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Technical Explanation SKYPER® 12

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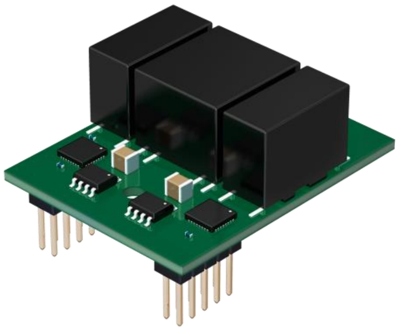
Keyword: IGBT Driver

1. Introduction

The SKYPER12R is an IGBT driver core for all IGBT modules in the range of 80A to 400A like MiniSKiiP Dual, SEMIX5 or SEMIX press-fit. The half bridge driver can be plugged or soldered with an adapter board on each module easily. With 30% fewer components than standard solutions, the driver achieves an MTBF (mean time between failures as per SN 29500) rate of over 8 million hours at full load.

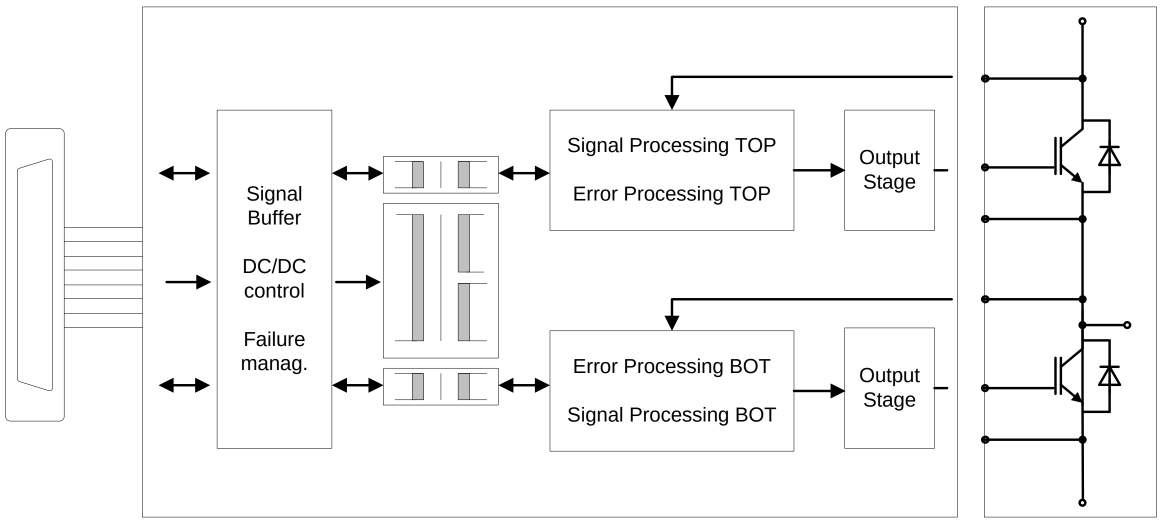
With 1W per channel SKYPER12R can drive IGBTs up to 400 Ampere and 1700V.

Figure 1: SKYPER 12® R



- Fits to 600V, 1200V & 1700V modules
- Robust rectangle signal transmission
- Two output channels
- Adjustable dead time
- Adjustable filter time
- Active clamping
- MLI ready
- Highest noise immunity with short pulse suppression
- Secondary side error input for insulated over temperature trip
- Under voltage protection (UVP) primary and secondary
- Dynamic Short Circuit Protection (DSCP) by VCE monitoring and direct SoftOff
- Fast mode detection for short circuits
- Integrated isolated power supply for the secondary side
- 1W output power per channel

Figure 2: Block diagram of SKYPER®12R



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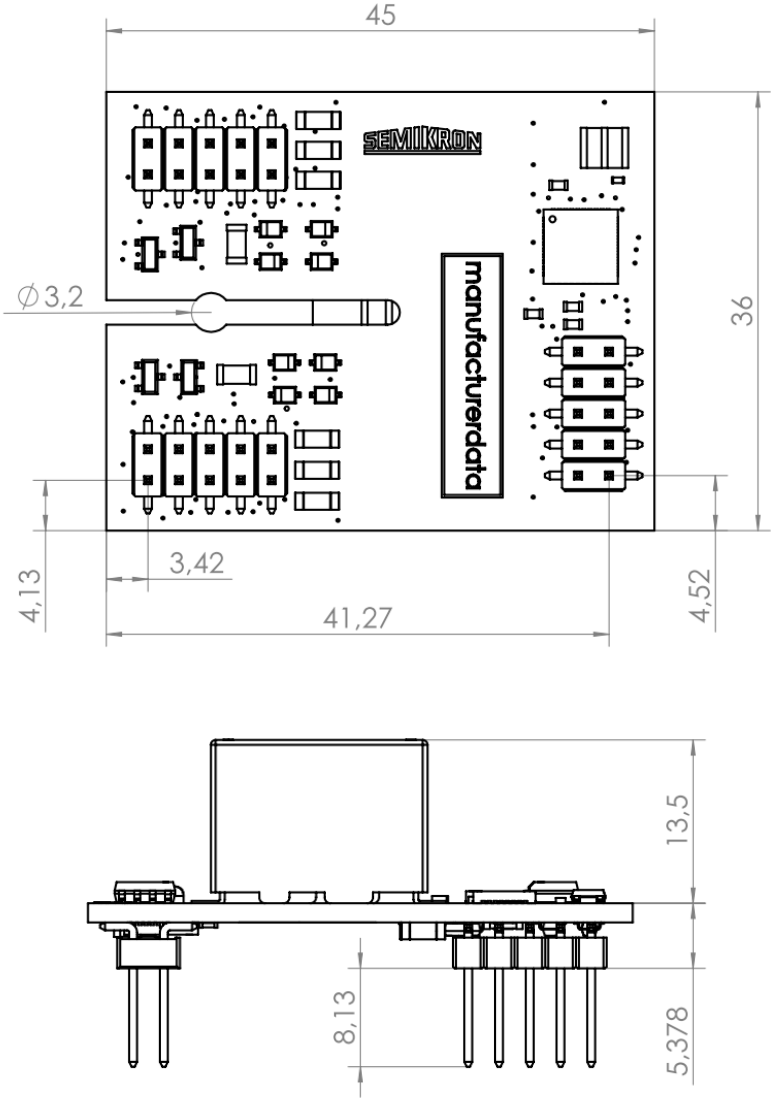
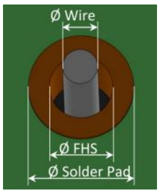
2. Mechanical information

2.1 Dimensions

Figure 3: Dimensions





If driver is soldered into adapter PCB:

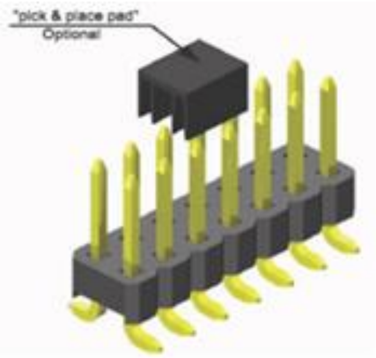
Ø Solder Pad: 1,9 mm

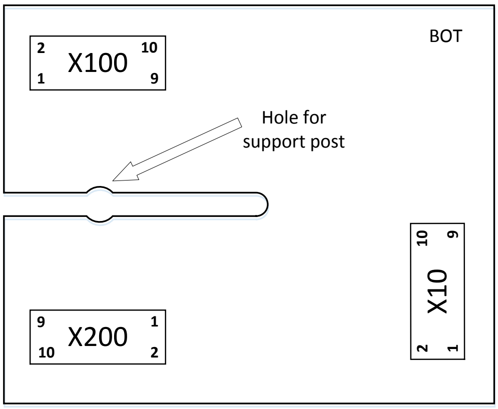
Ø FHS: 1,3 mm

Step files are available on request.

2.2 Connector

Figure 4: Connector X10, X100, X200 (male RM2.54 10p)





Product information of suitable female connectors and distributor contact information:
www.suyin-europe.com with order number 254303MA010S512ZR or
E-TEC with order number SS2-010-H140/09-55A PCB_Pin Header - 2.54mm - SSx - SMT standard

The driver can additionally be fixed on the user board by a support post.

Figure 5: Support post

Description: Nylon support post

Shape: Dual lock

Manufacturer: Richco

Art. No.: DLMSPM-8-01

If the driver is soldered, no reflow soldering should be applied but wave or selective soldering. To avoid overlapping of the pins, a support post on the connectors can be used.

3. Driver interface

3.1 Controller interface - primary side

PIN	Signal	Function	Specification
X10:01	PWR_GND	Ground	To be connected to ground (GND)
X10:02	CFG_SELECT	Interlock set up	HIGH (VP) = No interlock LOW (GND) = Interlock 2μs
X10:03	nERROR_OUT	Error output	LOW (GND) = Error HIGH (Open Drain) = No error Max 18V/10mA
X10:04	nERROR_IN	Error input	LOW (GND) = External error HIGH (VP) = No error 150kΩ impedance/ 15V
X10:05	MLI_SLCT	Error switch off setting for MLI configuration	LOW (GND) = Driver switches off on error HIGH (VP) = No switch off, just error indication
X10:06	FILTER_SLCT	Filter time set up	LOW (GND) = Analog filter HIGH (VP) = Digital filter
X10:07	TOP_IN	TOP Switching signal input	Digital 15V/ 0V LOW = TOP switches off HIGH = TOP switches on 33kΩ impedance/15V
X10:08	BOT_IN	BOT Switching signal input	Digital 15 V/ 0V LOW = BOT switches off HIGH = BOT switches on 33kΩ impedance/15V
X10:09	PWR_15P	Drive core power supply	Stabilized +15V ±3% (VP)
X10:10	PWR_15P	Drive core power supply	Stabilized +15V ±3% (VP)

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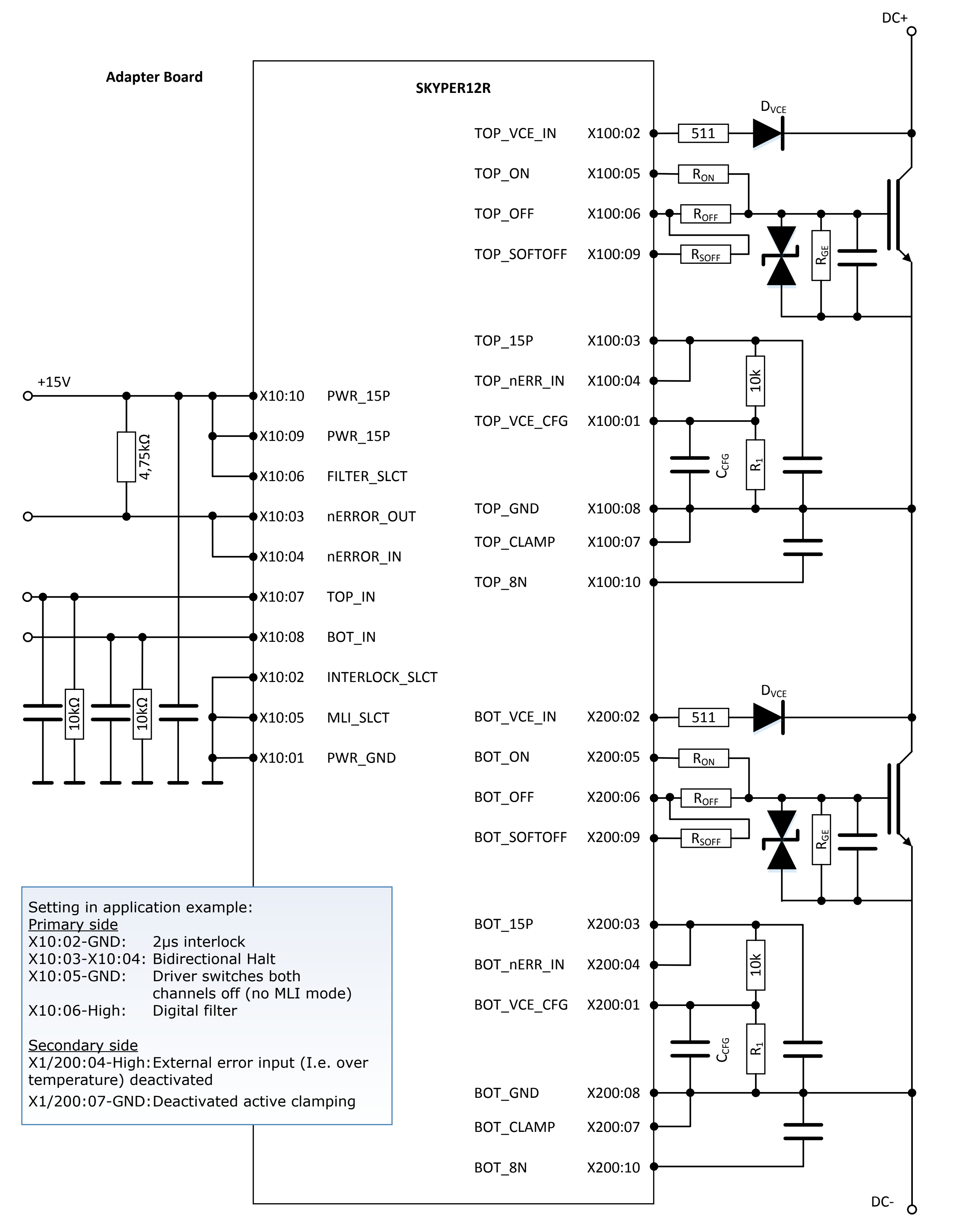
3.2 Module interface – secondary side

PIN	Signal	Function	Specification
TOP IGBT side			
X100:01	TOP_VCE_CFG	V_{CE} reference	Input reference voltage adjustment
X100:02	TOP_VCE_IN	Input V_{CE} monitoring	External blocking diode necessary
X100:03	TOP_15P	Output power supply	Stabilised +15V / max. 10mA[1] External buffer caps can be connected
X100:04	TOP_nERR_IN	External error input	15V logic input; LOW = ERROR; 150kOhm impedance/15V
X100:05	TOP_ON	On signal path to TOP IGBT	Connection to R_{On}
X100:06	TOP_OFF	Off signal path to TOP IGBT	Connection to R_{Off}
X100:07	TOP_CLMP	Over voltage TOP	High (VP) = active clamp Low (GND) = deactivated active clamp 150kOhm impedance/15V
X100:08	TOP_GND	GND for ps and digital signals	Emitter Potential
X100:09	TOP_SOFTOFF	SoftOff signal path to TOP IGBT	Connection to $R_{SoftOff}$
X100:10	TOP_8N	Output power supply	Stabilised -8V / max. 10mA[1] External buffer caps can be connected
BOT IGBT side			
X200:01	BOT_VCE_CFG	V_{CE} reference	Input reference voltage adjustment
X200:02	BOT_VCE_IN	Input V_{CE} monitoring	External blocking diode necessary
X200:03	BOT_15P	Output power supply	Stabilised +15V / max. 10mA[1] External buffer caps can be connected
X200:04	BOT_nERR_IN	External error input	15V logic input; LOW = ERROR; 150kOhm impedance/15V
X200:05	BOT_ON	On signal path to BOT IGBT	Connection to R_{On}
X200:06	BOT_OFF	Off signal path to BOT IGBT	Connection to R_{Off}
X200:07	BOT_CLMP	Over voltage BOT	High (VP) = active clamp Low (GND) = deactivated active clamp 150kOhm impedance/15V
X200:08	BOT_GND	GND for ps and digital signals	Emitter Potential
X200:09	BOT_SOFTOFF	SoftOff signal path to BOT IGBT	Connection to $R_{SoftOff}$
X200:10	BOT_8N	Output power supply	Stabilised -8V / max. 10mA[1] External buffer caps can be connected

[1] If symmetric load is applied. For unsymmetrical load -> 2mA.

3.3 Application example

Figure 6: Application specific wiring



Setting in application example:
Primary side
X10:02-GND: 2µs interlock
X10:03-X10:04: Bidirectional Halt
X10:05-GND: Driver switches both channels off (no MLI mode)
X10:06-High: Digital filter

Secondary side
X1/200:04-High: External error input (I.e. over temperature) deactivated
X1/200:07-GND: Deactivated active clamping

3.4 Power supply – primary

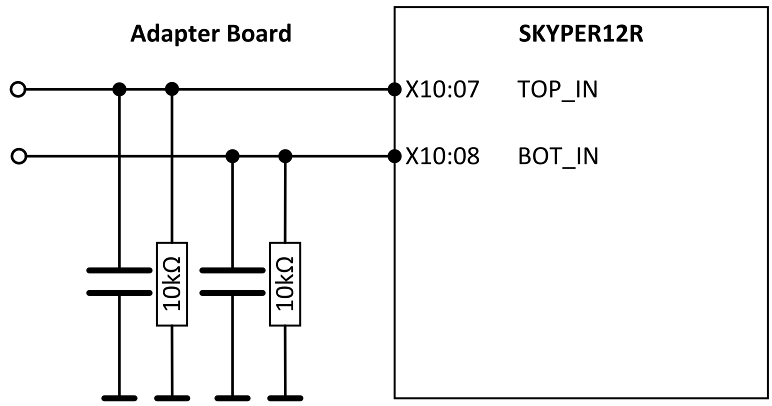
The customer power supply should deliver the 15V input and should be rated according the required maximum supply current in the application. During power on reset no switching signals should be applied, otherwise the driver will not leave error state.

Buffer for primary side power supply:
Please consider that the buffer capacitors on the primary side power supply have to be calculated according to the secondary side buffer capacitors. Example: 10µF (=2,5µC) secondary side buffer capacitors, require a 10µF buffer capacitance on the 15V supply input. Details chapter 3.11.

3.5 Switching signals – primary

The inputs have schmitt trigger characteristic (HIGH = IGBT on; LOW = IGBT off).
It is mandatory to use circuits which switch active to +15V and 0V. The duty cycle of the driver can be adjusted between 0 – 100%. It is forbidden to apply switching pulses shorter than 1µs.

Figure 7: TOP and BOT inputs



A capacitor should be connected to the inputs to obtain high noise immunity. For current limited line drivers this capacitor can cause a neglectable delay of a few ns. The capacitors have to be placed as close as possible to the driver interface. In addition a small series resistor can be added for even higher robustness with the consequence of a longer delay time.

Parameter	Min	Typ	Max
Threshold high	-	-	10V
Threshold low	5V	-	-

3.6 Error output – primary

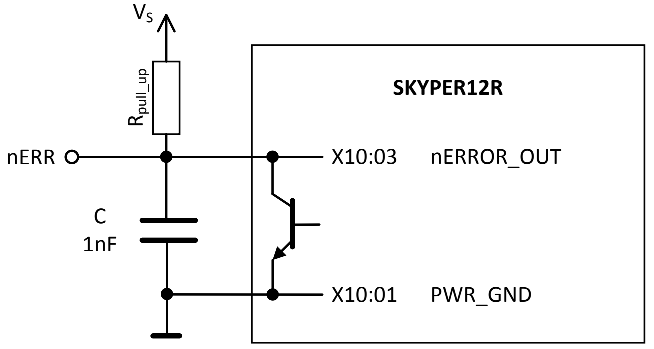
The error output nERROR_OUT is low active and any error will force it into low state. The error state will be active for at least 30µs. For detailed error management please see chapter 4.1 Failure management.

The pin is an open collector output, that requires an external pull-up-resistor. This gives the opportunity that, when error in- and outputs are connected together, multiple drivers can share one error line. In this case one driver, that enters error mode, directly switches of the parallel drivers (see Figure 9).

Figure 8: Error output

- The pull up resistor has to be in the range of VP / I_{max} < R_{pull_up} < 10kΩ.
- To reset the TOP/BOT signals must be set to low for $t_{pERRRESET}$ > 9µs
- nERROR_OUT can operate at 16V can switch a maximum of 10mA.

Important: A pull up resistor must be used!

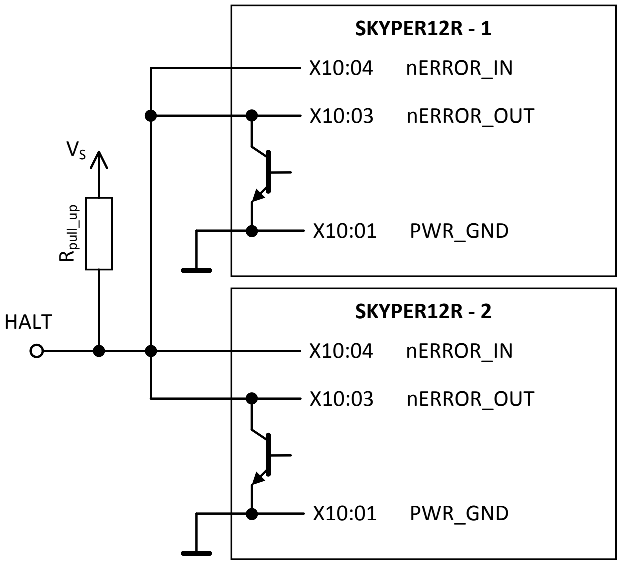


Parameter	Min	Typ	Max
Input Current	-	-	10mA
Voltage @10mA and error active	-	-	0,3V

3.7 Error input – primary

The nERROR_IN pin is low active and allows external deactivation of the driver i.e. by connecting a monitoring circuit. The pin can also be connected to nERROR_OUT to have a **bidirectional error (=HALT).**

Figure 9: Example for bidirectional error with two drivers



Parameter	Min	Typ	Max
Threshold high	-	-	11 V
Threshold low	7,5 V	-	-

3.8 MLI error mode - primary

The error behavior of the driver can be changed via pin MLI_SLCT.

MLI_SLCT = low (default)
The driver switches off any error and indicates the error state at nERROR_OUT.

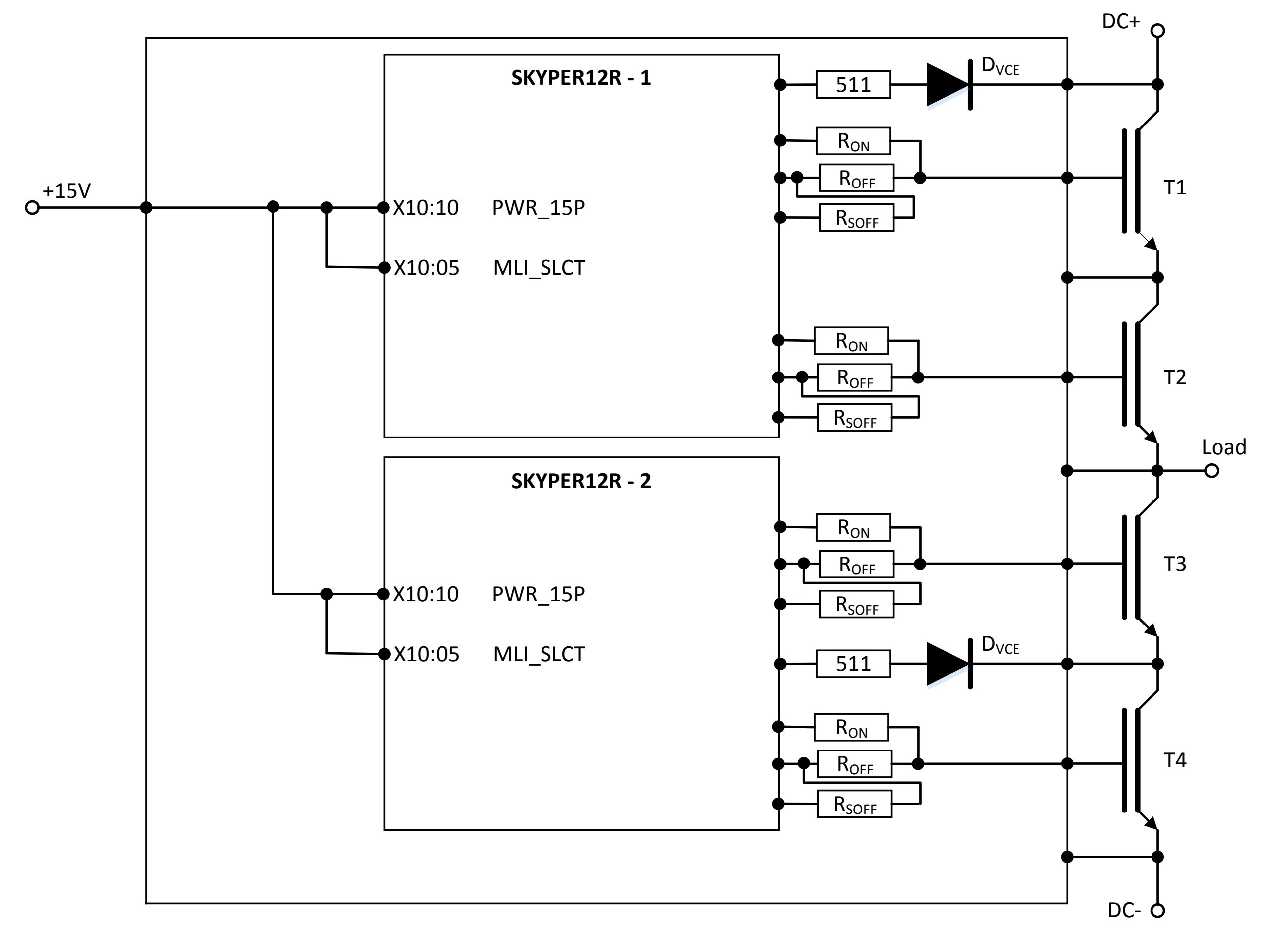
MLI_SLCT = high (MLI mode)
In case of an short circuit the driver will switch off if the V_{CE} detection is activated but the other driver channel will not be switched off by the driver. In that case the error state is only indicated at nERROR_OUT and the customer has to switch off the second driver channel. Nevertheless if an under voltage condition happens the driver switches off.

Parameter	Min	Typ	Max
Threshold high	-	-	11 V
Threshold low	7,5 V	-	-

When switching MLI the drivers have to be set the following way:

- One driver for T1 and T2 (two upper switches)
- One driver for T3 and T4 (two lower switches)
- V_{CE} monitoring of T2 and T3 deactivated (on secondary side)
- Activated MLI mode for both drivers
- Active clamping for all T1/2/3/4 in addition to softoff to cover all error scenarios can be used

Figure 10: Concept for MLI applications

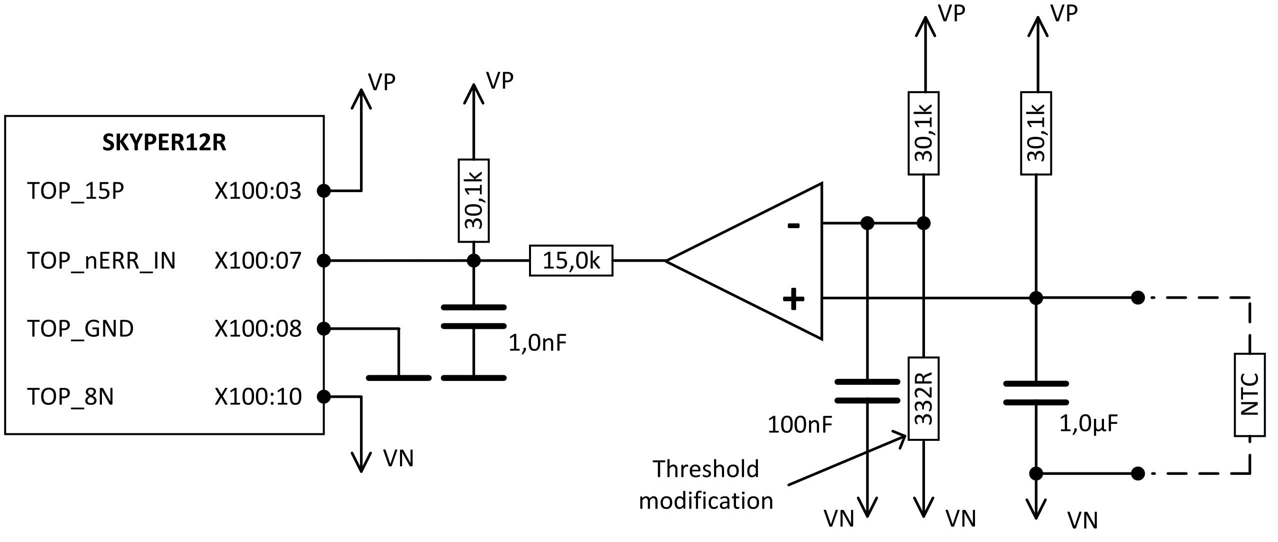


3.9 External error input – secondary

Each secondary side of the driver can handle an external error event like overtemperature or overcurrent that is signalized via the TOP_nERR_In/BOT_nERR_IN inputs. The error events are evaluated and transmitted to the primary side.

Figure 11: External failure input on secondary side

- The inputs are active low
- The error inputs can be disabled by connecting them to VP



Example for a NTC overtemperature circuit, on the TOP secondary side, using the external error input.

Parameter	**Min**	**Typ**	**Max**
Threshold high	-	-	13 V
Threshold low	2 V	-	-

3.10 Gate resistors – secondary

The turn-on and turn-off speed of each IGBT can be set by the external resistors R_{ON} and R_{OFF}.
Gate resistors should be surge proof. The MELF and Mini-MELF resistors in the table below are recommended.

Description	Shape	Manufacturer	Art. no.
MELF resistors	MELF / MiniMELF SMD	Vishay Beyschlag, Vishay Draloric, Vitrohm	PRO MELF resistors, SMM0207, SMM 0204, ZC series

The values of the gate resistors depends on the IGBT chip. To specify the optimum value the maximum overvoltage during switch off has to be checked regarding DC link voltage and the dI/dt during switch on.

3.11 External boost capacitors

The rated gate charge of the driver can be increased by adding boost capacitors to the supply rails to drive IGBTs with a large gate capacitance.

<table>
<tr><th colspan="2">Figure 12: Boost capacitors</th></tr>
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- SKYPER 12 has internal capacitors to charge gate capacitance up to 1 µC
- External capacitors can be calculated the following way: $C_{boost} = 4\frac{\mu F}{\mu C} \cdot Q_{Out} - 4\mu F$
- The maximum rating for output charge per pulse of the gate driver has to be considered.
- The boost capacitors have to be mirrored to the primary side. Further all boost capacitors should have the same value: $C_{boostPrim} = C_{boost15P} = C_{boost8N}$
- The external boost capacitors should be connected as close as possible to the gate driver to achieve low inductance.

Examples for boost capacitors:
AVX 12103C106K_Z2A

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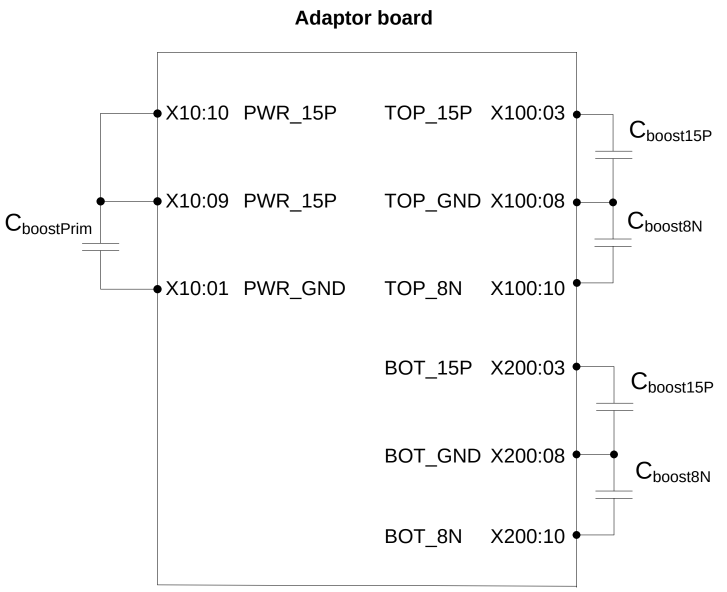

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4. Protection features

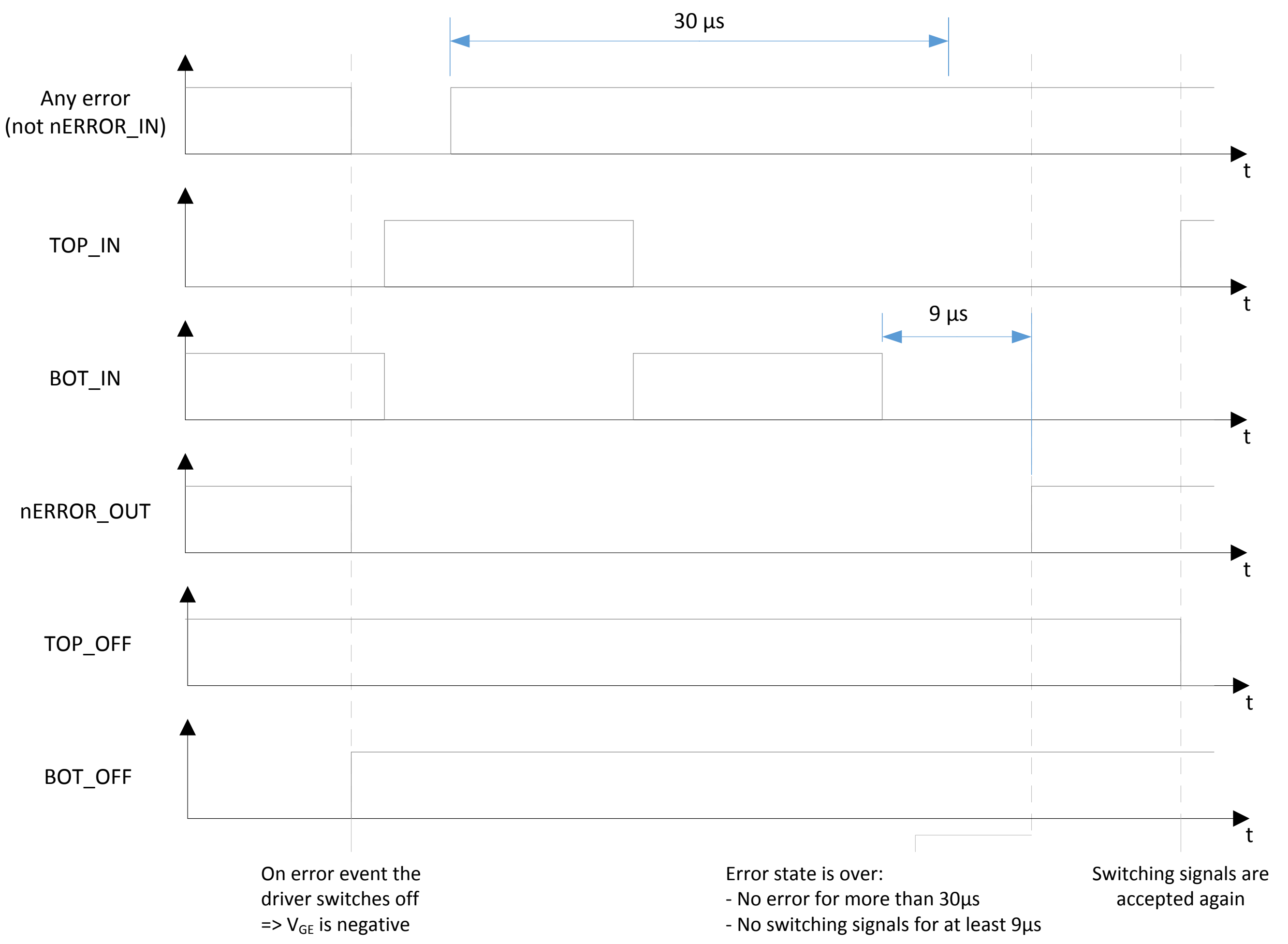
4.1 Failure management

The SKYPER 12 detects undervoltage on primary and secondary side, short circuit of the IGBTs and external error events like overtemperature conditions. Any error detected will force the output nERROR_OUT to low state and has to be reset by the customer controller. When entering error state the IGBTs will be switched off (IGBT driving signals are set to VN). Active switching signals at the inputs of the driver will be ignored. Nonetheless the input signals have to be set to low for 9µs to confirm the error and the error root cause has to be solved for 30µs.

The following failures are indicated at the error output:

- Undervoltage of primary side supply voltage
- Undervoltage of secondary side voltages
- Short circuit of the IGBTs
- External errors (e.g. over temperature circuits from the adapterboard)

Figure 13: Behavior on error event in default mode -> MLI_SLCT = low



4.2 Dead time generation (Interlock TOP / BOT)

The internal dead time of SKYPER 12 can be adjusted between 2µs and deactivated mode.

Deadtime activated

The deadtime function 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. It is possible to control the driver with one switching signal and its inverted signal. No error signal will be generated when signals are overlapped.

Case	Controller dead time	Total dead time
Controller > driver	4µs	4µs
Controller < driver	1µs	2µs
Controller no dead time	No dead time	2µs

Deadtime deactivated

When deadtime is deactivated the two IGBTs can be switched independent from each other. In this mode the two channels even can be switched on at the same time. Further the mapping to TOP and BOT-IGBT is no longer relevant and can be interchanged.
Important: When deadtime function is deactivated a shoot through is not prevented reliably.

4.3 Short pulse suppression

This driver functionality suppresses short on- and off-pulses on the switching signal inputs. This way the IGBTs are protected against electromagnetic noise. The filter time can be set by the customer via the FILTER_SLCT pin. When using the digital filter the tolerances are very low over the full temperature range. The analogue setting can be chosen for ambitious applications, like magnetic resonance imaging, which require very low jitter values below 2ns. The propagation delay times depend on the filter setting.

Signal	Function	Specification
FILTER_SELECT = HIGH	Digital filter	Filter time: 375ns Delay time: 800ns Jitter: 30ns
FILTER_SELECT = LOW	Analog filter	Filter time: 200ns Delay time: 600ns Jitter: 2,5ns

Parameter	Min	Typ	Max
Threshold high	-	-	14 V
Threshold low	1 V	-	-

4.4 Under voltage protection

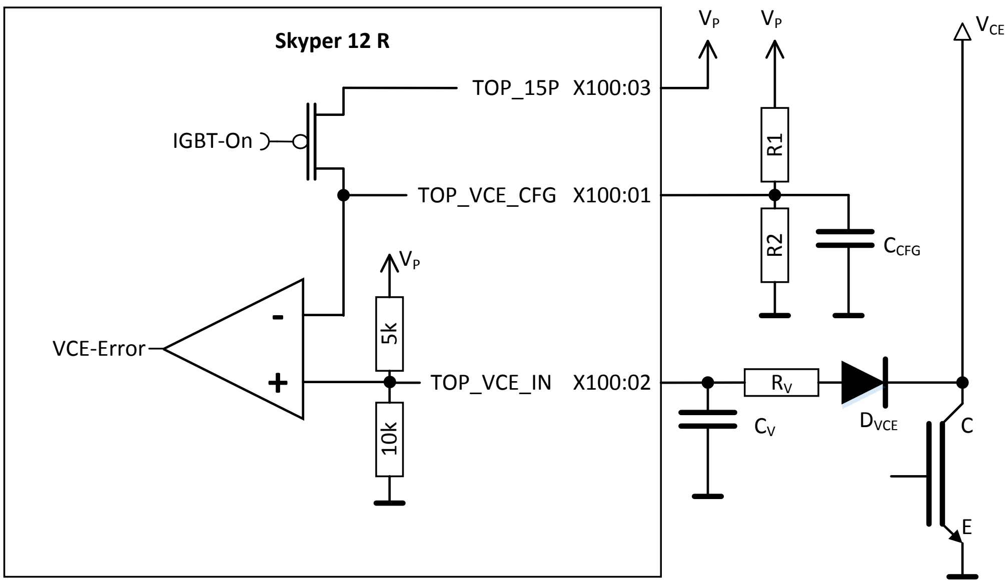
If the power supply drops below a negative threshold level the driver switches the IGBTs off and indicates an error on Pin X10:03. After passing the positive threshold, the driver can operate again.

Parameter	Min	Typ	Max
Threshold negative	12,2V	-	-
Threshold positive	-	-	13,9V

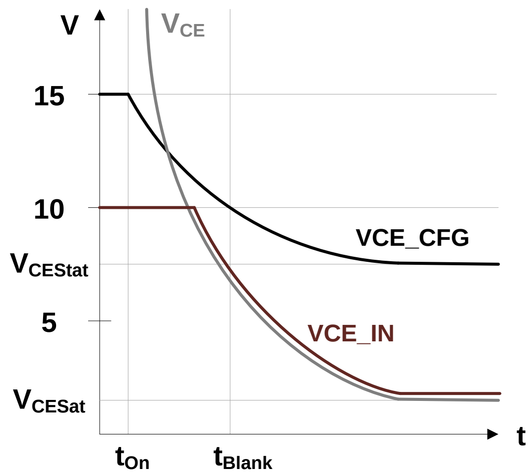
4.5 Dynamic short circuit protection

The dynamic short circuit monitor supervises the collector-emitter voltage V_{CE} of the IGBT during its on-state. The protection circuit is called dynamic, because immediately after turn-on of the IGBT, a higher value is effective than in steady state. When an error is detected the affected IGBT is turned off via the SOFTOFF path. Further an error is reported to the primary side.

Figure 14: Application design for the V_{CE} monitoring (example for TOP secondary side)



- In off-state the pin V_{CE_CFG} is pulled to V_P => The external capacitor C_{CFG} is charged and has the same potential as V_P.
- After switch on the internal pull-up transistor is deactivated and the voltage at the reference input V_{CE_CFG} is defined by the external voltage divider (R1 and R2). The capacitor ensures that the reference voltage does not sink below the V_{CE} voltage (V_{CE_IN}) during a standard switch on process.
- The maximum reference voltage is 9,5V which is related to the Vce comparator.
- The blanking time t_{Blank} describes the duration from start of the switch on process to the point of time when *VCE_CFG* crosses the 10V threshold.
- After t_{Blank} has passed, the V_{CE} monitoring will be triggered as soon as $V_{CE\_IN} > V_{CE\_CFG}$ and will turn off the IGBT.
- The voltage on V_{CE_IN} is equal to the V_{CE} voltage in addition to the forward voltage of the high voltage diode D_{VCE} and the voltage drop over R_V. The voltage at V_{CE_IN} is limited to 10V, by the internal voltage divider. As long as the V_{CE} voltage is higher than 10V the diode blocks it.

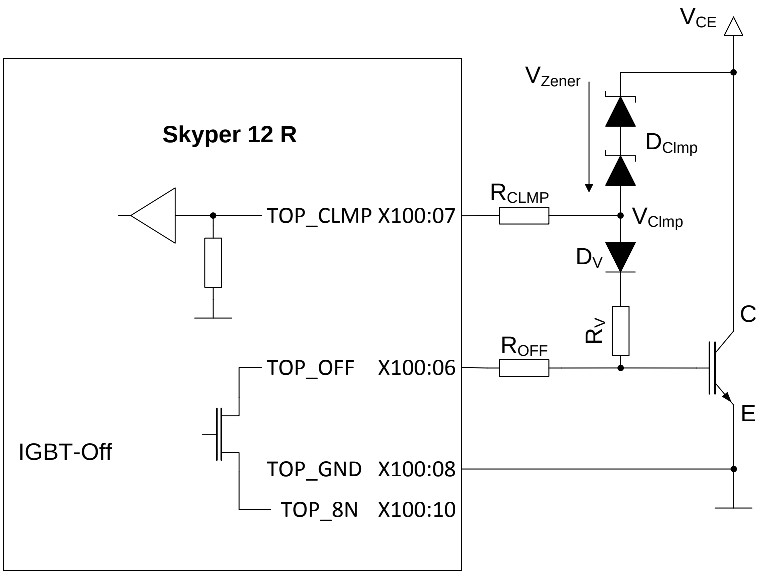


$$V_{CEStat} = V_P \frac{R2}{R1 + R2}$$

$$t_{Blank} = -C_{CFG} \cdot \frac{R_1 \cdot R_2}{R_1 + R_2} \cdot \ln\left(\frac{\frac{10V}{V_P}(R_1 + R_2) - R_2}{R_1}\right)$$

4.6 Active clamping

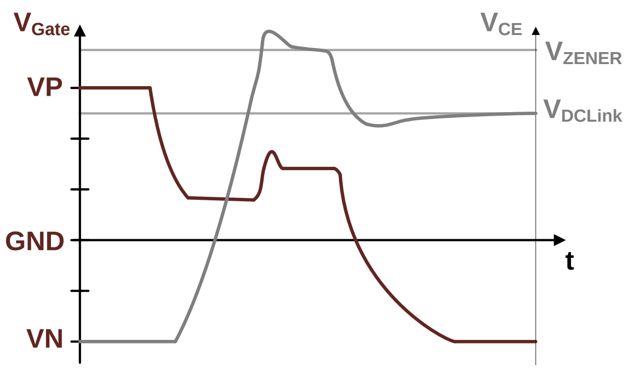
Figure 15: Application example for active clamping



The driver offers the possibility of reducing over voltages during switching. The voltage level where the clamping starts is set by the breakdown voltage of the component with zener characteristic e.g. D_{CLmp}.
If, during a switch off V_{ce} raises beyond V_{Zener} the clamping diodes get conductive. This current switches the gate on again until the V_{CE} voltage is reduced below the V_{Zener} reference.

Important: During the clamping process the IGBT is working in linear mode and is producing additional losses coming from the energy stored in the stray inductance. So active clamping must not work during standard switching to avoid thermal overstress and reduced IGBT lifetime. It should only be used in case of error.

The *CLMP* input indicates the driver that the clamping is active so the driver output stage can be deactivated and losses on the driver can be reduced. The resistors R_{CLMP} and R_V have to be set, so that the input voltage on the clamping input raises above the threshold (13V) during active clamping. Also consider the internal pull-down resistor for the dimensioning.



Parameter	Min	Typ	Max
Threshold high CLMP-input	-	-	13 V
Threshold low CLMP-input	2 V	-	-

4.7 Soft Off

In the event of short circuit, the SoftOff feature increases the resistance in series with R_{Goff} and slows down the turn-off speed of the IGBT. The reduced di/dt reduces the voltage spike above the collector emitter in the short circuit case. The SoftOff resistor should be calculated 10 times as high as the standard off resistor. Typical values depend on the IGBT chip but lie in the range between 30-50 ohm. Target is to stay within the short circuit proofed time of the IGBT but at the same time reduce the overvoltage below the maximum collector emitter voltage of the IGBT.

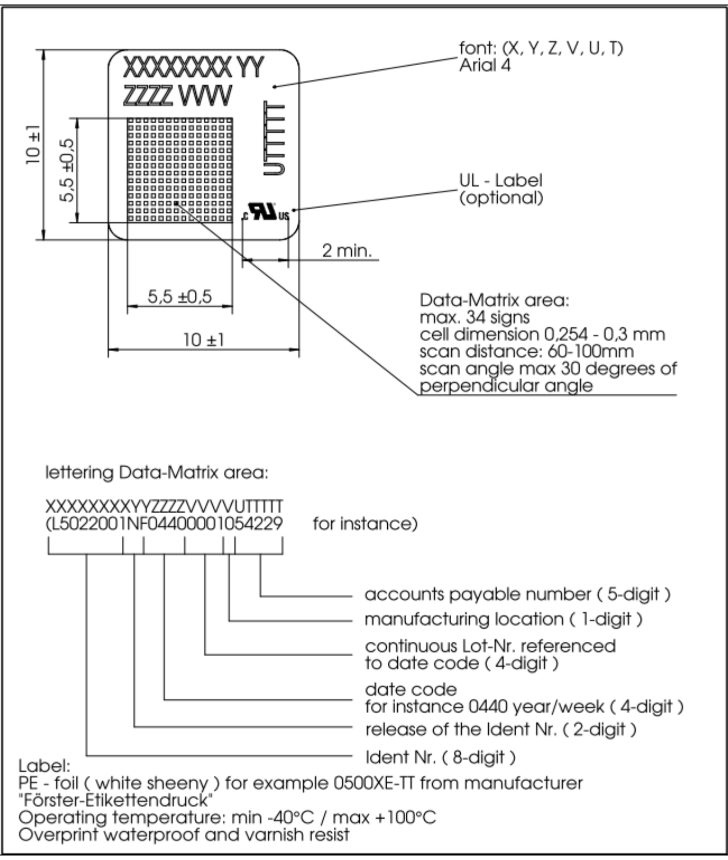
5. Environmental conditions

Insulation parameters		**Rating**
Grid voltage (grounded delta)		690V
Climatic Classification Pollution Degree (PD)		PD2
Maximum permanent DC link voltage (EN 61800-5-1)		1200V
Climate class		3K3 – IEC 60721-3-3
Maximum altitude (above sea level)		2000 meter above sea
Overvoltage category (according to EN 61800-5-1)		OVC 3
Isolation resistance test, Prim-Sec, two times per lot as series test. Insulation test must be performed in the system.		5000 V_{AC}, rms,2s (10s as type test)
Partial discharge (tested 100% of transformer)		2,2kV/1,8kV
Creepage/clearance distance primary/secondary side		14mm
Creepage distance secondary secondary		10,4mm
Clearance distance secondary secondary (within a circuit, OVCI)		6,1mm
CTI of PCB		II (400-600)
CTI of transformer		I (600)
Environmental Condition	**Norm / Standard**	
Operating/storage temperature		-40.. +85 °C
High humidity		85 °C, 85%
Flammability	UL94 V0	Heavy flammable materials only
	RoHS / WEEE / China RoHS/ UL	

EMC Condition	Norm / Standard	Parameter
ESD	IEC 61000-4-2 IEC 61800-3 EN 50121-3-2	6 kV contact discharge / 8 kV air discharge
Burst	IEC 61000-4-4 IEC 61800-3 EN 50121-3-2	≥ 2kV on adaptor board for signal lines ≥ 4kV for AC lines
Immunity against radiated interference	IEC 61000-4-3 IEC 61800-3 EN 50121-3-2	≥ 20V/m 80MHz – 1000MHz
Immunity against conducted interference	IEC 61000-4-6 IEC 61800-3 EN 50121-3-2	≥ 20V 150kHz – 80MHz
Shock Vibration		
Vibration	Sinusoidal 20Hz … 500Hz, 5g, 2h per axis (x, y, z), 26 sweeps Random 10Hz … 2000Hz, 3g, 2 h per axis (x, y, z)	
Shock	180 Shocks (6 axis; +-x, +-y, +-z, 30 shocks per axis), 30g, 11ms Connection between driver and PCB has to be reinforced by support post	
Quality		

6. Marking

Figure 16: Labeling



References

[1] www.SEMIKRON.com
[2] A. Wintrich, U. Nicolai, W. Tursky, T. Reimann, "Application Manual Power Semiconductors", ISLE Verlag 2011, ISBN 978-3-938843-666

HISTORY

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