SCALE™-2+ 2SC0106T
Preliminary Description & Application Manual

Dual-channel ultra-compact SCALE™-2+ driver core

Abstract

The new SCALE™-2+ dual-driver core 2SC0106T combines unrivalled compactness with broad applicability. The driver was designed for universal applications requiring high reliability. The 2SC0106T drives all usual IGBT modules up to 450A/1200V or 600A/650V.

The 2SC0106T is the most compact driver core available for industrial applications, with a footprint of only 45.5mm x 31mm and an insertion height of 13mm. It allows even the most restricted insertion spaces to be efficiently used.

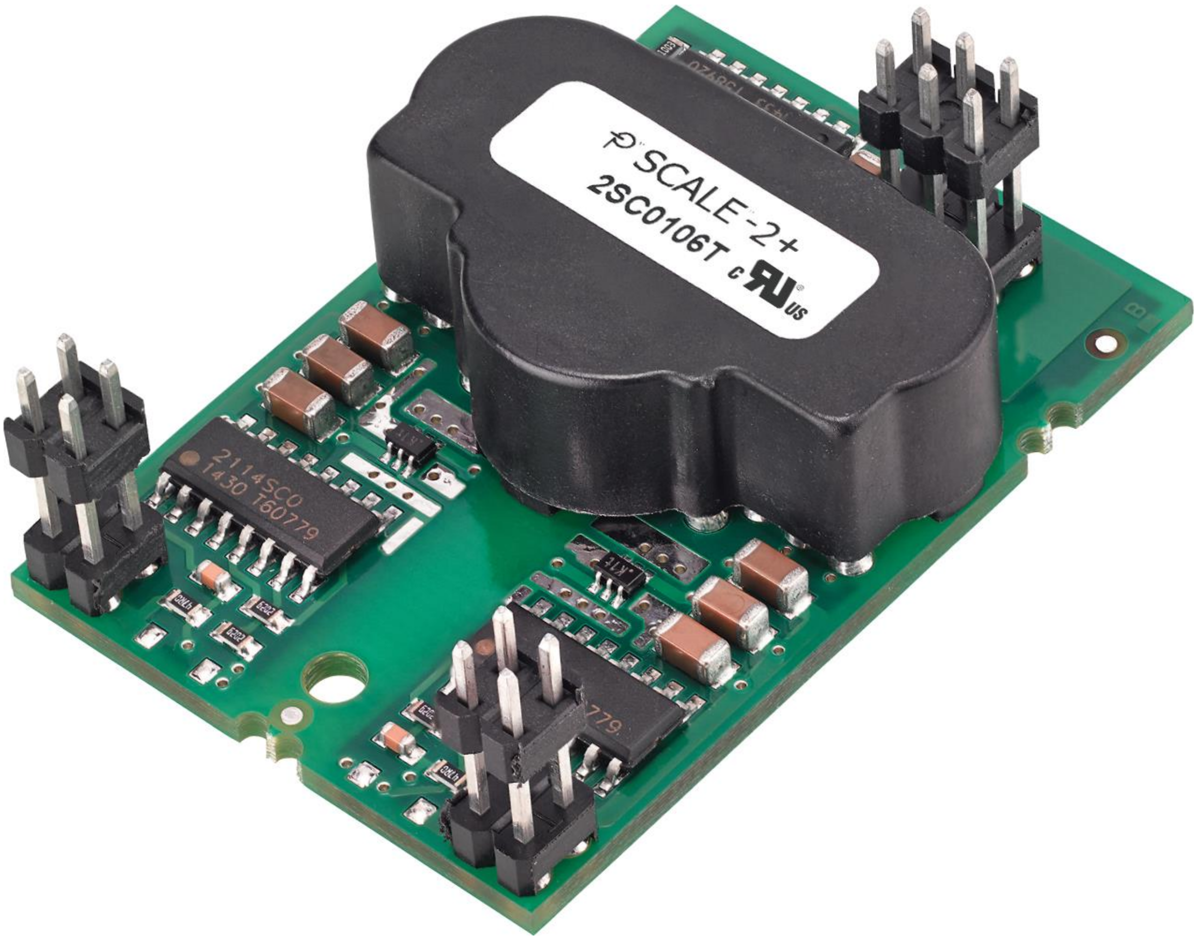

Fig. 1   2SC0106T driver core

Contents

Driver Overview

The 2SC0106T is a driver core equipped with Power Integrations' latest SCALE-2+ chipset. The SCALE-2+ chipset consists of two application-specific integrated circuits (ASICs) that cover the main range of functions needed to design intelligent gate drivers. The driver core targets applications using 600V-1200V IGBTs such as general purpose drives, UPS, solar converters and medical applications. The driver supports switching frequencies up to 50kHz. It comprises all functionality for an advanced dual-channel IGBT gate driver including an isolated DC/DC converter, short-circuit protection, Soft Shut Down (SSD) and supply-voltage monitoring.

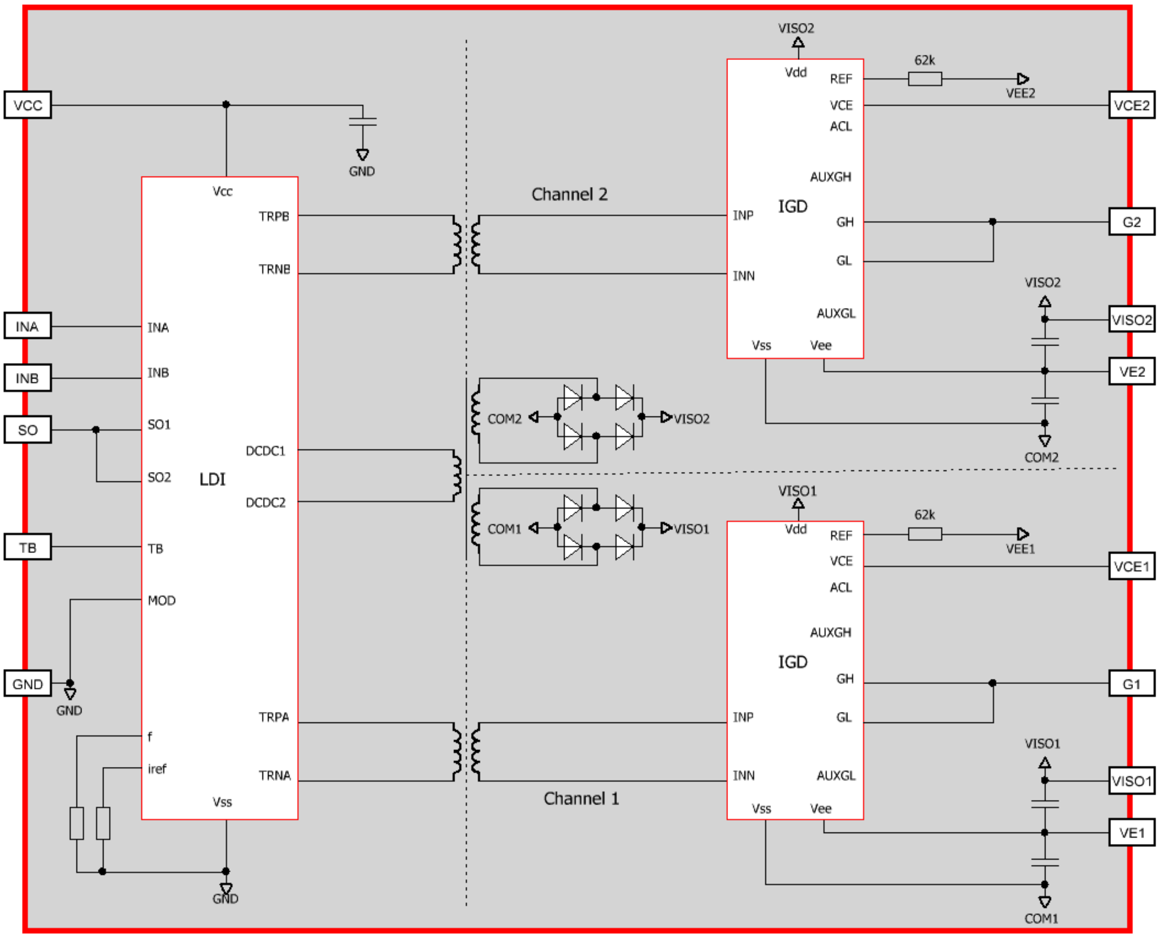

Fig. 2 Block diagram of driver core 2SC0106T

Mechanical Dimensions

The gate driver core must be mounted onto the carrier board with the transformer upside down. The header stacks must not be pressed together. The driver top side is free of components.

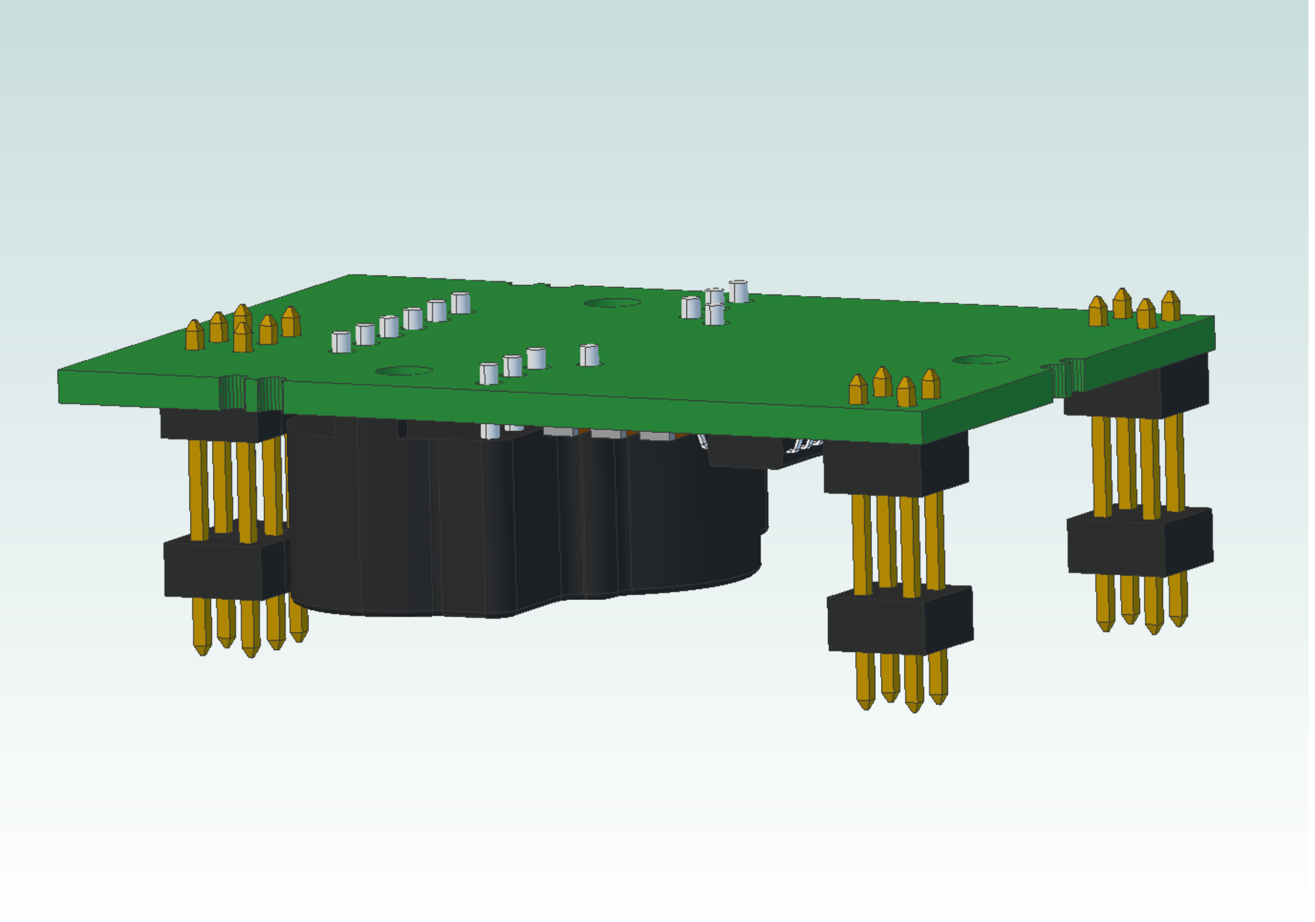

Fig. 3 Interactive 3D drawing of 2SC0106T

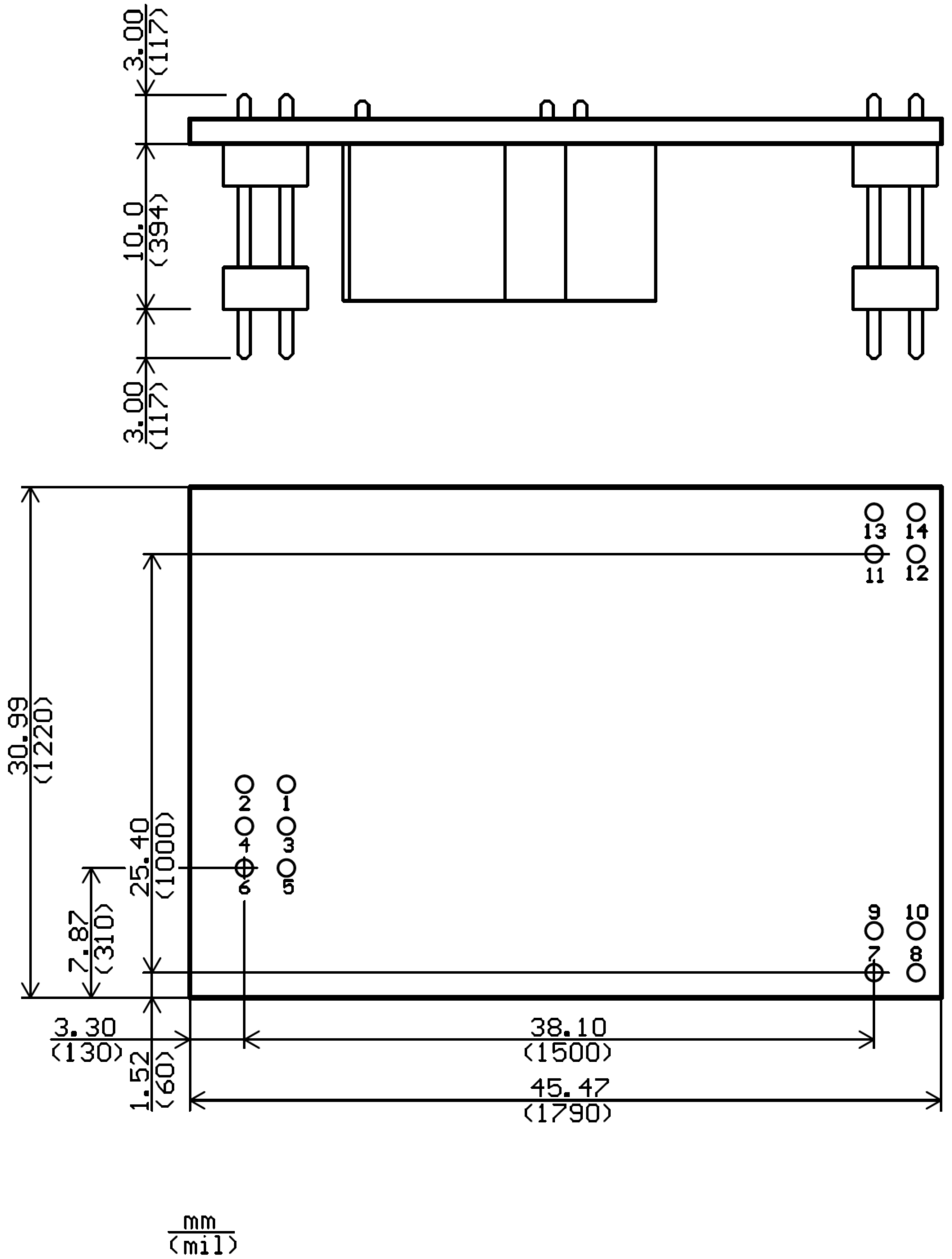

Fig. 4 Mechanical drawing of 2SC0106T (side view, top view)

The primary-side and secondary-side pin grid pitch is 2.54mm (100mil) with a pin cross section of 0.64mm x 0.64mm. Total outline dimensions of the board are 31mm x 45.5mm. The total height of the driver is 13mm measured from the bottom of the pin bodies to the maximum point of the driver.

Recommended diameter of solder pads: Ø 2mm (79mil)

Recommended diameter of drill holes: Ø 1mm (39mil)

Pin Designation

Pin No. and Name	Function
Primary Side	
1 TB	Set blocking time
2 SO	Status output channels 1 and 2 combined; normally high-impedance, pulled down to low on fault
3 VCC	Supply voltage; 15V supply for primary side
4 GND	Ground
5 INB	Signal input B (Channel 2); non-inverting input relative to GND
6 INA	Signal input A (Channel 1); non-inverting input relative to GND
Secondary Sides	
7 VE1	Emitter channel 1; connect to (auxiliary) emitter of power switch
8 VCE1	V_{CE} sense channel 1; connect to IGBT collector through resistor network
9 VISO1	Regulated 15V; for Miller clamping
10 G1	Gate channel 1; connect to gate resistor
11 VISO2	Regulated 15V; for Miller clamping
12 G2	Gate channel 2; connect to gate resistor
13 VE2	Emitter channel 2; connect to (auxiliary) emitter of power switch
14 VCE2	V_{CE} sense channel 2; connect to IGBT collector through resistor network

Recommended Interface Circuitry for the Primary-Side Connector

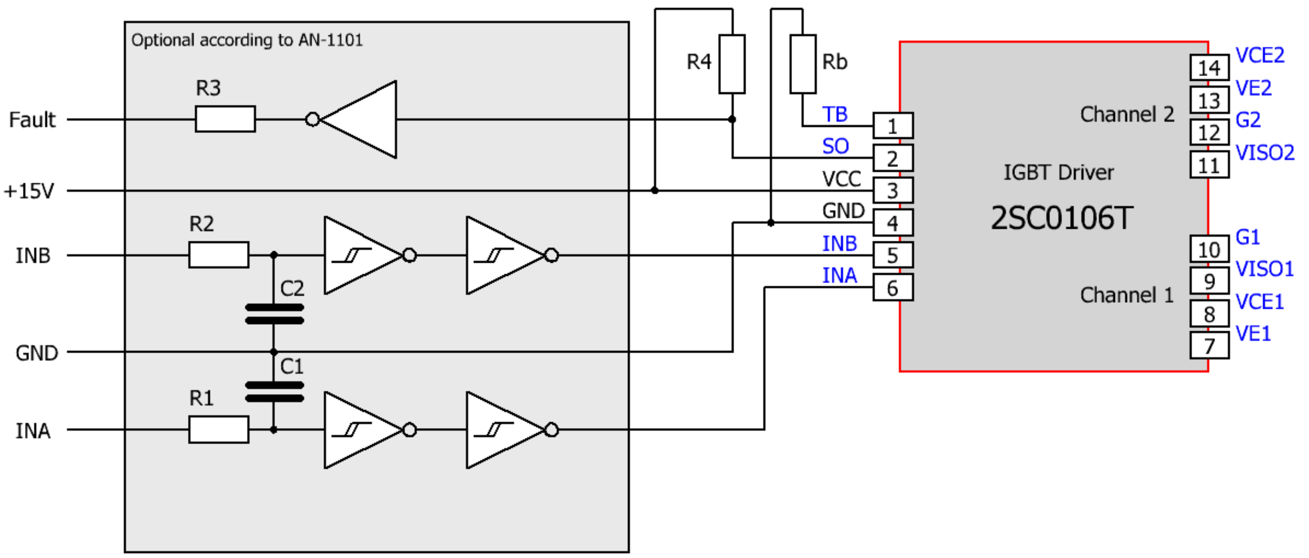

Fig. 5 Recommended user interface of 2SC0106T (primary side)

Note: 2SC0106T is an ultra-fast gate driver core. Any input noise on INA and INB with an amplitude of more than 2.6V will be transferred to a secondary-side gate switching signal. This can overload the DC-DC converter and damage the driver. The corresponding IGBTs or MOSFETs can also be damaged. Appropriate protection circuits are recommended according to the specific setup. Application note AN-1101 /1/ proposes corresponding protection circuits.

Description of Primary-Side Interface

General

The primary-side interface of the driver 2SC0106T is very simple and easy to use. The primary side is fully insulated from both secondary (high-voltage) sides. The driver channels work independently of each other.

The driver primary side is equipped with a 6-pin interface connector with the following terminals:

- 1 x power-supply terminal
- 2 x drive signal inputs
- 1 x status output (fault return)
- 1 x input to set the blocking time
- 1x ground terminal GND

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. It supplies the primary-side electronics as well as the DC-DC converter to supply the secondary sides with 15V.

The driver limits the inrush current at startup and no external current limitation of the voltage source for VCC is needed for this purpose.

INA, INB (channel drive inputs, e.g. PWM)

INA and INB are drive inputs. They safely recognize signals in the whole logic-level range between 3.3V and 15V. Both input terminals feature Schmitt-trigger characteristics. An input transition is triggered at any edge of an incoming signal at INA or INB.

SO (status output)

The output SO has an open-drain transistor. When no fault condition is detected, the output has high impedance. An internal current source of 1mA pulls the SO output to a voltage of about 4V when left open. When a fault condition (primary-side supply undervoltage, secondary-side supply undervoltage, IGBT short circuit) is detected, the status output SO goes to low (connected to GND).

The maximum SO current in a fault condition must not exceed the value specified in the driver data sheet /2/.

How the status information is processed

a) A fault on one of the secondary sides (detection of IGBT module short-circuit or supply undervoltage) is immediately transmitted to the SO output. This output is automatically reset (returning to a high impedance state) after a blocking time T_b has elapsed (refer to "TB (input for adjusting the blocking time Tb)" for timing information).

b) A supply undervoltage on the primary side is indicated immediately to the SO output. This output is automatically reset (returning to a high impedance state) after the undervoltage on the primary side disappears and the blocking time T_b has elapsed. Note that the blocking time does not run fully synchronously on both channels. It is therefore possible that the blocking time of one channel has already elapsed (the channel is free) while the other channel has not yet been released (the channel is blocked) and SO is still in a fault condition. This time mismatch is typically in the range of 5% of the programmed blocking time (e.g. 6ms for a blocking time of 120ms). It is therefore recommended to wait long enough after a fault reset before applying switching impulses to ensure that both channels have been effectively released.

TB (input for adjusting the blocking time T_b)

The terminal TB allows the blocking time T_b to be set by connecting a resistor R_b to GND (see Fig. 5). 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):

$R_b[k\Omega] = 1.0 \cdot T_b[ms] + 51$ with $20ms < T_b < 130ms$ and $71k\Omega < R_b < 181k\Omega$

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

Recommended Interface Circuitry for the Secondary-Side Connectors

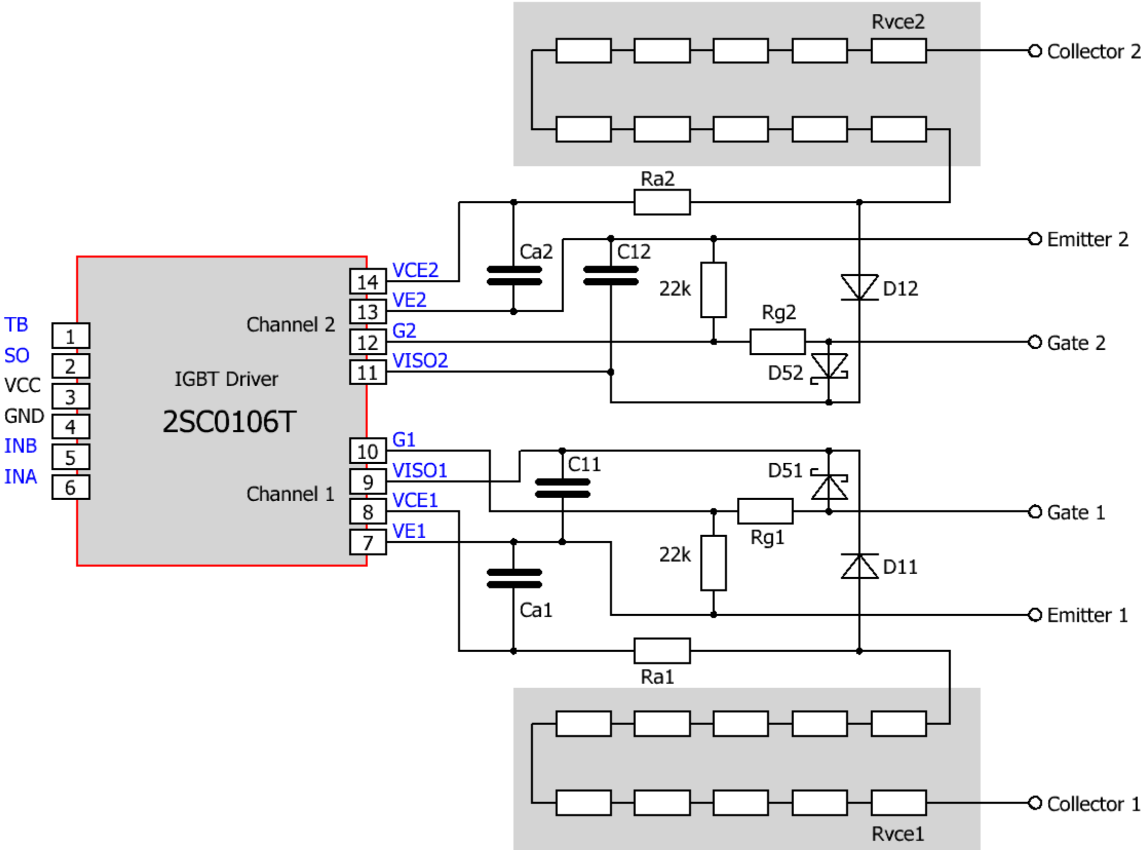

Fig. 6 Recommended user interface of 2SC0106T (secondary sides)

Description of Secondary-Side Interfaces

General

Each driver's secondary side (driver channel) is equipped with a 4-pin interface connector with the following terminals (x stands for the number of the drive channel 1 or 2):

- 1 x emitter terminal VEx
- 1 x collector sense terminal VCEx
- 1 x gate terminal Gx
- 1 x regulated 15V terminal VISOx

All inputs and outputs are ESD-protected.

DC/DC output (VISOx) and emitter (VEx) terminals

The driver is equipped with blocking capacitors on the secondary side of the DC/DC converter (for values, refer to the data sheet /2/).

Power semiconductors with a gate charge of up to 4µC can be driven without additional capacitors on the secondary side. For IGBTs or MOSFETs with a maximum gate charge of up to 8 µC, a minimum value of 2.5µF external blocking capacitance is recommended for every 1µC gate charge beyond 4µC. The blocking capacitors must be placed between VISOx and VEx (C_{1x} in Fig. 6). Their capacitance value must not exceed 10 µF. They must be connected as close as possible to the driver's terminal pins with minimum inductance. Ceramic capacitors with a dielectric strength ≥25V are recommended.

Collector sense (VCEx) with resistors

The collector sense of each channel of the 2SC0106T must be connected to the IGBT collector or MOSFET drain with the circuit shown in Fig. 6 or Fig. 7 in order to detect an IGBT or MOSFET short circuit.

During the IGBT off-state, the driver's internal MOSFET connects pin VCEx to pin COMx. The capacitor C_{ax} is then precharged/discharged to the negative supply voltage, which is about -9V referred to VEx (red circle in Fig. 7). During this time, a current flows from the collector (blue circle in Fig. 7) via the resistor network and the diode D_{1x} (BAS416) to VISOx. The current is limited by the resistor chain.

It is recommended to dimension the resistor value of the resistor chain R_{vcex} in order to obtain a current of about I_{Rvcex}=0.6-1mA flowing through R_{vcex} (e.g. 800kΩ-1MΩ for $V_{DC-LINK}$=800V). The current through R_{vcex} must not exceed 1mA. A high-voltage resistor as well as series-connected resistors may be used. In any case, the minimum creepage distance required for the application must be considered and the resistor chain must not be allowed to overheat.

The reference voltage is set by an internal resistor R_{thx}=62kΩ to 9.3V. The driver will therefore safely protect the IGBT against short-circuit, but not against overcurrent. Overcurrent protection has a lower timing priority and is recommended to be realized within the host controller.

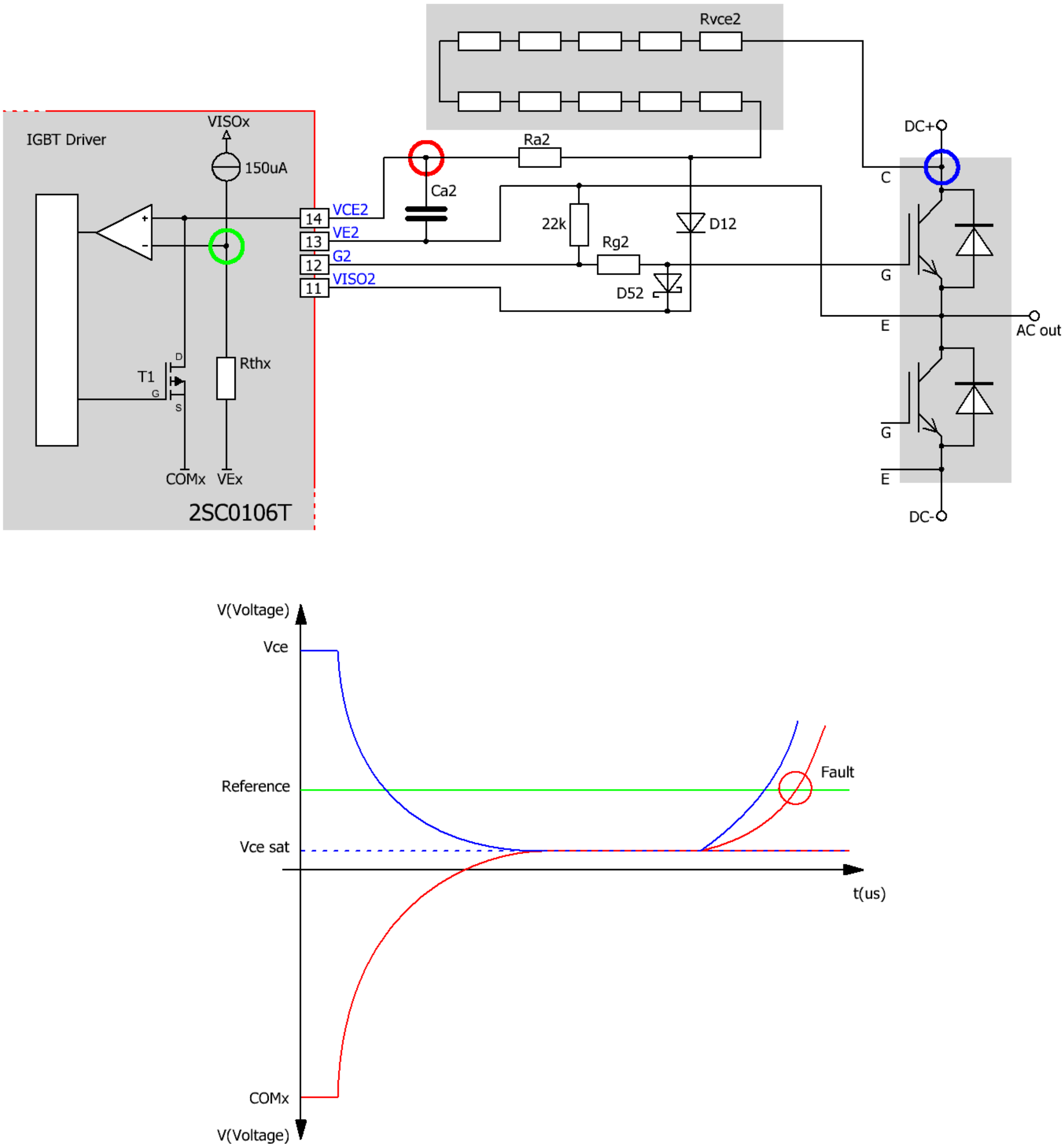

Fig. 7 Principe of V_{CE} desaturation protection with resistors

At IGBT turn-on and in the on-state, the driver's internal MOSFET turns off. While V_{CE} decreases (blue curve in Fig. 7), C_{ax} is charged from the COMx potential to the IGBT saturation voltage (red curve in Fig. 7). The time required to charge C_{ax} depends on the DC bus voltage, the value of the resistor R_{ax} and the value of the capacitor C_{ax}. For 1200V IGBTs it is recommended to set R_{ax}=120kΩ. For 600V and 650V IGBTs the recommended value is R_{ax}=62kΩ.

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 voltage is measured. It corresponds to the duration of the short circuit.

The value of the response time capacitors C_{ax} can be determined from the following table in order to set the desired response time (R_{vcex}=1MΩ, R_{ax}=120kΩ, DC-link voltage $V_{DC\text{-}LINK}$>500V):

C_{ax} [pF]	Response time [µs]
15	4.5
22	5.9
27	6.9
33	8.2
47	11.2

Table 1 Typical response time as a function of the capacitance C_{ax}

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

Note that the response time increases at DC-link voltage values lower than 500V (R_{ax}=120kΩ).

The diode D_{1x} in Fig. 6 and Fig. 7 must have a very low leakage current and a blocking voltage >40V (e.g. BAS416). Schottky diodes must be explicitly avoided.

The components C_{ax}, R_{ax}, and D_{1x} must be placed as close as possible to the driver. A large collector-emitter loop must also be avoided.

When a short-circuit fault is detected, the driver switches off the corresponding power semiconductor. The fault status is immediately transferred to the SO output. The power semiconductor is kept in the off state (non-conducting) and the fault is shown at pin SO as long as the blocking time T_b is active.

The blocking time T_b is applied independently to each channel. T_b starts as soon as a fault has been detected. As 2SC0106T drivers feature only one SO fault signal, the user cannot know from which channel a fault condition has been generated. It is therefore recommended to switch off both driver channels as soon as a fault condition is detected and to keep both driver channels in the off-state as long as a fault condition is present.

Desaturation protection with sense diodes

2SC0106T also provides desaturation protection with high-voltage diodes as shown in Fig. 8. However, the use of high-voltage diodes has some disadvantages compared to the use of resistors:

- Common-mode current relating to the rate of change dv_{CE}/dt of the collector-emitter voltage: High-voltage diodes have large junction capacitances C_j. These capacitances in combination with the dv_{CE}/dt generate a common-mode current I_{com} flowing in and out of the measurement circuit.
$$I_{com} = C_j \cdot \frac{dv_{CE}}{dt}$$
- Price: High-voltage diodes are more expensive than standard 0805/150V or 1206/200V SMD resistors.
- Availability: Standard thick-film resistors are comparatively easier to source on the market.
- Limited ruggedness: The reaction time does not increase at lower V_{CE} levels. Consequently, false triggering may occur at higher IGBT temperatures, higher collector currents, resonant switching or phase-shift PWM.

During the IGBT off-state, D_{4x} (and R_{ax}) sets the VCEx pin to COMx potential, thereby precharging/discharging the capacitor C_{ax} to the negative supply voltage, which is about -9V referred to VEx. At IGBT turn-on, the capacitor C_{ax} is charged via R_{ax}. When the IGBT collector-emitter voltage drops below that limit, the voltage of C_{ax} is limited via the high-voltage diodes D_{1x} and D_{2x}. The voltage across C_{ax} can be calculated by:

$$V_{Cax} = V_{CEsat} + V_{F(D1x)} + V_{F(D2x)} + 330\Omega \cdot \frac{15V - V_{CEsat} - V_{F(D1x)} - V_{F(D2x)}}{R_{ax} + 330\Omega}$$

The reference voltage V_{refx} must be higher than V_{Cax}. The reference voltage is set up by an internal resistor R_{thx}=62kΩ to 9.3V.

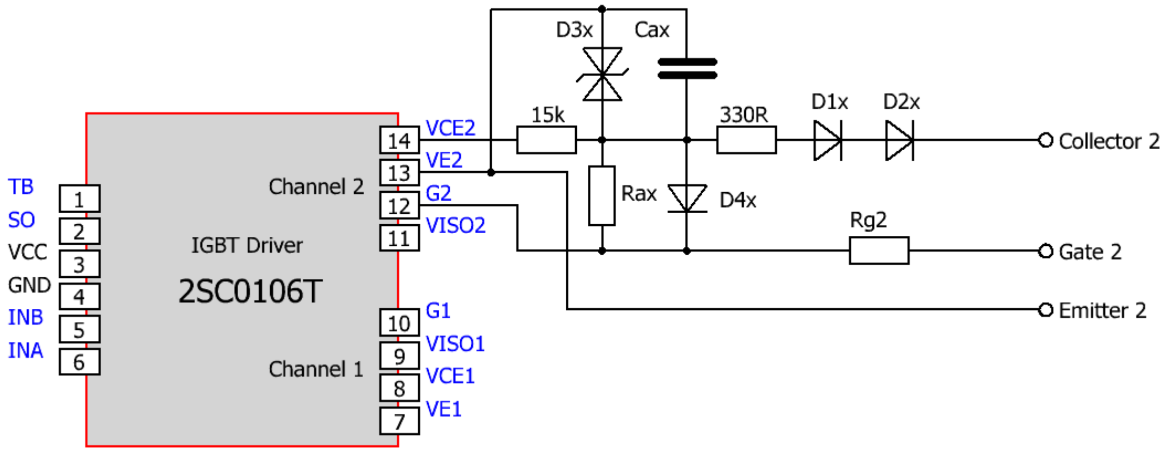

Fig. 8 Recommended circuit for desaturation protection with sense diodes (only one channel shown)

The value of the resistance R_{ax} can be calculated with the following equation in order to program the desired response time T_{ax} at turn-on:

$$R_{ax}[k\Omega] \approx \frac{1000 \cdot T_{ax}[\mu s]}{C_{ax}[pF] \cdot \ln(\frac{15V + |V_{GLx}|}{5.7V})}$$

V_{GLx} is the absolute value of the turn-off voltage at the driver output. It depends on the driver load and can be found in the driver data sheet /2/. Recommended components $D_{1x}/D_{2x}/D_{3x}/D_{4x}$ and values for R_{ax} and C_{ax} are:

- High-voltage diodes D_{1x}/D_{2x}: 1x 1N4007 for ≤650V IGBTs
2x 1N4007 for 1200V IGBTs
- D_{3x}: Transient voltage suppressor of the voltage class 12V…15V with small junction capacitance such as CDDFN2-12C from Bourns.
- D_{4x}: High-speed diode as BAS316. Schottky diodes must be avoided.
- R_{ax}=24kΩ…62kΩ
- C_{ax}=100pF…560pF

Note that C_{ax} must include the parasitic capacitance of the transient voltage suppressor D_{3x} and the PCB.

Note also that the instantaneous V_{CE} threshold voltage is 9.3V minus the voltage across the 330Ω resistor as well as the forward voltages across D_{1x} and D_{2x}.

The minimum off-state duration should not be shorter than about 1μs in order not to significantly reduce the response time for the next turn-on pulse.

Disabling the $V_{CE,sat}$ detection

To disable the $V_{CE,sat}$ measurement of 2SC0106T, a resistor with a minimum value of 33kΩ must be placed between VCEx and VEx according to Fig. 9.

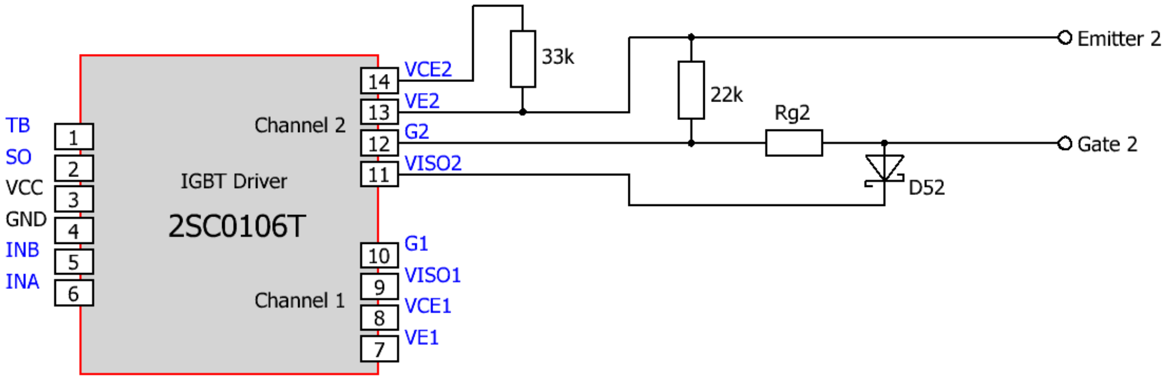

Fig. 9 Disabling the $V_{CE,sat}$ detection

Gate terminal (Gx)

This terminal allows the (turn-on and turn-off) gate resistor to be connected to the gate of the power semiconductor.

The turn-off losses of IGBTs from the latest generation are usually almost independent of the turn-off gate resistance. Turn-on losses are however strongly dependent on the turn-on gate resistance. Different turn-on and turn-off resistance values can be obtained using additional resistors with a series connected diode if required.

Gate clamping and STO (Safe Torque Off)

Gate driver core 2SC0106T provides a regulated 15V supply voltage on the VISOx terminal. Schottky diode D_{5x} according to Fig. 6 clamps the gate voltage to the regulated 15V.

This has the following advantages:

- The use of an additional transient voltage suppressor (TVS) between gate and emitter is not required.
- Reduction of the dissipated energy in the power semiconductor in case of short circuit due to better clamping performance of the gate-emitter voltage. The short circuit energy is a function of the gate-emitter voltage: a lower gate-emitter voltage results in a lower short-circuit current.
- STO function by unpowered driver core. In case of any dv/dt coming from the DC-bus system, which causes a current flow through the Miller capacitance of the IGBT, the diode D_{5x} provides a conducting path for this current to the buffer capacitors. This prevents an unintended turn-on of the IGBT even if the gate-driver is unpowered (for more details, please contact Power Integrations' Support): www.power.com/igbt-driver/go/support

Recommended Schottky diodes for D_{5x} include PMEG4010CEJ or STPS340U.

Soft Shut Down (SSD) function

The SSD function reduces the turn-off di/dt to limit the V_{CE} overvoltage as soon as a short-circuit condition is detected. An excessive turn-off overvoltage is therefore avoided and the power semiconductor is turned off within its safe operating area.

The SSD function is realized with a closed loop scheme which is activated as soon as an IGBT short circuit is detected. The driver then measures the gate-emitter voltage and adjusts it according to the three following phases:

- In a first step, the gate-emitter voltage is decreased to a defined level controlled with the closed loop feedback.
- The defined level of the gate-emitter voltage is held at the given level to ramp down the collector current smoothly (e.g. with lower di/dt) until the gate charge profile of the power semiconductor has reached the end of the Miller plateau. The end of the Miller plateau is detected by evaluating the gate current.
- The gate-emitter voltage is then reduced to its end value, following a given reference value.

The SSD function is only active under short-circuit conditions and not under normal operating conditions (e.g. at nominal current or under over-current conditions). It may therefore be necessary to increase the turn-off gate resistance or to take appropriate measures (e.g. lower DC-link stray inductance) to avoid excessive turn-off overvoltages under normal operating conditions.

Note that the SSD function uses a closed-loop scheme. It may therefore not necessarily perform better with a higher value of the turn-off gate resistor.

Even if the SSD function of 2SC0106T uses a closed-loop regulation scheme, it has performance limitations. Excessive DC-link stray inductance values may therefore lead to excessive turn-off overvoltages in the short-circuit condition. It is therefore necessary to characterize the short-circuit behavior of the IGBT under all application-relevant conditions, especially over the full IGBT and driver ambient temperature range, and to consider sufficient safety margins of the V_{CE} peak voltage to achieve a rugged design.

If the V_{CE} peak voltage is excessively high and cannot be lowered by other means, Power Integrations recommends using the 2SC0106T driver with active clamping (same topology as for 2SC0108T drivers, refer to /3/).

How Do 2SC0106T 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. All transformers (DC-DC and signal transformers) feature safe isolation to IEC 60664-1 between the primary side and either secondary side.

Note that the driver requires a stabilized supply voltage.

Power-supply monitoring

The driver's primary-side as well as both secondary-side driver channels are equipped with a local undervoltage monitoring circuit.

In the event of a primary-side supply undervoltage, the power semiconductors are driven with a negative gate voltage to keep them in the off-state (the driver is blocked) and the fault is transmitted to output SO until the fault disappears (refer also to "SO (status output)" for more details).

In case of a secondary-side supply undervoltage, the corresponding power semiconductor is driven with a negative gate voltage to keep it in the off-state (the channel 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.

Additional application support for 2SC0106T

For additional application support using 2SC0106T drivers, please refer to Application Note AN-1101 /1/ on www.power.com/igbt-driver/go/app-note.

Electrical Ratings for UL recognized types

The following ratings apply for the UL recognized product versions according to the UL definitions:

Power/Channel	Gate Current	Control Circuit (Input/Output)	System Voltage
1.2W	6A	15Vdc	730Vac/dc

Bibliography

/1/ Application Note AN-1101: Applications with SCALE™-2 Gate Driver Cores, Power Integrations

/2/ Data sheets SCALE™-2+ driver core 2SC0106T, Power Integrations

/3/ 2SC0108T Description & Application Manual, Power Integrations

Note: These documents are available at www.power.com/igbt-driver

The Information Source: SCALE-2+ Driver Data Sheets

Power Integrations 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.power.com/igbt-driver.

Quite Special: Customized SCALE-2+ Drivers

If you need an IGBT driver that is not included in our delivery range, please do not hesitate to contact Power Integrations or your Power Integrations sales partner.

Power Integrations has more than 30 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.

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Preliminary Description & Application Manual

Ordering Information

Our international terms and conditions of sale apply.

Type Designation	Description
2SC0106T2A1-12	SCALE-2+ driver core with SSD and enhanced frequency and temperature range
2SC0106T2A1C-12	SCALE-2+ driver core with SSD, enhanced frequency and temperature range and conformal coating

Product home page: www.power.com/igbt-driver/go/2SC0106T
Refer to www.power.com/igbt-driver/go/nomenclature for information on driver nomenclature.

Information about Other Products

For other driver cores:

Direct link: www.power.com/igbt-driver/go/cores

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

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