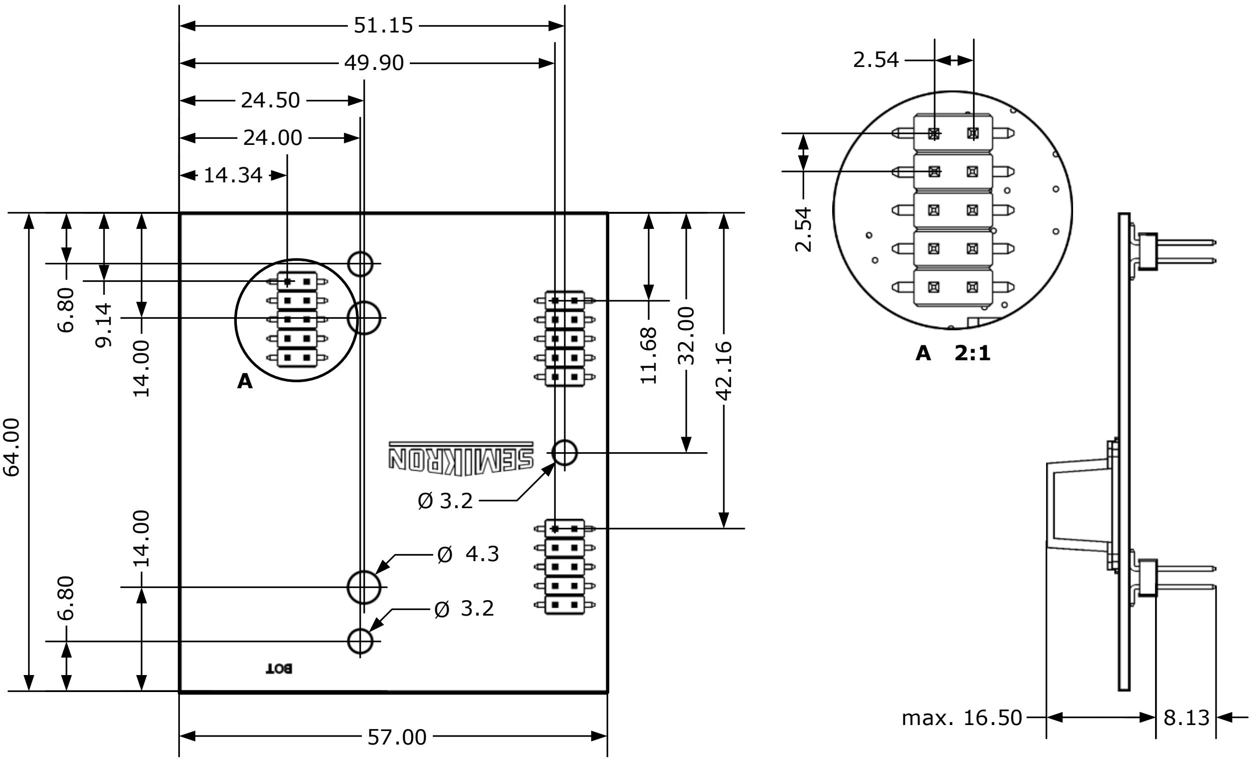
3.2 UL specified remarks

- The equipment shall be installed in compliance with the mounting and spacing requirements of the end-use application.
- The SKYPER® 32 2nd edition shall be supplied by an isolated limited voltage / limited current source or a Class 2 source. The 15 A peak rating is an instantaneous peak rating only.
- These devices do not incorporate solid-state motor overload protection. The need for overload protection and over-current protection devices shall be determined in the end-use product.
- These devices have not been evaluated to over-voltage, over-current, and over-temperature control, and may need to be subjected to the applicable end-product tests.
- Temperature and tests shall be considered in the end-use. Due to the limited current source, only the effect of heat generating components in this device on adjacent components in the end product needs to be considered.
- Connectors have not been evaluated field wiring; all connections are to be factory wired only.

4. Application Instruction

4.1 Dimensions

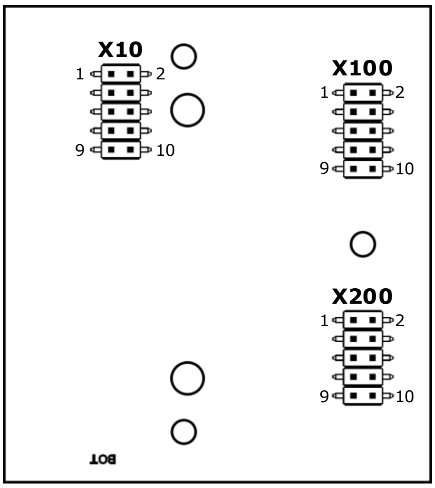
Figure 4: SKYPER® 32 2nd edition | Dimensions



All dimensions in mm. Please consider higher tolerances of connector position according to IPC A 610.
STEP file on request.

4.2 Footprint

Figure 5: SKYPER® 32 2nd edition | Footprint



4.3 Pin assignment

4.3.1 Pin assignment of pin header X10 | Primary side

Table 1: SKYPER® 32 2nd edition | Pin assignment – Primary side | X10

Pin	Signal	Function	Specification
X10:01	PRIM_PWR_GND	GND for power supply and GND for digital signals	
X10:02	PRIM_PWR_GND	GND for power supply and GND for digital signals	
X10:03	PRIM_ERROR_OUT	ERROR output	LOW = NO ERROR; open collector output; max. 30V / 15mA
X10:04	PRIM_nERROR_IN	ERROR input	5V logic; LOW active
X10:05	PRIM_PWR_GND	GND for power supply and GND for digital signals	
X10:06	PRIM_PWR_GND	GND for power supply and GND for digital signals	
X10:07	PRIM_TOP_IN	Switching signal input (TOP switch)	Digital 15 V; 10 kOhm impedance LOW = TOP switch off HIGH = TOP switch on
X10:08	PRIM_BOT_IN	Switching signal input (BOTTOM switch)	Digital 15 V; 10 kOhm impedance LOW = BOT switch off HIGH = BOT switch on
X10:09	PRIM_PWR_15P	Drive core power supply	Stabilized +15V ±4%
X10:10	PRIM_PWR_15P	Drive core power supply	Stabilized +15V ±4%

4.3.2 Pin assignment of pin header X100 | Secondary side | TOP

Table 2: SKYPER® 32 2nd edition | Pin assignment – Secondary side | TOP | X100

Pin	Signal	Function	Specification
X100:01	SEC_TOP_VCE_CFG	Input reference voltage adjustment	
X100:02	SEC_TOP_VCE_IN	Input V_{CE} monitoring	
X100:03	SEC_TOP_15P	Output power supply for external buffer capacitors	Stabilized +15V
X100:04	SEC_TOP_15P	Output power supply for external buffer capacitors	Stabilized +15V
X100:05	SEC_TOP_GND	GND for power supply and GND for digital signals	
X100:06	SEC_TOP_IGBT_ON	Switch on signal TOP IGBT	

X100:07	SEC_TOP_GND	GND for power supply and GND for digital signals	
X100:08	SEC_TOP_IGBT_OFF	Switch off signal TOP IGBT	
X100:09	SEC_TOP_8N	Output power supply for external buffer capacitors	Stabilized -7V
X100:10	SEC_TOP_8N	Output power supply for external buffer capacitors	Stabilized -7V

4.3.3 Pin assignment of pin header X200 | Secondary side | BOT

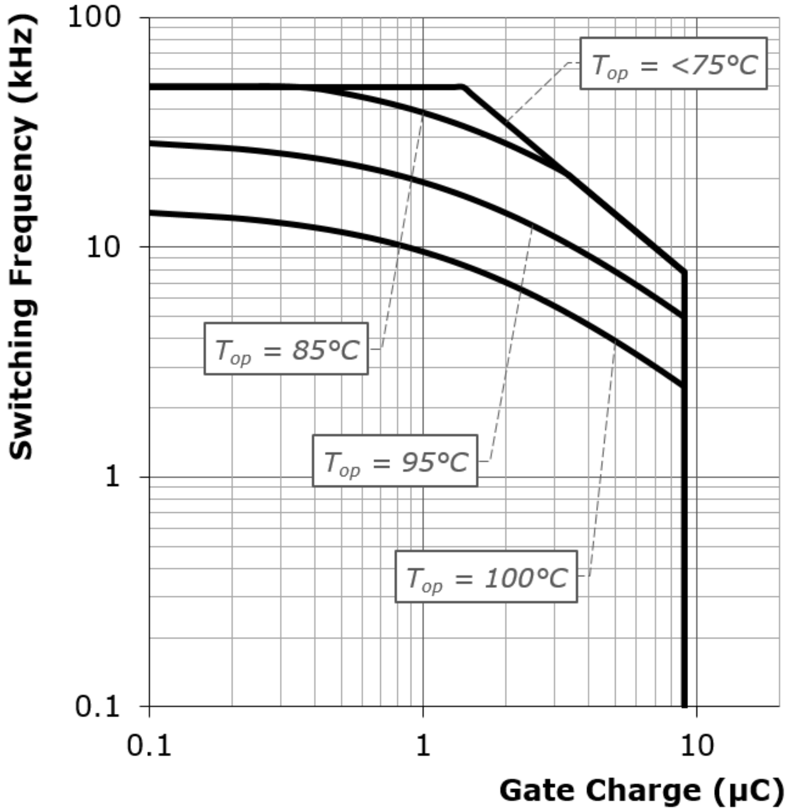
Table 3: SKYPER® 32 2nd edition | Pin assignment – Secondary side | BOT | X200

Pin	Signal	Function	Specification
X200:01	SEC_BOT_VCE_CFG	Input reference voltage adjustment	
X200:02	SEC_BOT_VCE_IN	Input V_{CE} monitoring	
X200:03	SEC_BOT_15P	Output power supply for external buffer capacitors	Stabilized +15V
X200:04	SEC_BOT_15P	Output power supply for external buffer capacitors	Stabilized +15V
X200:05	SEC_BOT_GND	GND for power supply and GND for digital signals	
X200:06	SEC_BOT_IGBT_ON	Switch on signal BOT IGBT	
X200:07	SEC_BOT_GND	GND for power supply and GND for digital signals	
X200:08	SEC_BOT_IGBT_OFF	Switch off signal BOT IGBT	
X200:09	SEC_BOT_8N	Output power supply for external buffer capacitors	Stabilized -7V
X200:10	SEC_BOT_8N	Output power supply for external buffer capacitors	Stabilized -7V

4.4 Driver Performance

The driver is designed for application utilizing half bridge or single switch module configurations and a maximum gate charge per pulse of less than 2.5µC (up to 9µC with external boost capacitors). 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 -7V. Therefore, the gate voltage will change by 22V during each switching cycle. 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 graphically prolonged to +22V for an estimation of the 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 equation and is limited by the average current of the driver power supply and the power dissipation of driver components.

Figure 6: SKYPER® 32 2nd edition | Maximum switching frequency



$$f_{sw} = \frac{560mA - 5.33\frac{mA}{K} \times (T_{op} - 273.15K)}{Q_{out/pulse} + 1.79\mu As}$$

$$0mA \leq Q_{out/pulse} \times f_{sw} \leq 70mA \qquad 0kHz \leq f_{sw} \leq 50kHz$$

f_{sw} = switching frequency (kHz) T_{op} = operating temperature (K) $Q_{out/pulse}$ = Output charge per pulse (µC)

Please note:
The maximum value of the switching frequency is limited to 50kHz due to design constraints.

4.5 Insulation

Magnetic transformers are used as insulation barrier between gate driver primary and secondary side. The transformer set consists of pulse transformers which are used bidirectional for turn-on and turn-off signals of the IGBT and the error 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 (TOP and BOT) sides of the driver. Thus, external transformers for external power supply are not required.

Table 4: SKYPER® 32 2nd edition | Creepage and clearance distance	
Primary to secondary	min 12.2 mm

4.6 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 effects. Hence, repeated isolation voltage tests should be performed with reduced voltage. The test voltage must be reduced by 20% for each repeated test.
The isolation of the isolation barrier (transformer) is checked and verified 100% in production. Besides this isolation barrier, no further active parts are used in this SKYPER design that potentially could limit the isolation voltage at a lower level than specified. 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.

Please note:
An isolation test is not performed at SEMIKRON as a series test. This shall be performed in the application as part of the mandatory system test requirements.

4.7 Auxiliary power supply

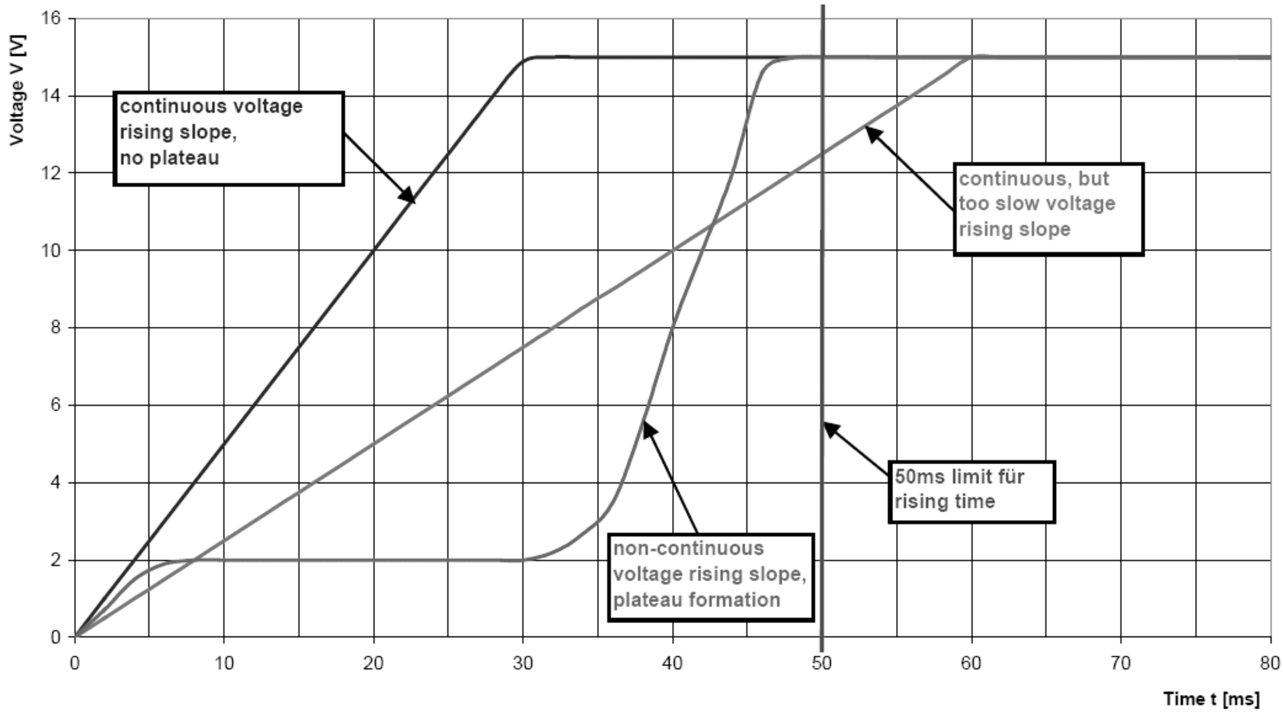
A few basic rules should be followed when dimensioning the customer side power supply for the driver. The following table shows the required features of an appropriate power supply.

Table 5: SKYPER® 32 2nd edition | Requirements of the auxiliary power supply	
Regulated power supply	+15V ±4%
Maximum rise time of auxiliary power supply	50ms
Minimum peak current of auxiliary supply	1A
Power on reset completed after	150ms

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. The supply's output characteristic needs to be considered. Switched mode power supplies with fold-back characteristic or hiccup-mode can create problems if sufficient over current margin to ride through the power up current demand of the SKYPER is not available. The voltage has to rise continuously and without any plateau formation as shown in the following diagram to ensure proper boot-up of the SKYPER.

Figure 7: SKYPER® 32 2nd edition | Rising slope of the power supply voltage



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. The resulting 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 and other undesired interferences.
The driver is ready for operation typically 150ms after applying the supply voltage. The driver error signal PRIM_ERROR_OUT is operational after this time. Without any error present, the error signal will be reset.
To assure a high level of system safety the TOP and BOT signal inputs should stay in a defined state (OFF state, LOW) during driver turn-on time. Only after the end of the power-on-reset, IGBT switching operation shall be permitted.

4.8 Under voltage protection of driver power supply (UVP)

The internally detected supply voltage of the driver has an under voltage protection. The table below gives an overview of the trip level.

Table 6: SKYPER® 32 2nd edition | UVP level of supply voltage	
Regulated power supply	+13.5V

If the internally detected supply voltage of the driver falls below this level, the IGBTs will be switched off (IGBT driving signals set to LOW). The input side switching signals of the driver will be ignored. The error memory will be set, and the output PRIM_ERROR_OUT changes to high impedance state.

4.9 Input signals

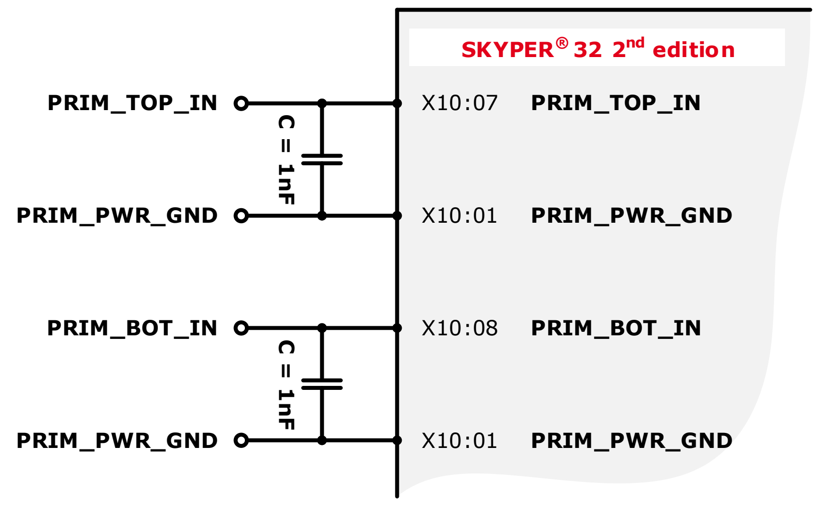
The signal transfer to each IGBT is made through the before mentioned pulse transformers, used for switching on and switching off of the IGBT. The inputs have a Schmitt Trigger characteristic and a positive / active high logic (input HIGH = IGBT on; input LOW = IGBT off).

It is mandatory to use circuits which switch active to +15V and 0V. Pull up and open collector output stages must not be used for TOP / BOT control signals. It is recommended to consider line drivers according to the required length of the signal lines.

Please note:
It is not permitted to apply switching pulses shorter than 1µs.

A capacitor could be connected to the driver's inputs to obtain high noise immunity. This capacitor can cause for current limited line drivers a little delay of a few nsec. Please ensure the capacitive load is covered in the selected line driver and that the created delay is small enough to be neglected. The capacitors have to be placed as close as possible to the driver interface.

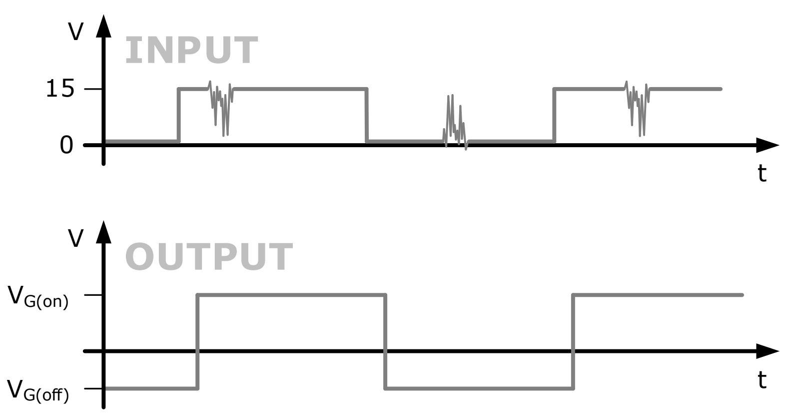
Figure 8: SKYPER® 32 2nd edition | TOP / BOT input



4.10 Short pulse suppression (SPS)

This circuit suppresses short turn-on and off-pulses of incoming signals. This way the IGBTs are protected against spurious noise as they can occur due to bursts on the signal lines. Pulses shorter than 625ns are suppressed and all pulses longer than 750ns get through. Pulses with a length in-between 625ns and 750ns can be either suppressed or get through.

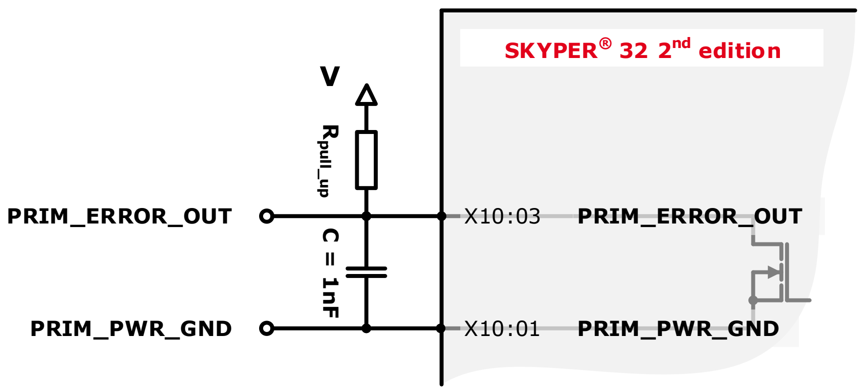
Figure 9: SKYPER® 32 2nd edition | Pulse pattern – SPS



4.11 Error management

Any error detected will set the error latch and the output PRIM_ERROR_OUT to high impedance. Switching pulses from the controller will be ignored. Connected and switched off IGBTs remain turned off. A reset of the latched error memory is only possible if no failure is present anymore and if the TOP and BOT input signals are set to the LOW level for a period of $t_{pERRRESET}$ > 9µs.
The output PRIM_ERROR_OUT is an open collector output. For the error evaluation an external pull-up-resistor is necessary pulled-up to the positive operation voltage of the control logic (LOW signal = no error present, wire break safety is assured).

Figure 10: SKYPER® 32 2nd edition | Open collector error transistor



Application hints:
An external resistor to the controller logic high level is required. The resistor has to be in the range of V / Imax < R_{pull_up} < 10kΩ.
PRIM_ERROR_OUT can operate to maximum 30V and can switch a maximum of 15mA.

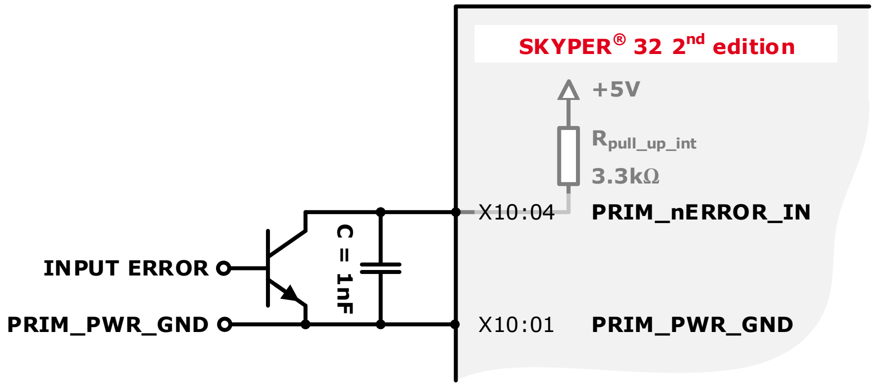
Example:
For V = +15V the needed resistor should be in the range of: R_{pull_up} = (15V/15mA) … 10kΩ ⇒ 1kΩ… 10kΩ.

Please note:
The error output PRIM_ERROR_OUT is not short circuit proof.

4.12 Shut down input (SDI)

The shut down input / error input signal can gather error signals of other hardware components for switching off the IGBT (input HIGH = no turn-off; input LOW = turn-off).
A LOW signal at PRIM_nERROR_IN will set the error latch and the output PRIM_ERROR_OUT to high impedance. Switching pulses from the controller will be ignored. A reset of the latched error memory is only possible if no LOW signal at PRIM_nERROR_IN is present anymore and if the TOP and BOT input signals are set to the LOW level for a period of $t_{pERRRESET}$ > 9µs.
The SDI function can be disabled by no connection or connecting to 5V.

Figure 11: SKYPER® 32 2nd edition | Connection SDI

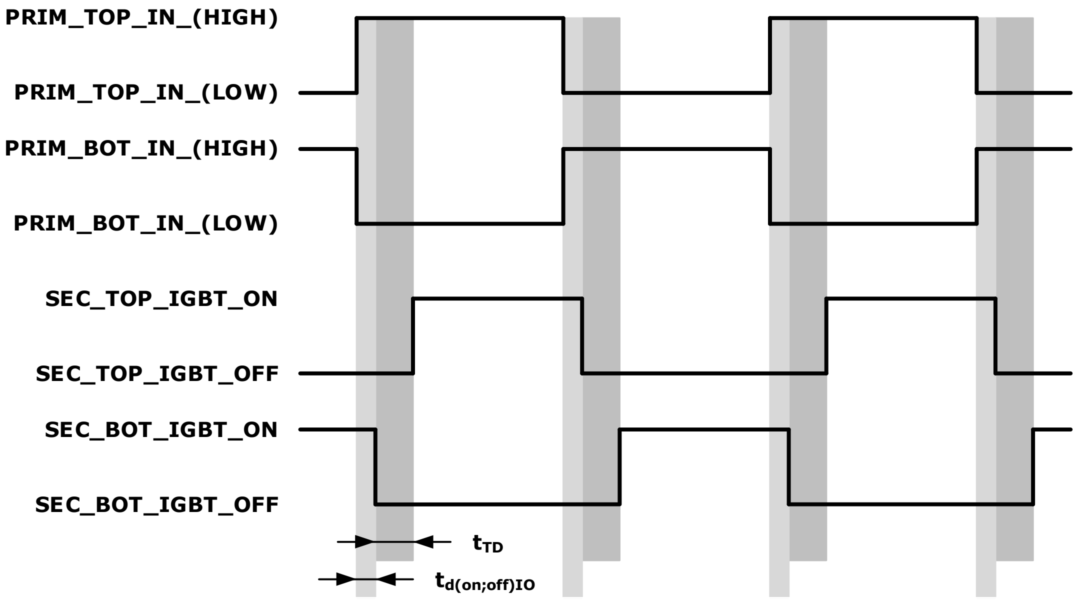


4.13 Dead time generation (Interlock TOP / BOT) (DT)

The DT circuit prevents, that TOP and BOT 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.

Please note:
The generated dead time is fixed and cannot be changed.

Figure 12: SKYPER® 32 2nd edition | 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). In case both channel inputs (PRIM_TOP_IN and PRIM_BOT_IN) are at high level, the IGBTs will be turned off. If only one channel is switching, there will be no interlock dead time.

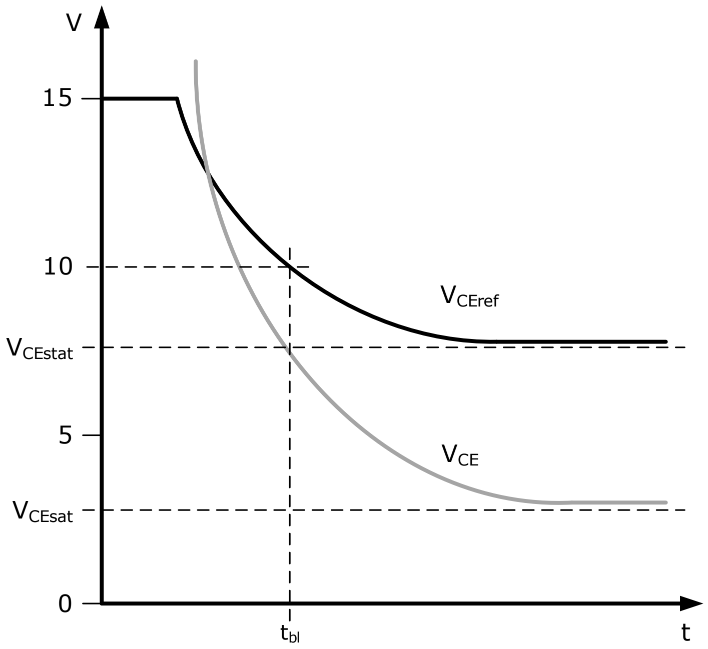
Please note:
No error message will be generated when overlap of switching signals occurs.

4.14 Dynamic short circuit protection by V_{CEsat} monitoring / de-saturation monitoring (DSCP)

The DSCP 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 DSCP circuit switches off the IGBTs and an error is indicated.

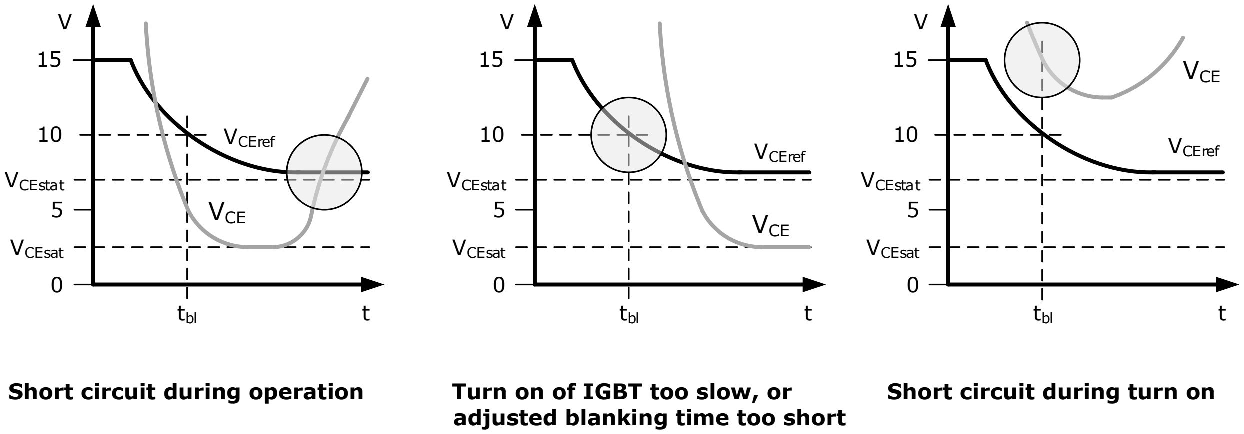
The reference voltage V_{CEref} may dynamically be adapted to the IGBTs switching behavior. Immediately after turn-on of the IGBT, a higher value is effective than in steady state. This value will, however, be reset, when the IGBT is turned off. V_{CEstat} is the steady-state value of V_{CEref} and is adjusted to the required maximum value for each IGBT by an external resistor R_{CE}. It may not exceed 10V. The time constant for the delay (exponential shape) of V_{CEref} may be controlled by an external capacitor C_{CE}, which is connected in parallel to R_{CE}. It controls the blanking time t_{bl} which passes after turn-on of the IGBT before the V_{CEsat} monitoring is activated. This makes an adaptation to a wide range of IGBT switching behavior possible.

Figure 13: SKYPER® 32 2nd edition | Reference voltage (V_{CEref}) characteristic



After t_{bl} has passed, the V_{CE} monitoring will be triggered as soon as $V_{CE} > V_{CEref}$ and will turn off the IGBT. The error memory will be set, and the output PRIM_ERROR_OUT changes to high impedance. Possible failure modes are shown in the following pictures.

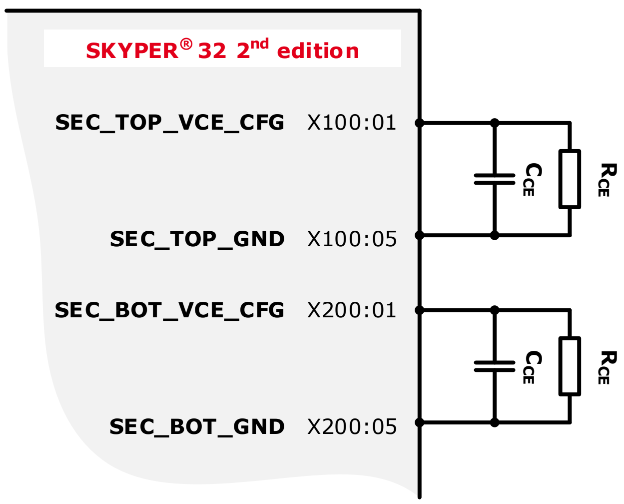
Figure 14: SKYPER® 32 2nd edition | Trigger conditions



4.14.1 Adjustment of DSCP

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

Figure 15: SKYPER® 32 2nd edition | Connection R_{CE} and C_{CE}



$$R_{CE}[k\Omega] = -17k\Omega \cdot \ln\left(1 - \frac{V_{CEstat} + R_{VCE} \cdot \frac{V}{k\Omega}}{8{,}5V}\right)$$

$$C_{CE}[pF] = \frac{t_{bl}[\mu s] - 2{,}5\mu s - 0{,}11\frac{\mu s}{k\Omega} \cdot R_{CE}}{0{,}00323\frac{\mu s}{pF}}$$

V_{CEstat}: Collector-emitter threshold static monitoring voltage
t_{blx}: Blanking time

V_{CEstat_max} = 8V (R_{VCE} = 0Ω)
V_{CEstat_max} = 7V (R_{VCE} = 1kΩ)

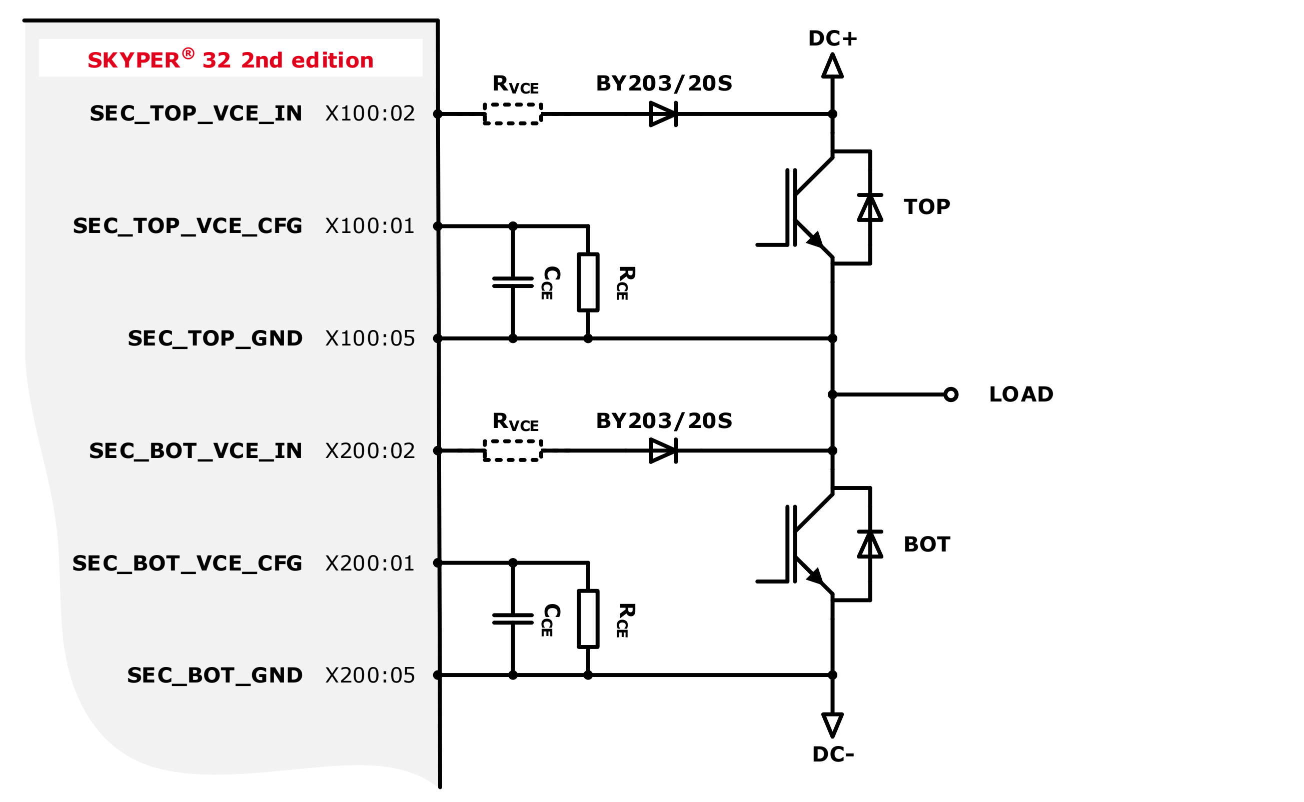
Please Note:
The equations are calculated considering the use of high voltage diode BY203/20S. The calculated values V_{CEstat} and t_{bl} are typical values at room temperature. These values can and do vary in the application (e.g. tolerances of used high voltage diode, resistor R_{CE}, capacitor C_{CE}).
The DSCP function is not recommended for over current protection.

Application hints
If the DSCP function is not used, for example during the experimental phase, SEC_TOP_VCE_IN must be connected with SEC_TOP_GND for disabling SCP @ TOP side and SEC_BOT_VCE_IN must be connected with SEC_BOT_GND for disabling SCP @ BOT side.

4.14.2 High voltage diode for DSCP

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.

Figure 16: SKYPER® 32 2nd edition | Connection high voltage diode



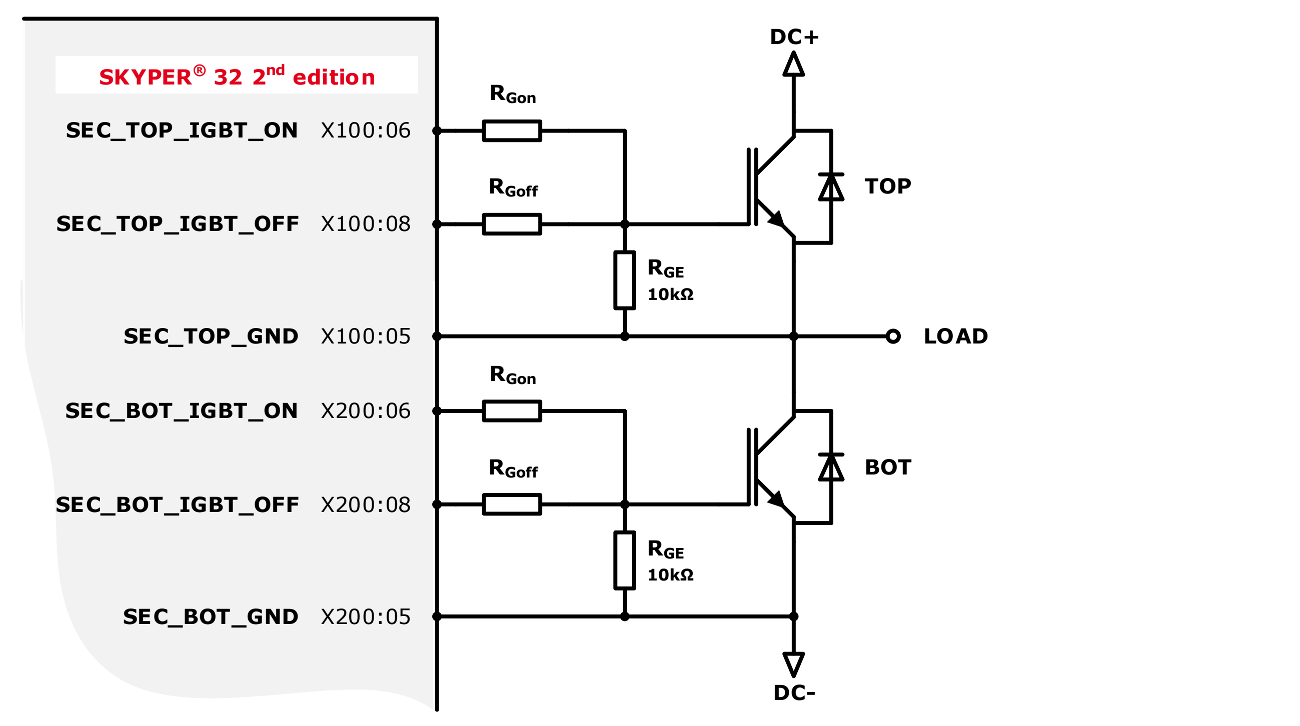
- Reverse blocking voltage of the diode shall be higher than the used IGBT.
- Reverse recovery time of the fast diode shall be lower than V_{CE} rising of the used IGBT.
- Forward voltage of the diode: 1.5V @ 2mA forward current (T_j=25°C).

A collector series resistance R_{VCE} (1kΩ / 0.4W) must be connected for 1700V IGBT operation.

4.15 Gate resistors

The output transistors of the driver are MOSFETs. The sources 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.

Figure 17: SKYPER® 32 2nd edition | Connection R_{Gon}, R_{Goff}



Application hints

The gate resistor influences the switching time, switching losses, dv/dt behavior, 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 behavior 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.

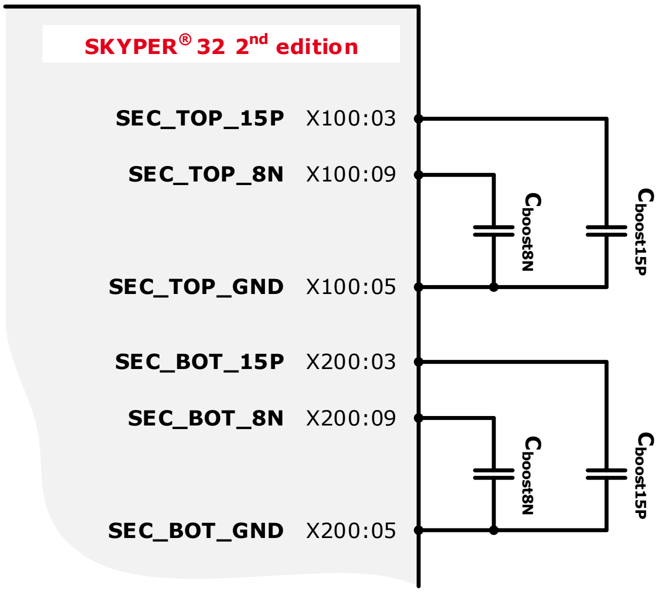
Please note:

Do not connect the terminals SEC_TOP_IGBT_ON with SEC_TOP_IGBT_OFF and SEC_BOT_IGBT_ON with SEC_BOT_IGBT_OFF, respectively.

4.16 External boost capacitors (BC)

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

Figure 18: SKYPER® 32 2nd edition | Connection external boost capacitors



- $C_{boost15P}$ [µF] = Q_{GE} [µC] × 1/V – 2.2µF
- $C_{boost8N}$ [µF] = Q_{GE} [µC] × 2/V – 4.7µF
- Q_{GE}: Gate charge of the IGBT @ VGE = -7 …+15V
- Minimum rated voltage $C_{boost15P}$: 25V
- Minimum rated voltage $C_{boost8N}$: 16V
- Type of capacitor: ceramic capacitor

Please consider the maximum specified rating of the 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 ensure a low inductance of the connection.

4.17 Application example

Figure 19: SKYPER® 32 2nd edition | Connection schematic | Primary side

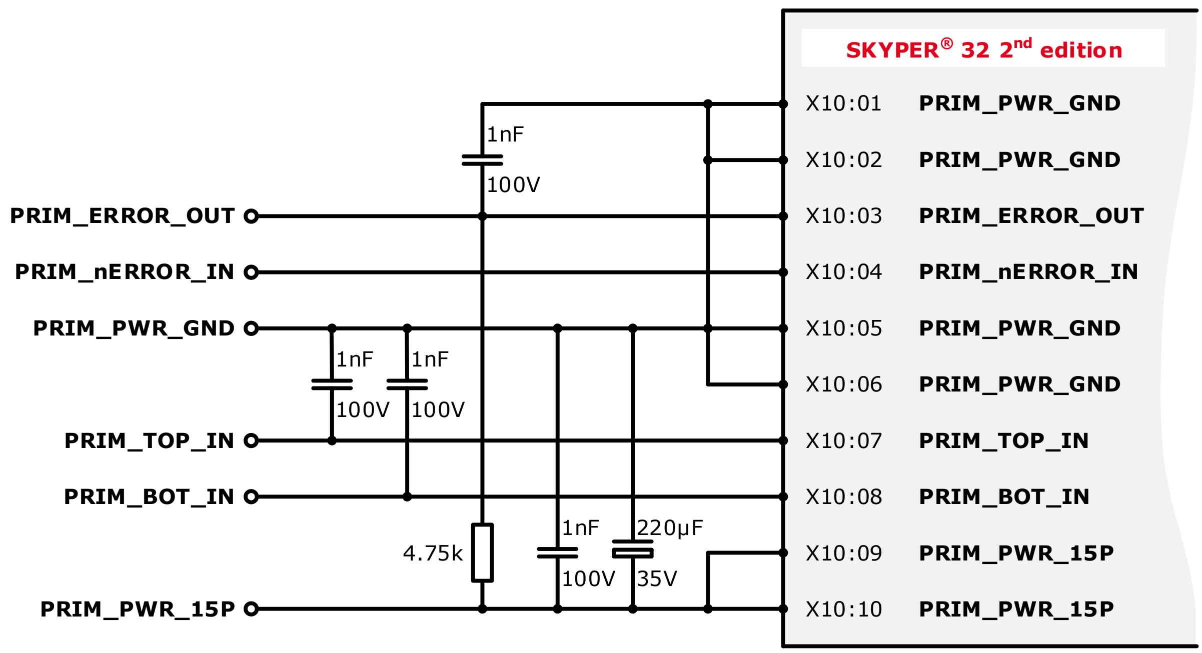
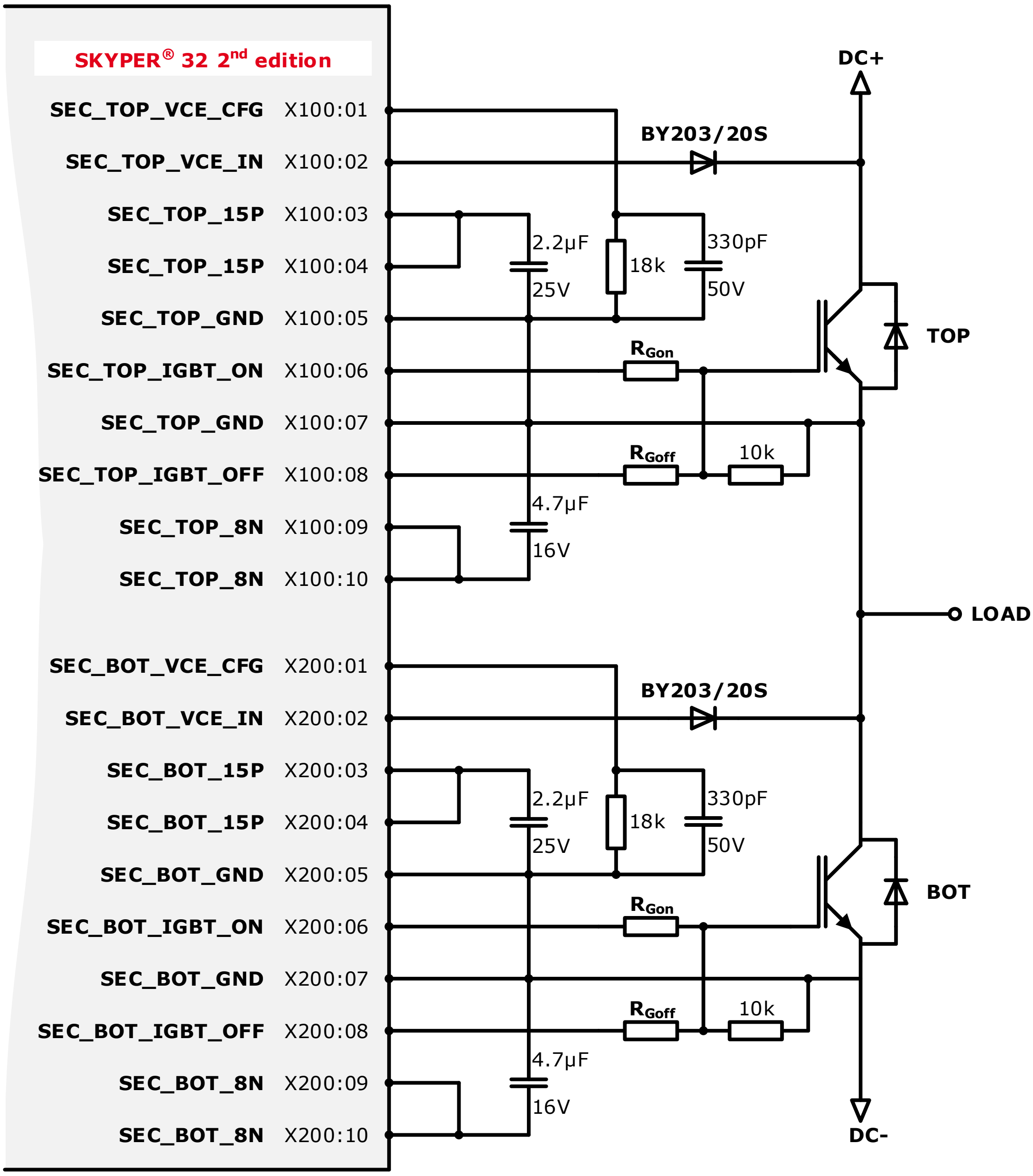


Figure 20: SKYPER® 32 2nd edition | Connection schematic | Secondary side



application example for 1200V IGBT; $Q_{out/pulse}$ = 5µC; V_{CEref} = 5.5V; t_{bl} = 5.5µs

5. Mounting notes

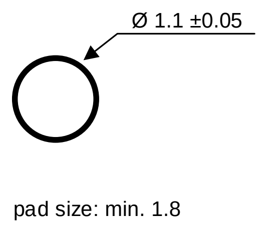
5.1.1 Soldering hints

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.

Figure 21: SKYPER® 32 2nd edition | Finished hole & pad size in mm

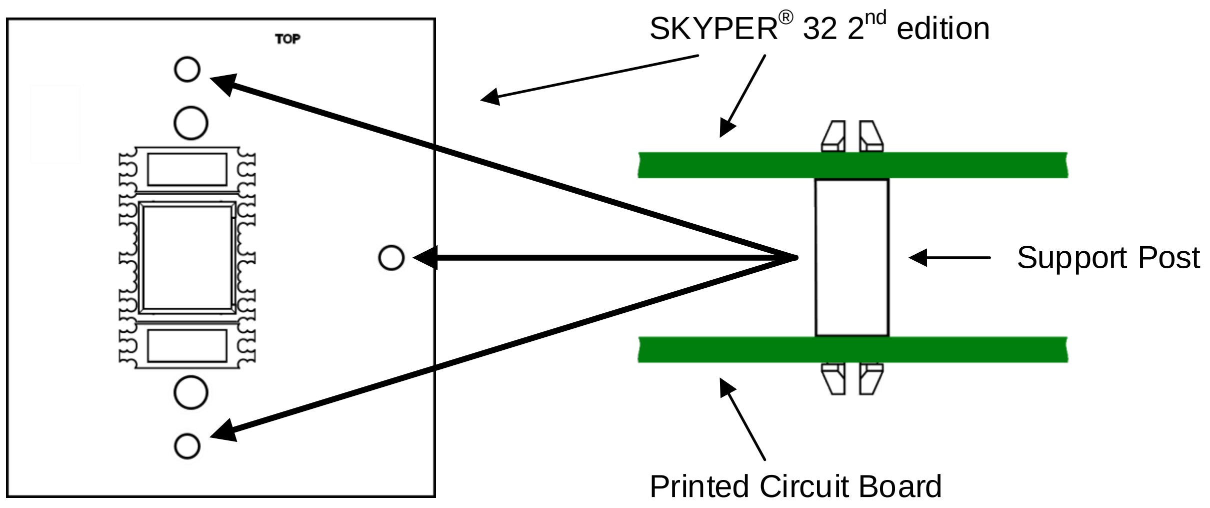


Please note:
The driver is not suited for hot air reflow or infrared reflow processes.

5.1.2 Support posts

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

Figure 22: SKYPER® 32 2nd edition | Use of support posts



Product information of suitable support posts and distributor contact information is available at e.g. https://www.essentracomponents.com (e.g. series DLMSPM, LCBST).

When using the support posts the support post length has to be longer than 12.4mm.

6. Environmental Conditions

The driver core is type tested under the environmental conditions below

Table 7: SKYPER® 32 2nd edition | Environmental conditions	
Conditions	**Values (max.)**
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, 5g, 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.

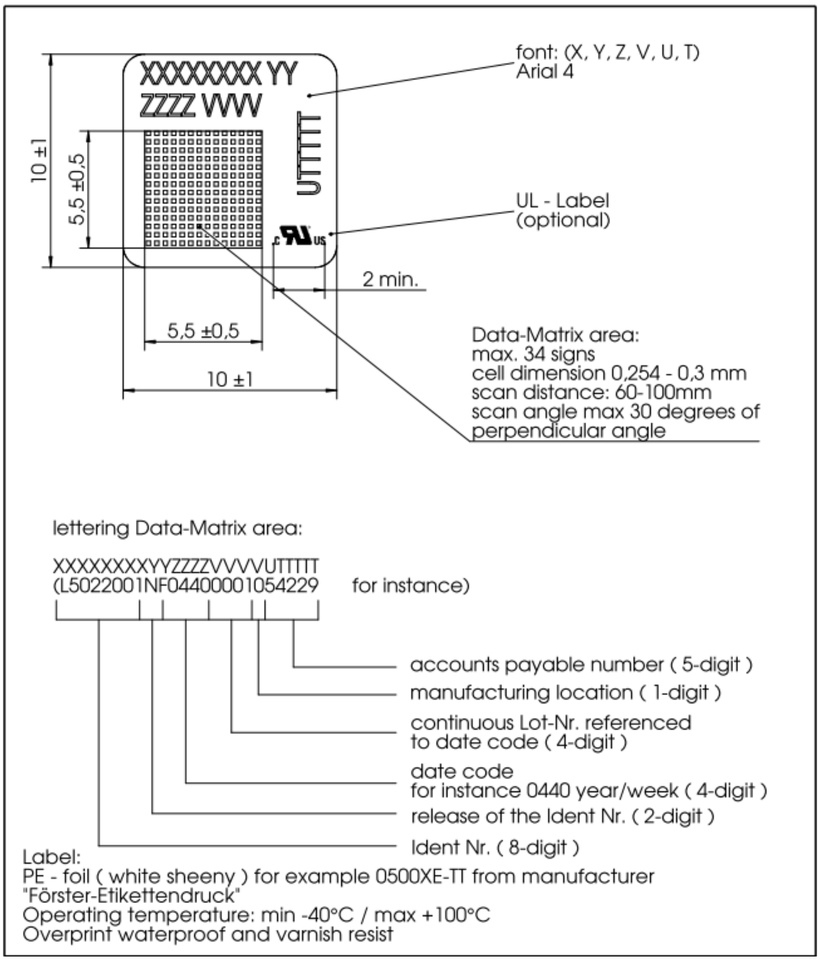
The characteristics and further environmental conditions are indicated in the data sheet.

Please note:
The use of aggressive materials in cleaning and potting process of driver core may be detrimental for the device parameters. If the driver core is coated by the user, any warranty (Gewährleistung) expires.

7. Marking

Every driver core is marked. The marking contains the items shown in figure 23.

Figure 23: SKYPER® 32 2nd edition | Marking



References

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IMPORTANT INFORMATION AND WARNINGS

SEMIKRON INTERNATIONAL GmbH
Sigmundstrasse 200, 90431 Nuremberg, Germany
Tel: +49 911 6559 6663, Fax: +49 911 6559 262
sales@semikron.com, www.semikron.com