Absolute maximum ratings			
Symbol	**Term**	**Value**	**Unit**
V_S	supply voltage non stabilized	30	V
V_{iH}	input signal voltage (high)	18	V
V_{CE}	collector emitter voltage (max.)	1700	V
dv/dt	rate of rise and fall of voltage (secondary to primary side)	50	kV/µs
$Visol_{IO}$	isolation test voltage (AC, rms, 2 sec.) input – output	4000	V
$Visol_{PD}$	partial discharge extinction voltage, rms, $Q_{PD} \leq 10$ pC	1500	V
$Visol_{12}$	isolation test voltage (AC, rms, 2 sec.) output 1 - output 2	1500	V
f	switching frequency	20	kHz
T_{op} (T_{stg})	operating (storage) temperature range	- 25 ... + 70	°C

Electrical characteristics (T_{amb} = 25 °C)		Values			
Symbol	**Term**	**min**	**typ**	**max.**	**Units**
V_{S2}	supply voltage non stabilised	13	24	27	V
I_{S2}	supply current max	$1/V_{S2}$*[7,8W+1,21(W/kHz)*f(kHz)+power dissipation for the current sensors]			A
V_{iT+}	input threshold voltage (High)	9	–	13.1	V
V_{iT-}	input threshold voltage (Low)	3,1	–	6,8	V
R_{in}	input resistance	–	10	–	kΩ
$V_{G(on)}$	turn-on gate voltage output	–	+15	–	V
$V_{G(off)}$	turn-off gate voltage output	–	-8	–	V
$t_{d(on)io}$	input-output turn-on propagation time	–	1	–	µs
$t_{d(off)io}$	input-output turn-off propagation time	–	1	–	µs
t_{pRESET}	ERROR memory RESET time	–	9	–	µs
t_{TD}	top - bottom switch interlock dead-time	no inter-lock	–	4	µs
V_{CEstat}	collector-emitter threshold static monitoring voltage	4,7	5,2	5,7	V
t_{bl}	V_{CEstat} blanking time at turn-on	3,5	4	4,5	µs
I_{TRIPSC}	over current trip level ($I_{analogOUT}$ = 10V)	197	–	517	A
T_{tp}	over temperature protection	–	115	–	°C
C_{ps}	coupl. capacitance primary-secondary	–	27	–	pF
C_{in}	Input capacitance	-	1	-	nF
m	weight		110		g

SEMIDRIVER™
SKHI 64

Gate driver for SKiM® 4

Features

- current source driving technology (CSDT)
- snap-on technology
- spring connected to power section
- wide range power supply
- V_{CE}-monitoring
- short circuit protection
- over current protection (trip level can be adjusted by the customer via DIP switches)
- DC-link voltage detection
- temperature sensing
- under voltage monitoring
- interlock top/bottom switch (interlock time (1µs, 2µs. 3µs, 4µs or no interlock) can be adjusted by the customer via DIP switches)
- error latch / output
- isolation by transformers
- GB / GD mode
- DC bus voltage up to1200V
- separate interfaces to connect external phase current sensors

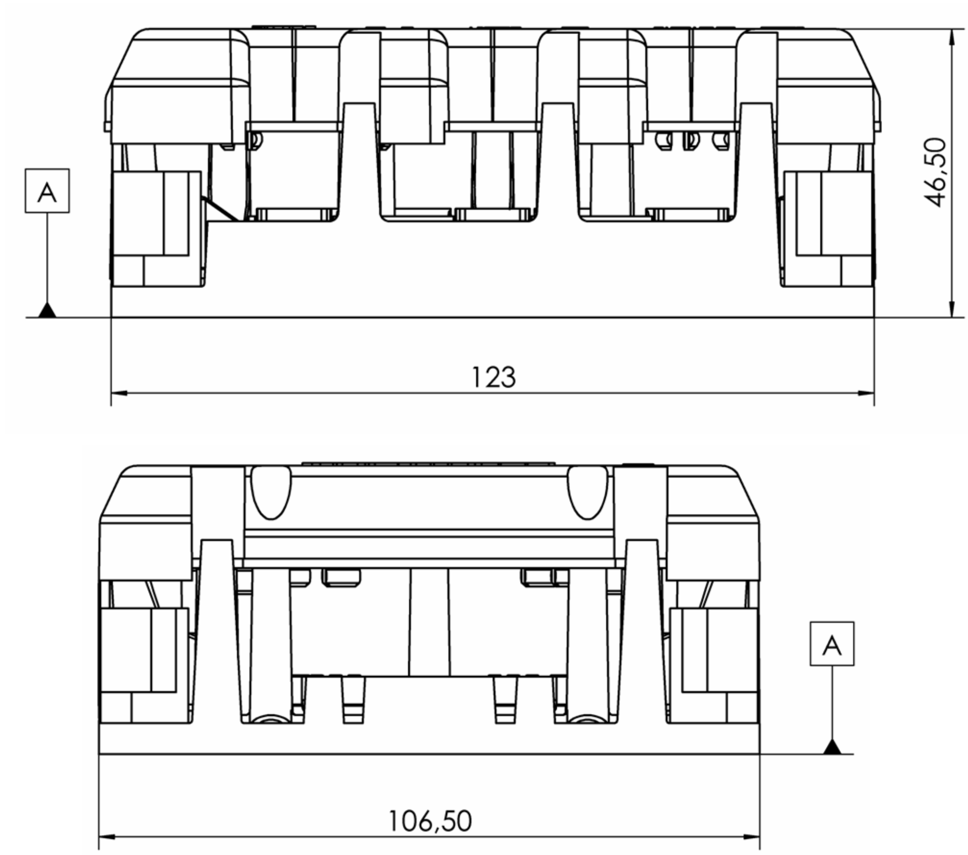


Fig. 1: Dimensions

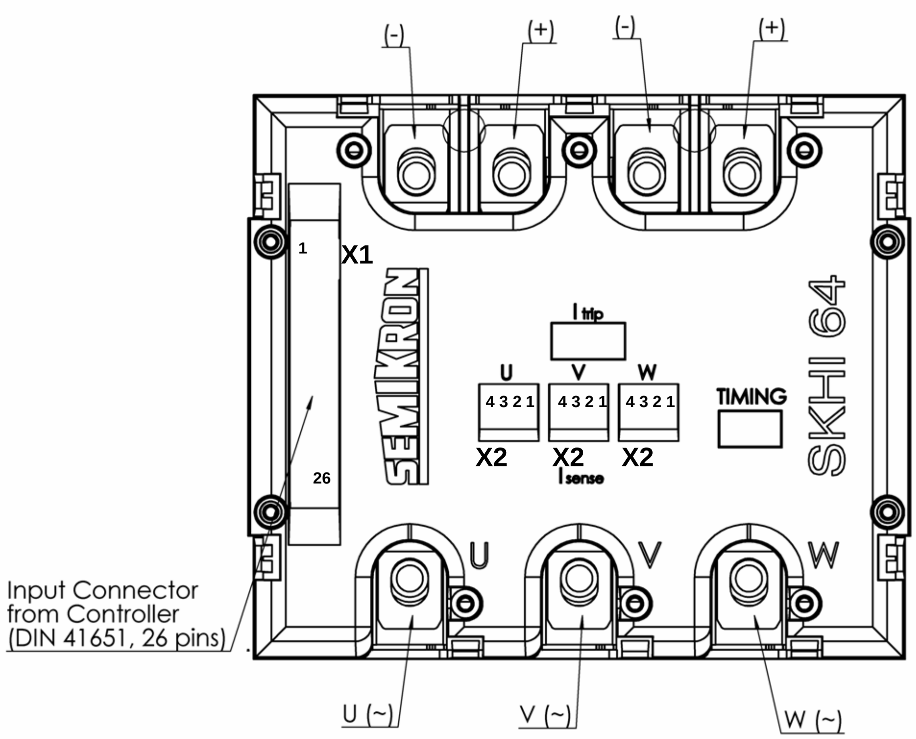


Fig. 2: Connectors and Pin array

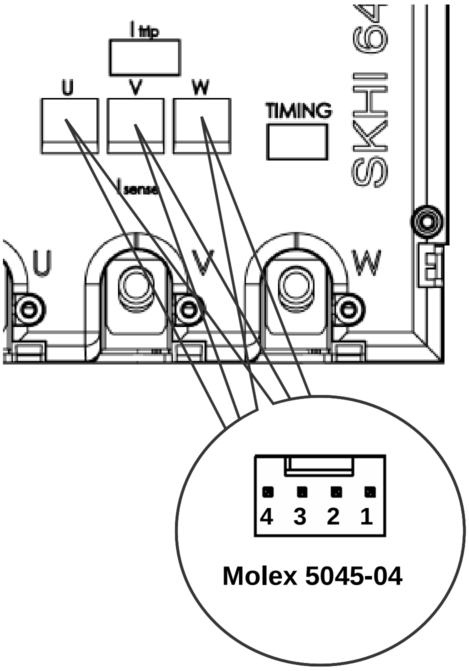
PIN array

X1: (DIN 41651 connector 26 pin)

Pin	signal	remark
1	shield	connected to GND when shielded cable is used
2	BOT HB 1 **(W)** IN	positive 15 V CMOS logic; 10 kOhm impedance
3	ERROR HB 1 **(W)** OUT [1)]	short circuit monitoring HB1 **(W)** LOW = NO ERROR; open collector output; max. 30V / 15mA
4	TOP HB 1 **(W)** IN	positive 15 V CMOS logic; 10 kOhm impedance
5	BOT HB 2 **(V)** IN	positive 15 V CMOS logic; 10 kOhm impedance
6	ERROR HB 2 **(V)** OUT [1)]	short circuit monitoring HB2 **(V)** LOW = NO ERROR; open collector output; max. 30V / 15mA
7	TOP HB 2 **(V)** IN	positive 15 V CMOS logic; 10 kOhm impedance
8	BOT HB 3 **(U)** IN	positive 15 V CMOS logic; 10 kOhm impedance
9	ERROR HB 3 **(U)** OUT [1)]	short circuit monitoring HB 3 **(U)** LOW = NO ERROR; open collector output; max. 30V / 15mA
10	TOP HB 3 **(U)** IN	positive 15 V CMOS logic; 10 kOhm impedance
11	Overtemp. OUT [1)]	LOW = NO ERROR = ϑ_{DCB} < 115 ± 5°C open Collector OUTPUT; max. 30 V / 15 mA
12	ERRORSUM	under voltage monitoring (if ERROR HB 1, 2, 3 OUT is LOW) LOW = NO ERROR; open collector output; max. 30V / 15mA
13	U_{DC} analog OUT	actual DC-link voltage $U_{DCanalogOUT} = U_{DC\text{-}link} / 100$ (accuracy ±2%) U_{DCmax} = 1200V max. output current 5mA
14	+ V_S IN	min. 13V; max. 27V
15	+ V_S IN	
16	+ 15 V_{DC} OUT	15 V_{DC} + 4 %, min. 13,9V; I_{out} = 50mA
17	+ 15 V_{DC} OUT	
18	GND	GND for power supply and GND for digital signals
19	GND	
20	Temp. analog OUT	$V(T_{ana})=11*10^{-3}*(1321+(1000*(1+7,635*10^{-3}*(T_h-25)+17,31*10^{-6}*(T_h-25)^2)))-25$ max. output current 5 mA
21	GND aux	reference for analogue output signals
22	I analog OUT HB 1 **(W)**	current actual value 10 V refer to over current trip level max. output current 5mA current value > 0 ⇔ SKiM is source current value < 0 ⇔ SKiM is sink
23	GND aux	reference for analogue output signals
24	I analog OUT HB 2 **(V)**	current actual value 10 V refer to over current trip level max. output current 5mA current value > 0 ⇔ SKiM is source current value < 0 ⇔ SKiM is sink
25	GND aux	reference for analogue output signals
26	I analog OUT HB 3 **(U)**	current actual value 10 V refer to over current trip level max. output current 5mA current value > 0 ⇔ SKiM is source current value < 0 ⇔ SKiM is sink

[1)] open collector output, external pull up resistor necessary

X2: (plug-connectors for external current sensors)

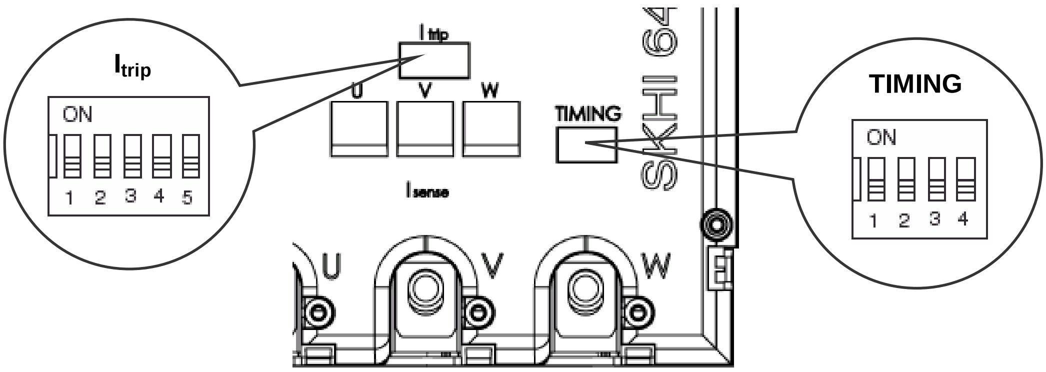


Please note:
The plug connectors for external current sensors are not short-circuit proof.

Product information of suitable female housing, female terminal and distributor contact information is available at http://www.molex.com

Pin	signal	remark
1	Supply voltage +15V	
2	Supply voltage –15V	
3	Measure	built-in measuring resistance (RM) of 7,15 Ω
4	0V / shield	

DIP SETTINGS:



Please note:
Please remove the foil from the DIP switches before the adjustment. This foil does not have to be set again after the DIP adjustment.

I_{trip}	
DIP	**signal**
1	adjustment over current trip level (see chapter "Over Current Protection (OCP) and short circuit protection")
2	
3	
4	
5	

TIMING	
DIP	**signal**
1	adjustment dead time generation (interlock TOP / BOTTOM) (see chapter "Dead time generation (interlock TOP / BOTTOM")
2	
3	
4	adjustment GB / GD mode (see chapter "GB / GD mode")

General description

SKHI 64 is a universal six pack gate driver for SKiM 4 IGBT modules, which can be used for all available voltage an current ranges.

This driver provides a complete solution with integrated protection and monitoring functions, potential isolation, connectors for external current sensors and an interface for controllers.

General features of the gate driver SKHI 64:

- wide range (13V – 27V) supply voltage
- 15V CMOS level input signals (positive logic)
- current source driving technology (CSDT)
- integrated power supply for secondary side and current sensors
- isolation between primary and secondary side
- open collector ERROR output
- GB-synchronisation
- DIN 41651 connector for controller interface

Protection and monitoring functions:

- interlock for TOP and BOTTOM IGBT – interlock time (1µs, 2µs, 3µs, 4µs or no interlock) can be adjusted via DIP switches
- short pulse suppression
- input pulse shaping
- under voltage monitoring
- transient over voltage protection of supply voltage by suppressor diode
- heat sink over temperature protection
- V_{CE}-monitoring (de-saturation monitoring)
- **O**ver **C**urrent **P**rotection (external current sensor necessary) – over current trip level can be adjusted via DIP switches
- DC link voltage sensing
- ERROR latch and ERROR feedback via open collector transistor (external pull up resistor necessary)

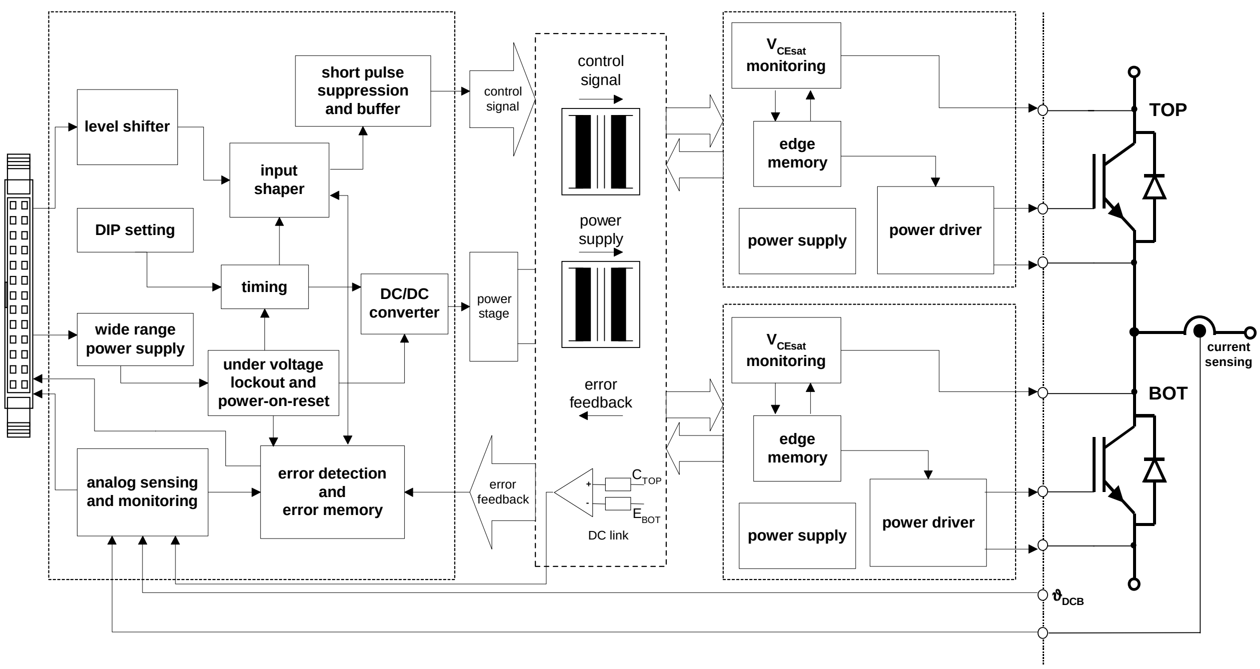


Fig. 3: Block diagram of one phase leg SKHI 64

Technical explanations

Current Source Driving Technology (CSDT)

SKHI 64 is a current source gate driver. The turn-on and turn-off of the IGBT is controlled via a positive and negative gate current. CSDT enables that only one type is sufficient to drive IGBTs with different chip technologies (e. g. Trench FS, Soft Punch Through), as well as to compensate the input capacitance variations resulting from wide current and voltage ranges. This unique property eliminates the need of any additional components to adapt the gate driver to the specific IGBT.
SKHI 64 is one gate driver, which can be used for all available SKiM 4 voltage and current ranges.

Insulation

Magnetic transformers are used for insulation between gate driver primary and secondary side. The circuit used for the DC voltage measurement is designed, manufactured and tested according to standard EN 50178 (VDE 0160).

> **Please note:**
> The insulation of the driver is a basic insulation only. Equipment which is designed according to EN 50178 must have further insulation for all parts which might be touched by a person.

The insulation test voltage is given in the absolute maximum ratings of the gate driver.

Auxiliary power supply

The gate driver SKHI 64 has got an integrated wide range auxiliary power supply 13V - 27V. The following table shows the required features of an appropriate power supply for the gate driver SKHI 64. When the gate driver is supplied with 13V – 27V it is possible to use 15V provided at the DIN 41651 connector of the gate driver as an auxiliary power supply, e.g. for a level-shifter at the controller’s output signals.

unregulated power supply	13V - 27V
+ 15 V_{DC} OUT (can be used if 13V – 30V supply is active)	< 50 mA
minimum peak current of auxiliary supply	1 A
power on reset completed after	150 ms

> **Please note:**
> Do not apply switching signals during power on reset.

The current consumption of the gate driver depends on the level of supply voltage used, the stand by current, the switching frequency, the capacitance of the IGBT gates in use and on the supply current for the external current sensors at rated output current.

In the electrical characteristics of the gate driver the following equation for the evaluation of the current consumption is given:

$$I_{S2} = 1 \;/\; \underbrace{V_{S2}}_{\substack{\text{supply voltage}\\ \text{gate driver}\\ \text{(13V – 27V)}}} \;*\; [\underbrace{7{,}8W}_{\text{stand by power}} + \underbrace{1{,}21(W/kHz)*f(kHz)}_{\substack{\text{power depending on}\\ \text{switching frequency}}} + \underbrace{\text{power dissipation for the current sensors}}_{\substack{\text{power depending on the supply current of}\\ \text{the external current sensors at rated}\\ \text{output current}}}]$$

User interface (X1: DIN 41651 connector)

The figures below shows the schematics of the SKHI 64 of the digital input and anlog output lines.

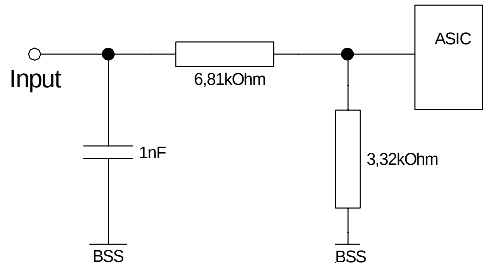


Fig. 4: Schematics of the SKHI 64 digital input lines

Short pulse suppression

The integrated short pulse suppression avoids very short switching pulses at the IGBT module caused by high-frequency interference pulses at the driver input signals. Turn-on- and turn-off-pulses shorter than 500ns are suppressed.

Under voltage protection

The under voltage protection monitors the internal 15V DC which is provided by the internal DC-DC converter (converts the unregulated input voltage to 15V DC). If the under voltage trip level is reached, the IGBTs are switched off and switching pulses from the controller are ignored, as long as the voltage is below the trip level. The error latch is set. The output ,,ERRORSUM“ is in HIGH state. The trip level of the internal regulated +15V is 13,5V.

Please note:
The output “ERRORSUM” is an open collector output, which needs external pull up resistor.

Dead time generation (Interlock TOP / BOTTOM)

The interlock circuit prevents, that the TOP and the BOTTOM IGBT of one half bridge are switched on at the same time (internal short circuit). The interlock time can be adjusted via DIP switches (fig. 5). The dead time does not add to a dead time given by the controller. In case of a different dead time of controller and driver, always the longer one is valid. It is possible to control SKHI 64 with on switching signal and its inverted signal No error message will be generated when overlap of switching signals occurs. It is possible to disable the interlock between top and bottom switch, to drive top and bottom switch synchronously in overlap mode.

TIMING			**interlock**
DIP 1	**DIP 2**	**DIP 3**	**[µs]**
on	on	off	1
off	on	off	2
on	off	off	3
off	off	off	4
X	X	on	no interlock

Please note:
Dead time adjustment by factory is 4µs.

Fig. 5: Adjustment of interlock TOP / BOTTOM

Temperature protection

The temperature sensor integrated in SKiM 4 modules is a semiconductor resistor with nearly proportional characteristic (PTC characteristic). The sensor is soldered isolated onto the ceramic substrate close to the IGBT and freewheeling diodes and indicates the actual substrate temperature which is usually close to the heat sink temperature under the substrate.
An evaluation circuit realised on the gate driver provides an analog voltage signal of the actual heat sink temperature value (fig. 6) at the DIN 41651 connector. The accuracy is ±5 °C.

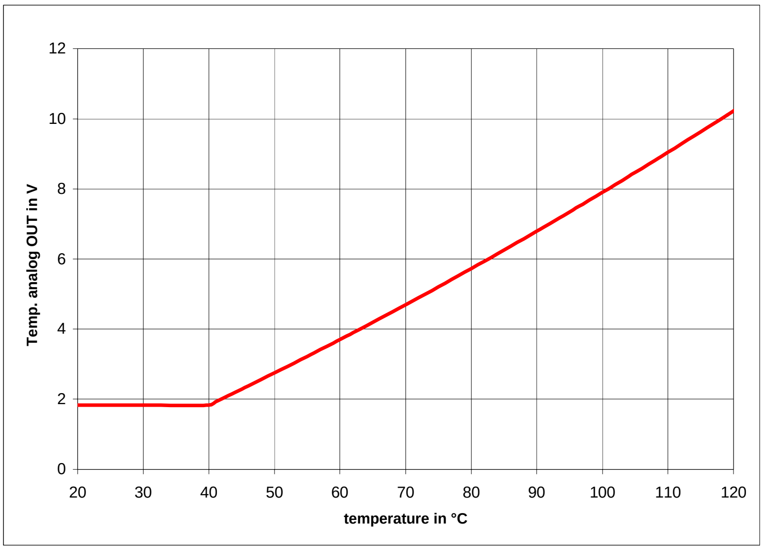


Fig. 6: Analog temperature signal $T_{analogOUT}$ vs. T_{sensor} (at pin „Temp. analog OUT")

At a maximum temperature of 115°C ±5 °C (trip level) the IGBTs are switched off and switching pulses from the controller are ignored. The error latch is set. The outputs "Overtemp. OUT" and "ERROR OUT" are in HIGH state.

Please note:
The outputs "Overtemp. OUT" and "ERROR OUT" are open collector outputs, which need external pull up resistors.

DC link voltage sensing

With the DC link voltage sensing, an analog voltage signal of the actual DC link voltage level is available at the DIN 41651 connector. The measurement is realised by a high impedance differential amplifier.

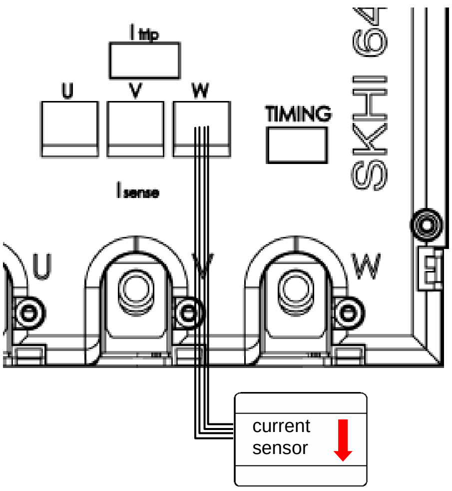
V_{CES}	$U_{DC\ analog\ OUT}$	Input Impedance
600V	400V ⇔ 4V	10 MOhm
1200V	900V ⇔ 9V	
1700V	1200V ⇔ 12V	

Please note:
A DC link over voltage protection is not integrated.

The failure of the measured signal is ±2% @ T_{amb} = 25°C. The analog output signal $U_{DC\ analog\ OUT}$ is filtered with a time of τ = 500µs.

Over Current Protection (OCP) and short circuit protection

External current sensors are required for the **O**ver **C**urrent **P**rotection (OCP) system and AC current control. Three sensors (close loop current sensors with magnetic probe and integrated electronics) have to be connected to the plug-connectors integrated in the gate driver (fig. 6). Electrical supply for the current sensors (supply voltage ±15V, reference current / compensation current) will be provided by the gate driver.



Please note:
The current direction is defined by the arrow on the current sensors.

Fig. 7: Connection of external phase current sensors

The evaluation electronics integrated in the gate driver analyses the current sensor signals of the external phase current sensors. If the AC output current is higher than a maximum permissible level, the IGBTs are immediately switched off and switching pulses from the controller are ignored. The error latch is set. The output ”ERROR OUT“ is in HIGH state.

Please note:
The output “ERROR OUT” is open collector outputs, which needs an external pull up resistors.

The over current trip level can be adjusted via DIP switches (fig. 8). OCP reacts independently of the temperature.

In addition SKHI 64 uses V_{CEsat} monitoring to protect the phase leg against internal short circuit (“shoot through” protection). Even if OCP is used, the V_{Cesat} monitoring remains active. Both protection functions monitor the power module in parallel and can generate a protective shutdown. If no external current sensors are connected, only the V_{Cesat} monitoring is active.

It is possible to connect only one or two external current sensor. In this case a total OCP protection is not available.

An analog voltage signal of the actual AC current level is available at the DIN 41651 connector.

The failure of the measured signal is ±3% (without current sensor). The accuracy of the adjusted over current trip level is ±5%.

DIP SETTINGS					over current trip level 1 : 2000	turns ratio of the current sensor			
						1 : 1000 IanalogOUT	**1 : 1500** IanalogOUT	**1 : 2000** IanalogOUT	**1 : 2500** IanalogOUT
DIP 1	**DIP 2**	**DIP 3**	**DIP 4**	**DIP 5**	**[A]**	**[mV / A]**	**[mV / A]**	**[mV / A]**	**[mV / A]**
on	on	on	on	on	517,3	38,66	25,77	19,33	15,46
off	on	on	on	on	495,6	40,35	26,90	20,18	16,14
on	off	on	on	on	471,6	42,41	28,27	21,20	16,96
off	off	on	on	on	453,5	44,10	29,40	22,05	17,64
on	on	off	on	on	429,4	46,57	31,05	23,29	18,63
off	on	off	on	on	414,4	48,27	32,18	24,13	19,31
on	off	off	on	on	397,5	50,32	33,55	25,16	20,13
off	off	off	on	on	384,5	52,01	34,68	26,01	20,81
on	on	on	off	on	363,6	55,00	36,67	27,50	22,00
off	on	on	off	on	352,8	56,69	37,79	28,35	22,68
on	off	on	off	on	340,5	58,75	39,16	29,37	23,50
off	off	on	off	on	330,9	60,44	40,29	30,22	24,17
on	on	off	off	on	317,9	62,91	41,94	31,46	25,16
off	on	off	off	on	309,6	64,60	43,07	32,30	25,84
on	off	off	off	on	300,0	66,66	44,44	33,33	26,66
off	off	off	off	on	292,6	68,35	45,57	34,17	27,34
on	on	on	on	off	278,6	71,78	47,85	35,89	28,71
off	on	on	on	off	272,2	73,47	48,98	36,74	29,39
on	off	on	on	off	264,8	75,53	50,35	37,76	30,21
off	off	on	on	off	259,0	77,22	51,48	38,61	30,89
on	on	off	on	off	251,0	79,69	53,13	39,85	31,88
off	on	off	on	off	245,7	81,39	54,26	40,69	32,55
on	off	off	on	off	239,7	83,44	55,63	41,72	33,38
off	off	off	on	off	234,9	85,13	56,76	42,57	34,05
on	on	on	off	off	227,0	88,12	58,75	44,06	35,25
off	on	on	off	off	222,7	89,81	59,87	44,91	35,92
on	off	on	off	off	217,7	91,87	61,24	45,93	36,75
off	off	on	off	off	213,8	93,56	62,37	46,78	37,42
on	on	off	off	off	208,3	96,03	64,02	48,02	38,41
off	on	off	off	off	204,7	97,72	65,15	48,86	39,09
on	off	off	off	off	200,4	99,78	66,52	49,89	39,91
off	off	off	off	off	197,1	101,47	67,65	50,74	40,59

Fig. 8: Adjustment of over current trip level and normalisation of the AC current

Please note:
Over current trip level adjustment by factory is 275,8A.
It is recommended not to use a trip level > 200% × I_C (I_C = rated current of the of the SKiM module @ T_S = 25 °C).

GB / GD mode

The function GB / GD mode enables the use of the six pack driver (GD mode) as a half bridge driver (GB mode). This can be adjusted via DIP switch. The table below shows the configuration.

TIMING	
mode	**DIP 4**
GB	on
GD	off

Please note:
Adjustment by factory is GD mode.

If the GB mode is activated, a signal at TOP HB 1 IN and BOT HB 1 IN enables the synchronous drive of all outputs. A fault distinction of HB1, HB 2 and HB 3 is possible.

Application hint GB mode:
Even if all conditions for optimal driver circuit and layout design have been fulfilled, an ideal static and dynamic symmetrization will not be achievable. Small differences in switching times might occur due to differing signal propagation times. Therefore, derating has to be considered with respect to the total load current of the switches. The consequent dynamic asymmetries may be minimized by series inductance in the connected load paths.

Error latch and error feedback

Any error detected will set the error latch and force the output “ERROR OUT“ into HIGH state. Switching pulses from the controller will be ignored. Reset of the error latch is only possible with no error present and all input signals in LOW state for t_{pRESET} > 9 µs.
All logical outputs are open collector transistors with max. 30V / 15mA. An external pull-up resistor to controller logic high level is required. (Low signal = no error - wire break monitoring).

	Pin 3 ERROR HB 1 OUT	**Pin 6 ERROR HB 2 OUT**	**Pin 9 ERROR HB 3 OUT**	**Pin 11 Overtemp. OUT**	**Pin 12 ERRORSUM**
under voltage protection HB 1					✔
under voltage protection HB 2					✔
under voltage protection HB 3					✔
V_{CE} protection HB 1	✔				
V_{CE} protection HB 2		✔			
V_{CE} protection HB 3			✔		
OCP HB 1	✔	✔	✔		
OCP HB 2	✔	✔	✔		
OCP HB 3	✔	✔	✔		
temperature protection	✔	✔	✔	✔	✔

Fig. 9: Fault output signals and fault generation

Operation range and application limits

The maximum load current I_{LOAD} may be calculated with the following formula and dependence of the gate charge, switching frequencies and turns ratio of the connected current sensors @ $T_s = 25°C$.

$$I_{LOAD}(A) = \frac{ü}{3000}\left(500mA - \left(12 \cdot Q_{GATE}(\mu Q) \cdot f(KHz)\right)\right)$$

Fig 10. shows the current sensors with the different turns ratio for the driver and the allowed maximum current load.

turns ratio of the current sensor	ü	$I_{LOADMAX}$
1 : 1000	1000	259 A
1 : 1500	1500	388 A
1 : 2000	2000	517 A
1 : 2500	2500	646 A

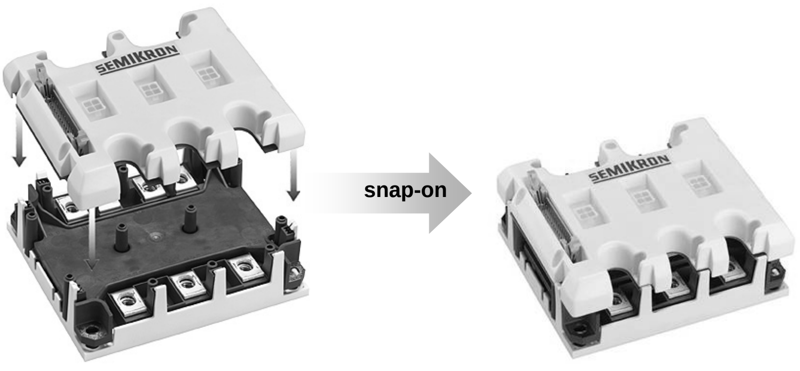
Fig. 10: Turns ratio of the permitted current sensors

For example a SKIM module with a gate charge of 2µC per switch, a current sensor with a turns ratio of 1:2000 allows a maximum load current of 253A at a maximum switching frequency of 5KHz.

Assembly

SKHI 64 does not need any soldering, wire or plug-in connection. The electrical connections are realised via spring-contacts integrated in SKiM modules and landing pads on the bottom side of the gate driver. After assembly (snap-on technology), the landing pads of the gate driver press onto the spring-contacts of the power module, leading to a pressure contacted electrical connection.

A mounting instruction is available at http://www.semikron.com (product page SKiM, link "Mounting instructions SKiM").



Please note:
It is mandatory to fix the gate driver with screws.

Fig. 11: Snap-on assembly

Auxiliaries

Snubber capacitors

SEMIKRON provides film capacitors which can be adapted onto the DC terminals of the SKiM. These capacitors reduce the over voltage peak during commutation and are recommended by SEMIKRON. The table below lists the available types.

capacitance / DC voltage	recommended for use with	part number
4,7µF / 630V	600V SKiM	41064600
2,2µF / 1000V	1200V SKiM	41064610
1,5µF / 1600V	1700V SKiM	41064620

Application and handling instructions

- The standard connection to the SKHI 64 is done via a DIN 41651 connector. Because of voltage drop and for immunity against electromagnetic interference the maximum length of the flat cable should not exceed 3 meters. To avoid interferences, the flat cable should be placed as far as possible away from the power terminals, the power cables, the DC-link capacitors and all other noise sources. It is highly recommended by SEMIKRON to use a shielded (flat) cable.
- Please provide for static discharge protection during handling. As long as the hybrid driver is not completely assembled, the input terminals have to be short-circuited. Persons working with CMOS-devices have to wear a grounded bracelet. Any synthetic floor coverings must not be statically chargeable. Even during transportation the input terminals have to be short-circuited using, for example, conductive rubber. Worktables have to be grounded. The same safety requirements apply to MOSFET- and IGBT-modules.
- Any parasitic inductances within the DC-link have to be minimised. Over-voltages may be absorbed by C- or RCD-snubbers between the main terminals for PLUS and MINUS of the power module.
- When first operating a newly developed circuit, SEMIKRON recommends to apply low collector voltage and load current in the beginning and to increase these values gradually, observing the turn-off behaviour of the free-wheeling diode and the turn-off voltage spikes generated across the IGBT. An oscillographic control will be necessary. In addition to that the case temperature of the module has to be monitored. When the circuit works correctly under rated operation conditions, short-circuit testing may be done, starting again with low collector voltage.
- It is important to feed any errors back to the control circuit and to switch off the device immediately in such events. Repeated turn-on of the IGBT into a short circuit with a high frequency may destroy the device.

Further application support

Latest information is available at http://www.semikron.com. Further questions can be placed via http://faq.semikron.com/.