Technical Explanation SKYPER12 (T)MLI Driver Board

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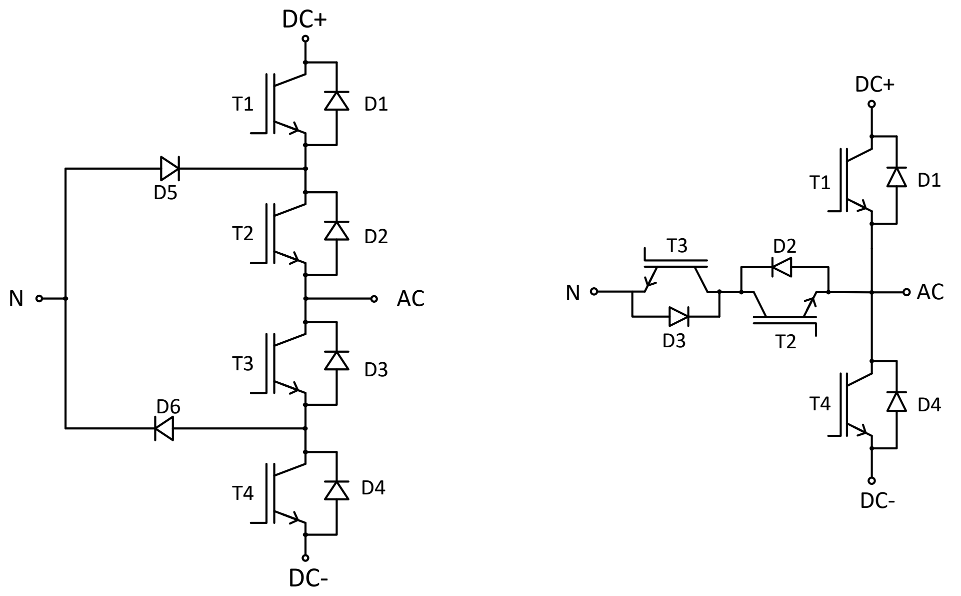
1. Introduction

SEMIKRON set up a driver board for operating MLI (up to 1200V blocking voltage) and TMLI (up to 1700/1200V blocking voltage) modules for evaluation purposes. The SKYPER12 (T)MLI Driver Board ("driver board") is designed to be operated with several SEMIKRON Application Samples (e.g. the SEMITOP E2 Inverter Board). It is designed to operate the module up to a DC-link voltage of 1500V (limited by insulation coordination) at a maximum switching frequency of 30kHz (limited by insulation coordination); i.e. higher switching frequencies are possible with a revision of the insulation coordination and the limitation of the gate driver needs to be taken into account.

Two standard 2L drivers (SKYPER12) are used to operate the 3L (T)MLI module; one driver operates switches T1 and T2, the other operates switches T3 and T4.
The failure management of the two SKYPER12 drivers is able to detect desaturation events at all switches (IGBTs T1 - T4) and can also monitor the module's built-in temperature sensors (NTC); one sense input at channel T1, the other at channel T4. In case the built-in temperature sensor exceeds a set temperature (can be set by user) the outer IGBTs are turned off immediately and the driver produces an error signal.
In standard configuration desaturation of the outer switches (IGBTs T1 and T4) leads to a shut-off of the outer IGBTs and produces an error signal while the inner switches (IGBTs T2 and T3) are not monitored.
Additionally an active clamping sense input is implemented at all four channels. In standard configuration the inner switches are protected by active clamping and the particular sense inputs are activated (at IGBTs T2 and T3).

Figure 1: MLI (left) and TMLI (right)



This Application Sample is dedicated to both universities and professional development engineers. It offers an easy way to set up high power inverters with standard MLI and TMLI modules and 2L drivers. Performance tests can be run to prove the possibility of operation at high DC-link voltages and the high output power.

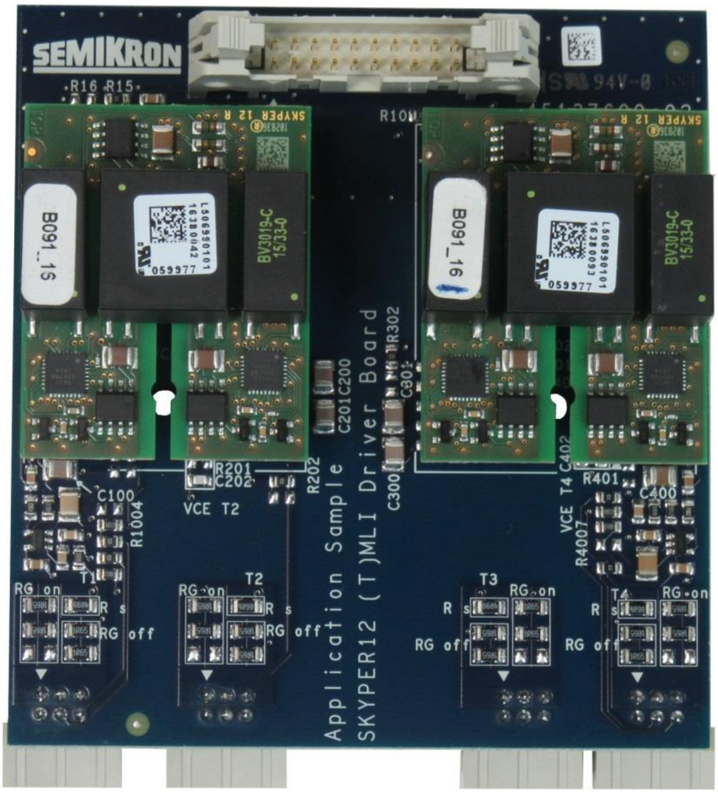
1.1 Features

The SKYPER12 (T)MLI Driver Board is designed as general purpose 3L driver board that contacts a variety of SEMIKRON Application Sample inverter boards.
As long as the boundaries of the board are not exceeded (e.g. maximum DC-link voltage, switching frequency, etc.) the driver board can be contacted to any 3L module.

1.2 Hardware of the SKYPER12 (T)MLI Driver Board

The SKYPER12 (T)MLI Driver Board consists of a printed circuit board (PCB): it is called "SKYPER12 (T)MLI Driver Board" with item number 45137601. It provides sockets for the four switches of a 3L MLI or TMLI configuration on the one hand and sockets for the SKYPER12 drivers and a user interface on the other.

Figure 2: SKYPER12 (T)MLI Driver Board top view



Depending on the power ratings of the used 3L module and the operating conditions (voltage, current, inductance of the DC-link connection) it might be necessary to adjust gate resistors, activate or deactivate active clamping sensing and trip levels of the safety circuits.
The Gerber files of the board are available on request. For ordering the board or the files please contact your SEMIKRON sales partner.

2. Safety Instructions

The SKYPER12 (T)MLI Driver Board bares risks when put in operation. Please carefully read and obey the following safety instructions to avoid harm or damage to persons or gear.

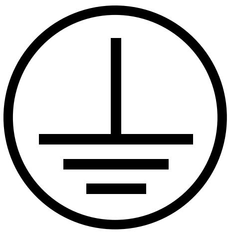
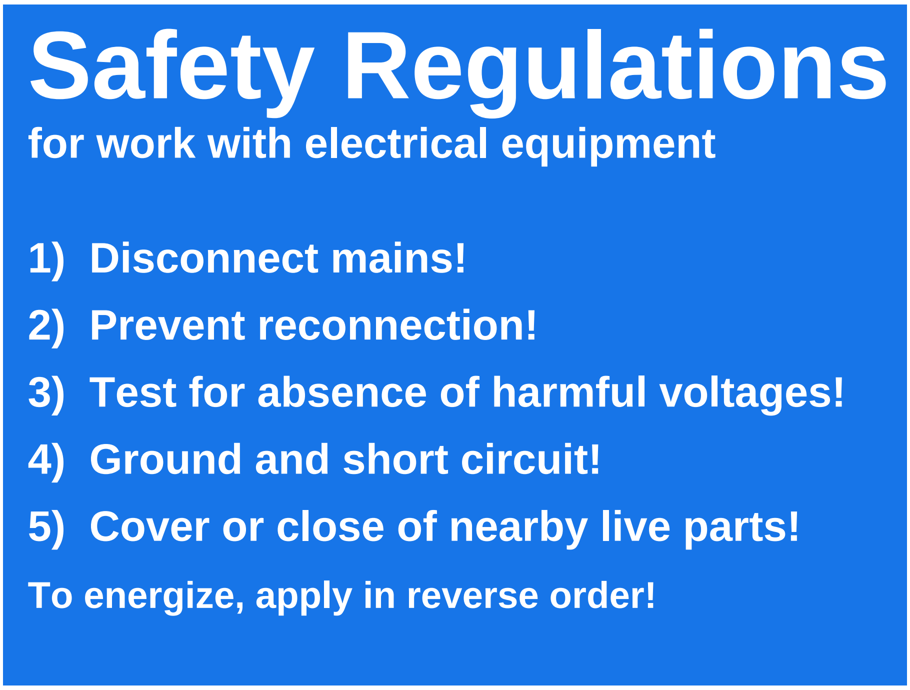
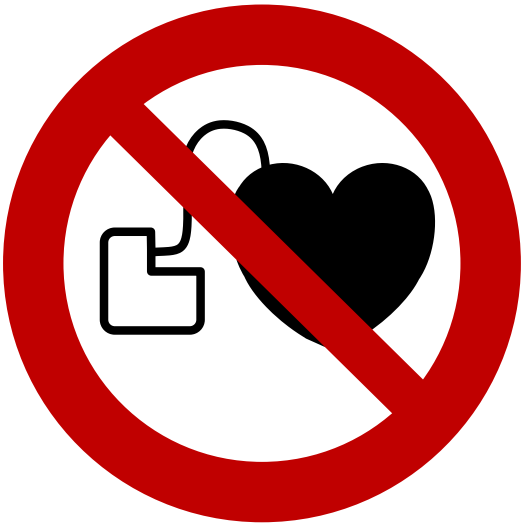
Table 1: Safety instructions	
	**In operation the SKYPER12 (T)MLI Driver Board inherits high voltages that are dangerous to life!** **Only qualified personnel should work with the Kit.**
	**Some parts of the SKYPER12 (T)MLI Driver Board or connected devices (e.g. heatsink) may reach high temperatures that might lead to burns when touched.**
	**When connected to DC-link capacitors it must be made sure that the DC-link voltage is reduced to values below 30V before touching the system.**
	**Insulation coordination and testing has been performed regarding a PE connection of one potential. It is mandatory to provide a PE connection with sufficient cross section when operating the SKYPER12 (T)MLI Driver Board.**

Table 2: Safety regulations for work with electrical equipment



Please follow the safety regulations for working safe with the SKYPER12 (T)MLI Driver Board.

Table 3: No access for people with active implanted cardiac devices!



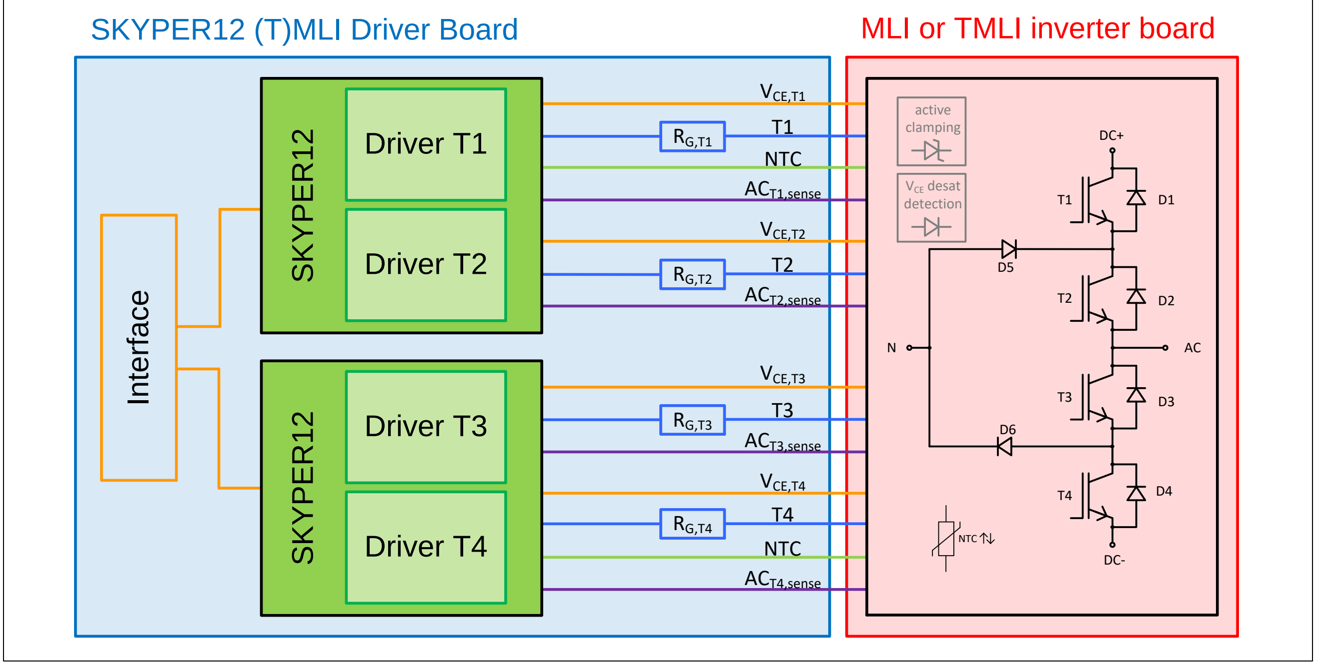
Operating the Application Sample may go along with electromagnetic fields which may disturb cardiac devices.
People with cardiac devices shall not operate the device.

3. Technical Data

3.1 Driver Kit block diagram

The electrical block diagram in Figure 3 shows two parts: the blue marked part is the driver board with sockets for the two SKYPER12 drivers (green), gate resistors, clamping and V_{CE} sensing circuitry. The red part symbolizes the 3-level inverter with V_{CE} clamping diodes and active clamping diodes at the particular switches that shall be monitored.

Figure 3: SKYPER12 (T)MLI Driver Board block diagram



3.2 Electrical and mechanical characteristics

With regard to the requirement specification the SKYPER12 (T)MLI Driver Board allows for operation within the following boundaries:

- Max. DC-link voltage	V_{DC} = 1500V in total, max. 750V per individual DC-link half
- Max. AC voltage	V_{AC} = 1000V_{RMS} (line-to-line)
- Max. switching frequency	f_{sw} = 30kHz (see chapter 5.5 for further information)
- Ambient temperature	T_a = 0°C…40°C (see chapter 5.6 for further information)
- CTI rating of AppS PCBs	> 175

Neglecting the above mentioned boundaries may lead to malfunction or damage of the SKYPER12 (T)MLI Driver Board.

An electrical insulation is implemented between the user interface (primary side) and the high voltage connections (secondary side) by using the SKYPER12's separation. The creepage and clearance distance on the driver board is 17mm between primary and secondary side.
The overall responsibility for a proper insulation coordination remains with the user.

Please note that further restrictions of the used driver (e.g. SKYPER12) may apply. According information can be found in the technical documentation of the particular driver (e.g. Technical Explanations on the SEMIKRON website [1]).

The driver board is 96mm long and 90mm wide. Including SKYPER12 drivers the total height is 28.5mm.

To prevent driver board and the SKYPER12 drivers from loosening from each other mounting holes for dual lock support posts are available (positions circled red in Figure 4). Please find further information in the technical explanation of SKYPER12 [1].
The blue marked area in Figure 4 indicates the primary side with the user interface socket. The insulation is provided by the galvanic insulation of the SKYPER12 drivers and the insulation gap on the driver board. All area besides the blue marking may be considered as high voltage area (secondary side).

Figure 4: SKYPER12 (T)MLI Driver Board ("driver board"), top side

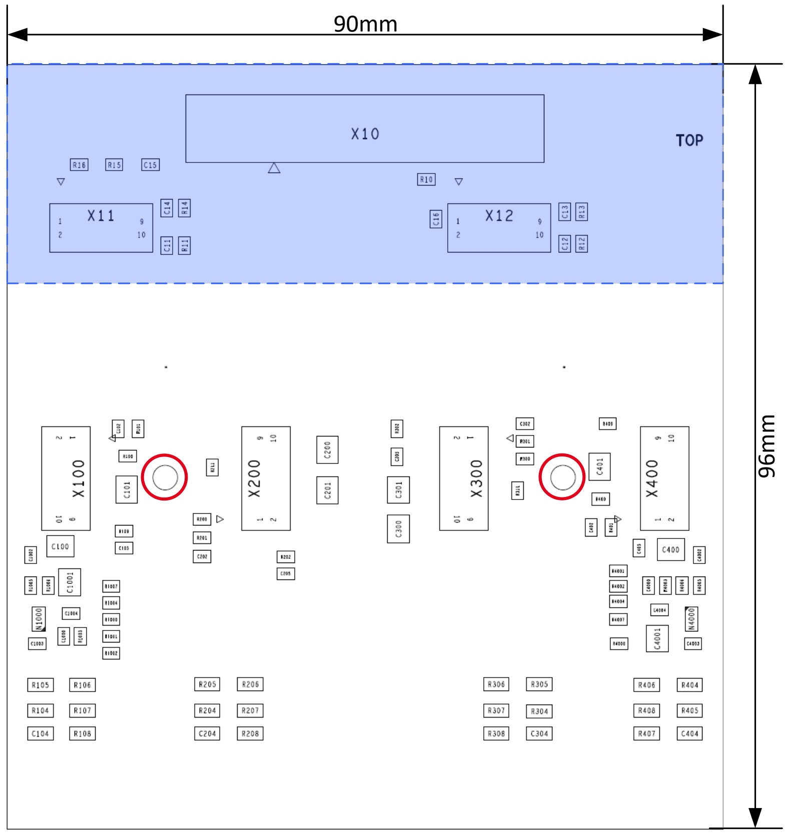
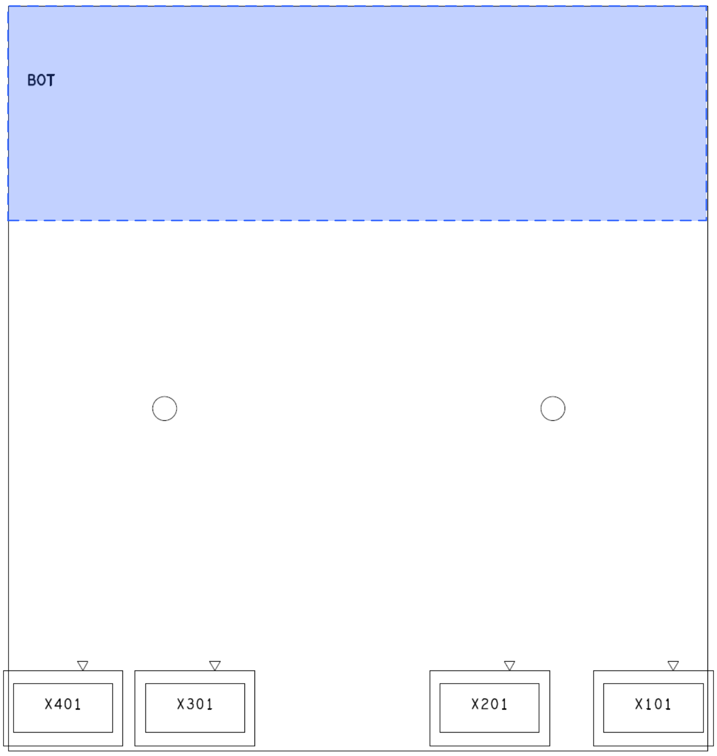


Figure 5: SKYPER12 (T)MLI Driver Board ("driver board"), bottom side



3.3 Integrated functions

The driver board has some optional integrated safety functions to protect the power module from certain harmful conditions.

3.3.1 Thermal protection

The SEMIKRON MLI/TMLI module's built-in NTC temperature sensor can be monitored by the error input of either IGBT T1 or IGBT T4 (outer switches; two NTC sensors can be monitored independently at the same time).
At a pre-defined temperature (to be defined by the user by adjusting a resistor) T1 (T4) is switched off immediately and the error is transmitted from secondary side (high voltage) to primary side (low voltage) by the driver. On the primary side an error is set and the user can react accordingly.

3.3.2 Desaturation detection

The voltage drop across each IGBT can be measured while conducting. As soon as the voltage rises above a pre-defined value (that correlates to very high current of a desaturation event) an error message is generated by the driver which the user shall react to. The driver automatically turns off the particular IGBT using the soft-turn-off gate resistor. The forward voltage drop threshold and the blanking time for the desaturation detection is set according to the Technical Explanation of the SKYPER12 driver [6] with a resistor (R_{CE}) and a capacitor (C_{CE}) in 0805 housing. The position of R_{CE} and C_{CE} can be mixed up as they are connected in parallel. R_{CE} and C_{CE} are framed yellow in Figure 6.
ATTENTION: Turning off an inner IGBT of an NPC topology while it cannot be guaranteed that the adjacent outer IGBT is already turned off may harm the power module.

3.3.3 Active clamping

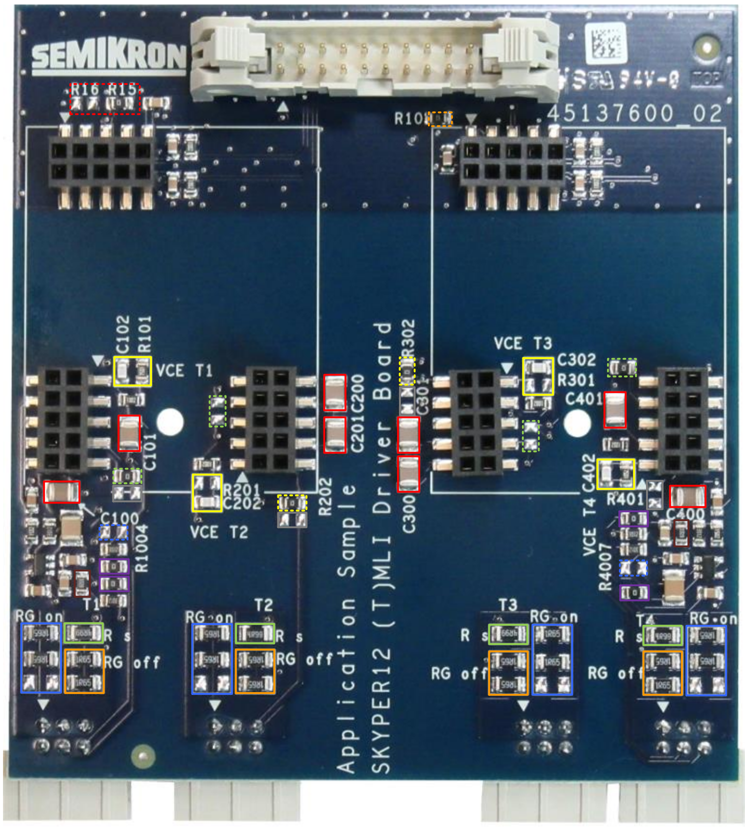
If the IGBTs shall be protected versus overvoltage by using active clamping circuits a feedback from this circuit can be connected to the driver. This feedback will turn off the output stage of the SKYPER12 during the clamping event in order not to work against the active clamping circuit.
The TVS diodes are not located on the driver board. Further information can be found in chapter 3.4.4.

3.4 Board description

Several components are meant to be changed by the user, i.e. an adaptation to the application conditions. The changeable components of the driver board are marked with different coloured frames in Figure 6; function and possible values are explained in chapters 3.4.1 to 3.4.6.

Figure 6: Top side of the driver board; user-changeable components are framed

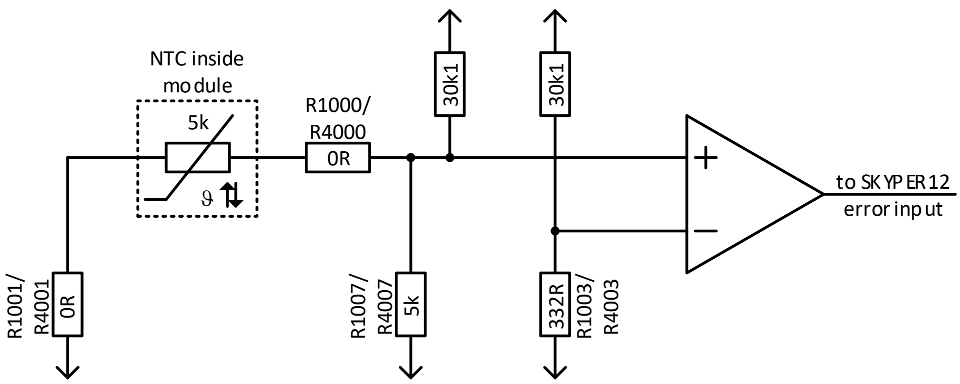
- (yellow) 0805 pads for V_{CE} setting (C_{CE} and R_{CE})
- (yellow, dashed) 0805 pads for V_{CE} disabling at T2/T3
- (grey) 0805 pads for V_{CE} input capacitor
- (blue) 3x MiniMELF / 1206 pads for turn-on resistors or capacitors
- (orange) 2x MiniMELF / 1206 pads for turn-off resistors or capacitors
- (green) 1x MiniMELF / 1206 pad for soft-turn-off resistor
- (red) additional capacitors for stabilizing secondary side voltages
- (purple) R1000 and R1001 (R4000 and R4003) connecting the module's NTC with the temperature error input of SKYPER12
- (brown) R1003 (R4003) for adjustment of temperature error threshold
- (light blue, dashed) R1007 (R4007) for simulating low temperature value by resistor
- (light green, dashed) R109, R211, R311, R409: line termination if no active clamping installed
- (light orange, dashed) R10, interconnection of error outputs of the two SKYPER12 drivers
- (light red, dashed) R15 – R16, configuration of SKYPER 12 primary error communication



3.4.1 Adjustment of temperature error threshold

A thermal overload can be detected by evaluating the SEMIKRON MLI/TMLI module's built-in NTC sensor. In case a thermal overload is detected the comparator shown in Figure 7 pulls the SKYPER12's error input to GND and so the driver can communicate an error message.
The resistor R1003 (R4003) (framed brown in Figure 6) can be used for adjusting the error temperature threshold.

Figure 7: Schematic of NTC evaluation



The standard values for R1003 (R4003) is 332Ω (refers to 115°C): the thermal overload detection is deactivated by leaving R1000 (R4000) and/or R1001 (R4003) unpopulated and populating R1007 (R4007) with e.g. 5kΩ to simulate a low sensor temperature. As soon as the module's NTC shall be evaluated R1007 (R4007) must not be populated.
An error is detected when the voltage at the inverting input of the comparator is greater than the voltage at the non-inverting input. The resistance of the NTC at a desired shut-off temperature can be taken from the diagram in Figure 8; R1003 (R4003) needs to be chosen to that value. A chip resistor with the size 0805 can be used for R1003 (R4003).

Figure 8: SEMIKRON (T)MLI modules' NTC characteristic (excerpt)

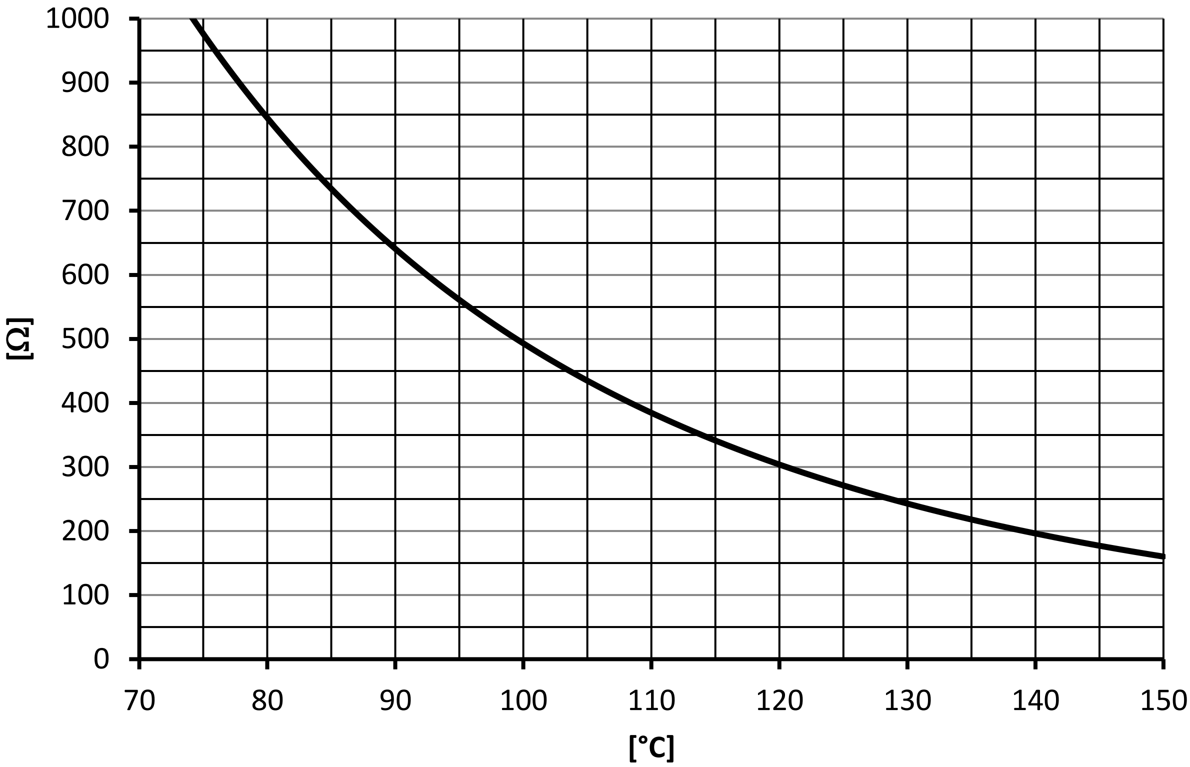


Figure 8 shows an excerpt of SEMIKRON modules' NTC characteristic which includes the most interesting temperature range between 70°C and 150°C. The full characteristic can be found in the Technical Explanations or can be calculated from the formula given in the module datasheets [1].

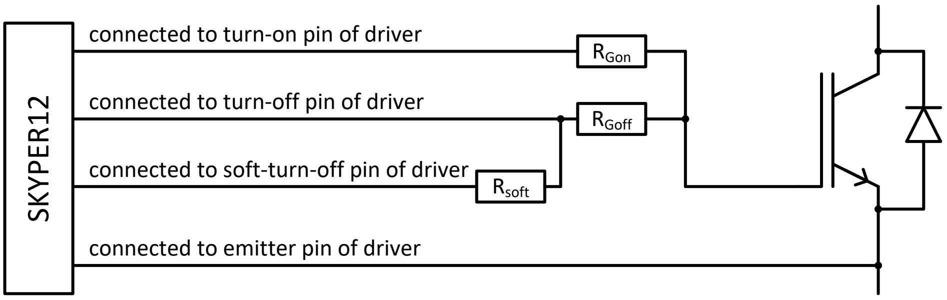
3.4.2 Buffer capacitors

C100, C200, C300 and C400 (10µF each) buffer the negative secondary supply voltage, C101, C201, C301 and C401 (10µF each) buffer the positive secondary supply voltage. In case the module's total chip gate charge (gate charges of all four switches) exceeds 4µC the buffer capacitors need to be equipped and the user must apply additional 100µF at the 15V supply voltage of the driver board.
By default the eight buffer capacitors are equipped.

3.4.3 Gate resistors

What is called gate resistor in this document for the sake of convenience is realized by one or more chips on the driver board. The SKYPER12 offers separate connections for turn-on (R_{Gon}), turn-off (R_{Goff}) and soft-turn-off (R_{soft}), see Figure 9. R_{Gon} is used for every turn-on event, R_{Goff} for every turn-off action. In case of an error the driver uses R_{soft} instead of the standard R_{Goff}. All resistor positions must be populated for proper operation.

Figure 9: Schematic of gate resistor arrangement



Turn-on resistor (R_{Gon}) / capacitor

The driver board offers three pads per IGBT (framed blue in Figure 6) taking MiniMELF or 1206 sized components. Resistor/capacitor values need to be chosen according to the particular application (DC-link voltage, DC-link inductance, switching frequency, switching losses, etc.) so there is no general recommendation.
It is necessary to calculate the power losses of the gate resistor in order not to overload and damage it.
Please refer to chapter 5.3 for further information.

Turn-off resistor (R_{Goff}) / capacitor

The driver board offers two pads per IGBT (framed orange in Figure 6) taking MiniMELF or 1206 sized components. Resistor/capacitor values need to be chosen according to the particular application (DC-link voltage, DC-link inductance, switching frequency, switching losses, etc.) so there is no general recommendation.
It is necessary to calculate the power losses of the gate resistor in order not to overload and damage it.
Please refer to chapter 5.3 for further information.

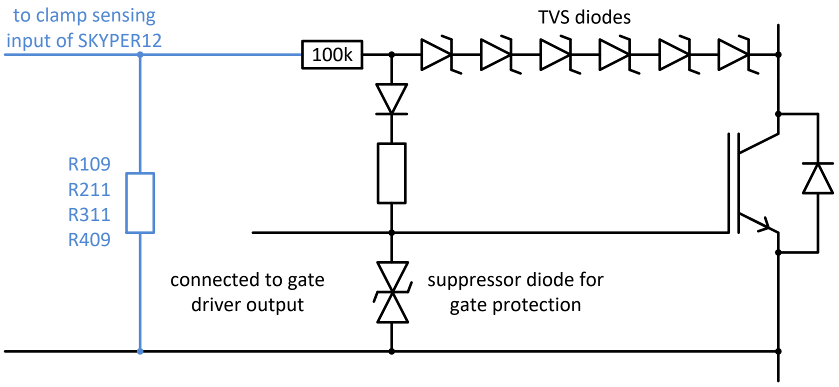
Soft-turn-off resistor (R_{soft})

The driver board offers one pad per IGBT (framed green in Figure 6) taking a MiniMELF or 1206 sized component. The resistor values need to be chosen according to the particular application (DC-link voltage, DC-link inductance, switching frequency, switching losses, etc.) so there is no general recommendation.
It is recommended to calculate the power losses of the gate resistor in order not to overload and damage it.
Please refer to chapter 5.3 for further information.

3.4.4 Active clamping

Figure 10 shows an exemplary schematic of an active clamping circuit and sense connection that may be connected to the driver board. If this connection exists the driver output stage is disconnected from the gate as soon as a clamping event occurs. Thus the driver output stage and active clamping do not operate against each other.
Resistors R109, R211, R311 and R409 (marked dotted green in Figure 6) can either be equipped with 0Ω disabling the feedback from the active clamping circuit or left unpopulated to activate the sensing functionality. If active clamping circuitry exists, the particular resistors may not be equipped to avoid damage. Without termination of the sense input (i.e. no resistor and no active clamping circuitry) the driver may be disturbed by EMI what might lead to malfunction.

Figure 10: Schematic of active clamping



Please refer to chapter 5.4 for further information.

3.4.5 V_{CE} monitoring

V_{CE} detection input capacitor

In some cases it might help stabilizing the V_{CE} monitoring by adding a capacitor to the V_{CE} detection input at the driver. With C105, C205, C305 and C405 an 0805 pad per input is available to populate such a capacitor. By default those pads are not equipped.

Disabling V_{CE} detection

If the V_{CE} detection shall not be operated at the inner switches T2 and T3 and the particular pins are not grounded on the connecting inverter board it can be deactivated by populating a 0Ω resistor at R202 and R302.
V_{CE} detection of T1 and T4 can only be deactivated on the connecting power board.
By default R202 and R302 are equipped with 0Ω.

3.4.6 Error management of SKYPER12 drivers

Error interaction of the two SKYPER12 drivers

The 0805 sized R10 (framed dotted orange in Figure 6) on the driver board may either be left open or equipped with a 0Ω jumper. In case of 0Ω the error outputs/inputs of the two SKYPER12 drivers are connected. In case R10 is not connected an error output of one driver would not be communicated to the error input of the other driver immediately. SEMIKRON recommends to equip R10 with 0Ω. Please refer to chapter 5.2 for detailed information.

Error communication of SKYPER12 drivers' channels

The 0805 sized resistors R15-R16 (framed dotted red in Figure 6) may be equipped as shown in Table 4. R15 and R16 set the error communication of the two SKYPER12 drivers' channels.
Any other combination (e.g. all resistors 0Ω or all resistors not connected) will lead to malfunction and may damage the system.

Table 4: Functional table for R15 – R16		
R15	0Ω	not equipped
R16	not equipped	0Ω
Function ➔	The secondary side producing an error turns off the particular IGBT and communicates the error to the primary side. At the primary side the error is communicated to the user interface, but the second channel of the driver is not affected (will not turn off due to the error; this is in the user's responsibility). ⇨ **Default setup (recommended)**	The secondary side producing an error turns off the particular IGBT and communicates the error to the primary side. At the primary side the error is communicated to the user interface and the second channel of the driver which will turn of the second IGBT as well.

4. User Interface

4.1 Inverter board interface

The connection between driver board and inverter board is established by X100, X200, X300 and X400 of the driver board.
Plugs X100 and X400 show the same pinout as well as plugs X200 and X300. The pinouts are explained in Table 5 and Table 6.

Table 5: X100 (X400) on SKYPER12 (T)MLI Driver Board interface to inverter board

Pin	Description
1	Gate potential of T1 (T4)
2	Active Clamping sense of T1 (T4)
3	Emitter potential of T1 (T4)
4	Pin T+ of MLI/TMLI module's NTC sensor T1 (T4)
5	$V_{CE,desat}$ detection of T1 (T4)
6	Pin T- of MLI/TMLI module's NTC sensor T1 (T4)

Table 6: X200 (X300) on SKYPER12 (T)MLI Driver Board interface to inverter board

Pin	Description
1	Gate potential of T2 (T3)
2	Active Clamping sense of T2 (T3)
3	Emitter potential of T2 (T3)
4	not connected
5	$V_{CE,desat}$ detection of T2 (T3)
6	not connected

4.2 User interface

The user interface is the 20-pin connector X10 located in the middle of the driver board's low voltage side. The pin description is given in Table 7.

Table 7: X10 pin description

Pin	Signal name	Description	Voltage level
1	IF_PWR_VP	Driver supply voltage	$15V_{DC}$±4%, max. 0.5A
2	IF_PWR_VP	Driver supply voltage	
3	GND	Ground	0V
4	GND	Ground	0V
5	GND	Ground	0V
6	IF_CMN_T1	PWM pattern IGBT T1	Off=0V / On=15V; R_{in}=10kΩ / 1nF
7	GND	Ground	0V
8	IF_CMN_T2	PWM pattern IGBT T2	Off=0V / On=15V; R_{in}=10kΩ / 1nF
9	GND	Ground	0V
10	IF_CMN_T3	PWM pattern IGBT T3	Off=0V / On=15V; R_{in}=10kΩ / 1nF
11	GND	Ground	0V
12	IF_CMN_T4	PWM pattern IGBT T4	Off=0V / On=15V; R_{in}=10kΩ / 1nF
13	GND	Ground	0V
14	GND	Ground	0V
15	IF_CMN_NERR_1	Error input/output T1/T2	Error=0V / ready-for-operation=15V (Pull-Up to 15V on user-side; $R_{pull-up}$=1.8kΩ..10kΩ)
16	GND	Ground	0V
17	IF_CMN_NERR_2	Error input/output T3/T4	Error=0V / ready-for-operation=15V (Pull-Up to 15V on user-side; $R_{pull-up}$=1.8kΩ..10kΩ)
18	GND	Ground	0V
19	GND	Ground	0V
20	GND	Ground	0V

5. Restrictions and Requirements

This chapter claims some restrictions that must be paid attention to in order to avoid damage to driver board or power semiconductor.

5.1 Switching pattern of (T)MLI modules

A detailed explanation of the (T)MLI switching pattern is given in the SEMIKRON Application Note AN-11001 [3]. Summed up always an inner IGBT (T2 or T3) must be switched on first, the corresponding outer IGBT (T1 or T4) after a short while, namely when the inner IGBT is entirely switched on. For switch-off this sequence must be maintained in reverse order: it must be made sure that T1 (T4) is thoroughly turned off before T2 (T3) may be switched off.
This sequence is recommended to be maintained at any time, even and especially in case of emergency shut-down (e.g. because of over current or desaturation).

5.2 Error treatment

If a desaturation event occurs, the desaturated IGBT must be turned off within maximum short circuit pulse duration (t_{psc}; stated in the semiconductor module datasheet), otherwise it might be destroyed by this extreme overload. The correct turn-of sequence (outer IGBT first, inner IGBT afterwards) is recommended to be maintained to prevent the commutating semiconductors from overvoltage.
The user needs to react appropriately to error messages sent from the driver board: the correct switching pattern is recommended and a switch-off time below t_{psc} is mandatory to avoid damage.

5.2.1 Secondary side error at T1 (T4)

In case a secondary side error (e.g. desaturation) occurs at T1 (T4) the error signal is communicated to the driver's primary side and an error message is produced and sent to the user interface using pin 15 (pin 17) of X10 (see Table 7). At the same time T1 (T4) is turned off using the soft-turn-off resistor and stays off as long as the error signal is active.
The second channel of the faulty driver needs to be turned off by the user (latest with the next regular PWM turn-off signal). As long as the error signal is active it cannot be turned on.

- When resistor R10 on the driver board is equipped with 0Ω the error message from driver of T1/T2 (T3/T4) is sent to the error input of the driver of T3/T4 (T1/T2). There, it does also not turn off IGBTs automatically; this must be done by the user (either as reaction to the error or with the next regular PWM turn-off signal). It prevents turned-off IGBTs from being turned on as long as the error message is active.
- Not connecting R10 means that one driver's error does not prevent the other driver from turning on the IGBTs. The correct and in-time shut-off needs to be ensured by the user.

5.2.2 Error treatment in 3-phase systems

In 3-phase systems there is no direct connection of the driver boards' error signals. This connection must be provided by the user. Please note that time is critical when an error occurs and therefore error treatment shall be performed using fast hardware.

5.3 Design limits gate resistors

5.3.1 Minimum gate resistor

The minimum gate resistor is determined by the maximum difference of the driver output voltages during switching; it turns from -8V to +15V or back, so the voltage difference is 23V. The peak current SKYPER12 is capable of driving is 20A, so the minimum total gate resistor that needs to be used is 1.15Ω.
The total gate resistor consists of the internal gate resistor of the module (that can be found in the module datasheet) and the gate-turn-on or gate-turn-off resistors R_{Gon} and R_{Goff}. The gate resistors can be calculated according to:

$$R_{Gon,min} = R_{Goff,min} = 1.15\Omega - R_{Gint}$$

If this value is ≤0Ω the value for R_{Gon} or R_{Goff} can be chosen to 0Ω without overpowering the driver. Otherwise this minimum gate resistance must be used to avoid damage to the SKYPER12.

5.3.2 Power rating of the gate resistors

Depending on the ohmic value of the gate resistors also their power rating needs to be chosen sufficiently high to avoid overload.
The gate resistors need to be able to withstand high pulse load. It needs to be made sure by the user to choose suitable resistors.
Please note that 1206 sized chip resistors have a lower power and pulse load rating than MiniMELF resistors.
Further information about the power rating and correct choice of gate resistors can be found in Application Note AN-7003 [4].

5.4 Design limits active clamping

The clamping voltage for protecting the IGBTs can be adjusted by changing the breakdown voltage of the TVS diodes.
SEMIKRON recommends to use diodes with the same breakdown voltage (if diodes are connected in series). Using less diodes and 0Ω jumpers instead or using diodes with different breakdown voltages influences the blocking voltage sharing of the individual pads. This might influence the overall insulation capability. Therefore the insulation capability needs to be checked in case this approach is desired.
The total breakdown voltage (sum of the breakdown voltages of all TVS diodes) must under all circumstances (tolerances of the breakdown voltage, thermal drift) be lower than the breakdown voltage of the IGBT that shall be protected.
On the other hand the clamping shall not work when just the maximum DC-link voltage is applied and the inverter is operating in normal operation (i.e. mac. DC-link voltage plus voltage overshoot in normal operation) in order not to increase the switching losses.

5.5 Design limits switching frequency

The maximum switching frequency is determined by the used modules and their gate charge and the power of the SKYPER12 drivers. It is limited to 30kHz by insulation coordination. Further information on calculating the switching frequency limit can be found in Application Note AN-7004 [5].

5.6 Design limits ambient temperature

This Application Sample has been developed as reference design for laboratory use and tested up to 40°C accordingly.
However, it might be possible to extend the ambient temperature range; the responsibility to test and qualify this larger range remains with the user.

5.7 SEMIKRON assembly

SEMIKRON has tested three of the Application Samples with the SEMITOP E2 1200V MLI Inverter Board utilizing a not optimized forced air cooled heatsink. All results shown are valid for the particular revisions shown in Table 8 only.

Table 8: Part revisions for SEMIKRON tests

Part	Revision
SEMITOP E2 1200V MLI Inverter Board	45137502_02
SKYPER12	L5069901
SKYPER12 (T)MLI Driver Board	45137601_02
SK150MLIT12F4TE2	Datecode: 17010P R
SK150MLIB12F4TE2	Datecode: 17010P R

Variable part values have been chosen according to Table 9.

Table 9: Part values for SEMIKRON tests

Part	Resulting value for T1 and T4	Resulting value for T2 and T3
R_{Gon}	1.65Ω	1.65Ω
R_{Goff}	1.65Ω	1.65Ω
R_{Soft}	5.1Ω	5.1Ω
Active Clamping	4x 170V (i.e. four TVS diodes with a nominal breakdown voltage of 170V)	4x 170V (i.e. four TVS diodes with a nominal breakdown voltage of 170V)
R_{CE}	7.5kΩ	n.c.
C_{CE}	820pF	820pF
$R_{temp,threshold}$	332Ω	

With the above mentioned values an absolute maximum operation up to 1500V_{DC} and 75A_{RMS} is possible at all power factor values at a maximum ambient temperature of 40°C.
It can also withstand soft and hard short circuits, when the active clamping circuits at IGBTs T2 and T3 are adjusted to come into action at V_{CE}=1000..1100V.
The SKYPER12 (T)MLI Driver Board has passed isolation and partial discharge tests.

It is up to the customer to optimize gate resistor values according to the particular operation and do the necessary tests with these changes.

Symbols and Terms

Letter Symbol	Term
3L	Three level
DC-	Negative potential (terminal) of a direct voltage source
DC+	Positive potential (terminal) of a direct voltage source
f_{sw}	Switching frequency
GND	Ground
IGBT	Insulated Gate Bipolar Transistor
N	Neutral potential (terminal) of a direct voltage source; midpoint between DC+ and DC-
n.c.	not connected
NTC	Temperature sensor with negative temperature coefficient
PELV	Protective Extra Low Voltage
PWM	Pulse Width Modulation
R_{Gint}	Internal gate resistance
R_{Goff}	External gate series resistor at switch-off
R_{Gon}	External gate series resistor at switch-on
RMS	Root Mean Square
SELV	Safety Extra Low Voltage
T_a	Ambient temperature
T_j	Junction temperature
TNPC	T-type Neutral Point Clamped
TVS	Transient voltage suppressor
V_{CE}	Collector-emitter voltage
V_{DC}	Total supply voltage between DC+ and DC-

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

References

[1] www.SEMIKRON.com
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[6] J. Krapp, "Technical Explanation SKYPER®12 – rev5", SEMIKRON Technical Explanation, 2017
[7] R. Agostini, "Technical Explanation SEMITOP® – rev5", SEMIKRON Technical Explanation, 2017

IMPORTANT INFORMATION AND WARNINGS

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