1SC2060P Description & Application Manual

Single-Channel High-Power and High-Frequency SCALE-2 Driver Core

Abstract

The 1SC2060P is a 20W, 60A SCALE-2 driver core. It is designed for high-power and high-frequency IGBT and MOSFET applications such as induction heating, resonant and high-frequency power conversion as well as parallel gate driving of large modules.

The 1SC2060P features newly developed planar transformer technology for a real leap forward in power density, noise immunity, and reliability.

With its extremely compact outline of 44mm x 74mm and a total height of typ. 6.5mm, the driver delivers high power density with an attractive form factor. The component count is reduced by 80% compared to conventional solutions thanks to the highly integrated SCALE-2 chipset. This results in significantly increased reliability and reduced costs.

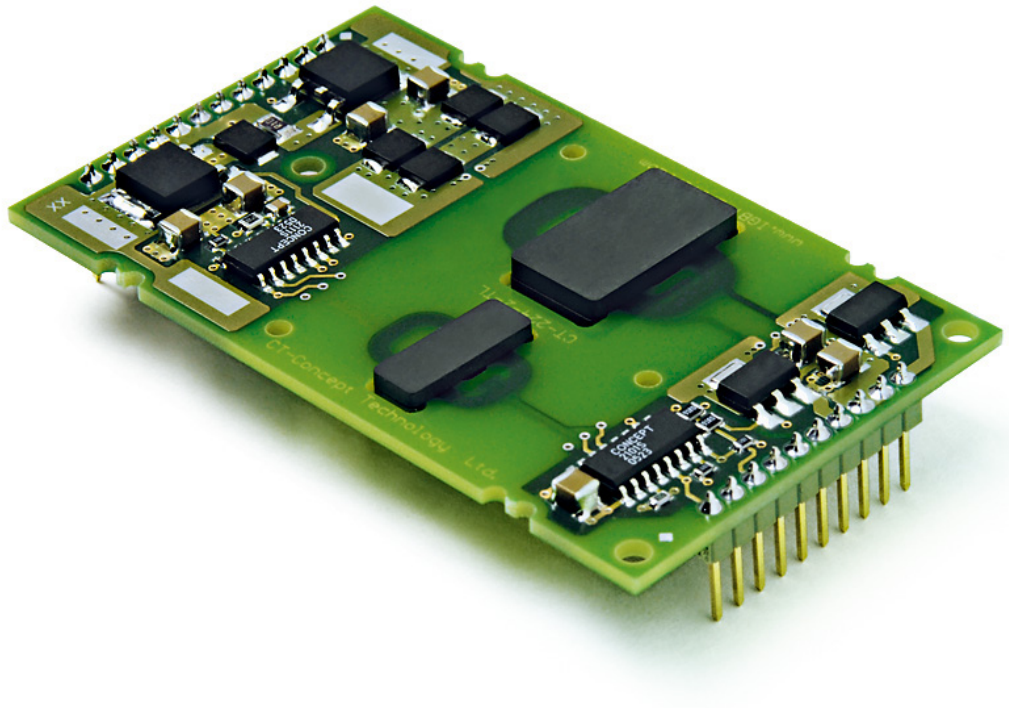

Fig. 1 1SC2060P driver core

Contents

Description and Application Manual

Driver Overview

The 1SC2060P is a driver core equipped with CONCEPT's latest SCALE-2 chipset as well as newly developed planar transformer technology. The SCALE-2 chipset is a set of application-specific integrated circuits (ASICs) that cover the main range of functions needed to design intelligent gate drivers. The SCALE-2 driver chipset is a further development of the proven SCALE technology /2/.

The 1SC2060P targets high-power, single-channel IGBT and MOSFET applications such as induction heating, resonant and high-frequency power conversion as well as parallel gate driving of large modules. The driver supports switching up to 500kHz at best-in-class efficiency. The 1SC2060P comprises a complete single-channel IGBT driver core, fully equipped with an isolated DC/DC converter, short-circuit protection, advanced active clamping and supply-voltage monitoring.

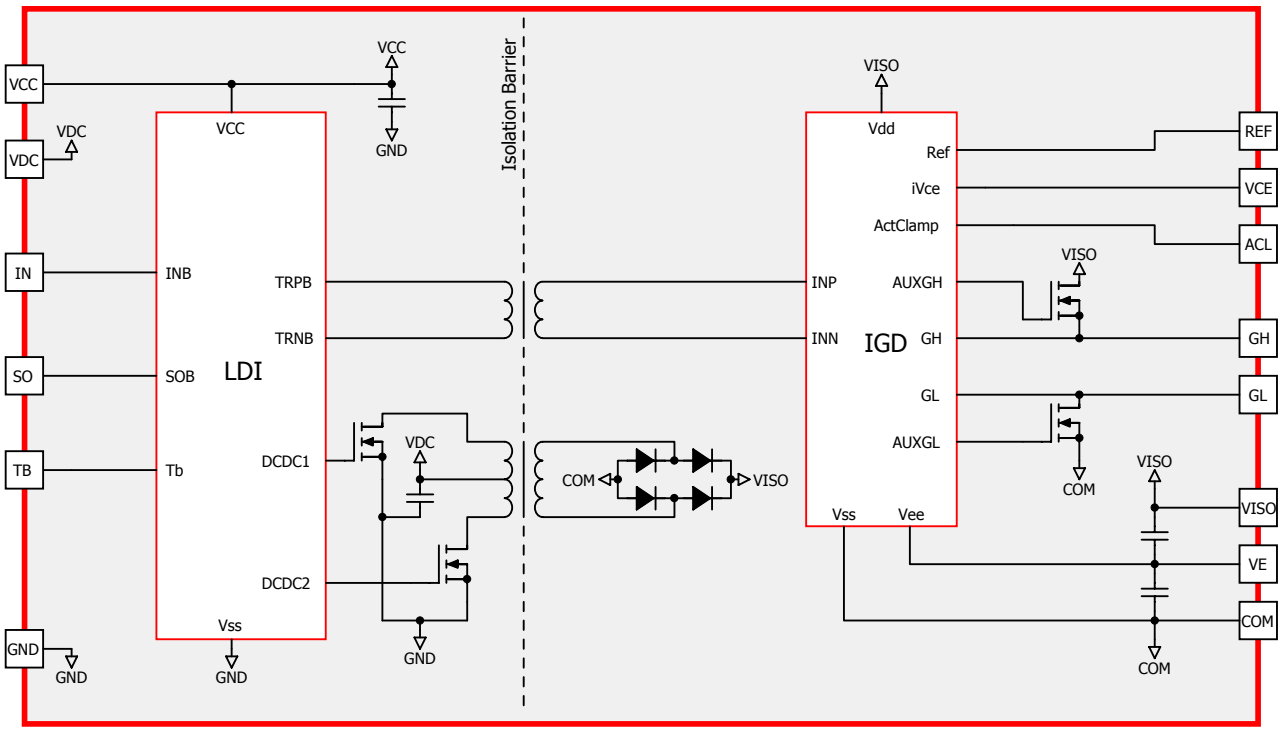

Fig. 2 Block diagram of the driver core 1SC2060P

Mechanical Dimensions

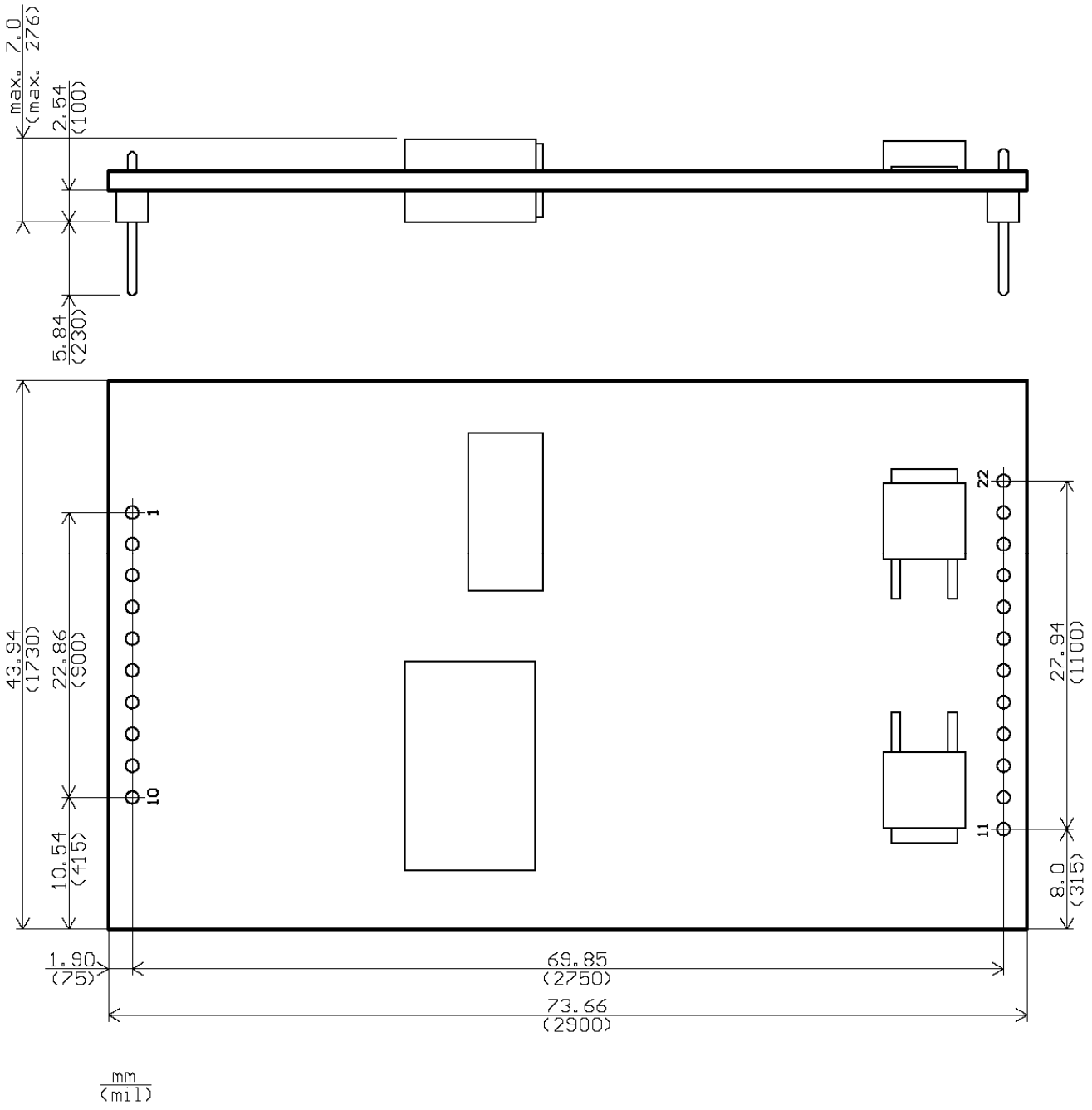

Fig. 3 Mechanical drawing

The primary side and secondary side pin grid is 2.54mm (100mil) with a pin cross section of 0.64mmx0.64mm. Total outline dimensions of the board are 44mmx73.7mm. The total height of the driver is max. 7mm measured from the bottom of the pin bodies to the top of the populated PCB.

Recommended diameter of solder pads: Ø 2mm (79 mil)
Recommended diameter of drill holes: Ø 1mm (39 mil)

Pin Designation

Pin No. and Name	Function
Primary Side	
1 IN	Signal input; non-inverting input relative to GND
2 SO	Status output; normally high-impedance, pulled down to low on fault
3 TB	Set blocking time
4 VCC	Supply voltage; 15V supply for primary side
5 GND	Ground
6 GND	Ground
7 GND	Ground
8 VDC	DC/DC converter supply
9 VDC	DC/DC converter supply
10 GND	Ground
Secondary Side	
11 COM	Secondary side ground
12 VISO	DC/DC output
13 VISO	DC/DC output
14 COM	Secondary side ground
15 REF	Set V_{ce} detection threshold; resistor to VE
16 ACL	Active clamping feedback; leave open if not used
17 VCE	V_{ce} sense; connect to IGBT collector through resistor network
18 GH	Gate high; pulls gate high through turn-on resistor
19 GH	Gate high; pulls gate high through turn-on resistor
20 GL	Gate low; pulls gate low through turn-off resistor
21 GL	Gate low; pulls gate low through turn-off resistor
22 VE	Emitter; connect to (auxiliary) emitter of power switch

Recommended Interface Circuitry for the Primary Side Connector

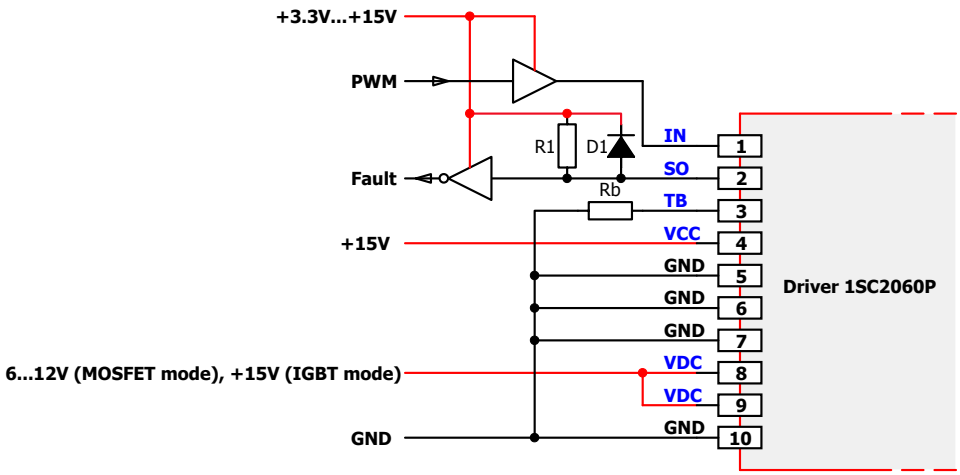

Fig. 4 Recommended user interface of 1SC2060P (primary side)

All ground pins must be connected together with low parasitic inductance. A common ground plane or wide tracks are strongly recommended. The connecting distance between ground pins must be kept at a minimum.

Description of Primary Side Interface

General

The primary side interface of the driver 1SC2060P is very simple and easy to use.

The driver primary side is equipped with a 10-pin interface connector with the following terminals:

- 3 x power-supply terminals
- 1 x drive signal input
- 1 x status output (fault return)
- 1 x input to set the blocking time

All inputs and outputs are ESD-protected. Moreover, all digital inputs have Schmitt-trigger characteristics.

VCC terminal

The driver has one VCC terminal on the interface connector to supply the primary side electronics with 15V.

VDC terminal

The driver has two VDC terminals on the interface connector to supply the DC-DC converters for the secondary side.

If the driver is used in IGBT mode (see "IGBT and MOSFET operation mode" page 13), VDC should be supplied with 15V. It is recommended to connect the VCC and VDC terminals to a common +15V power

supply. In this case the driver limits the inrush current at startup and no external current limitation of the voltage source for VDC is needed.

If the driver is used in MOSFET mode (see "IGBT and MOSFET operation mode" page 13), VDC should be supplied with 6V…12V depending on the desired gate voltage and on the load (for a detailed specification, refer to the driver data sheet /3/).

IN (drive input, e.g. PWM)

IN is the drive input. It safely recognizes signals in the whole logic-level range between 3.3V and 15V. The input terminal IN features Schmitt-trigger characteristics (refer to the driver data sheet /3/). An input transition is triggered at any edge of an incoming signal at IN.

SO (status output)

The output SO has an open-drain transistor. When no fault condition is detected, the output SO has high impedance. An internal current source of 500µA pulls the SO output to a voltage of about 4V when leaved open. When a fault condition (primary side supply undervoltage, secondary side supply undervoltage, IGBT/MOSFET short-circuit or overcurrent) is detected, the status output SO goes to low (connected to GND).

The diode D_1 must be a Schottky diode and must only be used when using 3.3V logic. For 5V…15V logic, it can be omitted.

The maximum SO current in a fault condition must not exceed the value specified in the driver data sheet /3/.

The SO outputs of multiple 1SC2060P can be connected together to provide a common fault signal (e.g. for one phase). However, it is recommended to evaluate the status signals individually to allow for fast and precise fault diagnostics.

How the status information is processed

a) A fault on the secondary side (detection of short-circuit of IGBT/MOSFET or supply undervoltage) is transmitted to the SO output immediately. The SO output is automatically reset (returning to a high impedance state) after a blocking time T_b has elapsed (refer to the driver data sheet for timing information /3/).

b) Supply undervoltage on the primary side is also indicated at the SO output. This fault is automatically reset (SO returning to a high impedance state) when the undervoltage on the primary side disappears.

TB (input for adjusting the blocking time T_b)

The terminal TB allows the blocking time to be set by connecting a resistor R_b to GND (see Fig. 4). The following equation calculates the value of R_b connected between pins TB and GND in order to program the desired blocking time T_b (typical value):

$$R_b[k\Omega] = 1.0 \cdot T_b[ms] + 51 \qquad \text{where} \quad 20ms<T_b<130ms \text{ and } 71k\Omega<R_b<181k\Omega$$

The blocking time can also be set to a minimum of 9µs (typical) by selecting R_b=0Ω. The terminal TB must not be left floating.

Note: It is also possible to apply a stabilized voltage at TB. The following equation is used to calculate the voltage V_b between TB and GND in order to program the desired blocking time T_b (typical value):

$$V_b[V] = 0.02 \cdot T_b[ms] + 1.02 \qquad \text{where} \quad 20ms<T_b<130ms \text{ and } 1.42<T_b<3.62V$$

Recommended Interface Circuitry for the Secondary Side Connector

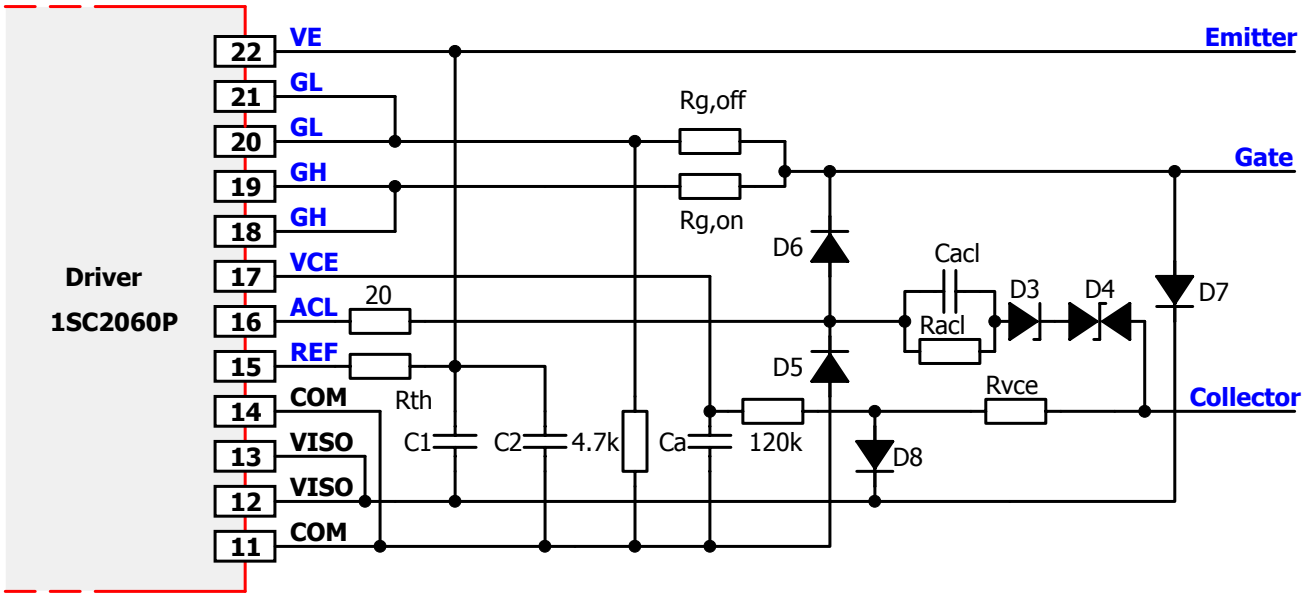

Fig. 5 Recommended user interface of 1SC2060P for IGBT mode with advanced active clamping (secondary side)

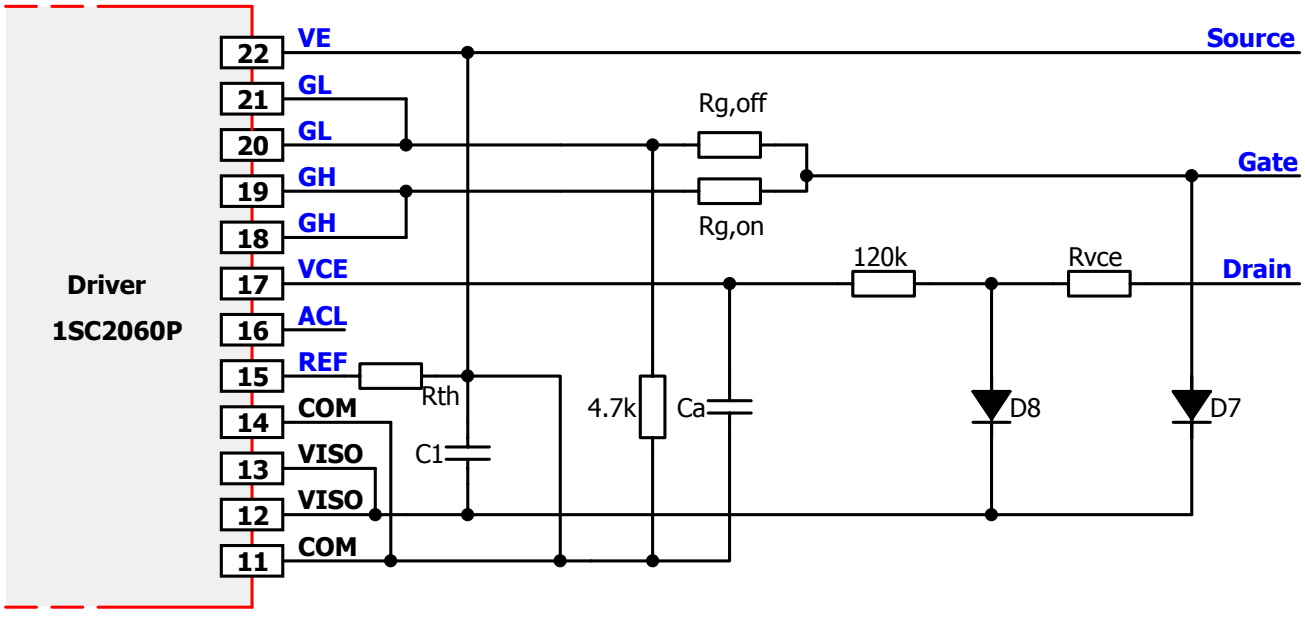

Fig. 6 Recommended user interface of 1SC2060P for MOSFET mode without advanced active clamping (secondary side)

Description of Secondary Side Interface

General

The driver's secondary side is equipped with a 12-pin interface connector with the following terminals:

- 2 x DC/DC output terminals VISO
- 1 x emitter terminal VE
- 1 x reference terminal REF for overcurrent or short-circuit protection
- 1x collector sense terminal
- 1x active clamping terminal
- 2x turn-on gate terminals
- 2x turn-off gate terminals

All inputs and outputs are ESD-protected.

DC/DC output (VISO), emitter (VE) and COM terminals

The driver is equipped with blocking capacitors on the secondary side of the DC/DC converter (for values, refer to the data sheet /3/).

Power semiconductors with a gate charge of up to 3µC can be driven without additional capacitors on the secondary side. For IGBTs or MOSFETs with a higher gate charge, a minimum value of 3µF external blocking capacitance is recommended for every 1µC gate charge beyond 3µC. The blocking capacitors must be placed between VISO and VE (C_1 in Figs. 5 and 6) as well as between VE and COM (C_2 in Fig. 5). They must be connected as close as possible to the driver's terminal pins with minimum inductance. It is recommended to use the same capacitance value for both C_1 and C_2 (IGBT mode). Ceramic capacitors with a dielectric strength >20V are recommended. Insufficient external blocking can lead to reduced driver efficiency and thus to thermal overload.

If the capacitances C_1 or C_2 exceed 150µF, please contact CONCEPT's support service.

No static load must be applied between VISO and VE, or between VE and COM. A static load can be applied between VISO and COM if necessary.

Reference terminal (REF)

The reference terminal REF allows the threshold to be set for short-circuit and/or overcurrent protection with a resistor placed between REF and VE. A constant current of 150µA is provided at pin REF.

Collector sense (VCE)

The collector sense must be connected to the IGBT collector or MOSFET drain with the circuit shown in Figs. 5 and 6 in order to detect an IGBT or MOSFET overcurrent or short-circuit.

- It is recommended to dimension the resistor value of R_{vce} in order to get a current of about 0.6-1mA flowing through R_{vce} (e.g. 1.2-1.8MΩ for $V_{DC\text{-}LINK}$=1200V). The current through R_{vce} must not exceed 1mA. It is possible to use a high-voltage resistor as well as series connected resistor. In any case, the min. creepage distance related to the application must be considered.
- The diode D_8 must have a very low leakage current and a blocking voltage of > 40V (e.g. BAS416). Schottky diodes must be explicitly avoided.

For more details about the functionality of this feature and the dimensioning of the response time, refer to "V_{ce} monitoring / short-circuit protection" on page 13.

Active clamping (ACL)

Active clamping is a technique designed to partially turn on the power semiconductor as soon as the collector-emitter (drain-source) voltage exceeds a predefined threshold. The power semiconductor is then kept in linear operation.

Basic active clamping topologies implement a single feedback path from the IGBT's collector through transient voltage suppressor devices (TVS) to the IGBT gate. The 1SC2060P supports CONCEPT's advanced active clamping, where the feedback is also provided to the driver's secondary side at pin ACL: as soon as the voltage on the right side of the 20Ω resistor (see Fig. 5) exceeds about 1.3V, the turn-off MOSFET is progressively switched off in order to improve the effectiveness of the active clamping and to reduce the losses in the TVS. The turn-off MOSFET is completely off when the voltage on the right side of the 20Ω resistors (see Fig. 5) approaches 20V (measured to COM).

It is recommended to use the circuit shown in Fig. 5. The following parameters must be adapted to the application:

- TVS D_3, D_4. It is recommended to use:
  - Six 80V TVS with 600V IGBTs with DC link voltages up to 430V. Good clamping results can be obtained with five unidirectional TVS P6SMBJ70A and one bidirectional TVS P6SMBJ70CA from Semikron or with five unidirectional TVS SMBJ70A-E3 and one bidirectional TVS SMBJ70CA-E3 from Vishay.
  - Six 150V TVS with 1200V IGBTs with DC link voltages up to 800V. Good clamping results can be obtained with five unidirectional TVS SMBJ130A-E3 and one bidirectional TVS SMBJ130CA-E3 from Vishay or five unidirectional TVS SMBJ130A-TR from ST and one bidirectional TVS P6SMBJ130CA from Diotec.
  - Six 220V TVS with 1700V IGBTs with DC link voltages up to 1200V. Good clamping results can be obtained with five unidirectional TVS P6SMB220A and one bidirectional TVS P6SMB220CA from Diotec or five unidirectional TVS SMBJ188A-E3 and one bidirectional TVS SMBJ188CA-E3 from Vishay.

  At least one bidirectional TVS (D_4) must be used in order to avoid negative current flowing through the TVS chain during turn-on of the antiparallel diode of the IGBT module due to its forward recovery behavior. Such a current could, depending on the application, lead to undervoltage of the driver secondary voltage VISO to VE (15V).

  Note that it is possible to modify the number of TVS in a chain. The active clamping efficiency can be improved by increasing the number of TVS used in a chain if the total threshold voltage remains at the

same value. Note also that the active clamping efficiency is highly dependent on the type of TVS used (e.g. manufacturer).

- R_{acl} and C_{acl}: These parameters allow the effectiveness of the active clamping as well as the losses in the TVS and the IGBT to be optimized. It is recommended to determine the value with measurements in the application. Typical values are: R_{acl}=0…150Ω and R_{acl}*C_{acl}=100ns…500ns. R_{acl}=0Ω is recommended to improve the effectiveness of active clamping.
- D_5, D_6 and D_7: it is recommended to use Schottky diodes with blocking voltages >35V (>1A depending on the application).

Please note that the 20Ω resistor as well as diodes D_5, D_6 and D_7 must not be omitted if advanced active clamping is used. If advanced active clamping is not used, the 20Ω resistor as well as diodes D_5 and D_6 can be omitted.

Gate turn-on (GH) and turn-off (GL) terminals

These terminals allow the turn-on (GH) and turn-off (GL) gate resistors to be connected to the gate of the power semiconductor. The GH and GL pins are available as separated terminals in order to set the turn-on and turn-off resistors independently without the use of an additional diode. Please refer to the driver data sheet /3/ for the limit values of the gate resistors used. Both terminals GH and GL are available on two pins: this allows for a better heat transfer from the driver to the host PCB. Driver cooling can be aided by connecting copper plates to GL and GH on the host PCB. However, the load limitations given in the driver data sheet /3/ are valid without additional heat transport over the GH and GL pins.

A resistor between GL and COM of 4.7k (other values are also possible) may be used in order to provide a low-impedance path from the IGBT/MOSFET gate to the emitter/source even if the driver is not supplied with power. No static load (e.g. resistors) must be placed between GL and the emitter terminal VE.

Note however that it is not advisable to operate the power semiconductors within a half-bridge with a driver in the event of a low supply voltage. Otherwise, a high rate of increase of Vce may cause partial turn-on of these IGBTs.

How Do 1SC2060P SCALE-2 Drivers Work in Detail?

Power supply and electrical isolation

The driver is equipped with a DC/DC converter to provide an electrically insulated power supply to the gate driver circuitry. The signal and power isolation is implemented by newly developed planar transformer technology for a real leap forward in power density, noise immunity, and reliability. Both planar transformers feature safe isolation to EN 50178, protection class II.

Note that the driver requires a stabilized supply voltage.

Power-supply monitoring

Both the driver's primary and secondary sides are equipped with a local undervoltage monitoring circuit.

In the event of a primary-side supply undervoltage, the power semiconductor is driven with a negative gate voltage to keep it in the off-state (the driver is blocked) and the fault is transmitted to the output SO until it disappears.

In the event of a secondary side supply undervoltage, the power semiconductor is driven with a negative gate voltage to keep it in the off-state (the driver is blocked) and a fault condition is transmitted to the SO output. The SO output is automatically reset (returning to a high impedance state) after the blocking time.

IGBT and MOSFET operation mode

The driver features two operation modes:

- The first mode is the default IGBT setup with both a positive (regulated) turn-on voltage of 15V (typical) and a second (non-regulated) turn-off voltage (see Fig. 5).
- The second mode has been specifically designed for ultra-fast MOSFET switching. It incorporates a single turn-on voltage only. The turn-off voltage is set to 0V. This MOSFET mode is activated by connecting the secondary-side terminals COM and VE (see Fig. 6). The turn-on voltage in MOSFET mode is directly derived from the primary-side input voltage VDC and can freely take on values between 10V and 20V (read the driver data sheet for more information /3/).

V_{ce} monitoring / short-circuit protection

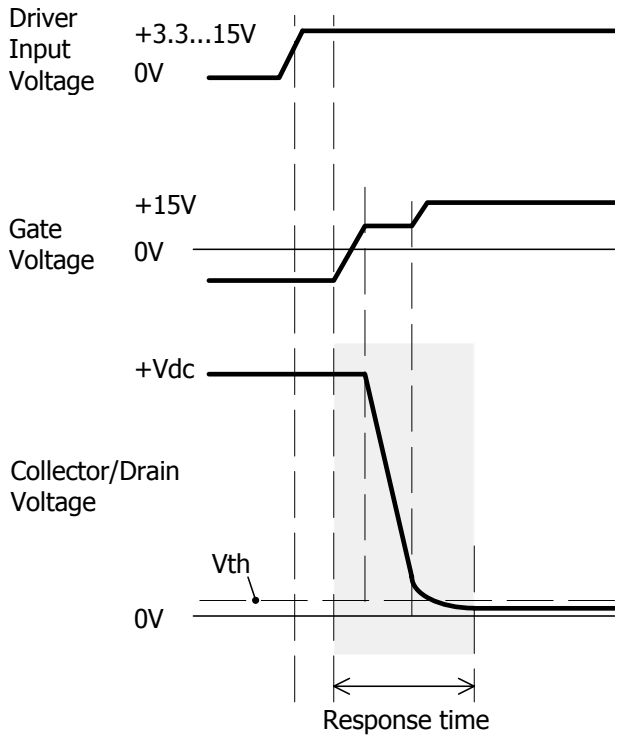

Fig. 7 Turn-on characteristic of an IGBT or MOSFET

The 1SC2060P driver is equipped with a V_{ce} monitoring circuit. The recommended circuit is illustrated in Figs. 5 and 6. A resistor (R_{th} in Figs. 5 and 6) is used as the reference element for defining the turn-off threshold. The value of the current through R_{th} is 150µA (typical). It is recommended to choose threshold levels of about 10V (R_{th} values around 68kΩ). In this case the driver will safely protect the IGBT/MOSFET against short-circuit, but not necessarily against overcurrent. Overcurrent protection has a lower timing priority and is recommended to be realized within the host controller.

In order to ensure that the 1SC2060P can be applied as universally as possible, the response time capacitor C_a is not integrated in the driver, but must be connected externally.

During the response time, the V_{ce} monitoring circuit is inactive. The response time is the time that elapses after turn-on of the power semiconductor until the collector/drain voltage is measured (see Fig. 7).

V_{ce} is checked after the response time at turn-on to detect a short circuit or overcurrent. If the measured V_{ce} at the end of the response time is higher than the programmed threshold V_{th}, the driver detects a short circuit or overcurrent. The driver then switches off the power semiconductor. The fault status is immediately transferred to the SO output. The power semiconductor is kept in off state (non-conducting) and the fault is shown at pin SO as long as the blocking time T_b is active.

The value of the response time capacitors C_a can be determined with the following table in order to set the desired response time (IGBT mode, R_{vce}=1.8MΩ, DC-link voltage $V_{DC\text{-}LINK}$>550V):

C_a [pF]	R_{th} [kΩ]/V_{th} [V]	Response time [µs]
0	43 / 6.45	1.2
15	43 / 6.45	3.2
22	43 / 6.45	4.2
33	43 / 6.45	5.8
47	43 / 6.45	7.8
0	68 / 10.2	1.5
15	68 / 10.2	4.9
22	68 / 10.2	6.5
33	68 / 10.2	8.9
47	68 / 10.2	12.2

Table 1 Typical response time in function of the capacitance C_a and the resistance R_{th}

As the parasitic capacitances on the host PCB may influence the response time it is recommended to measure it in the final design. It is important to define a response time which is smaller than the maximum allowed short-circuit duration of the used power semiconductor.

Note that the response time increases at DC-link voltage values lower than 550V and/or higher threshold voltage values V_{th}. The response time will decrease at lower threshold voltage values.

Desaturation protection with sense diodes

If desaturation protection with sense diodes is required with 1SC2060P, please refer to the application note AN-1101 /4/ on www.IGBT-Driver.com/go/app-note.

Parallel connection of 1SC2060P

If parallel connection of 1SC2060P drivers is required, please refer to the application note AN-0904 /5/ on www.IGBT-Driver.com/go/app-note.

3-level or multilevel topologies

If 1SC2060P drivers are to be used in 3-level or multilevel topologies, please refer to the application note AN-0901 /6/ on www.IGBT-Driver.com/go/app-note.

Additional application support for 1SC2060P

For additional application support using 1SC2060P drivers, please refer to the application note AN-1101 /4/ on www.IGBT-Driver.com/go/app-note.

Bibliography

/1/ "Smart Power Chip Tuning", Bodo's Power Systems, May 2007

/2/ "Description and Application Manual for SCALE Drivers", CONCEPT

/3/ Data sheet SCALE-2 driver core 1SC2060P, CONCEPT

/4/ Application note AN-1101: Application with SCALE-2 Gate Driver Cores, CONCEPT

/5/ Application note AN-0904: Direct Paralleling of SCALE-2 Gate Driver Cores, CONCEPT

/6/ Application note AN-0901: Methodology for Controlling Multi-Level Converter Topologies with SCALE-2 IGBT Drivers, CONCEPT

Note: These papers are available on the Internet at www.IGBT-Driver.com/go/papers

The Information Source: SCALE-2 Driver Data Sheets

CONCEPT offers the widest selection of gate drivers for power MOSFETs and IGBTs for almost any application requirements. The largest website on gate-drive circuitry anywhere contains all data sheets, application notes and manuals, technical information and support sections: www.IGBT-Driver.com

Quite Special: Customized SCALE-2 Drivers

If you need an IGBT driver that is not included in the delivery range, please don't hesitate to contact CONCEPT or your CONCEPT sales partner.

CONCEPT has more than 20 years experience in the development and manufacture of intelligent gate drivers for power MOSFETs and IGBTs and has already implemented a large number of customized solutions.

Technical Support

CONCEPT provides expert help with your questions and problems:

www.IGBT-Driver.com/go/support

Quality

The obligation to high quality is one of the central features laid down in the mission statement of CT-Concept Technologie AG. The quality management system covers all stages of product development and production up to delivery. The drivers of the SCALE-2 series are manufactured to the ISO9001:2000 quality standard.

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This data sheet specifies devices but cannot promise to deliver any specific characteristics. No warranty or guarantee is given – either expressly or implicitly – regarding delivery, performance or suitability.

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Type Designation	Description
1SC2060P2A0-17	Single-channel SCALE-2 driver core

Product home page: www.IGBT-Driver.com/go/1SC2060P

Refer to www.IGBT-Driver.com/go/nomenclature for information on driver nomenclature

Information about Other Products

For other driver cores:

Direct link: www.IGBT-Driver.com/go/cores

For other drivers, product documentation, evaluation systems and application support

Please click onto: www.IGBT-Driver.com

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