

SCALE™-2 1SP0340V / 1SP0340D

Preliminary Description & Application Manual

Driver solution for high-voltage and high-power IGBT modules with fiber-optic interface for 2-level, 3-level and multilevel converter topologies with paralleling capability of IGBT modules

Abstract

1SP0340 are single-channel drivers for the reliable driving of up to four paralleled high-voltage and high-power IGBT modules. The driver concept is based on a master-slave principle:

- 1SP0340V (master) is equipped with versatile fiber-optic links (AVAGO HFBR-x522ETZ)
- 1SP0340D (slave) is directly connected to a master or slave driver via a paralleling interface.

The drivers are based on Power Integrations' SCALE™-2 chipset, a highly integrated technology for the reliable driving and safe operation of IGBTs.

Perfectly matched driver versions are available for all mechanically compatible IGBT modules. The plug-and-play capability of the driver allows immediate operation after mounting. The user needs invest no effort in designing or adjusting it to a specific application.

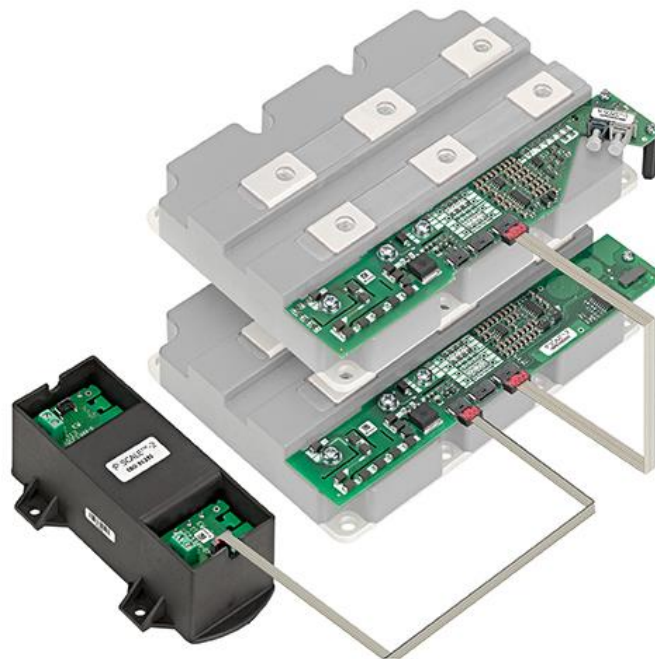


Fig. 1 1SP0340D (slave) with 1SP0340V (master) each screwed onto a 4.5kV IGBT module (left: DC/DC converter ISO5125I connected to 1SP0340D)

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System Overview

The 1SP0340 are plug-and-play drivers based on the highly integrated SCALE-2 chipset developed by Power Integrations /1/. This 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/.

1SP0340 drivers are specifically designed for the reliable and safe driving of high-voltage and high-power IGBT modules from the 4500V voltage class. The driver concept relies on a master-slave principle that allows the safe operation of parallel connected IGBT modules. The master 1SP0340V can be used as a standalone driver without a slave to drive IGBT modules without parallel connection or it can be used with one to three 1SP0340D slaves to drive up to four parallel-connected IGBT modules. The following sections explain the basic topology of the 1SP0340V (master), the 1SP0340D (slave) as well as the parallel operation of master and slave(s).

1. 1SP0340V (Master)

The basic topology of the 1SP0340V drivers is shown in Fig. 2. The same driver can be used as a standalone driver without a slave or with up to three slaves. The three slaves can be connected directly to the master or other slaves via the provided paralleling interfaces X2 and X3. The X2 and X3 interfaces are fully identical.

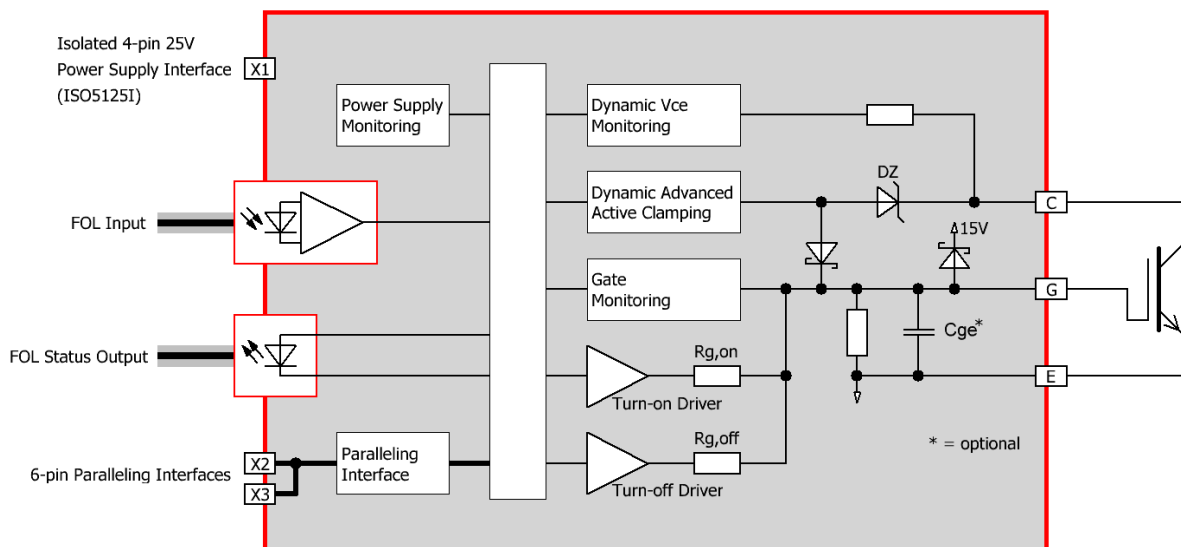


Fig. 2 Basic schematic of the 1SP0340V drivers

The driver is equipped with the following features:

- Power supply monitoring
- Fiber-optic interface (drive input and status feedback)
- Dynamic V_{CE} monitoring (short-circuit protection)
- Dynamic Advanced Active Clamping DA²C (overvoltage protection at turn-off)
- Gate monitoring
- Paralleling interfaces X2 and X3 for the master-slave connection

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The power supply (isolated DC/DC converter ISO5125I) has not been integrated in the driver. It is a separate unit.

All the components required for the optimal and safe driving of the relevant IGBT module such as smallest gate resistors designed to minimize switching losses, gate clamping, etc. are included on the driver. Moreover, it includes components for setting the V_{CEsat} monitoring turn-off trip level and the response time. Its plug-and-play capability means that it is ready to operate immediately after mounting. The user needs invest no effort in designing or adjusting the driver to a specific application.

The values for the gate resistors and other key components can be found in the specific driver data sheets for a given IGBT module /3/.

2. 1SP0340D (Slave)

The basic topology of the 1SP0340D drivers is shown in Fig. 3. 1SP0340D drivers can only be used in conjunction with 1SP0340V drivers when parallel connection of IGBT modules is required. 1SP0340D drivers can be connected via the paralleling interface X2 or X3 to a 1SP0340V master or to another 1SP0340D slave. Up to three slaves (and a master) can be directly connected in parallel.

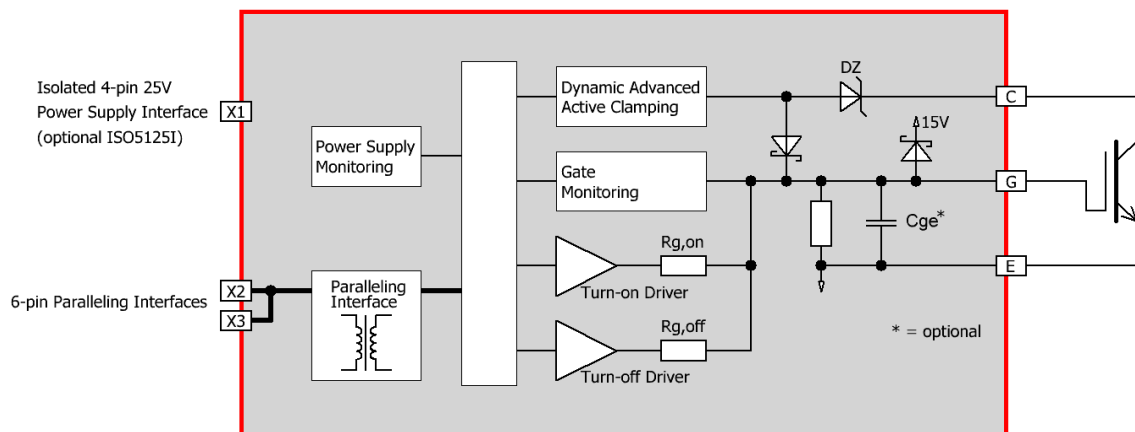


Fig. 3 Basic schematic of the 1SP0340D drivers

The driver is equipped with the following features:

- Power supply monitoring
- Dynamic Advanced Active Clamping DA²C (overvoltage protection at turn-off)
- Gate monitoring
- Paralleling interfaces X2 and X3 for the master-slave or slave-slave connection

All the components required for the optimal and safe driving of the relevant IGBT module such as smallest gate resistors designed to minimize switching losses, gate clamping, etc. are included on the driver.

The supply voltage as well as the input signal are delivered from the master via the paralleling interfaces X2 or X3. The power supply interface X1 allows an additional isolated DC/DC converter ISO5125I to be connected to each slave in those cases where the DC/DC converter connected to the master would not be sufficiently powerful (this is not required in most applications). No fiber optics are present on the 1SP0340D driver. Moreover, no desaturation protection is implemented on the slave, as it is already realized on the master.

Its plug-and-play capability means that it is ready to operate immediately after mounting. The user needs invest no effort in designing or adjusting the driver to a specific application.

The values for the gate resistors and other key components can be found in the specific driver data sheets for a given IGBT module /3/.

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3. Parallel connection of IGBT modules with master and slave(s)

If parallel connection of two to four IGBT modules is required, one master as well as one to three slaves must be used. The basic principle is illustrated in Fig. 4.

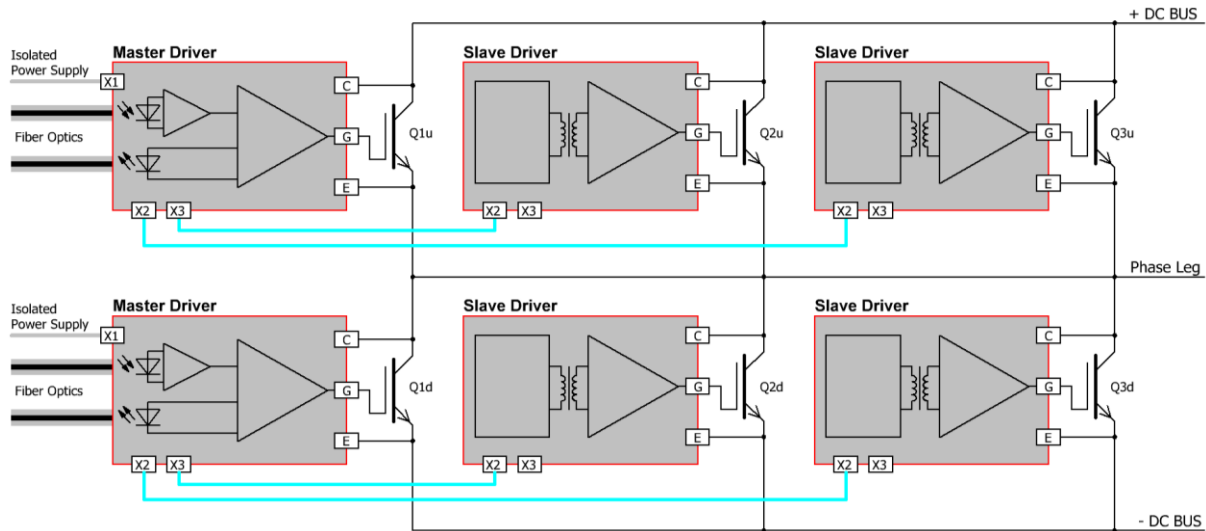


Fig. 4 Principle of parallel connection of 1SP0340 drivers with one master and two slaves in a half-bridge configuration (example)

The electrical isolation of the power supply must be realized with a separate unit (e.g. DC/DC converter ISO5125I). The electrical isolation of the signals is realized on the master (fiber-optic interface for the input signal and the status feedback). The power supply of the slave as well as the input signal and gate monitoring feedback are transmitted to/from the slave and from/to the master via the interface bus connected to the paralleling interfaces X2 and/or X3 respectively. Both interfaces X2 and X3 are fully identical and interchangeable on the master as well as on the slave. The paralleling interface X2 or X3 makes sure that all paralleled drivers switch on and off synchronously.

The Five Steps to Success

The following steps point out the easy way to use 1SP0340 drivers in power converters:

1. Choose a suitable driver

When applying 1SP0340 drivers, you should note that they are specifically adapted to a particular type of IGBT module.

The type designation of the driver consequently also includes a number corresponding to a specific IGBT module (see "Ordering Information").

If no parallel connection of IGBT modules is required, only one 1SP0340V master is to be used. If parallel connection is required, one master as well as one to three slaves are to be used.

These drivers are not valid for IGBT modules other than those specified. Incorrect use may result in failure.

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2. Attach the drivers to the IGBT modules (one driver per IGBT module)



Any handling of IGBT modules or drivers is subject to the general specifications for protecting electrostatic-sensitive devices according to international standard IEC 60747-1, Chapter IX or European standard EN 100015 (i.e. the workplace, tools, etc. must comply with these standards).

If these specifications are ignored, both IGBTs and drivers may be damaged.

The driver can be easily mounted onto an IGBT module by screwing the corresponding terminals.

3. Connect the driver to the control electronics

Master: Connect the power supply plug X1 as well as the fiber-optic transmitters and receivers. If parallel connection is required, the paralleling interfaces X2 and/or X3 must be connected to the slave(s).

Slave(s): Connect the paralleling interfaces X2 or X3 to the master or another slave. One master must be used in conjunction with the slave(s).

4. Check the driver function

Check the gate voltage of all drivers (master and slaves): For the off-state, the nominal gate voltage is specified in the relevant data sheet /3/. For the on-state, it is +15V. Also check the input current consumption of the driver without clock signals and at the desired switching frequency.

These tests should be performed before installation, as the gate terminals may otherwise not be accessible.

5. Set up and test the power stack

Before starting up the system, it is recommended that each logical switch (parallel connection of IGBT modules) be checked separately under power-cycling conditions. It is usually sufficient to apply the single or double-pulse technique. Power Integrations specially recommends users to check that the IGBT modules switch inside the SOA in the worst case condition. In case of parallel connection of IGBT modules it is also recommended to check the current sharing. These parameters strongly depend on the specific converter construction.

Even if only single IGBTs are tested, all the system's gate drivers must be supplied with energy. All the other IGBTs are then kept in the off state by applying negative gate voltages. This is particularly important when switching the IGBTs under test.

The short-circuit behavior can also be verified at this point.

The system is then ready to start under real-world load conditions. This allows the thermal behavior of the whole arrangement to be determined.

The system must be re-qualified over the entire specified range of temperature and load conditions.

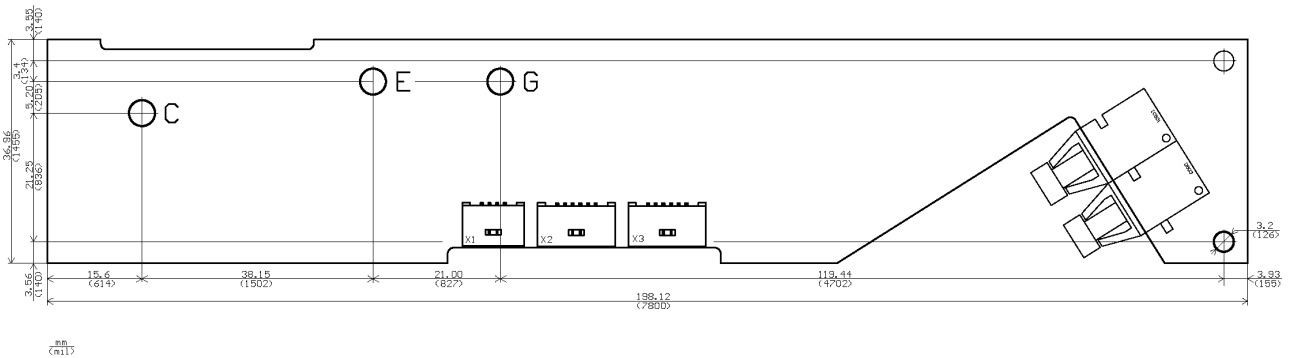


CAUTION: All handling with high voltages involves risk to life. It is imperative to comply with the respective safety regulations!

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Mechanical Dimensions

1. 1SP0340V (Master)



Maximum driver height: 10mm measured from the bottom layer

Fig. 5 Mechanical dimensions of 1SP0340V

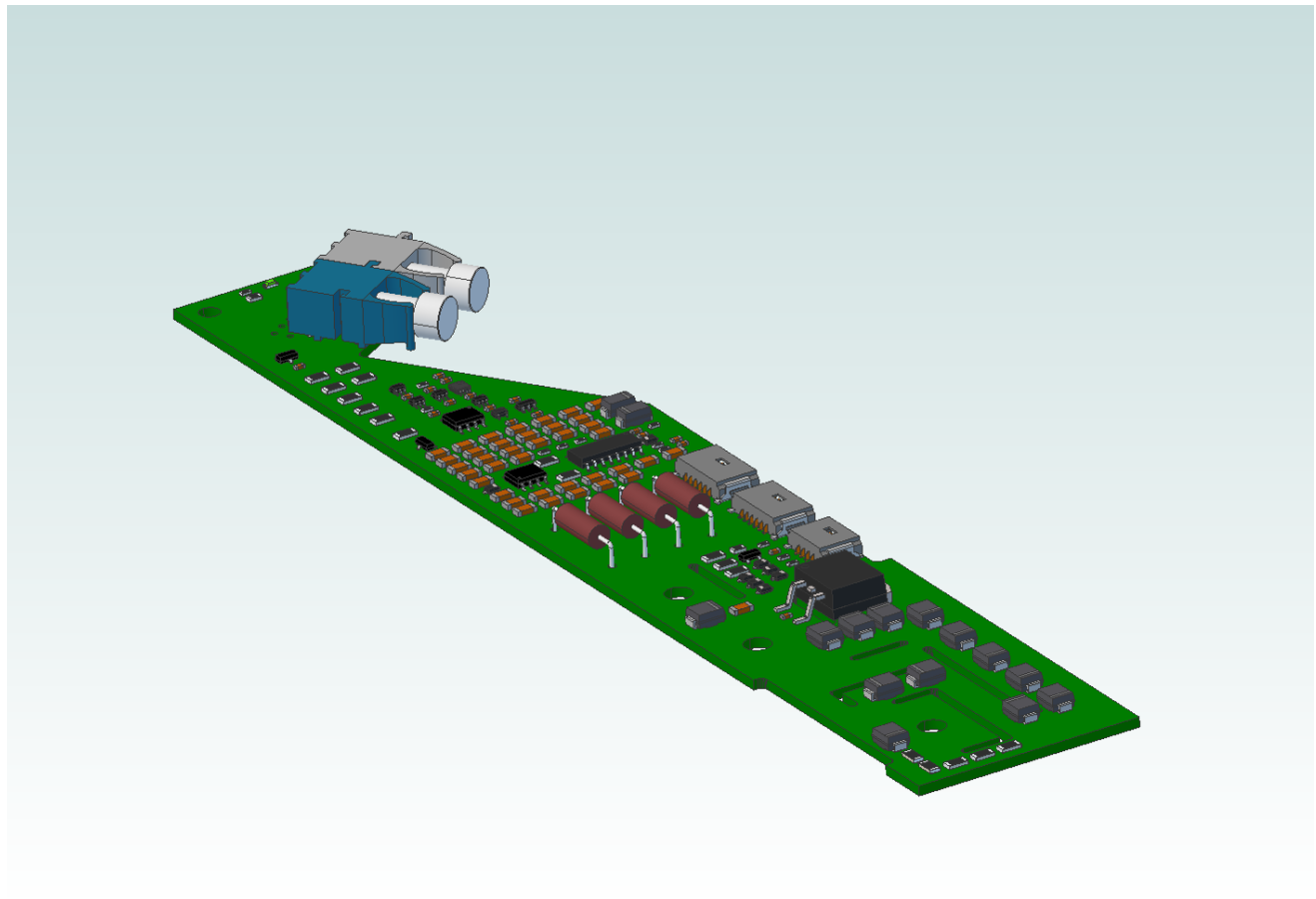
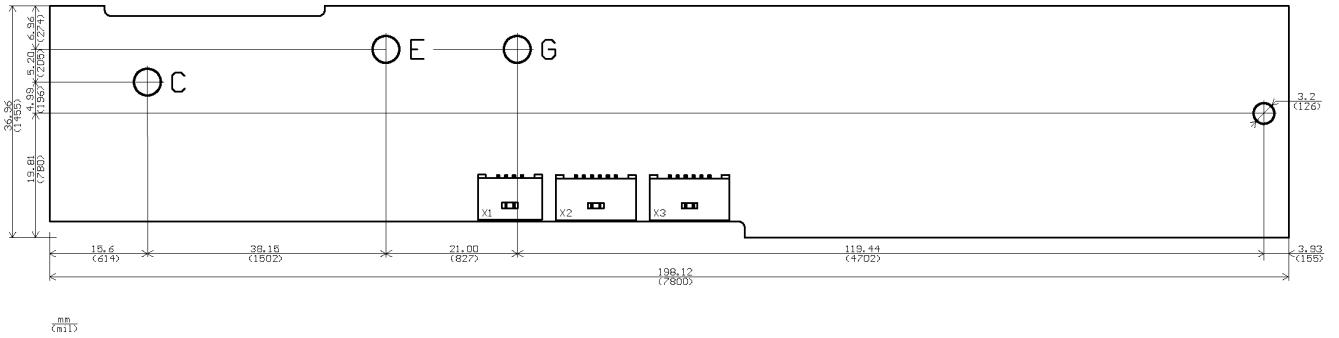


Fig. 6 Interactive 3D drawing of 1SP0340V

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2. 1SP0340D (Slave)



Maximum driver height: 7mm measured from the bottom layer

Fig. 7 Mechanical dimensions of 1SP0340D

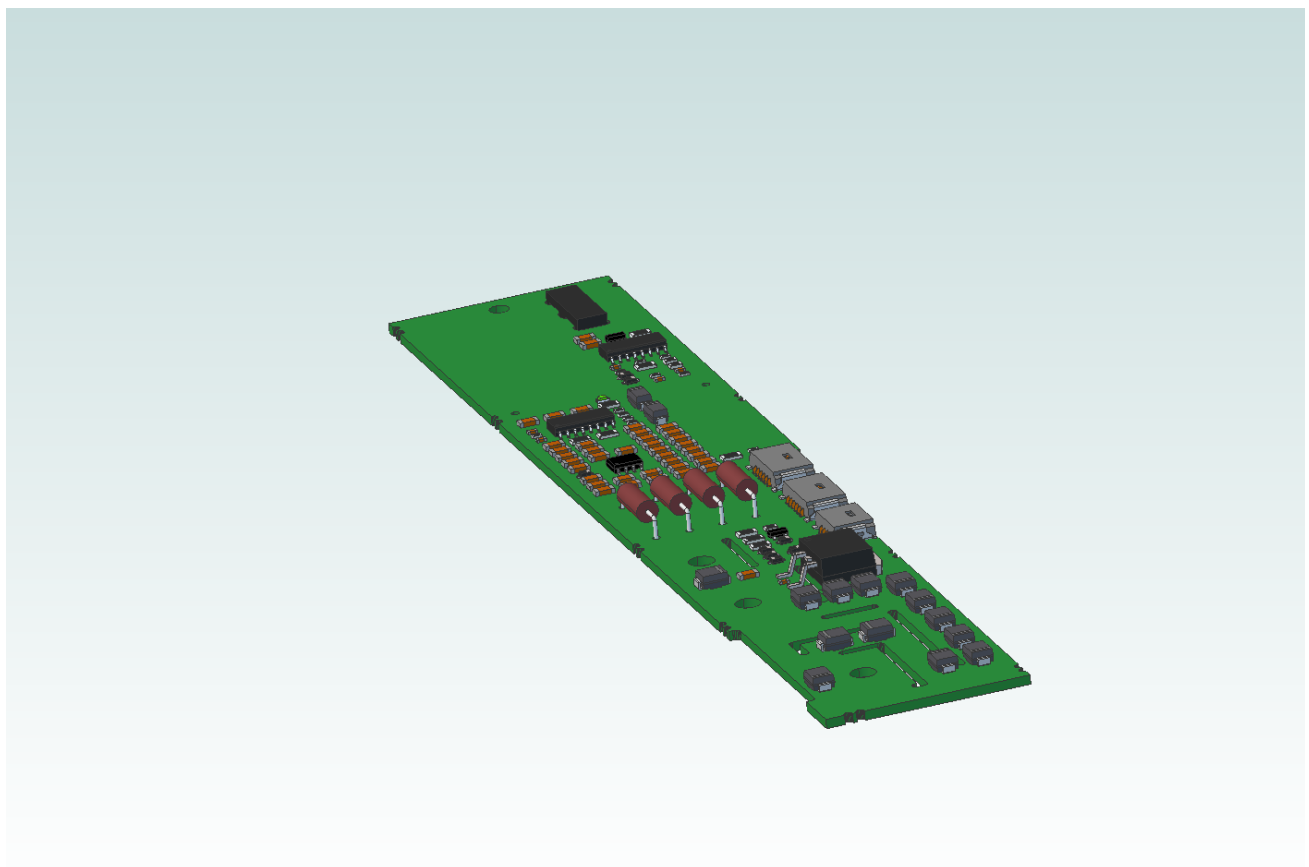



Fig. 8 Interactive 3D drawing of 1SP0340D

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Recommended Cables and PCB Connectors

The following cables and PCB connectors for the interfaces X1 and X2/X3 are recommended and can be ordered from Power Integrations or from ERNI according to the following table. Refer to Fig. 9 for more details about the cable arrangement:

Accessories	Interface	Length/ Type	Power Integrations Ordering Number	ERNI Ordering Number	Picture
Cable (Power Supply, 3-pin)	ISO5125I	100cm	MBC31-100-0	IDCCS_SRC_1.27_03_SPX_SPX_1000_HT	
Cable (Power Supply, 4-pin)	X1	35cm	MBC41-035-0	IDCCS_SRC_1.27_04_SPX_SPX_350_HT	
	X1	45cm	MBC41-045-0	IDCCS_SRC_1.27_04_SPX_SPX_450_HT	
	X1	70cm	MBC41-070-0	IDCCS_SRC_1.27_04_SPX_SPX_700_HT	
	X1	110cm	MBC41-110-0	IDCCS_SRC_1.27_04_SPX_SPX_1100_HT	
Cable (Paralleling, Master to Slave, 6-pin)	X2/X3	30cm	MBC61-030-0	IDCCS_SRC_1.27_06_SPX_SPX_300_HT	
	X2/X3	50cm	MBC61-050-0	IDCCS_SRC_1.27_06_SPX_SPX_500_HT	
	X2/X3	70cm	MBC61-070-0	IDCCS_SRC_1.27_06_SPX_SPX_700_HT	
	X2/X3	110cm	MBC61-110-0	IDCCS_SRC_1.27_06_SPX_SPX_1100_HT	
PCB connector (3-pin)	ISO5125I	Right angle	MBCON-3-1-0	234450	
	ISO5125I	Vertical	MBCON-3-2-0	284696	
PCB connector (4-pin)*	X1	Right angle	MBCON-4-1-0	214012	
	X1	Vertical	MBCON-4-2-0	284697	

*The 4-pin PCB connectors are not required if the external DC/DC converter ISO5125I is used.

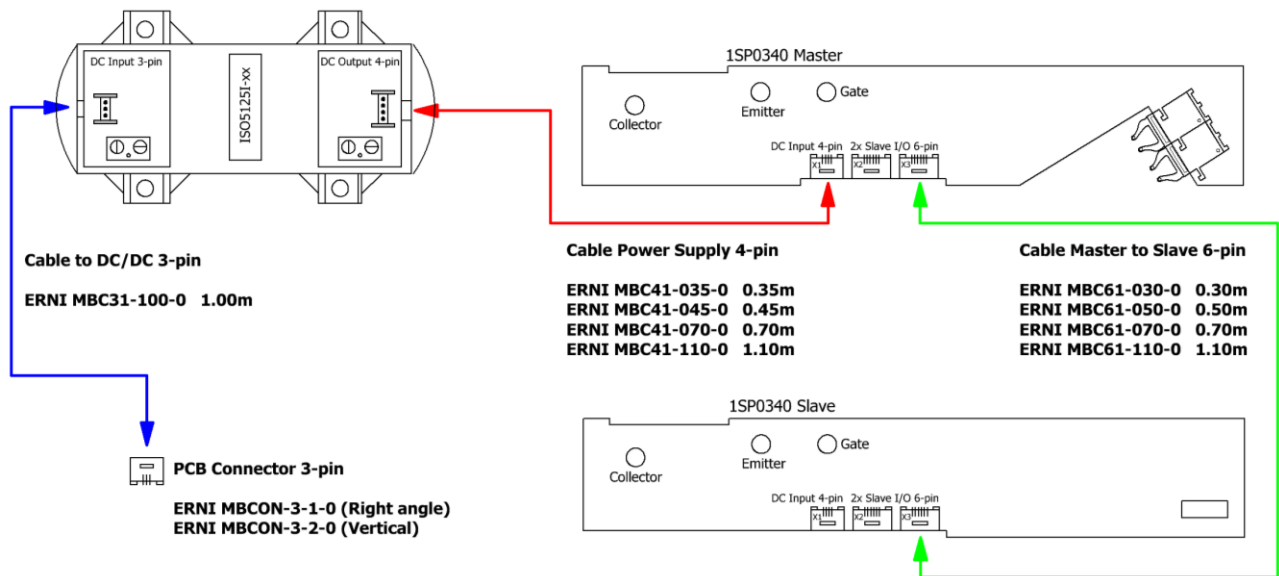


Fig. 9 Cable arrangement for 1SP0340 (master only or master and slave) and DC-DC converter ISO5125I

All cables are delivered with straight plugs on both sides.

The PCB connectors can be ordered as "right angle" types (the cable is plugged in parallel to the PCB) or as "vertical" types (the cable is plugged vertically to the PCB) according to Fig. 10.

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Right angle male connector



Vertical male connector



Fig. 10 Right angle male and vertical male connectors

Refer to www.power.com/igbt-driver/go/ext_erni for more information.

Please note that the paralleling cables as well as the supply cables carry high potential. The voltage rating of the recommended cables is only 300V. They must therefore be isolated. The user is fully responsible to apply sufficient isolation to the delivered cables.

Pin Designation of Connector X1 (Power Supply of 1SP0340x)

Pin	Des.	Function	Pin	Des.	Function
1	GND	Ground	2	VDC	+25V isolated power supply
3	VDC	+25V isolated power supply	4	GND	Ground

Description of Interface X1 (Power Supply of 1SP0340x)

The driver is equipped with a 4-pin interface connector for the power supply. It is recommended to connect both GND as well as both VDC pins. For recommended cables, please read the paragraph "Recommended Cables and PCB Connectors" on Page 9.

Note that no galvanic isolation for the power supply is implemented on 1SP0340V. It is therefore recommended to use the ISO5125I as an external DC/DC converter to supply the driver with power. A cable length of up to 3m between ISO5125I and 1SP0340 has been successfully tested.

Please note that the cable at interface X1 carry high potential. The voltage rating of the recommended cables is only 300V. They must therefore be isolated in an adequate way.

The interface X1 is usually not required on 1SP0340D (slaves) as the supply voltage is already available from the master ("2. 1SP0340D (Slave)" on Page 4)

Description of the Fiber-Optic Input (1SP0340V)

This is the drive (command signal) input.

Description of the Fiber-Optic Output (1SP0340V)

During normal operation (i.e. the driver is supplied with power at nominal voltage, and there is no fault anywhere), the status feedback is given by a "light on" at the optical link. A malfunction is signaled by a "light off".

Each edge of the control signal is acknowledged by the driver with a short pulse (the light is off for a period of $t_{(ack)}$). Because this can be observed by the host controller, this method allows simple and continuous

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monitoring of all drivers and fiber-optic links of the system. Fig. 11 shows the control and response signals of a gate driver in normal operation.

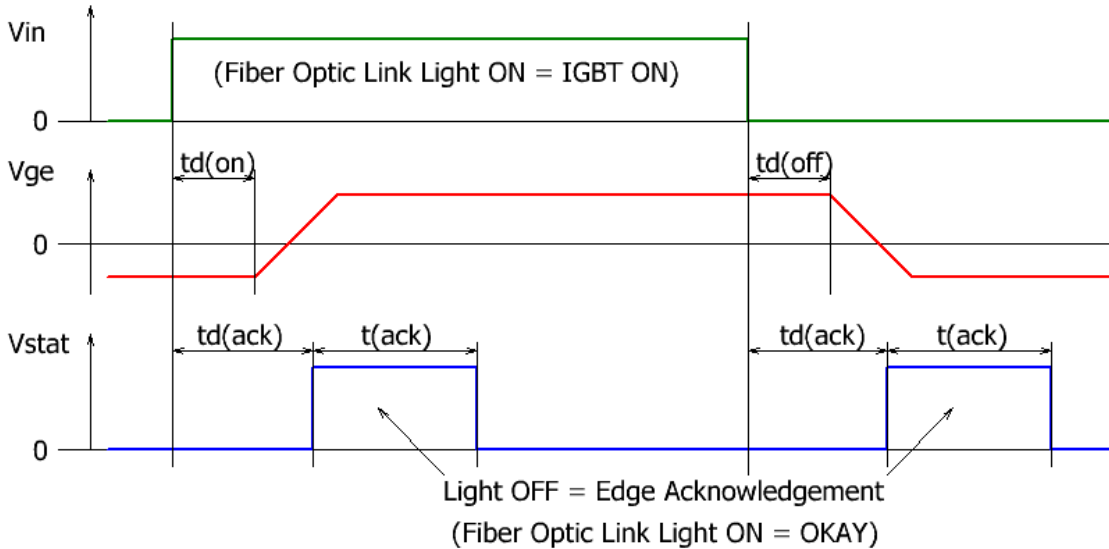


Fig. 11 Driver behavior and status feedback in normal operation

Fig. 12 shows the response of the driver in the event of a short-circuit fault. The fault status is transferred to the status feedback terminal after the response time. The light is then driven "off" during the delay to clear the fault state ($t_{(block)}$). The driver shuts the IGBT off with a delay of $t_{(cshd)}$ after the response time. Refer to /3/ for timing information. The IGBT can be turned on again by applying a positive edge to the corresponding fiber-optic input after the fault status has disappeared.

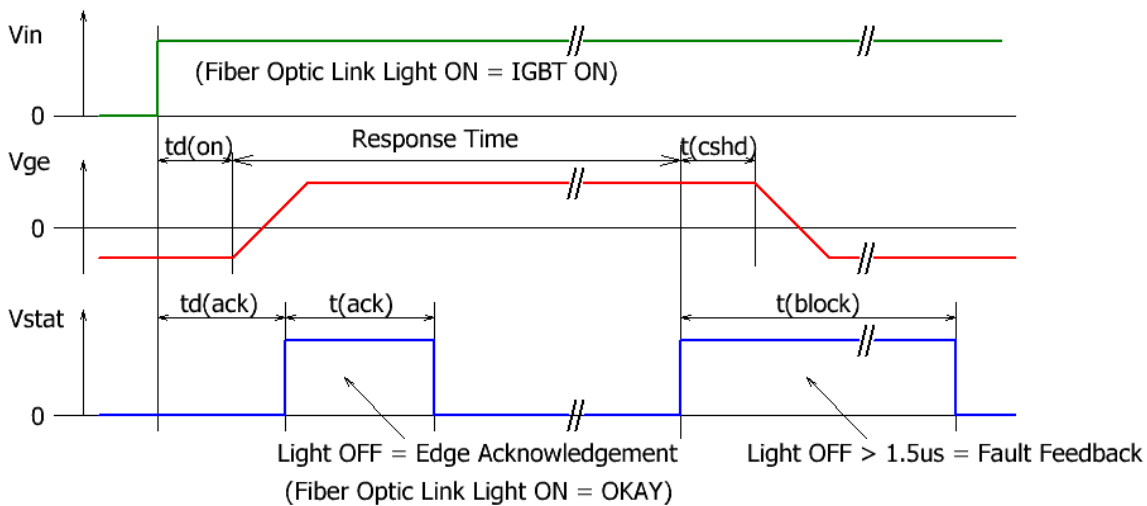


Fig. 12 Driver behavior and status feedback in the short-circuit condition

In the event of a gate monitoring fault, the fault status is transferred to the status feedback terminal after the filter delay (refer to the relevant data sheet /3/ for timing information) and remains active as long as the gate-monitoring fault is present.

If the driver goes from the "off state" to the "on state", and the gate-emitter voltage of one or more parallel connected drivers does not turn on, the driver response (V_{ge2} does not switch) is shown in Fig. 13. The fault status is transferred to the status feedback terminal after the filter delay. The driver shuts the IGBT off with a delay of $t_{(cshd)}$ after the filter delay, and thus clears the fault condition. The light is driven "off" during the time $t_{(block)}$.

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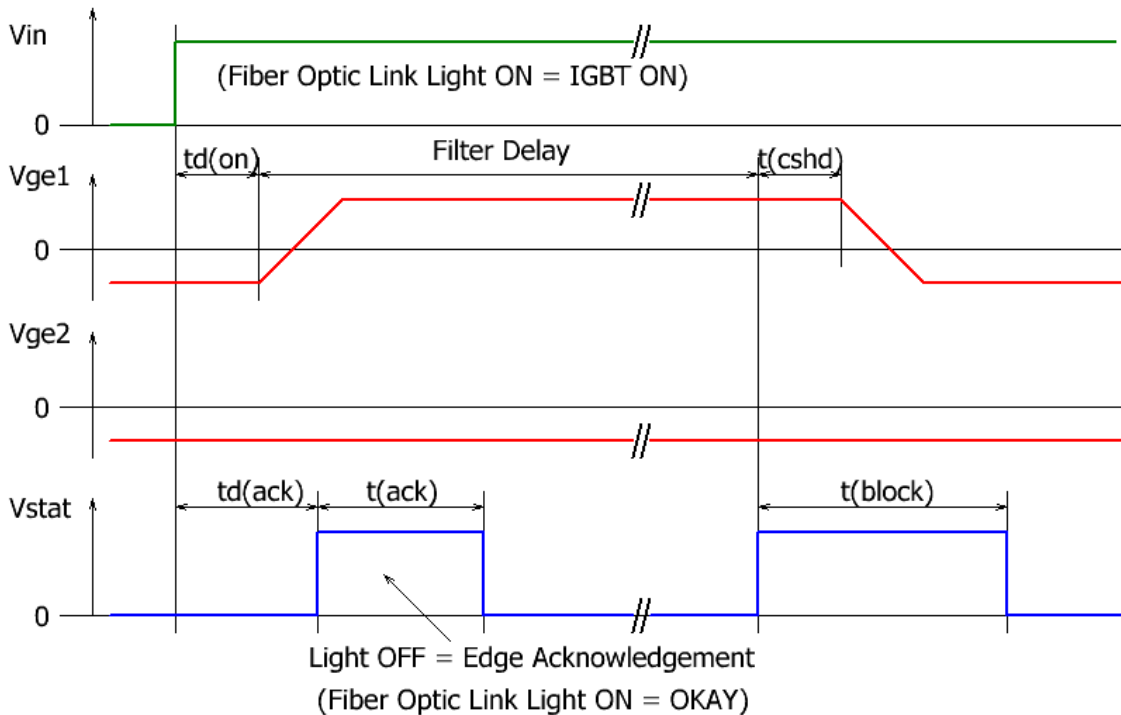


Fig. 13 Driver behavior and status feedback in the event of a gate-monitoring fault at turn-on

If the driver goes from the "on state" to the "off state", and the gate-emitter voltage of one or more parallel connected drivers does not turn off, the fault is applied to the status feedback terminal as long as it is present.

In case of a secondary supply undervoltage fault on the master driver, the fault status remains active and the driver is locked as long as this undervoltage remains. The driver response in the event of a supply undervoltage on Viso-Vee is shown in Fig. 14.

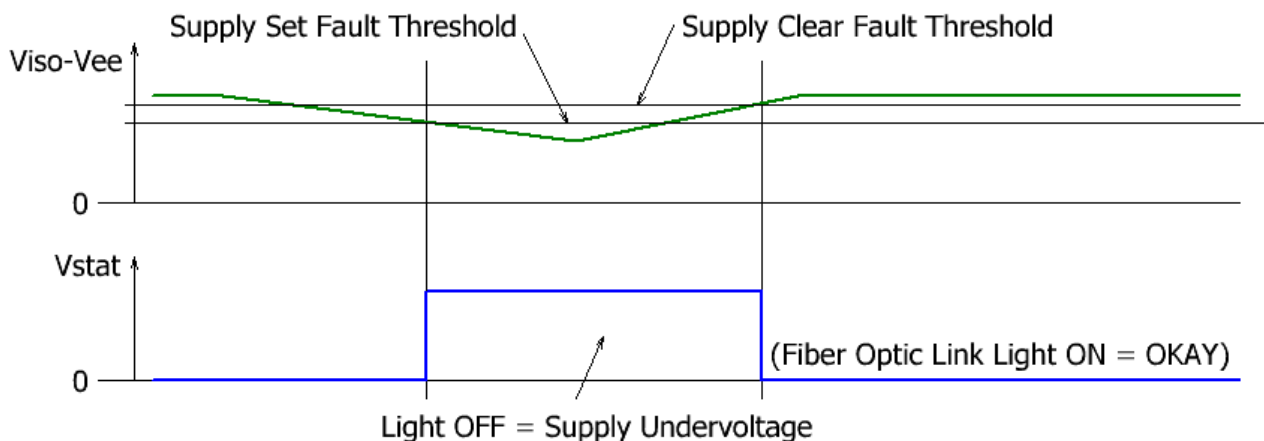


Fig. 14 Status feedback in the event of a supply undervoltage of the master driver

N.B. During power up, the status feedback will also show a fault condition until the supply undervoltage disappears.

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Recommended Interface Circuitry for Fiber Optics (1SP0340V)

The recommended circuitry for the fiber-optic links is given in Fig. 15.

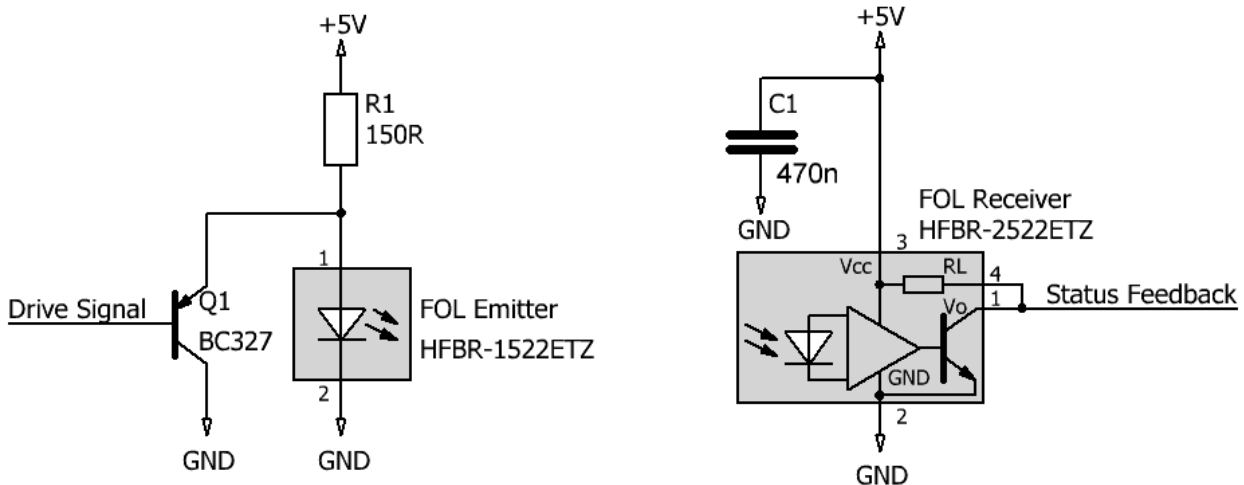


Fig. 15 Recommended circuitry for the "versatile" fiber-optic links (1SP0340V)

Description of Paralleling Interfaces X2 and X3

The paralleling interfaces X2 and X3 are available on the 1SP0340V (master) as well as on the 1SP0340D (slave). They allow the following to be connected:

- A master to one or two slaves.
- A slave to the master or to another slave.

Both connectors X2 and X3 are connected in parallel. The following signals are available on this interface:

- Supply voltage from the master to the slaves.
- Drive signal from the master to the slaves. The drivers are configured so that all paralleled IGBT modules switch on and off synchronously.
- Gate-monitoring signal from the slaves to the master.

For recommended cables, please read the paragraph "Recommended Cables and PCB Connectors" on Page 9.

The immunity of the paralleling interface against a high rate of change of magnetic fields (inductive coupling) and electrical fields (capacitive coupling) has been extensively tested in the laboratory. Even in harsh field environments it was not possible to disturb the driver function using the recommended paralleling cables. It is however recommended to place the paralleling cables in locations with low magnetic and electrical field coupling. Note that the immunity against inductive coupling can be increased by using a flat ribbon cable with twisted cable pairs and/or by shielding the cables.

Please note that the paralleling cables carry high potential. The voltage rating of the recommended cables is only 300V. They must therefore be isolated in an adequate way.

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LED-Status Indicators

To facilitate verification, master and slave drivers are each equipped with a green status LED. These are located close to the power-supply connector X1 and light up under normal operation. A turned-off LED means that the respective driver is not supplied with voltage, the supply voltage is too low (master and slave) or that the gate monitoring function has detected a fault condition (master). Moreover, in case of IGBT short-circuit, the LED on the master is switched off during the delay to clear the fault state (refer to data sheet /3/ for timing information).

How Do 1SP0340V SCALE-2 Drivers Work in Detail (Master)?

Overview

The 1SP0340V series of plug-and-play single-channel drivers is designed for high-power and high-voltage IGBT modules. 1SP0340V SCALE-2 drivers are equipped with the usual protection functions such as dynamic V_{CE} monitoring for short-circuit protection, supply-undervoltage shutdown and status feedback. A gate monitoring function is also implemented on 1SP0340V drivers. Moreover a paralleling interface allows the parallel connection up to four IGBT modules using 1SP0340D slave drivers (Fig. 4).

Outstanding features of 1SP0340V SCALE-2 drivers are: compact size, simple mounting - directly onto the IGBT module, the Dynamic Advanced Active Clamping function DA²C and a very low propagation delay time. Active clamping describes an active scheme designed to protect the IGBTs against overvoltage during turn-off. It is particularly relevant when turning an IGBT off in cases of high DC-link voltage and collector current or short circuit.

Power supply and electrical isolation

In contrast to the other SCALE-2 plug-and-play drivers, the drivers of the 1SP0340 family are modular in the sense that the driver card and power supply (DC/DC converter) are two separate units.

Thanks to this modular concept, any driver unit that was developed to match a specific IGBT module can be used for any required insulation specifications. Only the separate power supply unit must be chosen or adjusted to a specific application. On the basis of this concept, the drivers for IGBTs in the voltage class of 4.5kV can be implemented in 2-level, 3-level and multi-level inverter topologies.

The power supply unit is designed as a separate module attached close to the IGBT (Fig. 1). The DC/DC converter needs a stabilized +15V supply voltage. An automatic-reset thermal fuse protects the power supply, wiring and driver PCB in case of incorrect polarity or IGBT and driver defects.

Separate data sheets /5/ are available on the corresponding DC/DC converters.

Please note that the supply cable carry high potential. The voltage rating of the recommended cables is only 300V. They must therefore be isolated in an adequate way.

Clearance and creepage distances on the drivers are designed according to IEC 60077-1.

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Power-supply monitoring

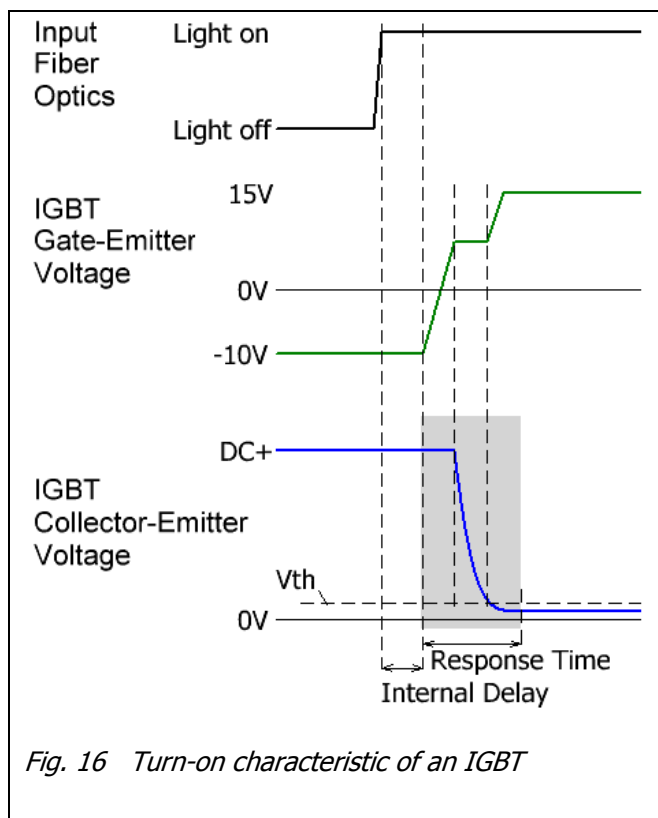
The driver is equipped with a local undervoltage monitoring circuit.

In case of supply undervoltage, the IGBT (as well as all paralleled IGBTs if parallel-connected IGBTs are used) 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 fiber-optic status feedback.

Even in the case of a low power supply voltage, the driver provides a low-impedance path from the IGBT gate to the emitter.

Within a half-bridge, it is advised not to operate the IGBTs with an IGBT driver in the event of a low supply voltage. Otherwise, a high rate of increase of V_{CE} may cause partial turn-on of these IGBTs.

V_{CE} monitoring / short-circuit protection



A dynamic V_{CE} monitoring circuit is implemented in 1SP0340V gate drivers. The IGBT collector-emitter voltage is measured with a resistor network.

V_{CE} is checked after the response time (Fig. 16) at turn-on to detect a short circuit. If this voltage is higher than the programmed threshold V_{th} , the driver detects a short circuit at the IGBT and signals it immediately to the fiber-optic status feedback. After an additional delay, the corresponding IGBT is switched off. The fault feedback is automatically reset after the delay to clear the fault state. The IGBT is turned on again as soon as the next positive edge is applied to the fiber-optic input after the fault status has disappeared.

The dynamic V_{CE} monitoring circuit allows the V_{CE} curve form to be given a better fit.

It should be noted that the response time is dependent on the DC-link voltage. It remains constant between about 50% to 100% of the maximum DC-link voltage and increases at lower DC-link voltages. Please read the relevant driver data sheet for timing information /3/.

Note: The desaturation function is for short-circuit detection only and cannot provide overcurrent protection. However, overcurrent detection has a lower time priority and can be easily provided by the application.

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Gate monitoring

The driver is equipped with a gate monitoring function. The average value $V_{GE,mean}$ of all gate voltages (master and all slaves) is filtered and compared to reference values at turn-on and turn-off (refer to the corresponding data sheet for the values /3/). If the specified values are not met ($V_{GE,mean} < V_{GE,on,min}$ at turn-on resp. $V_{GE,mean} > V_{GE,off,max}$ at turn-off), the driver turns off all parallel-connected IGBTs and a fault is transmitted to the status output.

The gate monitoring function allows converter operation to be avoided if one or more paralleled drivers are not switching according to the reference value (drive signal input).

Note that the gate monitoring function does not apply to slaves not connected to the master over the paralleling interface (missing paralleling cable). In this case, the corresponding slave will not switch, but no gate monitoring fault will be generated.

How Do 1SP0340D Drivers Work in Detail (Slaves)?

Overview

The 1SP0340D series of plug-and-play single-channel drivers (slaves) are designed for high-power and high-voltage IGBT modules. They can only be used in conjunction with 1SP0340V SCALE-2 drivers (masters) when parallel connection of IGBT modules is required. A paralleling interface allows connection of the 1SP0340D slaves with the 1SP0340V master driver (Fig. 3).

The drivers are equipped with protection functions such as supply undervoltage shutdown and the gate monitoring function. No V_{CE} monitoring is implemented on 1SP0340D drivers, as this function is already realized on the master driver.

Outstanding features of 1SP0340D drivers are: compact size, simple mounting - directly onto the IGBT module, the dynamic advanced active-clamping function DA²C and a very low propagation delay time. The slave drivers are fully synchronized with the master driver thanks to the paralleling interface. Moreover they do not need a separate power supply as this is delivered via the paralleling interface.

Power supply and electrical isolation

The power supply of 1SP0340D is delivered from the master driver via the paralleling interfaces X2 or X3. The insulation is provided by the external DC/DC converter.

However, an insulation of $200V_{peak}$ is provided on the slave drivers. This allows dynamic voltage differences between parallel-connected drivers to be withstood in case the switching operation is not fully symmetrical.

The signal insulation is realized with a planar transformer.

Coreless common mode coils are placed in the supply conductors in order to limit the dynamic equalizing currents flowing from and to the master during not fully symmetrical switching operation. Please read the corresponding data sheet for allowed maximum values /3/. It is recommended to measure the resulting equalizing current flowing via the paralleling interface.

Note that the peak value as well as the RMS value of the equalizing current can be reduced by inserting a ferrite core via the paralleling cables if required.

Clearance and creepage distances are designed according to IEC 60077-1.

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Power-supply monitoring

The slave drivers are equipped with a local undervoltage monitoring circuit.

In case of a supply undervoltage, the corresponding IGBT is driven immediately with a negative gate voltage to keep it in the off-state (the channel is blocked). Only the corresponding IGBT is switched off immediately, and not all paralleled IGBTs. However, all other parallel-connected IGBTs will be turned off by the gate monitoring function implemented on all drivers after the given delay (refer to corresponding data sheet /3/ for timing information).

In the event of a supply voltage interruption, it cannot be predicted which driver (master or slaves) will detect the supply undervoltage first. In order to avoid asynchronous turn-off of parallel connected IGBT modules in case of a local undervoltage supply voltage detection of a slave driver, the user is advised to implement an additional supply voltage monitoring on the primary supply voltage of the DC/DC converter (ISO5125I). It is recommended to set the threshold limit at 13V. As soon as the main supply voltage of the DC/DC converter falls below this limit, the master driver must be turned off. All parallel-connected IGBT modules will then be switched off synchronously.

Even in the case of a low power supply voltage, the driver provides a low-impedance path from the IGBT gate to the emitter.

Within a half-bridge, it is advised not to operate the IGBTs with an IGBT driver in the event of a low supply voltage. Otherwise, a high rate of increase of V_{CE} may cause partial turn-on of these IGBTs.

V_{CE} monitoring / short-circuit protection

No V_{CE} monitoring circuit is implemented on the slave drivers, as this function is already realized on the master driver.

Gate monitoring

Refer to the paragraph "Gate monitoring" on page 17.

General Considerations using 1SP0340V/1SP0340D

Parallel connection of IGBT modules using 1SP0340 drivers

When using 1SP0340 drivers to drive parallel connected IGBT modules, it is important – like in every parallel connection of IGBT modules – to ensure their symmetrical operation. Measurements in half-bridge topologies have shown that highly symmetrical operation of the paralleled IGBT modules can be reached when using a properly designed converter. The following points must especially be considered:

- The converter should be constructed as symmetrically as possible with respect to the paralleled IGBT modules in order to ensure symmetrical operation. The DC-link stray inductance of each paralleled IGBT module in particular should be similar ($L_{s1x} \approx L_{s2x}$, $L_{s5} \approx L_{s6}$ in Fig. 17).
- It is important – except for the load terminals (L_{s5} and L_{s6}) – to have a low-inductance connection between all paralleled IGBT modules. This avoids large voltage differences between these modules.
- Generally speaking, it is advantageous to keep the DC-link stray inductance of the converter low.

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- Increasing the output inductances Ls5 and Ls6 helps to reduce the dynamic current imbalance during commutation.
- Some power semiconductor manufacturers offer selected IGBT modules for parallel connection. If available, it is strongly recommended to use selected IGBT modules in order to avoid current imbalances during operation.

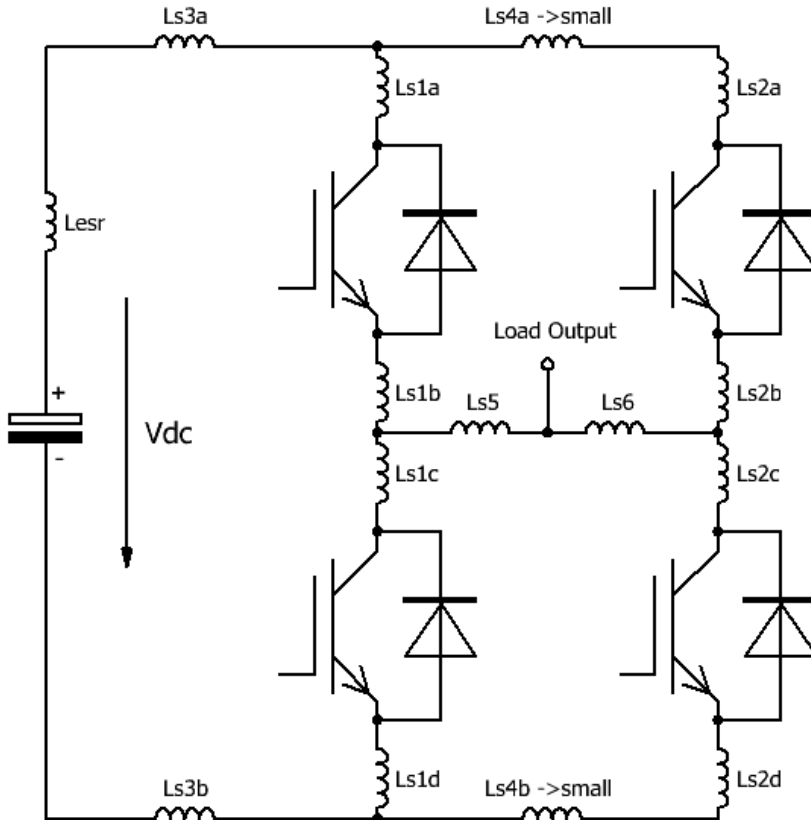


Fig. 17 Half-bridge topology with stray inductances

Fig. 18 shows an exemplary turn-off and turn-on transition (collector voltages and currents) of two 900A/4500V IGBT modules controlled with 1SP0340 drivers.

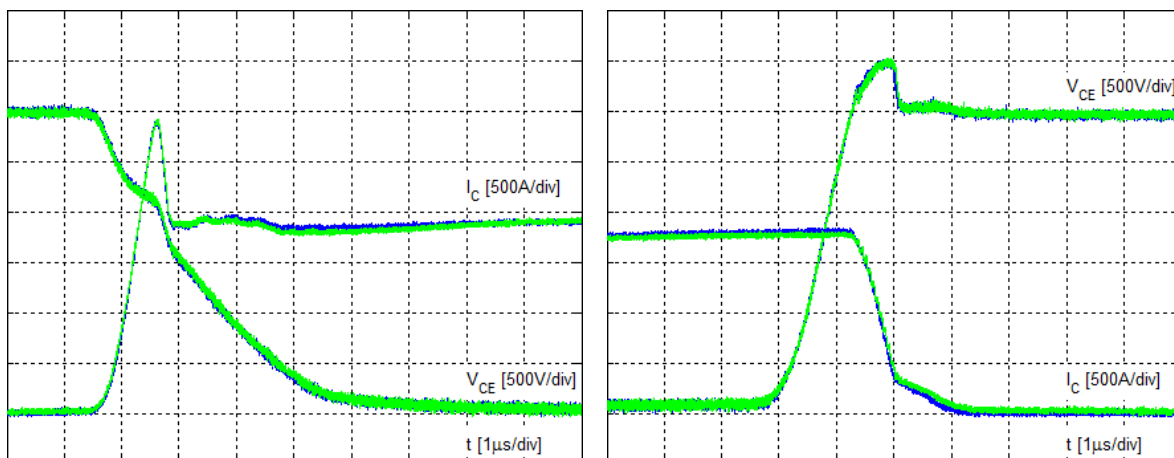


Fig. 18 Turn-on (left) and turn-off (right) behavior of two 900A/4500V IGBT modules in parallel connection at a DC-link voltage of 3000V and a collector current of 1800A each

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Dynamic behavior of IGBTs

The dynamic behavior of IGBT modules depends on their type and manufacturer due to the specific behavior of the included IGBT and diode chips, the particular module construction and the distribution of the internal gate resistances and inductances. Note that different module types from the same manufacturer may also require a specific gate-driver adaptation.

Power Integrations therefore supplies specific versions of SCALE-2 plug-and-play drivers adapted to the particular IGBT module. These drivers must not be used with IGBT modules other than those for which they were specified.

Turn-on of the IGBT / commutation of diode current

When a driver input goes high (light on), the gate driver turns on the corresponding IGBT. The driver already includes the gate resistors, which are matched to the relevant IGBT module.

The driver is optimized to achieve minimum switching losses for the case of relatively low inductances within the power stack. It is recommended to check the commutation behavior within the final system assembly.

Turn-off of the IGBT

The IGBT is turned off when the corresponding input turns low (light off). The gate resistors are determined by Power Integrations and must not be altered.

Fast turn-off of the IGBT may cause overvoltage, which increases with DC-link voltage or load current. The turn-off overvoltage can be approximated by:

$$V_{tr} = -L_s * di_c/dt$$

where V_{tr} is the turn-off overvoltage, i_c the collector current and L_s the stray inductance.

Overvoltage limitation at turn-off is essential for high-power or high-voltage IGBTs. To solve this problem, SCALE-2 plug-and-play drivers provide a Dynamic Advanced Active Clamping function DA²C which is described below.

Dynamic Advanced Active Clamping DA²C

Active clamping is a technique designed to partially turn on the IGBT in case the collector-emitter voltage exceeds a predefined threshold. The IGBT is then kept in linear operation. The basic circuit for active clamping can be found in /4/.

Basic active-clamping topologies implement a single feedback path from the IGBT's collector through transient voltage suppressor devices (TVS) to the IGBT gate. 1SP0340 SCALE-2 drivers support Power Integrations' Dynamic Advanced Active Clamping (DA²C) based on this principle:

- When active clamping is activated, the turn-off MOSFET of the driver is switched off in order to improve the effectiveness of the active clamping and to reduce the losses in the TVS. This feature – called Advanced Active Clamping – is mainly integrated in the secondary-side ASIC.
 - Additional transient voltage suppressors (TVS) have been added in series to the TVS required to withstand the maximum DC-link voltage under switching operation. These TVS are short-circuited during the IGBT on state as well as during about 15-20us after the turn-off command to guarantee efficient active clamping. After this delay, these additional TVS are activated and allow the DC-link voltage to be increased to a higher value during the IGBT off-state (e.g. after emergency shut-down). This feature – together with Advanced Active Clamping – is called Dynamic Advanced Active Clamping
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DA²C. Note that the time during which the voltage can be applied above the value for switching operation should be limited to short periods (< 60 seconds).

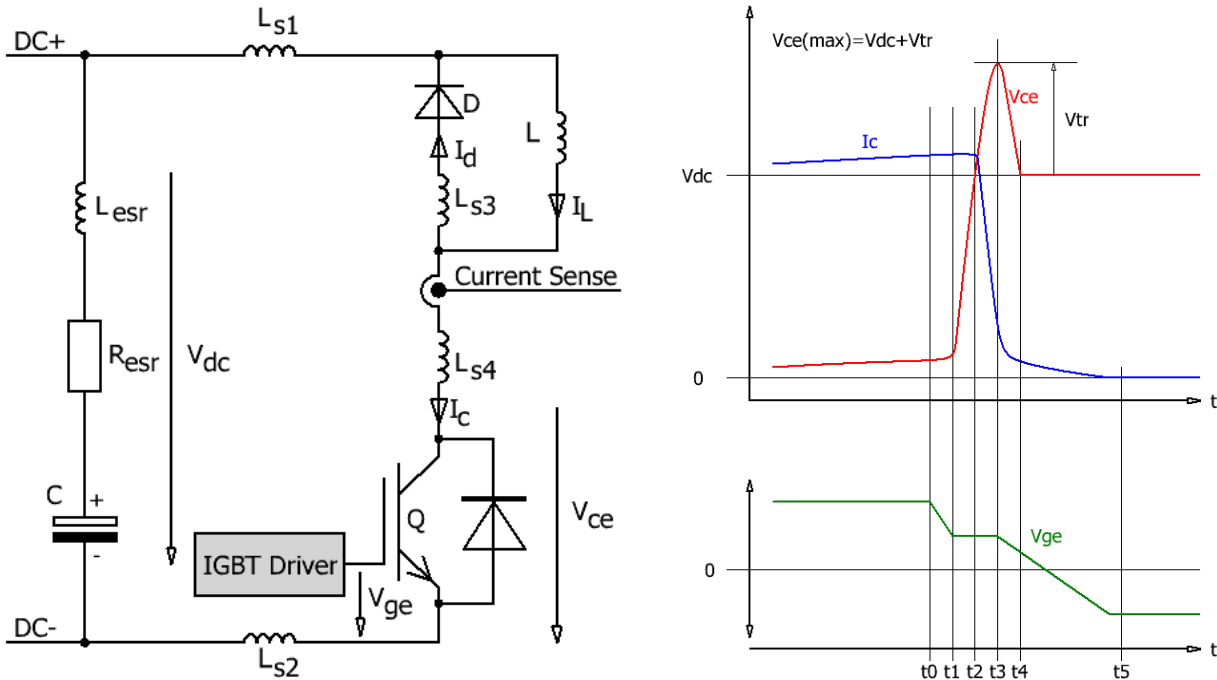


Fig. 19 Test circuit (left) and typical switching behavior (right)

Legend to Fig. 19

- t0 = Initiation of the turn-off process
- t1 = Start of turn-off time
- t2 = Start of collector current fall time
- t3 = Maximum collector to emitter voltage
- t4 = IGBT is blocking, start of tail current
- t5 = End of tail current

In comparison with other driving methods, active clamping allows enhanced utilization of the IGBT modules during normal operation by increasing the switching speed and therefore reducing switching losses. The overvoltage at turning off an overcurrent is also managed by active clamping.

The value of the maximum DC-link voltage under switching operation and in IGBT off state can be found in the specific data sheets for a given IGBT module /3/.

Fig. 20 shows an exemplary turn-off transition of a 1200A/4500V IGBT module controlled with a 1SP0340V driver.

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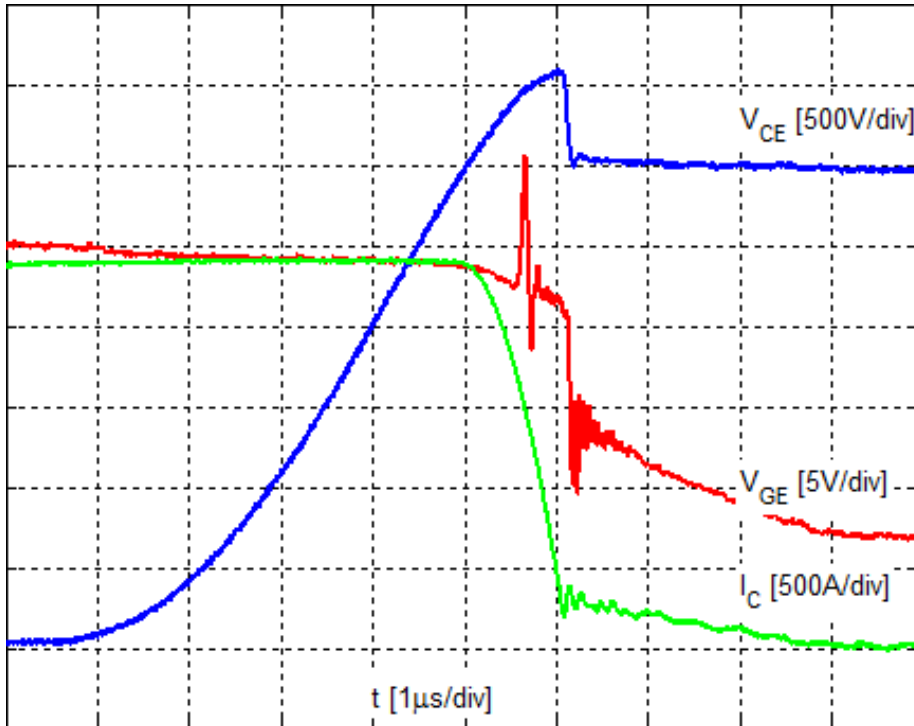


Fig. 20 Behavior of a 1200A/4500V IGBT module turning off at a DC-link voltage of 3000V a collector current of 2400A, which is twice the nominal collector current

Low-inductance layout

The active-clamping function should not lead anyone to forget about the inductances of the power stack. For several reasons, it is still necessary to reduce the DC-link stray inductance to about 50nH...200nH with 1SP0340 plug-and-play drivers.

3-level and multilevel topologies

If 1SP0340 drivers are to be used in 3-level or multilevel topologies, please refer to application note AN-0901 /6/.

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Higher requirements for traction applications or similar

The power-supply interface X1 as well as the paralleling interfaces X2 and X3 provide a mechanical interlock and are suitable for traction applications.

The vibration withstand capability of 1SP0340 SCALE-2 drivers can be improved by screw-fitting the driver board onto the cooler (Fig. 21). **However, it should be noted that these connections must be electrically insulated to comply with the particular clearance and creepage distance requirements (e.g. use of plastic distance bolts).**

Furthermore, an interlocking version of the fiber optic links is available (see Fig. 21).

Note that clearance and creepage distances are designed according to IEC 60077-1.

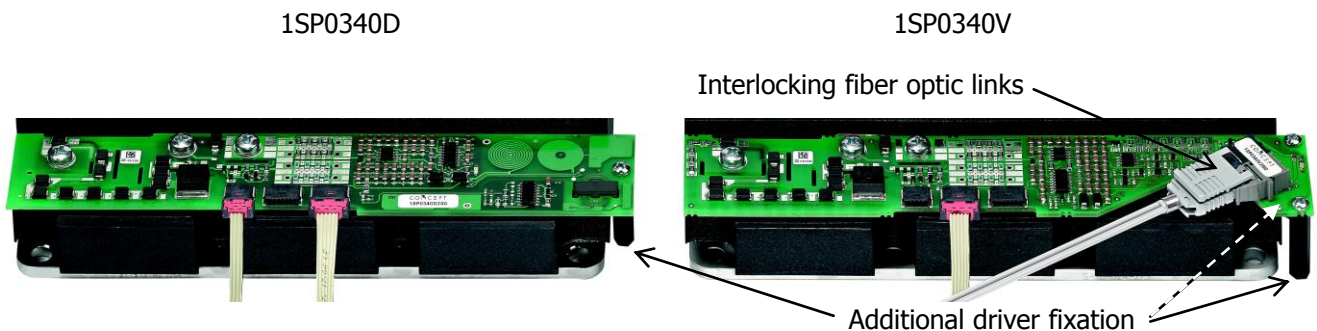


Fig. 21 Additional measures for fixing driver and power-supply cables as well as the relevant version of interlocking fiber-optic links for the 1SP0340V

References

- /1/ Paper: Smart Power Chip Tuning, Bodo's Power Systems, May 2007
- /2/ Description and Application Manual for SCALE™ Drivers, Power Integrations
- /3/ Data sheets of SCALE™-2 plug-and-play driver 1SP0340x2x0-xxx, Power Integrations
- /4/ Paper: Advantages of Advanced Active Clamping, Power Electronics Europe, Nov/Dec 2009
- /5/ Data Sheet: DC/DC converter ISO5125I-xx, Power Integrations
- /6/ Application Note AN-0901: Methodology for Controlling Multi-Level Converter Topologies with SCALE™-2 IGBT Drivers, Power Integrations

Note: The Application Notes are available on the Internet at www.power.com/igbt-driver/go/app-note and the papers at www.power.com/igbt-driver/go/papers.

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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.

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 Power Integrations or your Power Integrations' sales partners.

Power Integrations has more than 25 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

Power Integrations provides expert help with your questions and problems:

www.power.com/igbt-driver/go/support

Quality

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Ordering Information

The general terms and conditions of delivery of Power Integrations Switzerland GmbH apply.

See the current list on www.power.com/igbt-driver/go/1SP0340.

Refer to www.power.com/igbt-driver/go/nomenclature for information on driver nomenclature.

Information about Other Products

For drivers adapted to other high-voltage or high-power IGBT modules

Direct link: www.power.com/igbt-driver/go/Plug-and-Play

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

Please click onto: www.power.com/igbt-driver

Manufacturer

Power Integrations Switzerland GmbH
Johann-Renfer-Strasse 15
2504 Biel-Bienne, Switzerland

Phone +41 32 344 47 47
Fax +41 32 344 47 40
Email igbt-driver.sales@power.com
Website www.power.com/igbt-driver

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Version 1.0 from 2015-08-07

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Power Integrations Worldwide High Power Customer Support Locations**World Headquarters**

5245 Hellyer Avenue
San Jose, CA 95138 | USA
Main +1 408 414 9200
Customer Service:
Phone +1 408 414 9665
Fax +1 408 414 9765
Email usasales@power.com

Switzerland (Biel)

Johann-Renfer-Strasse 15
2504 Biel-Bienne | Switzerland
Phone +41 32 344 47 47
Fax +41 32 344 47 40
Email igbt-driver.sales@power.com

Germany (Ense)

HellwegForum 1
59469 Ense | Germany
Phone +49 2938 643 9990
Email igbt-driver.sales@power.com

Germany (Munich)

Lindwurmstrasse 114
80337 Munich | Germany
Phone +49 895 527 39110
Fax +49 895 527 39200
Email eurosales@power.com

China (Shanghai)

Rm 2410, Charity Plaza, No. 88
North Caoxi Road
Shanghai, PRC 200030
Phone +86 21 6354 6323
Fax +86 21 6354 6325
Email chinasales@power.com

China (Shenzhen)

17/F, Hivac Building, No 2,
Keji South 8th Road,
Nanshan District
Shenzhen | China, 518057
Phone +86 755 8672 8725
Fax +86 755 8672 8690
Hotline +86 400 0755 669
Email chinasales@power.com

Italy (Milano)

Via Milanese 20, 3rd. Fl.
20099 Sesto San Giovanni | Italy
Phone +39 024 550 8701
Fax +39 028 928 6009
Email eurosales@power.com

UK (Herts)

First Floor, Unit 15, Meadway Court,
Rutherford Close, Stevenage,
Herts SG1 2EF | United Kingdom
Phone +44 1252 730 141
Fax +44 1252 727 689
Email eurosales@power.com

India (Bangalore)

#1, 14th Main Road
Vasanthanagar
Bangalore 560052 | India
Phone +91 80 4113 8020
Fax +91 80 4113 8023
Email indiasales@power.com

Japan (Kanagawa)

Kosei Dai-3 Bldg., 2-12-11, Shin-
Yokohama, Kohoku-ku, Yokohama-shi,
Kanagawa 222-0033 | Japan
Phone +81 45 471 1021
Fax +81 45 471 3717
Email japansales@power.com

Korea (Seoul)

RM 602, 6FL
Korea City Air Terminal B/D, 159-6
Samsung-Dong, Kangnam-Gu
Seoul 135-728 | Korea
Phone +82 2 2016 6610
Fax +82 2 2016 6630
Email koreasales@power.com

Taiwan (Taipei)

5F, No. 318, Nei Hu Rd., Sec. 1
Nei Hu Dist.
Taipei 11493 | Taiwan R.O.C.
Phone +886 2 2659 4570
Fax +886 2 2659 4550
Email taiwansales@power.com