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Technical Explanation SEMITRANS10MLI M7 Driver Board

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1. Introduction 1
1.1 Features 2
1.2 Hardware of the SEMITRANS10 MLI M7 Driver Board 3
2. Safety Instructions 5
3. Technical Data 7
3.1 Driver Kit block diagram 7
3.2 Electrical and mechanical characteristics 7
3.3 Integrated functions 8
3.3.1 Thermal protection 8
3.3.2 Active clamping 9
3.4 Board description 9
3.4.1 Adjustment of temperature error 9
3.4.2 Gate resistors 11
3.4.3 Gate-Emitter (GE) components 11
3.4.4 Active clamping 11
3.4.5 Filter for V_{CE} detection 12
3.4.6 Power supply boost capacitors 12
3.4.7 Error management 13
3.4.8 Interlock time of driver T1/T2 and driver T3/T4 14
3.4.9 Input pulse filtering driver T1/T2 and driver T3/T4 14
4. User Interface 15
4.1 Module interface 15
4.2 User interface 17
5. Recommended settings and restrictions 18
5.1 With short circuit detection 18
5.2 Without short circuit detection 18
5.3 Error treatment in paralleled drivers 18
5.4 Error treatment in 3-phase systems 19
5.5 Design limits gate resistors 19
5.5.1 Minimum gate resistor 19
5.5.2 Power rating of the gate resistors 19
5.6 Design limits active clamping 19
5.7 Design limits switching frequency 19
5.8 Design limits ambient temperature 19
5.9 SEMIKRON assembly 19

1. Introduction

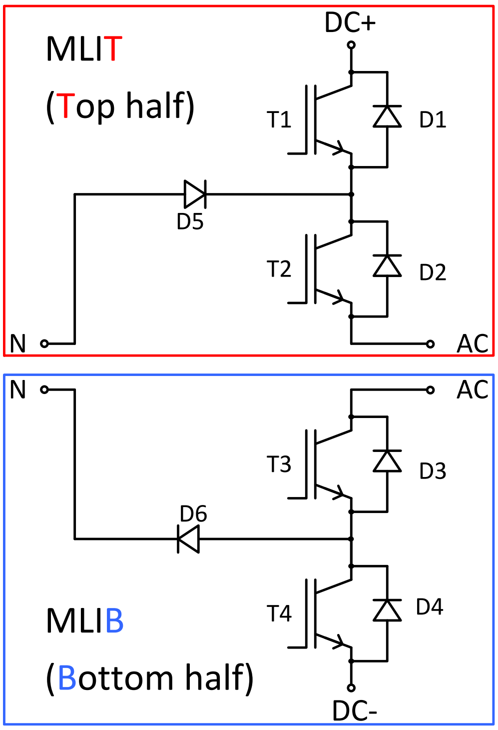
Beside the already existing driver board for SEMITRANS10 (ST10) 1200V MLI in Trench 4 (E4) technology SEMIKRON set up a driver board for operating Generation 7 (M7) modules for evaluation purposes.
The SEMITRANS10 MLI M7 Driver Board ("driver board") is able to operate the module up to a DC-link voltage of 1500V (limited by insulation coordination) at a maximum switching frequency of 30kHz for the ST10 MLI M7 modules (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 (SKYPER 42 LJ PV) are used to operate the 3L MLI module; one driver operates switches T1 and T2, the other operates switches T3 and T4.
The failure management of the two SKYPER 42 LJ PV drivers detects desaturation events at all four switches (IGBTs T1 to T4). The built-in temperature sensor is monitored on T1. The error management is set, that desaturation of any switch leads to an immediate shut-off of the particular IGBTs and produces an error signal. In this case all other IGBTs are immediately switched off by the linked error signal. The active clamping prevents voltage overload on IGBTs and allows to switch off IGBTs at any time without the need to follow a special switch off regime as it is usually required for MLI application.
In case the built-in temperature sensor exceeds a set temperature (can be set by user) the IGBTs are turned off immediately and the driver produces an error signal.

However, the error management can be changed by SKYPER's resistor settings to MLI mode. Means that the particular driver generates an error signal when a secondary side error occurs, but the concerned IGBTs are not turned off. The driver does not react to an external error signal; it stays in the previous state until it is turned off by PWM. See Error management 3.4.7

Please see Technical Explanation "Gate Driver Configuration and Short Circuit Protection for 3-Level Topologies" [8]

Figure 1: Split MLI in SEMITRANS10



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 modules and 2L drivers. Performance tests can be run to prove the possibility of operation at high DC-link voltages and high output power.

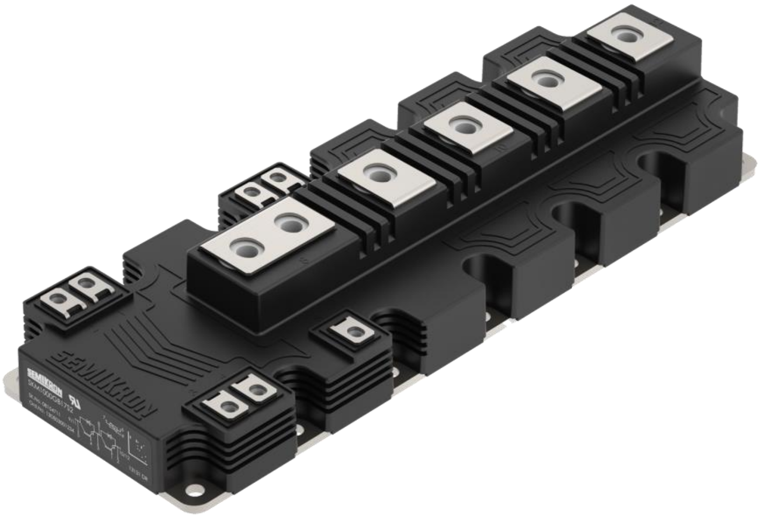
1.1 Features

The SEMITRANS10 MLI M7 Driver Board is designed for the SKM1400MLI12TM7 (top half module) and SKM1400MLI12BM7 (bottom half module). Both are rated 1400A and come with 1200V Generation 7 IGBTs.

In comparison to the modules in Trench 4 technology (SKM1200MLI12TE4 and SKM1200MLI12BE4), the modules in Generation 7 technology feature instead of temperature sensor on IGBT T3 a collector sensing auxiliary contact. Hence, the temperature is detected at IGBT T1 only.

The used driver core SKYPER® 42 LJ PV (L5073102) features a max. DC-Link voltage capability of up to 1500V for photovoltaic application and 35A peak current.

Figure 2: SEMITRANS10



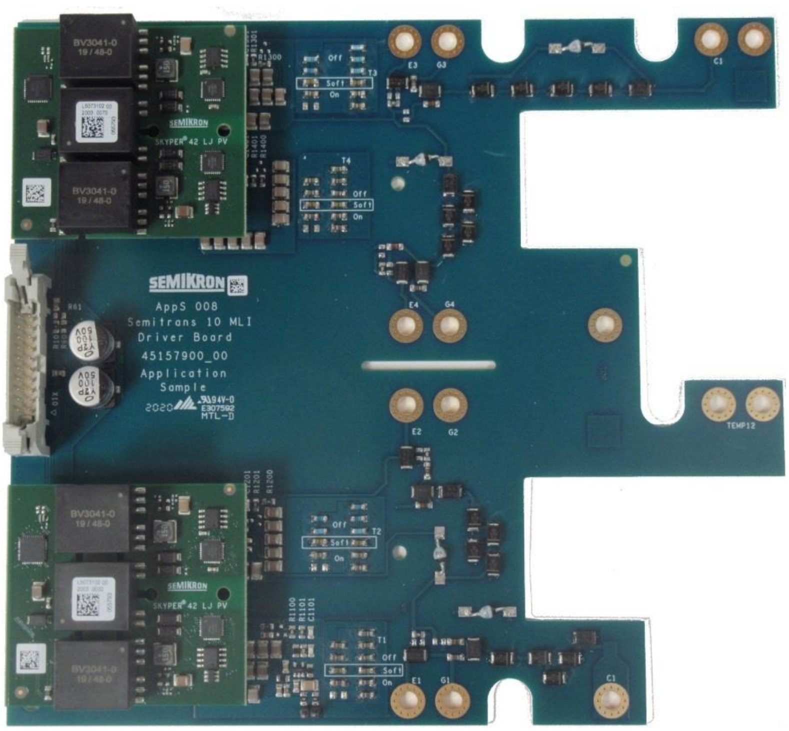
It is the most powerful MLI module in the SEMITRANS10 housing.

1.2 Hardware of the SEMITRANS10 MLI M7 Driver Board

The SEMITRANS10 MLI M7 Driver Board consists of a printed circuit board (PCB): it is called "SEMITRANS 10 MLI M7 Driver Board" ("driver board"; containing gate resistors, clamping circuitry, etc.) with item number 45157901. It contacts the SEMITRANS10 modules and provides sockets for the SKYPER 42 LJ PV drivers and a user interface.

The driver board is designed for 4mm distance between ST10 module housings. So the mounting hole distance between both modules is 20mm measured from top module right mounting hole to bottom module left mounting hole.

Figure 3: SEMITRANS10 MLI M7 Driver Board



The SEMITRANS10 MLI M7 module may be chosen according to the desired current and voltage rating.

Figure 4: SEMITRANS10 MLI M7 Driver Board with IGBT modules bird's eye view

Depending on the power rating and the operating conditions (voltage, current, inductance of the DC-link connection) it might be necessary to adjust gate resistors, clamping voltage 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 SEMITRANS10 MLI M7 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

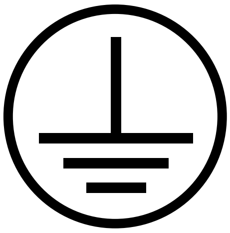
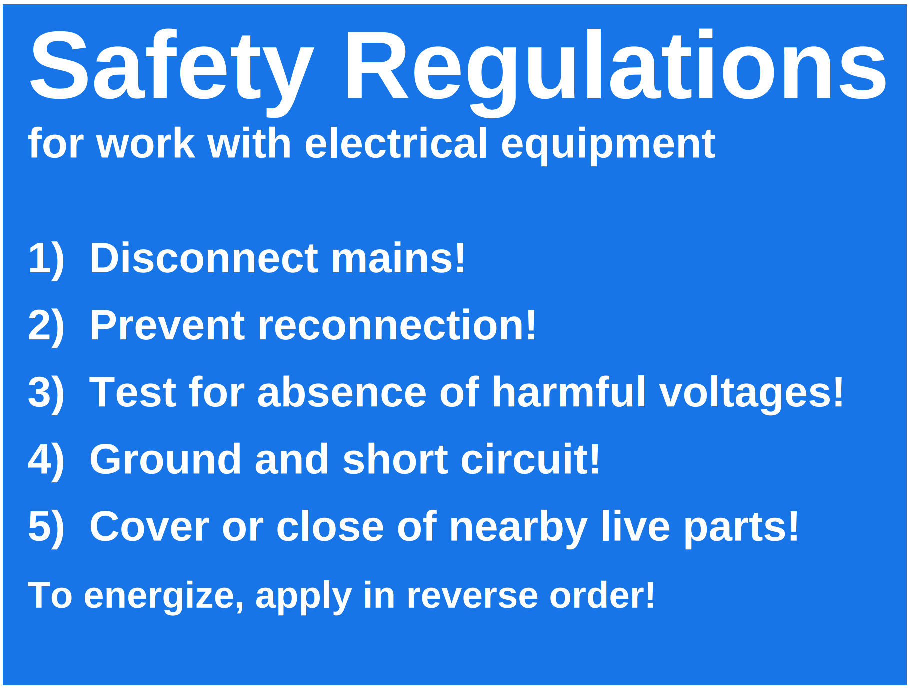
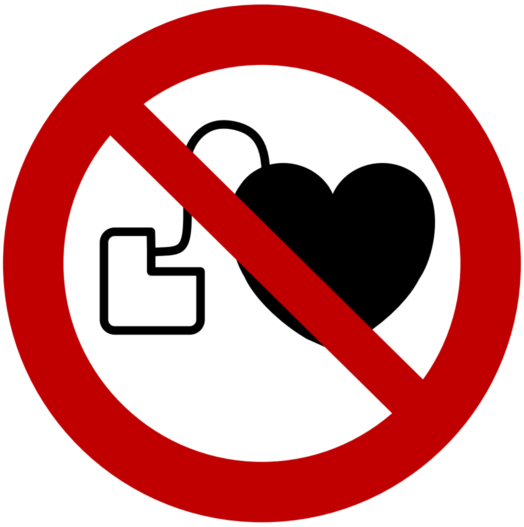
	**In operation the SEMITRANS10 MLI M7 Driver Board inherits high voltages that are dangerous to life!** **Only qualified personnel should work with the Kit.**
	**Some parts of the SEMITRANS10 MLI M7 Driver Board or connected devices (e.g. heatsink) may reach high temperatures that might lead to burns 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 SEMITRANS10 MLI M7 Driver Board.**

Table 2: Safety regulations for work with electrical equipment



Please follow the safety regulations for working safe with the SEMITRANS10 MLI M7 Driver Board.

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



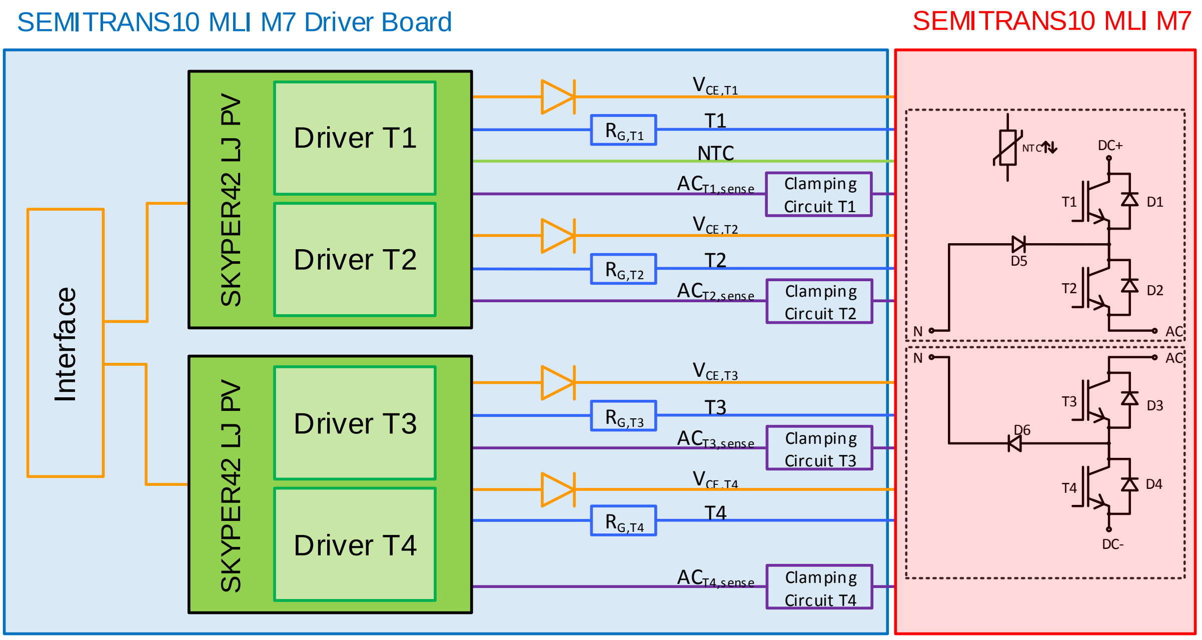
Operating the Application Sample may go along with electromagnetic fields which may disturb cardiac devices.
People with cardiac devices shall not operate the device.

3. Technical Data

3.1 Driver Kit block diagram

The electrical block diagram in Figure 5 shows two parts: the blue marked part is the driver PCB with sockets for the two SKYPER 42 LJ PV drivers (green), gate resistors, clamping, thermal protection and V_{CE} sensing circuitry. The red part symbolizes the 3-level module.

Figure 5 SEMITRANS10 MLI M7 Driver Board block diagram



3.2 Electrical and mechanical characteristics

With regard to the requirement specification the SEMITRANS10 MLI M7 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 5.7 for further information)
- Ambient temperature — T_a = 0°C…40°C (see chapter 5.8 for further information)
- CTI rating of AppS PCBs — > 175

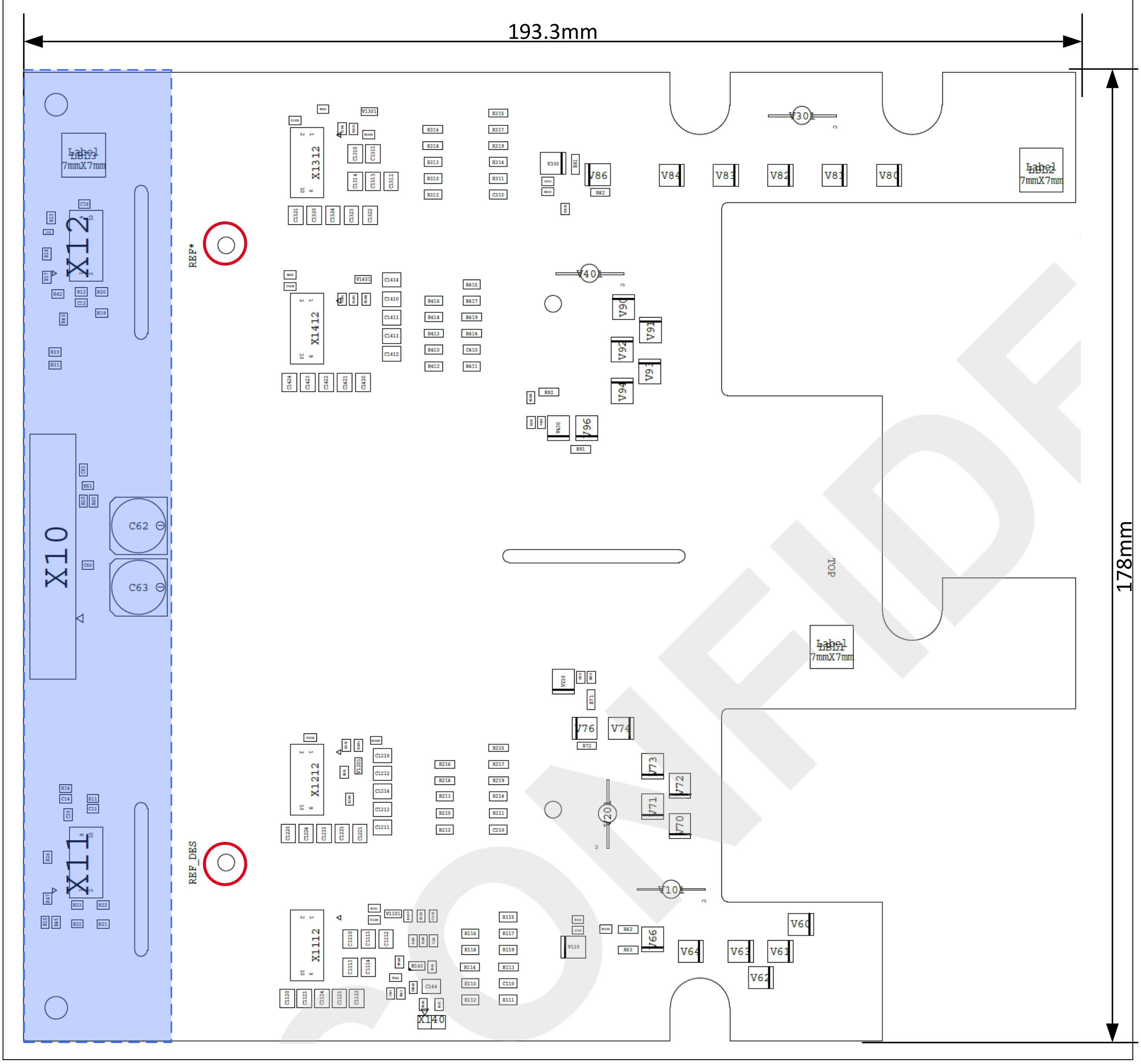
Neglecting the above mentioned boundaries may lead to malfunction or damage of the SEMITRANS10 MLI M7 Driver Board.
An electrical insulation is implemented between the user interface (primary side) and the high voltage connections (secondary side) by using the SKYPER 42 LJ PV's separation. The creepage distance on the driver board is 30mm and the clearance distance is 29mm 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. SKYPER 42 LJ PV) 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 193.3mm long and 178.mm wide. Including SKYPER 42 LJ PV drivers it adds a total height to the modules of 28.5mm.

To prevent the driver board and the SKYPER 42 LJ PV drivers from loosening from each other mounting holes for dual lock support posts are available (positions circled red in Figure 6). Please find further information in the technical explanation of SKYPER 42 LJ PV [6].
The driver board can be mounted to the SEMITRANS10 modules by using M4 screws and washers. Further information on maximum length of the screw and mounting torque can be found in the Mounting Instruction of SEMITRANS10 [1]. Before mounting the driver board the SEMITRANS10 modules need to be mounted to the heatsink. Information how to do so is also given in the SEMITRANS10 Mounting Instruction.

Figure 6: SEMITRANS10 MLI M7 Driver Board ("driver board")



The blue marked area in Figure 6 indicates the primary side with the user interface socket. The insulation is provided by the galvanic insulation of the SKYPER 42 LJ PV drivers and the insulation gap on the driver board. All area besides the blue marking may be considered as high voltage area (secondary side).

3.3 Integrated functions

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

3.3.1 Thermal protection

The SEMITRANS10 modules' built-in NTC temperature sensors are monitored by the error input of IGBT T1. At a pre-defined temperature (to be defined by the user by adjusting a resistor) T1 is switched off immediately and the error is transmitted from secondary side to primary side by the driver. In this case all other IGBTs are immediately switched off by the linked error signal Desaturation detection.
The voltage drop across all IGBTs T1 to T4 is 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.

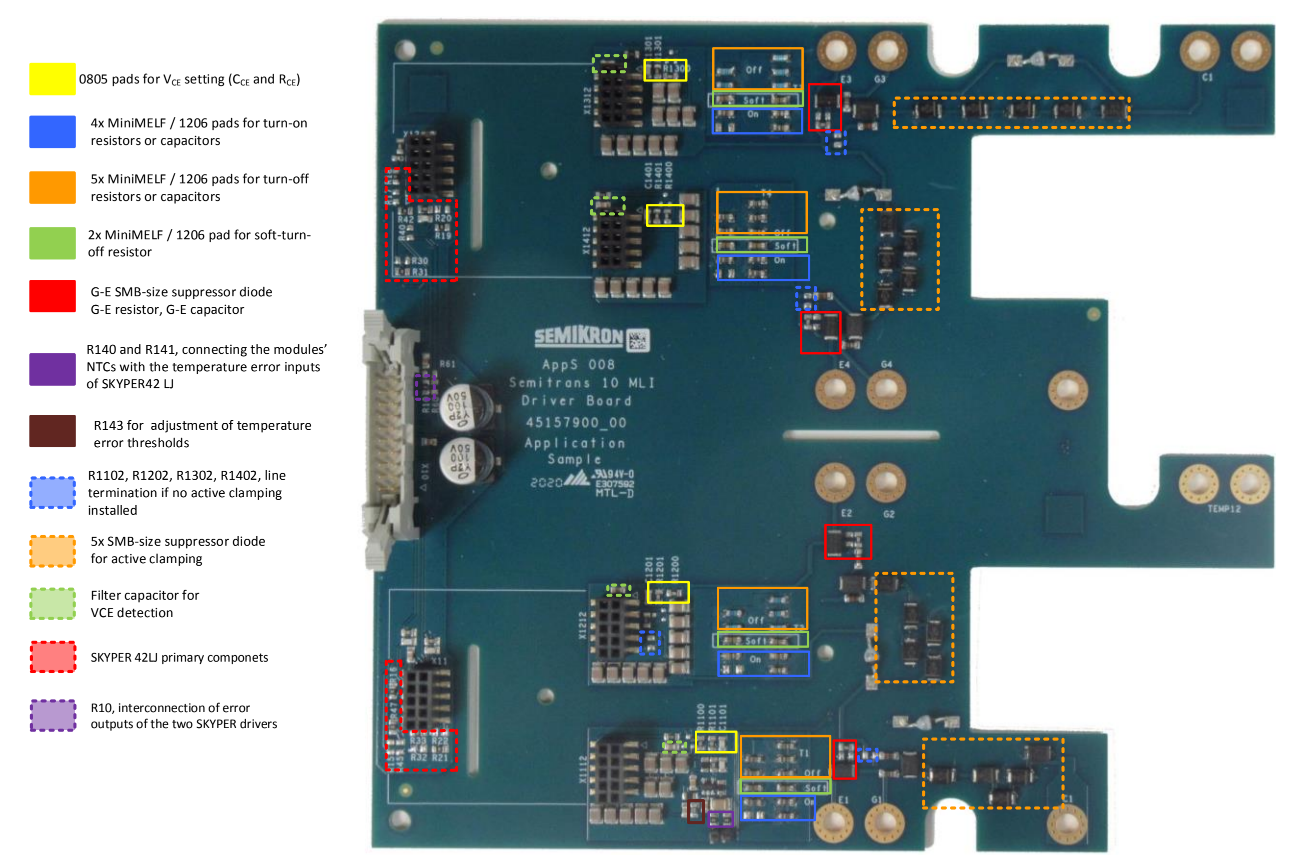
3.3.2 Active clamping

All switches (T1 to T4) are protected versus over voltage by active clamping. The clamping circuit's protection level shall be chosen to a value that does not affect the device in normal operation. At the same time the level should be low enough not to exceed the blocking voltage.
When active clamping comes in action the output stage of the SKYPER 42 LJ PV is switched off in order not to work against the active clamping.

3.4 Board description

The board comes along w/o gate resistors and active clamping diodes. The components need to be selected by the user according to the application conditions and DC-link design. Several mounted components are meant to be changed. The changeable components of the driver board are marked with different coloured frames in Figure 7; function and possible values are explained in chapters 3.4.1 to 3.4.4.

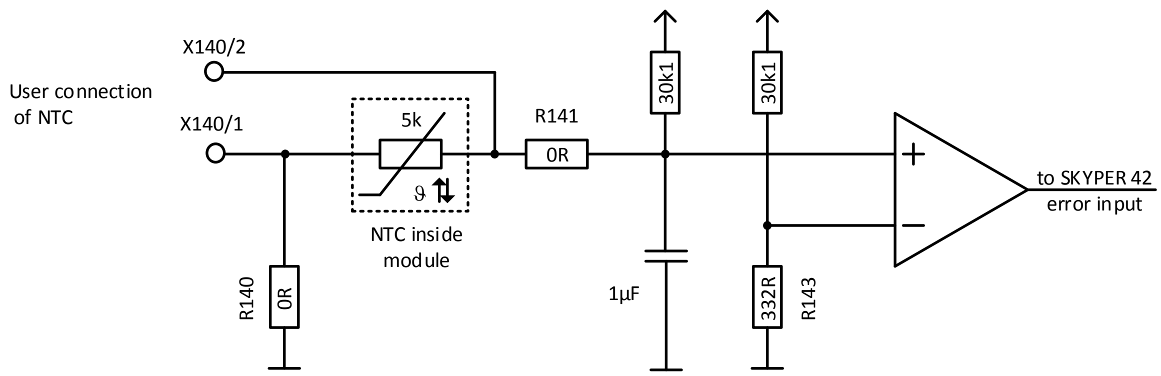
Figure 7: SEMITRANS10 MLI M7 Driver Board; user-changeable components are framed



3.4.1 Adjustment of temperature error

A thermal overload can be detected on both modules by evaluating the ST10 module's built-in NTC sensor. In case a thermal overload is detected the comparator shown in Figure 8 pulls the SKYPER's error input to GND and so the driver can communicate an error message.
The resistor R143 for top half module (framed brown in Figure 7) can be used for adjusting the error temperature threshold.

Figure 8: Schematic of NTC evaluation



The standard value for R143 is 332Ω (refers to a junction temperature of 116°C): The thermal overload detection is deactivated by leaving R140 and R141 unpopulated.
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 9; R143 needs to be chosen to that value. A chip resistors with the size 0805 can be used for R143.
It is possible to use a separate, user-specific thermal detection; in this case resistors R140 and R141 must be removed.

Figure 9: ST10 NTC characteristic (excerpt)

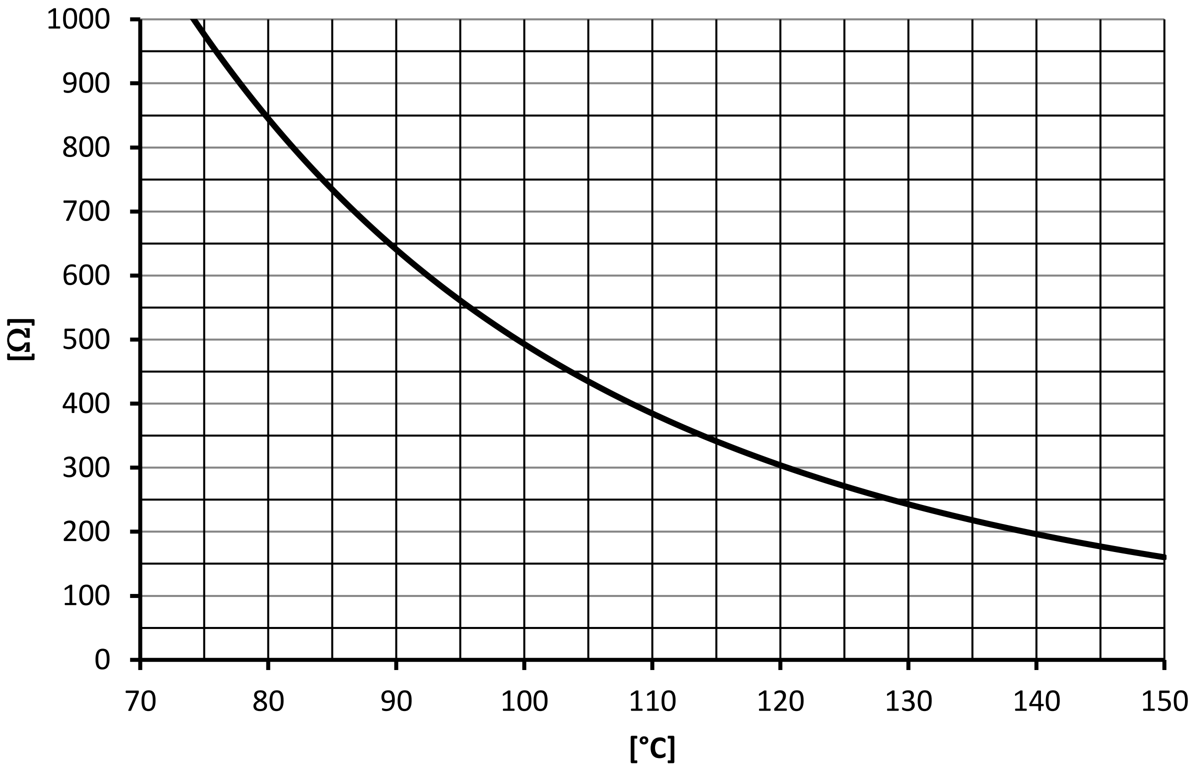
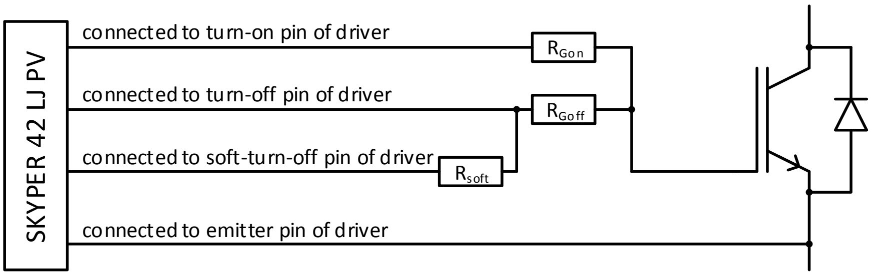


Figure 9 shows an excerpt of the ST10 NTC characteristic which includes the most interesting temperature range between 70°C and 150°C. The full characteristic can be found in the Technical Explanation or can be calculated from the formula given in the ST10 datasheets [1].

3.4.2 Gate resistors

What is called gate resistor in this document for the sake of convenience is realized by three resistors on the contact board. The SKYPER 42 LJ PV offers separate connections for turn-on (R_{Gon}), turn-off (R_{Goff}) and soft-turn-off (R_{soft}), see Figure 10. R_{Gon} is used for every turn-on process, 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.
An additional resistor between driver and the emitters of the paralleled modules reduces oscillations during switching.

Figure 10: Schematic of gate resistor arrangement



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

The driver board offers four pads per IGBT (framed blue in Figure 7) 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 5.5 for further information.

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

The driver board offers five pads per IGBT (framed orange in Figure 7) 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 5.5 for further information.

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

The driver board offers two pads per IGBT (framed green in Figure 7) 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.).
It is recommended to calculate the power losses of the gate resistor in order not to overload and damage it.
Please refer to chapter 5.5 for further information.

3.4.3 Gate-Emitter (GE) components

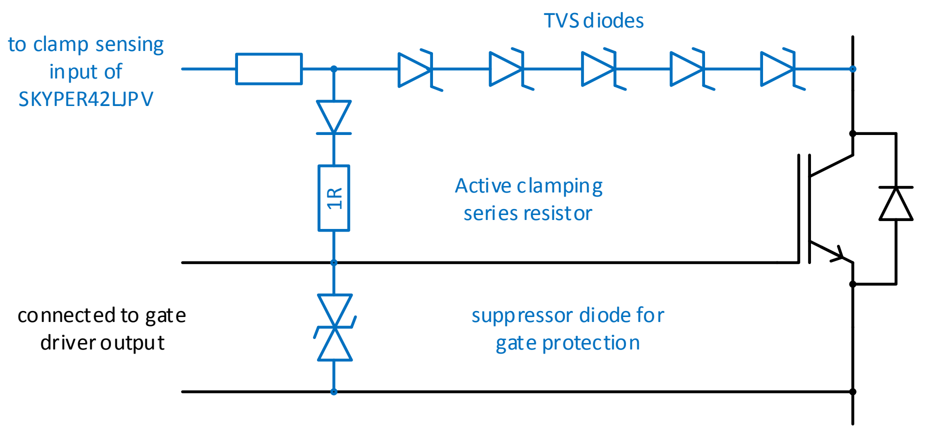
For every IGBT the contact board offers one pad sized SMB and two pads sized 0805 (framed red in Figure 7). SEMIKRON recommends to use one of the 0805 sized pads for placing a 10kΩ resistor and the SMB sized pad for placing a 15V bidirectional breakdown-diode for gate protection. The additional 0805 sized pad may be used for a GE capacitor if required.

3.4.4 Active clamping

Figure 11 shows the schematic of the active clamping used in the Application Sample. The driver board offers five pads sized SMB per IGBT (V60-V64, V70-V74, V80-V84 and V90-V94 framed dotted brown in Figure 7) for placing TVS diodes (transient voltage suppressor diodes). Additionally to the TVS diodes a resistor (R63, R71, R81, R91) limits the current charging the gate and a suppressor diode protects the gate from too high voltages. A standard diode (V66, V76, V86, V96) prevents the driver from feeding into the collector in standard operation. Further the chain of TVS diode is connected to the clamping input of the SKYPER 42 LJ

PV via a resistor. In case of a clamping event the driver stage is disconnected from the gate so that the gate charging effect of the active clamping and the driver don't work against each other.

Figure 11: Schematic of active clamping

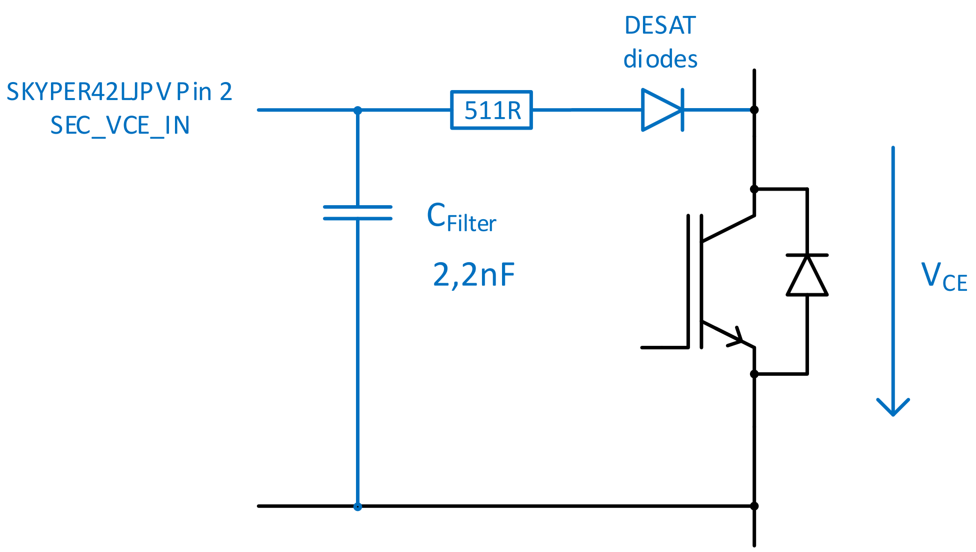


Please refer to chapter 5.6 for further information.

3.4.5 Filter for V_{CE} detection

Figure 12 shows the schematic for the filtering of the IGBT collector-emitter voltage V_{CE} (filter capacitor framed dotted green in Figure 7).
The filtering of IGBT collector-emitter voltage may be needed especially for inner IGBTs T2 and T3 to prevent spurious desaturation detection.
Explanation: T1 is switching on while T2 has already been switched on. Blanking time on T2 is over. A high load di/dt (e.g. capacitive load) can lead to a voltage spike on T2's and T3's Vce detection. This might lead to spurious triggering of desaturation detection. To prevent this triggering the voltage spike can be filtered.
The explanation is also valid for T3/T4 switching.

Figure 12: Filter for V_{CE} detection



3.4.6 Power supply boost capacitors

The board is equipped with 50µF boost capacitors on secondary side power supply to stabilize the gate voltages VG(on) and VG(off) during the semiconductor switching.

3.4.7 Error management

Error interconnection of SKYPER 42 LJ PV drivers

The 0805 sized R10 (framed dotted violet in Figure 7) 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 SKYPER 42 LJ 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.

Error handling of SKYPER 42 LJ PV

The 0805 sized resistors R15-R18 (framed dotted red in Figure 7) may be equipped as shown in Table 4 and Table 5. While R15 and R16 set the error handling for the driver of T1 and T2, R17 and R18 set the error handling for the driver of T3 and T4.
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 (error handling setup for T1 and T2)

R15	0Ω	not equipped
R16	not equipped	0Ω
Function →	The particular driver generates an error signal when a secondary side error occurs, but the concerned IGBTs are not turned off. The driver does not react to an external error signal; it stays in the previous state until it is turned off by PWM (in case of a previous error, the soft-turn-off resistor is used). A continuous error signal prevents the driver from turning on.	The particular driver generates an error signal and immediately turns off the concerned IGBTs using the soft-turn-off resistors when a secondary side error occurs. In case an external error signal is applied the driver turns off the two IGBTs. A continuous error signal prevents the driver from turning on. ⇨ **Default setup (recommended)**

Table 5: Functional table for R17 – R18 (error handling setup for T3 and T4)

R17	0Ω	not equipped
R18	not equipped	0Ω
Function →	The particular driver generates an error signal when a secondary side error occurs, but the concerned IGBTs are not turned off. The driver does not react to an external error signal; it stays in the previous state until it is turned off by PWM (in case of a previous error, the soft-turn-off resistor is used). A continuous error signal prevents the driver from turning on.	The particular driver generates an error signal and immediately turns off the concerned IGBTs using the soft-turn-off resistors when a secondary side error occurs. In case an external error signal is applied the driver turns off the two IGBTs. A continuous error signal prevents the driver from turning on. ⇨ **Default setup (recommended)**

Error input and error output of SKYPER 42 LJ PV

When error in- and outputs are connected to each other (R42=R47=0Ω), multiple drivers can share one error line. In this case one driver, that enters error mode, directly switches off the drivers connected to the same error line.

⇨ **Default setup (recommended)**

With unconnected error in- and outputs it is possible to detect which driver board set the error. For that all error outputs have to be routed to the controller. The controller can then switch off other drivers by triggering the error input or deactivating input signals.

3.4.8 Interlock time of driver T1/T2 and driver T3/T4

Interlock function has to be disabled since both IGBT T1 and T2 respectively T3 and T4 can be turned on at the same time.

Table 6: Functional table for R19 – R20 (interlock setup for T3 and T4)		
R19	0Ω	not equipped
R20	not equipped	0Ω
Function →	The interlock time between T3 and T4 is set to 0. That means that both IGBTs may be switched on at the same time. ⇨ **Default setup (recommended)**	The interlock time between T3 and T4 is activated and set to 2µs. That means that one IGBT may be switched on 2µs after the other IGBT switched off. The two IGBTs cannot be turned on at the same time.

Table 7: Functional table for R21 – R22 (interlock setup for T1 and T2)		
R21	0Ω	not equipped
R22	not equipped	0Ω
Function →	The interlock time between T1 and T2 is set to 0. That means that both IGBTs may be switched on at the same time. ⇨ **Default setup (recommended)**	The interlock time between T1 and T2 is activated and set to 2µs. That means that one IGBT may be switched on 2µs after the other IGBT switched off. The two IGBTs cannot be turned on at the same time.

3.4.9 Input pulse filtering driver T1/T2 and driver T3/T4

The 0805 sized resistors R30-R33 (framed dotted red in Figure 7) may be equipped as shown in Table 8 and Table 9. R30 and R31 set the input pulse filtering function for the driver of T3 and T4, R32 and R33 set the input pulse filtering for the driver of T1 and T2.
Any other combination (e.g. all resistors 0Ω or all resistors not connected) will lead to malfunction and may damage the system.

Table 8: Functional table for R30 – R31 (Input pulse filtering for T3 and T4)		
R30	0Ω	not equipped
R31	not equipped	0Ω
Function →	The input pulse filtering is set to digital operation. The filter time is 375ns, delay time typically 0.7µs and the jitter 30ns with very low tolerances over the whole temperature range.	The input pulse filtering is set to analogue operation. The filter time is 180ns, delay time typically 0.4µs and the jitter 2.5ns. ⇨ **Default setup**

Table 9: Functional table for R32 – R33 (Input pulse filtering for T1 and T2)		
R32	0Ω	not equipped
R33	not equipped	0Ω
Function ➔	The input pulse filtering is set to digital operation. The filter time is 375ns, delay time typically 0.7µs and the jitter 30ns with very low tolerances over the whole temperature range.	The input pulse filtering is set to analogue operation. The filter time is 180ns, delay time typically 0.4µs and the jitter 2.5ns. ⇨ **Default setup**

4. User Interface

4.1 Module interface

The pinout and circuit diagram of ST10 MLI M7 modules is shown in Figure 13 and explained in Table 10. All modules that are pin-compatible may be used with the driver kit.

Figure 13: ST10 MLI M7 interface for top half module and bottom half module

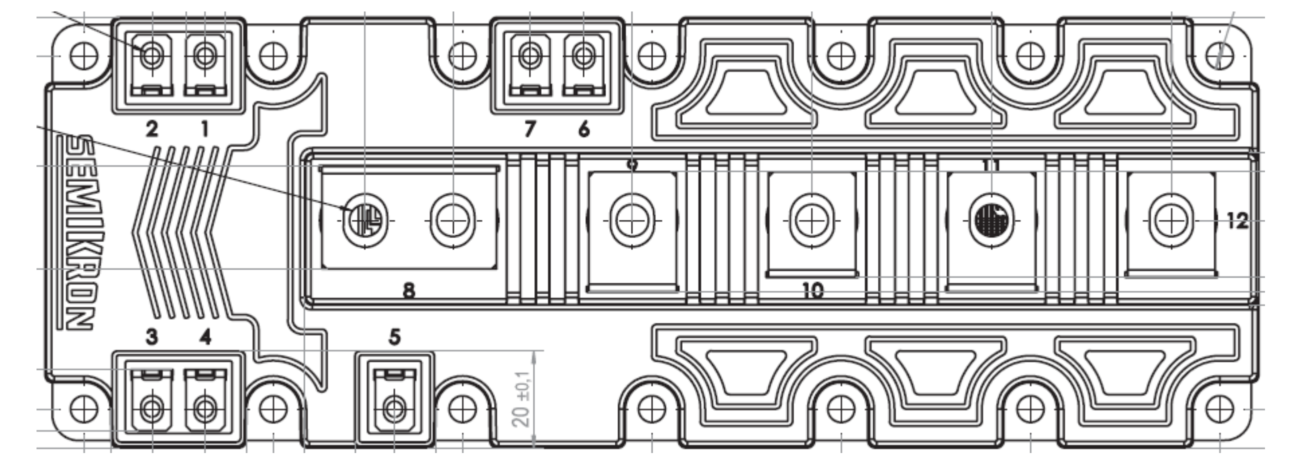
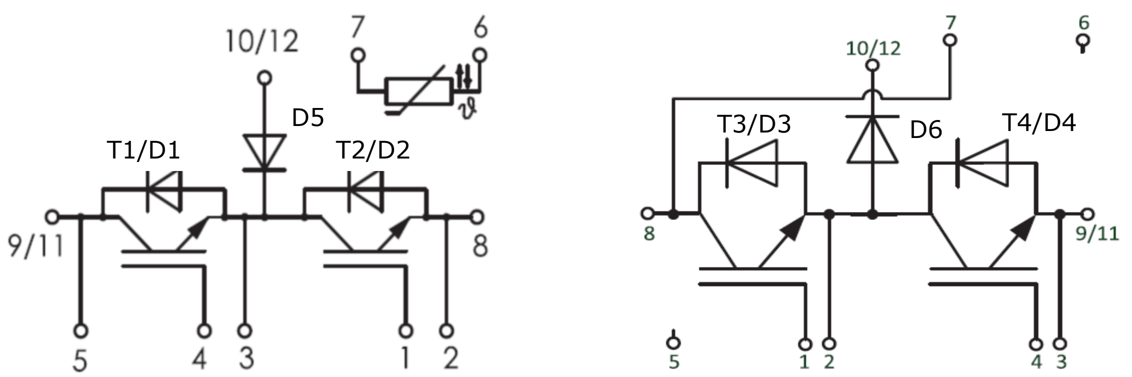


Figure 14: ST10 MLI M7 pin connection for

top half module **and** **bottom half module**



Pin 7 of bottom half module is not connected to collector T3 while pin 5 of top half is connected to collector of T1.

Table 10: ST10 MLI M7 pin description

Pin	SKM1400MLI12TM7 (top half module)	Pin	SKM1400MLI12BM7 (bot. half module)
1	Gate IGBT T2	1	Gate IGBT T3
2	Emitter IGBT T2	2	Emitter IGBT T3
3	Emitter IGBT T1	3	Emitter IGBT T4
4	Gate IGBT T1	4	Gate IGBT T4
5	Collector IGBT T1	5	not connected
6	NTC temperature sensor	6	not connected
7	NTC temperature sensor	7	Collector IGBT T3
8	AC terminal	8	AC terminal
9	DC+ terminal	9	DC- terminal
10	N terminal	10	N terminal
11	DC+ terminal	11	DC- terminal
12	N terminal	12	N terminal

Further information about module mounting, etc. may be found in the module datasheets and the ST10 technical explanation [1].

4.2 User interface

The user interface is the 20-pin connector X10 located in the middle of the driver board. The pin description is given in Table 11.

Table 11: X10 pin description

Pin	Signal name	Description	Voltage level
1	IF_PWR_VP	Driver supply voltage	$15V_{DC}$±4%, max. 0.5A @10kHz
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. Recommended settings and restrictions

5.1 With short circuit detection

The driver board offers desaturation detection and active clamping on all IGBTs T1 to T4. With this measure all IGBTs are protected against short circuit and overvoltage. The IGBTs can be switched off at any time without the need to follow special switch off regime as it is usually required for MLI application.
For this operation the driver board has to be set as follows:

R10=0Ω	Error interconnection of SKYPER 42 LJ drivers
R42=R47=0Ω	SKYPER 42 LJ PV error input and output connected.
R16=R18=0Ω	Driver switches off on error. Reacts on error input. See Table 4 and Table 5
R19=R21=0Ω	No interlock. See Table 6 and Table 7
$R_{Soft}=R_{Goff}$	Soft-turn-off gate resistor shall have same value as R_{Goff} to switch IGBT without delay in case of short circuit.

C1102; C1201, C1302, C1404 =2.2nF Filter capacitor for desaturation voltage detection

With this setting desaturation of any switch leads to an immediate shut-off of the particular IGBT and produces an error signal. All other IGBTs are immediately switched off by the linked error signal.
If inner IGBT T2/T3 detects error or is switching off by input signal first the active clamping limits the voltage across the IGBT.

5.2 Without short circuit detection

If short circuit detection is not required the desaturation detection diodes V101, V201, V301 and V401 are not needed. TVS diodes for overvoltage protection are usually needed on inner IGBTs to protect for overvoltage due to long commutation loop (reactive power operation).

R10=x	Can be open or 0Ω.
R42=R47=0Ω	SKYPER 42 LJ PV error input and output connected.
R15=R17=0Ω	Driver does not switch off on error. Does not react on error input. See Table 4 and Table 5
R19=R21=0Ω	No interlock. See Table 6 and Table 7
R1102=R1402=0Ω	Deactivate active clamping detection on T1 and T4
C1102=C1202= C1302=C1402=0Ω	Mount 0805 0Ω resistor instead of capacitor to deactivate desaturation function.
$R_{Soft}=R_{Goff}$	Soft-turn-off gate resistor. Value to be determined by measurements.

In case a secondary side error from over temperature detection (connected to T1) 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 of X10 (see Table 11). The IGBT is not switched off by the driver board.
All IGBTs have to be switched off by PWM signal from controller considering that the outer IGBT is switched off first and the inner IGBT follows several µs later. A detailed explanation of the MLI switching pattern is given in the SEMIKRON Application Note AN11001 [3].
Error interconnection of SKYPER 42 LJ PV drivers (R10) is not important since the drivers do not switch off on error.

5.3 Error treatment in paralleled drivers

It is possible to use several drivers in parallel to increase the inverter's output power by simply plug all parallel drivers to one controller cable. This method parallels all PWM signals and also the error messages. The errors of one driver board would be communicated to the other driver boards of one phase leg leading to the error handling as described above.

5.4 Error treatment in 3-phase systems

In 3-phase systems there is no direct connection of the driver error signals. This connection must be provided by the user; either by a hardware connection of the particular error lines or by routing the error messages and appropriate handling on the controller side. Please note that time is critical when an error occurs and therefore error treatment shall be performed using fast hardware.

5.5 Design limits gate resistors

5.5.1 Minimum gate resistor

The minimum gate resistor is determined by the maximum voltage change of the driver during switching; it turns from -8V to +15V or back, so the voltage change is 23V. The peak current SKYPER 42 LJ PV is capable of driving is 35A, so the minimum total gate resistor that needs to be used is 0.65Ω.
The total gate resistor consists of the internal gate resistor of the two modules (that can be found in the module datasheet) and the gate-turn-on or gate-turn-off resistors R_{Gon} and R_{Goff}.

5.5.2 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 AN7003 [4].

5.6 Design limits active clamping

The clamping voltage for protecting T1 to T4 can be adjusted by changing the breakdown voltage of the four SMB sized TVS diodes.
Please note that the suppressor diode designation is different from the real protection level. The protection level is depending on the current which flows through the diode chain to charge the gate. Further the temperature dependence and type spread has to be considered

SEMIKRON recommends to use all five diodes and no 0Ω jumpers instead to minimize the voltage stress on the didoes. 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. max. DC-link voltage plus voltage overshoot in normal operation) in order not to increase the switching losses.

5.7 Design limits switching frequency

The used modules, their gate charge and the power of the SKYPER 42 LJ PV drivers determine the maximum switching frequency. Further information on calculating the switching frequency limit can be found in Application Note AN7004 [5].

5.8 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.

5.9 SEMIKRON assembly

SEMIKRON has tested the Application Sample as it is shown in the photos above. All results shown are valid for the particular revisions shown in Table 12 only.

Table 12: Part revisions for SEMIKRON tests	
Part	**Revision**
SKYPER 42 LJ PV	L5073102
Semitrans 10 MLI M7 Driver Board	45157901
SKM1400MLI12TM7 SKM1400MLI12BM7	Datecode: 20330

Variable part values have been chosen according to Table 13.

Table 13: Part values for SEMIKRON tests		
Part	**Resulting value for T1 and T4**	**Resulting value for T2 and T3**
R_{Gon}	1.2Ω	1.4Ω
R_{Goff}	1Ω	5Ω
R_{Soft}	0Ω	0Ω
C_{GE}	-	-
C_{Filter}	2.2nF	2.2nF
Active Clamping	4x SMBJ188 + 1x SMBJ64	
R_{CE}	10kΩ (R1100, R1101, R1400, R1401)	10kΩ (R1200, R1201, R1300, R1301)
C_{CE}	820pF (C1102, C1402)	820pF (C1202, C1302)
$R_{temp,threshold}$	332Ω (R143)	

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

Figure 1: Split MLI in SEMITRANS10 2
Figure 2: SEMITRANS10 3
Figure 3: SEMITRANS10 MLI M7 Driver Board 3
Figure 4: SEMITRANS10 MLI M7 Driver Board with IGBT modules bird's eye view 4
Figure 5 SEMITRANS10 MLI M7 Driver Board block diagram 7
Figure 6: SEMITRANS10 MLI M7 Driver Board ("driver board") 8
Figure 7: SEMITRANS10 MLI M7 Driver Board; user-changeable components are framed 9
Figure 8: Schematic of NTC evaluation 10
Figure 9: ST10 NTC characteristic (excerpt) 10
Figure 10: Schematic of gate resistor arrangement 11
Figure 11: Schematic of active clamping 12
Figure 12: Filter for V_{CE} detection 12
Figure 13: ST10 MLI M7 interface for top half module and bottom half module 15
Figure 14: ST10 MLI M7 pin connection for top half module and bottom half module 15

Table 1: Safety instructions 5
Table 2: Safety regulations for work with electrical equipment 6
Table 3: No access for people with active implanted cardiac devices! 6
Table 4: Functional table for R15 – R16 (error handling setup for T1 and T2) 13
Table 5: Functional table for R17 – R18 (error handling setup for T3 and T4) 13
Table 6: Functional table for R19 – R20 (interlock setup for T3 and T4) 14
Table 7: Functional table for R21 – R22 (interlock setup for T1 and T2) 14
Table 8: Functional table for R30 – R31 (Input pulse filtering for T3 and T4) 14
Table 9: Functional table for R32 – R33 (Input pulse filtering for T1 and T2) 15
Table 10: ST10 MLI M7 pin description 16
Table 11: X10 pin description 17
Table 12: Part revisions for SEMIKRON tests 20
Table 13: Part values for SEMIKRON tests 20

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

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IMPORTANT INFORMATION AND WARNINGS

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