# Technical Explanation
# SKYPER®
# 12 PF

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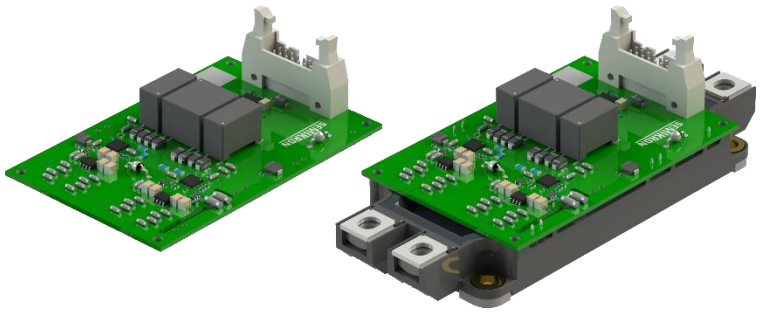
Keyword: IGBT Driver, SKYPER, Press-fit, SEMiX press-fit

## 1. Introduction

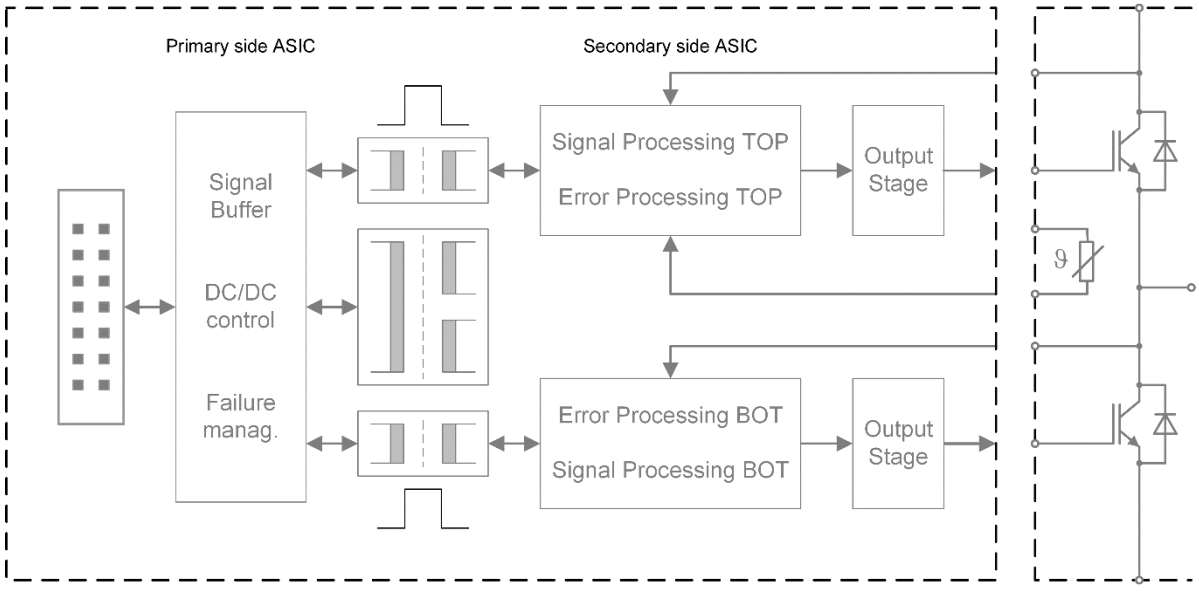
The SKYPER® 12 PF drivers family are dedicated for SEMIX press-fit and EconoDUAL press-fit modules. The half bridge driver can be mounted directly onto 17mm press-fit DUAL modules. With 30% fewer components than available plug & play solutions, the driver achieves a MTBF (Mean Time Between Failures as per SN 29500) rate of 7.5 million hours at full load.
With the 1W power supply per channel the SKYPER® 12 PF can drive semiconductors of up to 600 Ampere and 1700V rating. For further details and precautions please read carefully this document.

**Figure 1: SKYPER® 12 PF**



- Fits to 1200V & 1700V modules
- Drives EconoDUAL and SEMiX press-fit modules
- Qualified Safe Operating Area ensures best performance
- Safe short circuit handling over the entire temperature range
- Available with SEMIKRON and second source compatible interface
- Robust rectangle signal transmission
- Two output channels
- Highest noise immunity with short pulse suppression and EMC robust interface
- Insulated over temperature trip on secondary side
- Under voltage lockout (UVLO) employed on primary and secondary side
- Dynamic Short Circuit Protection (DSCP) by VCE monitoring and direct SoftOff
- Integrated isolated power supply for the secondary side
- 1W output power per channel
- Up to 8 µC gate charge
- MTBF rate > 7.5 Million hours

**Figure 2: SKYPER® 12 PF | Block Diagram**

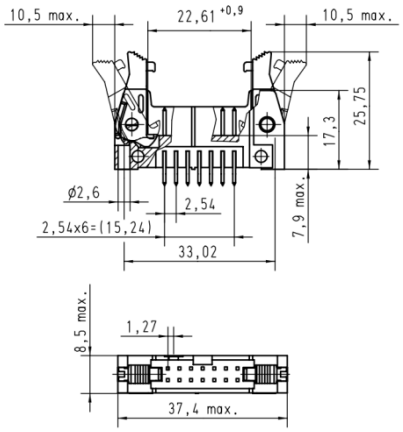


# 2. Driver interface

## 2.1 Controller interface

### 2.1.1 SEMIKRON interface – 14P primary side pinning – L50666xx

**Figure 3: Connector X10 (Harting DIN 41651 – 14 P)**




Product information of suitable female connectors and distributor contact information is available at e.g. http://www.harting.com (part number 09 18 514 7 904).

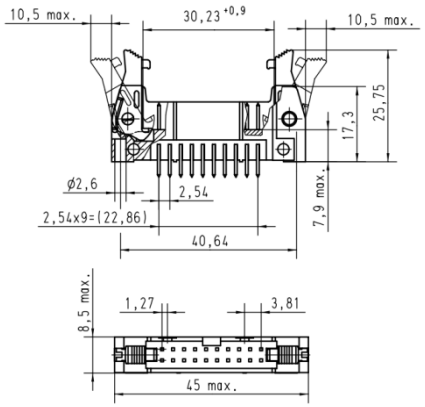
**Table 1: SKYPER® 12 PF | Interface**

| Pin | Signal | Function | Specification |
|---|---|---|---|
| X10:01 | reserved | | To be connected to ground |
| X10:02 | BOT_IN | Switching signal input (BOT) | 15V logic; 33kΩ/1nF (pull-down)<br>LOW = BOT switch off<br>HIGH = BOT switch on |
| X10:03 | nERR_OUT | Error output | Open Collector output; max. 18V/15mA (external pull-up resistor needed)<br>LOW = Error<br>HIGH = No error |
| X10:04 | TOP_IN | Switching signal input (TOP) | 15V logic; 33kΩ/1nF (pull-down)<br>LOW = TOP switch off<br>HIGH = TOP switch on |
| X10:05 | nERR_IN | Error input | 15V logic inverted; 150kΩ/10nF (pull-up)<br>LOW = External error<br>HIGH = No external error |
| X10:06 | reserved | | To be connected to ground |
| X10:07 | reserved | | To be connected to ground |
| X10:08 | PWR_VS | Driver power supply | Stabilised +15V ±4% |
| X10:09 | PWR_VS | Driver power supply | Stabilised +15V ±4% |
| X10:10 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |

| Pin | Signal | Function | Specification |
|---|---|---|---|
| X10:11 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |
| X10:12 | reserved | | To be connected to ground |
| X10:13 | reserved | | To be connected to ground |
| X10:14 | reserved | | To be connected to ground |

### 2.1.2 Second source compatible interface – 20P primary side pinning – L50669xx

**Figure 4: Connector X10 (Harting DIN 41651 – 20 P)**




Product information of suitable female connectors and distributor contact information is available at e.g. http://www.harting.com (part number 09 18 520 7 904).

**Table 2: SKYPER® 12 PF | Interface**

| Pin | Signal | Function | Specification |
|---|---|---|---|
| X10:01 | reserved | | Open pin |
| X10:02 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |
| X10:03 | reserved | | Open pin |
| X10:04 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |
| X10:05 | PWR_VS | Driver power supply | Stabilised +15V ±4% |
| X10:06 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |
| X10:07 | nERR_IN | Error input | 15V logic inverted; 150kΩ/10nF (pull-up)<br>LOW = External error<br>HIGH = No external error |

| Pin | Signal | Function | Specification |
|---|---|---|---|
| X10:08 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |
| X10:09 | nERR_OUT | Error output | Open Collector output; max. 18V/15mA (external pull-up resistor needed)<br>LOW = Error<br>HIGH = No error |
| X10:10 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |
| X10:11 | TOP_IN | Switching signal input (TOP) | 15V logic; 33kΩ/1nF (pull-down)<br>LOW = TOP switch off<br>HIGH = TOP switch on |
| X10:12 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |
| X10:13 | nERR_OUT | Error output | Open collector output; max. 18V/15mA (external pull-up resistor needed)<br>LOW = Error<br>HIGH = No error |
| X10:14 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |
| X10:15 | BOT_IN | Switching signal input (BOT) | 15V logic; 33kΩ/1nF (pull-down)<br>LOW = BOT switch off<br>HIGH = BOT switch on |
| X10:16 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |
| X10:17 | reserved | | Open pin |
| X10:18 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |
| X10:19 | reserved | | Open pin |
| X10:20 | PWR_GND | Ground potential for power supply and digital signals | To be connected to ground |

# 3. Protection features

## 3.1 Failure management

The SKYPER® 12 PF detects under voltages on primary and secondary side, short circuit and over temperature as fault conditions. Any error detected will force the output nERR_OUT to low level. The driver's output stages will be set to low level. The input side switching signals of the driver will be ignored in this condition. Both input signals have to be set to low level for at least 9µs to reset the nERR_OUT and to resume normal operation.

The following errors are indicated by the fault output
- Under supply voltage primary side
- Under supply voltage secondary side
- Short circuit with SoftOff
- Over temperature lockout

## 3.2 Adjustable dead time generation (Interlock TOP / BOT )

The internal dead time control of the SKYPER® 12 PF is set to 2µs. The dead time circuit prevents, that both TOP and BOT semiconductors of the same half bridge can be erroneously activated simultaneously (arm shoot through) for this predefined minimum time, which for the final application might nevertheless not be enough. This minimum dead time is realised in the mixed signal ASIC and it is not added to a dead time provided by the controller that might generate deadtimes higher than the minimum one depending on the application. The highest dead time, e.g. either the internally generated one or the µC generated one will dominate.

Example:

**Table 3: SKYPER® 12 PF | Dead time generation**

| | Controller dead time | SKYPER dead time | Total dead time |
|---|---|---|---|
| Controller > driver | 4µs | 2µs | 4µs |
| Controller < driver | 1µs | 2µs | 2µs |
| Controller no dead time | No dead time | 2µs | 2µs |

It is possible to control the driver with one switching signal and its inverted signal if the provided internal dead time of the SKYPER® 12 PF is sufficient for the application. No error signal will be generated when signals are overlapped.

## 3.3 Short pulse suppression (SPS)

The SKYPER's driver circuit suppresses short turn-on and off-pulses of incoming signals. This way the semiconductors are protected against spurious noise as they can occur due to bursts on the signal lines. Short or high noise pulses do not affect the driver on the controller side. The digital SPS is set to 390ns.

## 3.4 SoftOff

In in case of a detection of a secondary side error like a short circuit, the SoftOff feature increases the resistance in series with $R_{G(off)}$ and, hence, reduces the turn-off speed of the semiconductor. The reduced di/dt reduces the voltage spike across the IGBT's Collector and Emitter terminals in this short circuit case.

### 3.5 Dynamic short circuit protection by $V_{CE}$-monitoring (DSCP)

The DSCP monitors the Collector-Emitter voltage $V_{CE}$ of the semiconductor during its on-state. During the transient process at turn-on of the semiconductor, typically a higher value of the $V_{CE}$ is effective than in steady state, e.g. after the semiconductor is fully saturated. The dynamic short circuit protection circuitry as shown in bellows figure creates internally a reference signal as time varying $V_{CE}$ detection threshold that widely follows a typical saturation behavior of a bipolar semiconductor and, hence, provides a time depending short circuit protection level.

**Figure 5: SKYPER® 12 PF | Reference voltage ($V_{CEref}$ ) characteristic**

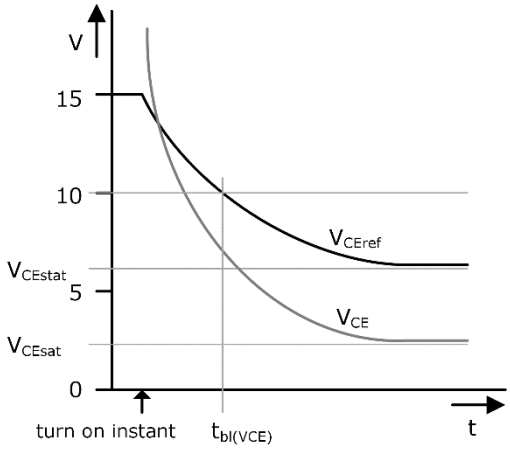



Figure 5 indicates that this short circuit protection operates in conjunction with the blanking time $t_{bl(VCE)}$ which blanks the high saturation voltages in the very early stage of the semiconductor's turn-on stage. After this blanking time $t_{bl(VCE)}$ has passed, the $V_{CE}$-monitoring will be triggered as soon as $V_{CE} > V_{CEref}$ and will turn off the semiconductor.

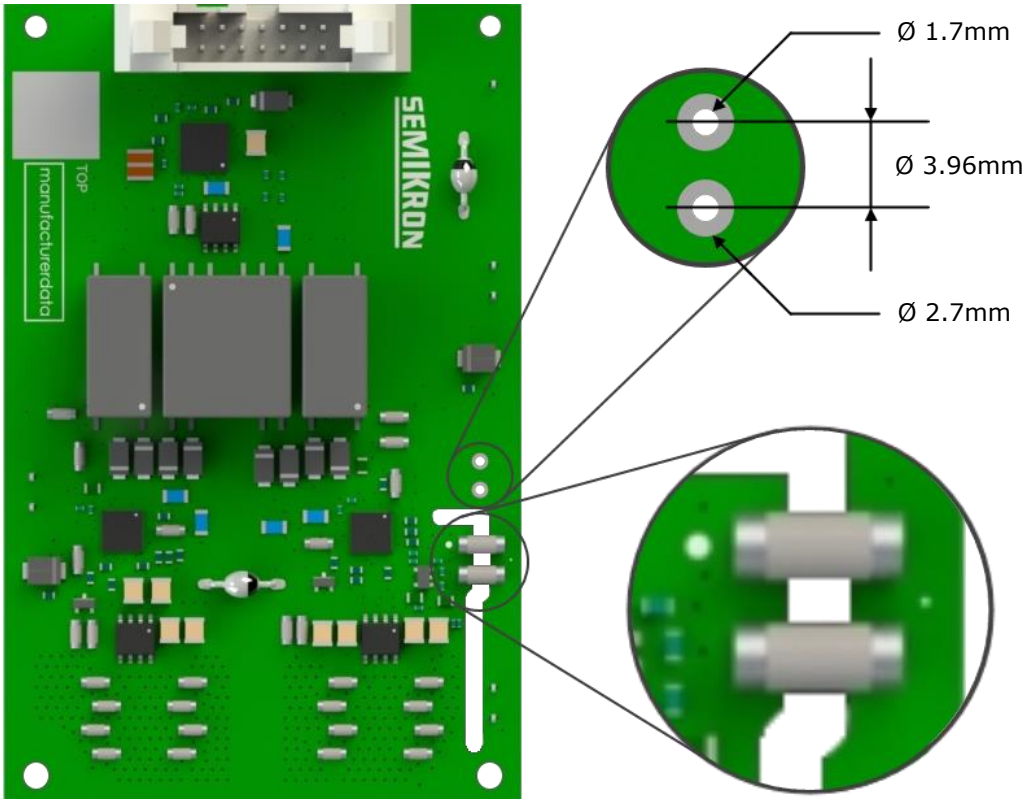
### 3.6 Over temperature lockout

The SKYPER® 12 PF driver offers an over temperature lockout feature which sets both driver output stages to $V_{G(off)}$ and ignores the switching signals on primary side as long as the electrical resistance of the applied temperature sensor is less than the specified over temperature lockout resistance value $R_{OTLO}$ (the value of $R_{OTLO}$ is given in the corresponding datasheet). In addition to the locked outputs, the driver's primary side reports an error at the nERR_OUT pin(s). This status is latched as long as the resistance of the temperature sensor is less than $R_{OTLO}$ and both switching signals have not been set to low state for at least 9µs initiating the reset of the SKYPER® 12 PF and allow resuming to normal operation. The over temperature lockout feature is designed for temperature sensors with an NTC resistor characteristic.

The lockout feature can be deactivated by removal of both populated zero-ohm jumpers, shown in Figure 6. If both jumpers are removed the module's temperature sensor's resistance can be acquired directly via the temperature sensor pads, also shown in Figure 6. The pads are foreseen for an industrial standard two pin terminal connector with 3.96mm pitch.

For proper and safe monitoring of the module's temperature sensor the corresponding datasheets and technical documentation must be read carefully. Especially the part describing the insulation of the temperature sensor needs an expert's assessment for safety reasons. It also has to be taken into account that populating a connector on the PCB, e.g. for a direct evaluation of the temperature sensor's resistance, may affect the driver's clearance and creepage distances.

**Figure 6: SKYPER® 12 PF | Over temperature lockout zero-ohm jumper**



## 4. Environmental Conditions

| Table 4: SKYPER® 12 PF \| Environmental Conditions | | |
|---|---|---|
| **Insulation parameters** | **Rating** | **Norm / Standard** |
| Grid voltage | 600V (480V by definition) | IEC 61800-5-1 |
| Pollution Degree | PD II | IEC 61800-5-1 |
| Maximum altitude | 2000 meter above sea | IEC 61800-5-1 |
| Overvoltage category | OVC III | IEC 61800-5-1 |
| Dielectric voltage withstand | 4000V AC rms, 60s | IEC 61800-5-1 |
| Impulse withstand voltage | 8kV Cat. III | IEC 60664-1 |
| Partial discharge | 1.86kV/1.49kV | IEC 61800-5-1 |
| Creepage/clearance distance, primary/secondary side | ≥12.2mm/≥12.2mm (CTI≥175) | IEC 61800-5-1 |
| Creepage/clearance distance, secondary/secondary side | ≥6.1mm/≥6.1mm (CTI≥175) | IEC 61800-5-1 |
| Creepage/clearance distance, temperature sensor/secondary side | ≥6.1mm/≥3.1mm (CTI≥175) | IEC 61800-5-1 |
| **Climate** | **Rating** | **Norm / Standard** |
| Climate class | 3K3 | IEC 60721-3-3 |
| Environmental conditions | Rating | Norm / Standard |
| Operating temperature | -40... +85 °C | |
| Storage temperature | -40... +85 °C | |
| Flammability | Heavy flammable materials only | UL94 V0 |
| Thermal Cycling | 500 cycles a 1h -40°C - 85°C | IEC 60068-2-14 |
| | | RoHS / WEEE / China RoHS |

| EMC Condition | Rating | Norm / Standard |
|---|---|---|
| ESD | 6 kV contact discharge /<br>8 kV air discharge | IEC 61000-4-2<br>IEC 61800-3 |
| Burst | ≥ 2kV for signal line<br>≥ 4kV for AC lines | IEC 61000-4-4<br>IEC 61800-3 |
| Immunity against external interference | ≥ 30V/m<br>80MHz – 1000 MHz | IEC 61000-4-3<br>IEC 61800-3 |
| Immunity against conducted interference | ≥ 20V<br>150kHz – 80MHz | IEC 61000-4-6<br>IEC 61800-3 |
| **Shock Vibration** | **Rating** | **Norm / Standard** |
| Vibration | Sinusoidal 20Hz … 500Hz, 5g, 2h per axis<br>Random 10Hz … 2000Hz, 1g, 2h per axis | IEC 60068-2-6 |
| Shock | 200 shocks (6 axis), 20g, 11ms | IEC 60068-2-27 |

## Symbols and Terms

| Letter Symbol | Term |
|---|---|
| ASIC | Application Specific Integrated Circuit |
| DSCP | Dynamic short circuit protection |
| IGBT | Insulated Gate Bipolar Transistor |
| MTBF | Mean time between failures |
| NTC | Negative temperature coefficient |
| $R_{G(off)}$ | Turn-off gate resistor |
| $R_{OTLO}$ | Threshold value for over temperature lookout |
| SPS | Short pulse suppression |
| $t_{bl(VCE)}$ | Blanking time for $V_{CE}$-monitoring |
| UVLO | Under voltage lockout |
| $V_{CE}$ | Collector-emitter voltage (IGBT) |
| $V_{CEref}$ | Reference voltage for $V_{CE}$-monitoring |
| $V_{CEsat}$ | Collector-emitter saturation voltage |
| $V_{CEstat}$ | Static threshold voltage for collector-emitter voltage monitoring |
| $V_{G(off)}$ | Turn-off gate voltage level |

A detailed explanation of the terms and symbols can be found in the "Application Manual Power Semiconductors" [2]

## References


[1] www.SEMIKRON.com

[2] A. Wintrich, U. Nicolai, W. Tursky, T. Reimann, “Application Manual Power Semiconductors”, 2nd edition, ISLE Verlag 2015, ISBN 978-3-938843-83-3


## IMPORTANT INFORMATION AND WARNINGS

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