1FSS0560 Data Sheet

Abstract

The 1FSS0560 is suitable for 3300V/4500V common modules and crimped modules. The hardware configuration of 5W/60A makes it easy to support up to the maximum 3 large modules in parallel (f ≤ 2kHz, the specific frequency depends on the different module models), further expanding the capacity of the converter.

The 1FSS0560 is based on Firstack's leading digital technology, which has the advantages of good EMC characteristics and is suitable for harsh electromagnetic field environment. It has been widely used in various fields such as industrial inverter, rail and smart grid.

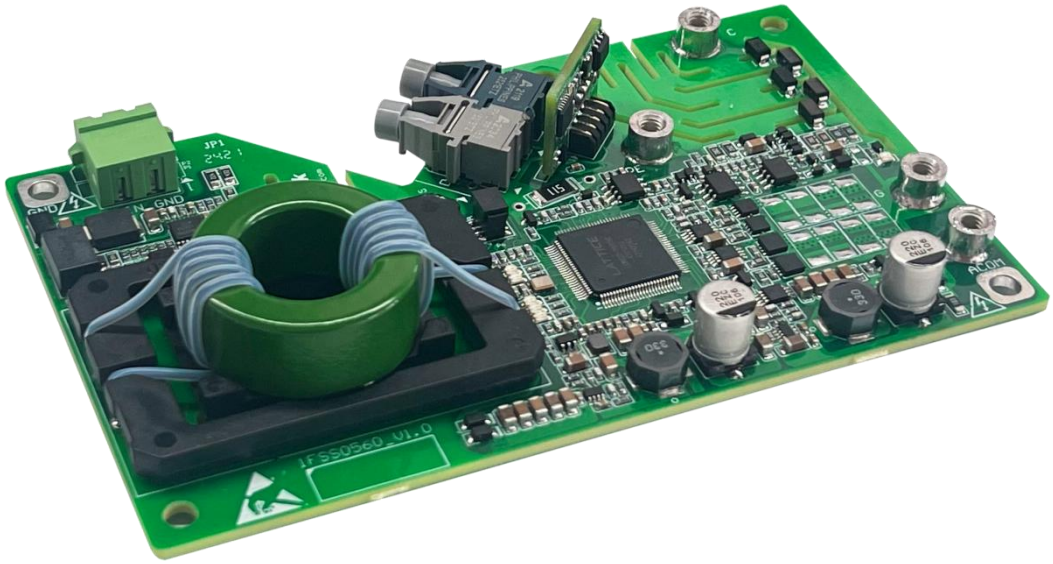


Fig.1 1FSS0560

Contents

System block diagram

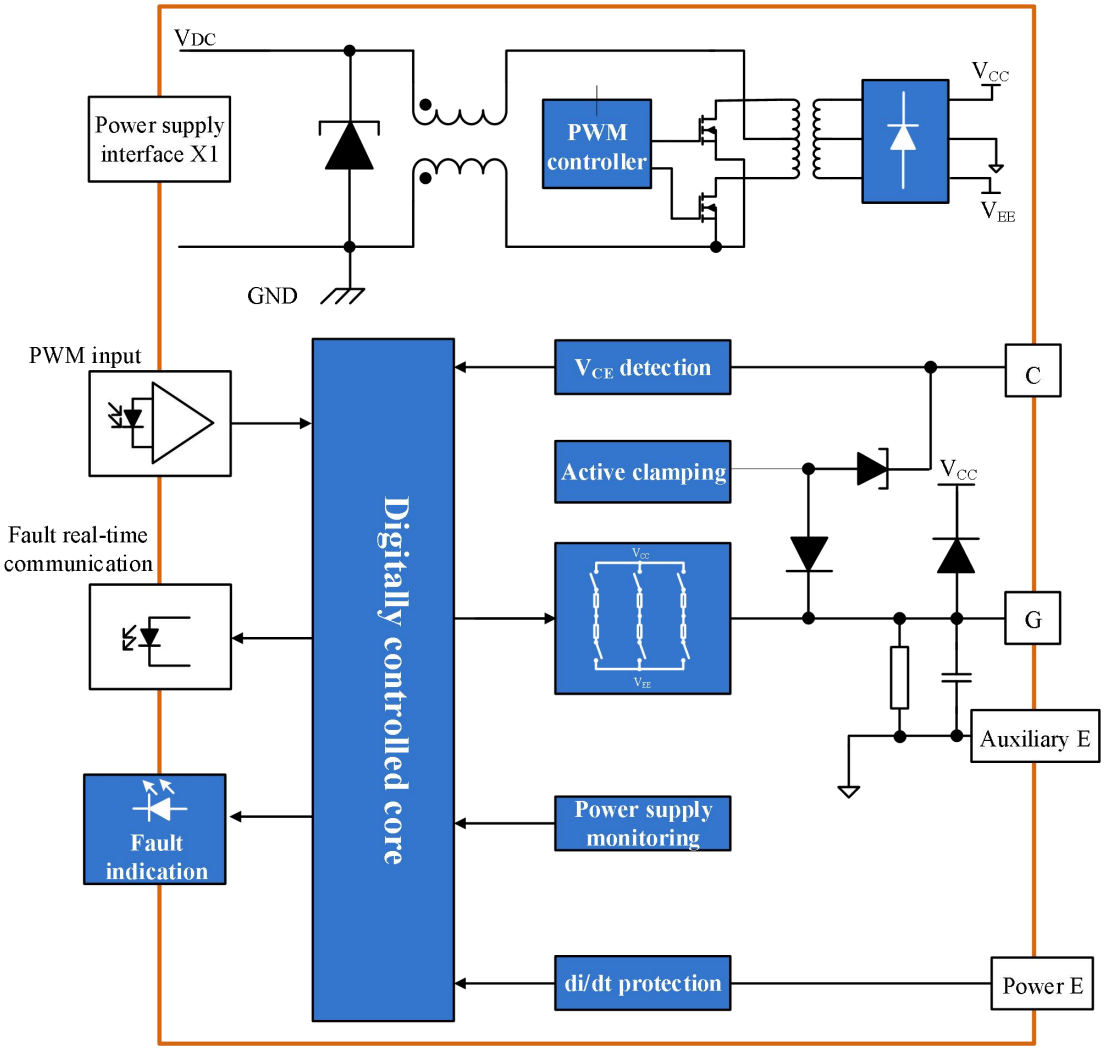


Fig.2 System block diagram

Use steps and safety notice

Simple use steps of the gate driver are as follows:

1. Choose suitable gate driver

When using the gate driver, pay attention to the part number of the IGBT module that the gate driver is adapted to. It is invalid for non-designated IGBT modules. Improper use may cause the gate driver and the module failure.

2. Install the gate driver on the IGBT module

Any treatment of IGBT modules or drivers should follow the general specifications for the protection of electrostatic sensitive devices required by the international standard IEC 60747-1, Chapter IX or IEC 60340-5-2 (that is, the workplace, tools, etc. must comply with these standards).

If these specifications are ignored, both the IGBT and the gate driver may be damaged.

3. Connect the gate driver to the control unit

Connect the gate driver connector (optical fiber) to the control unit and provide a suitable power supply voltage for the gate driver.

4. Check the function of the gate driver

Check the gate voltage: for the turn-off state, the rated gate voltage is given in the corresponding data sheet, for the turn-on state, the voltage is 15V. Please also check the input current of the gate driver with and without a control signal. For Firstack's digital gate driver, the gate driver status indicator TEST (green) remains on after the gate driver has been provided with a suitable supply voltage.

These tests should be performed before installation, because the gate terminal may not

be accessible after installation.

5. Set up and test the power unit

Before starting the system, it is recommended to check each IGBT module with a single pulse and double pulse test method separately.

Firstack specially reminds: even under the worst conditions, it is necessary to ensure that the IGBT module does not exceed the operating range specified by SOA.

Mechanical dimensions

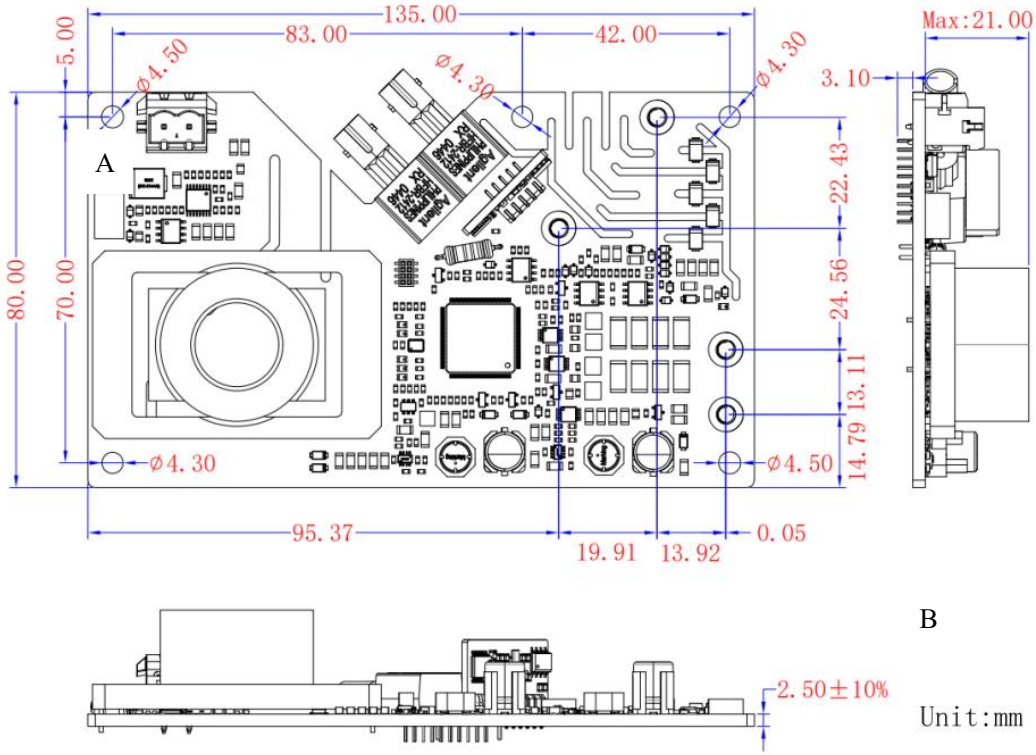


Fig.3 Mechanical dimensions of 1FSS0560

Note:

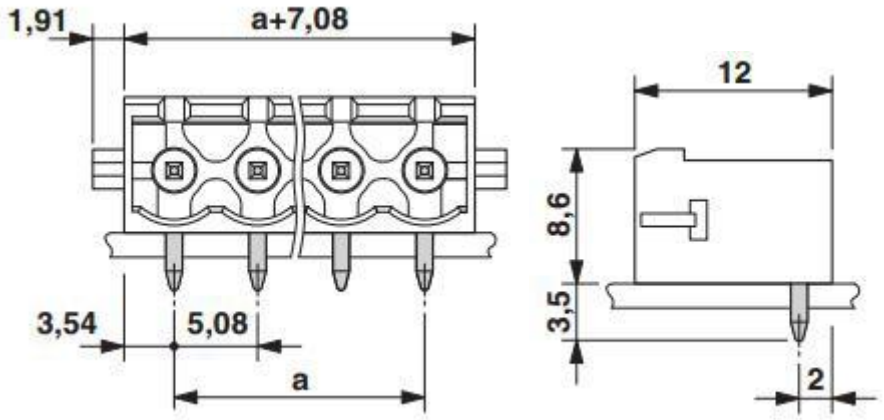
1. The thickness tolerance of the board is ±10%;

2. Other dimensional tolerances refer to GB/T1804-m;

3. In the figure above, the positioning hole A is electrically connected to the ground of primary side input power supply.

The positioning hole B is electrically connected to E of the secondary side power supply.

The rest of the positioning holes are not electrically connected.



Unit:mm

Fig.4 Connector size diagram

Connector Manufacturer and Part Number

Number	Label	Manufacturer	Part Number	Recommended Matching Terminals
1	P1	Phoenix	MSTBA 2,5/ 2-G-5,08-RN - 1926015	FKC 2,5/ 2-ST-5,08-RF - 1925692
2	P3, P5, P7, P8	WE		M4 screws made of 304 stainless steel Torque: 1.2Nm

Note: 15V power supply voltage

Pin functional description

P1 pin definition:

Pin	Pin Name	Pin Description	Pin	Pin Name	Pin Description
1	GND	Ground of Input Power Supply	2	VIN	15V Input

Optical fiber type

Label	Interface	Note	Label	Interface	Note
U1	PWM	HFBR2521Z	U3	FAULT	HFBR1521Z

LED status indicator

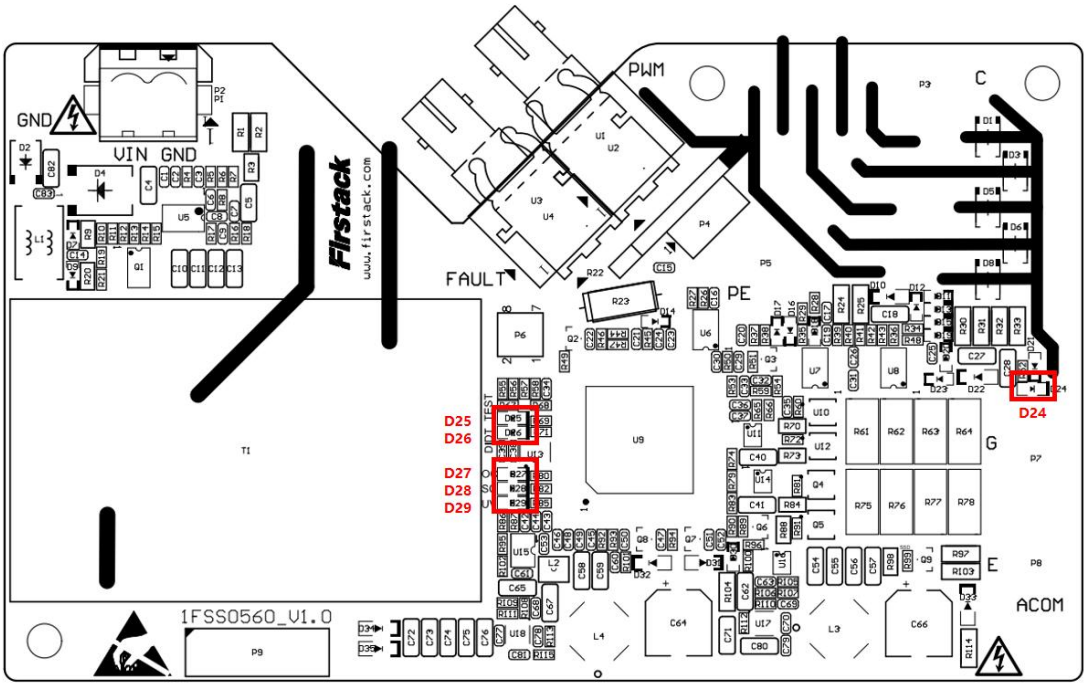


Fig.5 LED status indicator

For the convenience of customers, several LED status indicators are added on the Firstack driver board to facilitate customers to know the operating status of the driver board and converter. The specific explanation is as follows:

LED Status Indicator

Number	Label	Interface	Note
1	D25	TEST	Light up when the power supply is normal and there is no fault, otherwise off
2	D26	di/dt	Once triggered by a short-circuit, it is always on, unless restarted
3	D27	OC	Once triggered by a short-circuit, it is always on, unless restarted
4	D28	SC	Once triggered by overcurrent, it is always on, unless restarted
5	D29	UV	Once triggered by undervoltage, it is always on, unless restarted
6	D24	GE	Once triggered by over-temperature, it is always on, unless restarted

Driving parameters

Absolute Maximum Ratings

Parameter	Note	Min	Max	Unit
V_{DC}	GND	14	28	V
Gate peak current			60	A
Output power	$T_A \leq 85℃$		5	W
Test voltage (50Hz/1min)	Primary to secondary side	10500		V_{RMS}
Operating temperature		-40	+85	℃
Storage temperature		-40	+85	℃

Recommended Operating Condition

Parameter	Note	Min	Typ	Max	Unit
V_{DC}	15V input	14.5	15	15.5	V

Electrical Characteristics

Power Supply	Note	Min	Typ	Max	Unit
Power supply current	Without load, Note 1		0.15		A
Power Supply Monitoring					
Positive undervoltage threshold			13		V
Negative undervoltage threshold			-7		V
Short-circuit Protection					
di/dt short-circuit protection response time	Note 2		3.5		μs
Blocking time			90		ms

Timing Characteristics			
Turn-on delay	Note 3	840	ns
Turn-off delay	Note 4	700	ns
Rise time	Note 5	15	ns
Fall time	Note 6	15	ns
Fault hold time		32	μs
Output Characteristics			
Gate turn-on voltage		15	V
Gate turn-off voltage		-10	V
Gate Static impedance		10	kΩ
Electrical Isolation			
Creepage distance	Primary to secondary side	45	mm
	C- secondary side		mm
Clearance distance	Primary to secondary side	42	mm
	C- secondary side		mm

Unless otherwise specified, all data are based on +25℃ and V_{DC}=15V.

Note:

1. **Power Supply Current: no PWM input, but IGBT module is connected;**
2. **Response Time: the time from the occurrence of the fault to the start of soft shut down;**
3. **Turn-on Delay: the time required to transmit the rising edge of the PWM signal input from the primary side to the rising edge of the secondary side of the gate driver when the IGBT is not connected;**
4. **Turn-off Delay: the time required to transmit the falling edge of the PWM signal input from the primary side to the falling edge of the secondary side of the gate driver when the IGBT is not connected;**
5. **Rise Time: the amount of time from 10% of the gate turn-off voltage(-10V) to 90% of**

the gate turn-on voltage(+15V) when the IGBT is not connected;

6. Fall Time: the amount of time from 90% of the gate turn-on voltage(+15V) to 10% of the gate turn-off voltage(-10V) when the IGBT is not connected.

Functional description

◆ Short-circuit protection—di/dt

The driving circuit has di/dt protection function. The di/dt protection is based on voltage measurement of power emitter (PE) and auxiliary emitter (AE). The voltage V_{PA} between the auxiliary emitter and the power emitter is proportional to the rate of change di/dt of the collector current Ic.

When operates normally, di/dt is usually tens of amperes per microsecond, but when IGBT has a short-circuit fault, di/dt will reach thousands of amperes per microsecond, with a difference of hundreds of times. Because di/dt protection directly monitors the change rate of current, it does not need a blank time like VCE monitoring, so di/dt response is faster.

According to different operation modes, in the 2-level mode, soft shut down will be started, and IGBT will be turned off slowly.

Compared with VCE-based short-circuit protection, di/dt protection has faster response, higher signal-to-noise ratio and obvious competitiveness in multi-level applications.

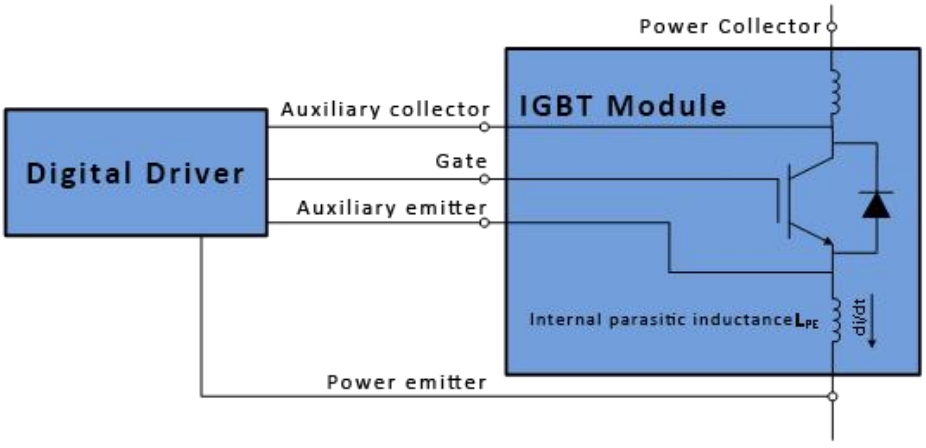


Fig.6 di/dt detection circuit

◆ Short-circuit protection—OC

The driving circuit judges whether the IGBT is in a short-circuit state by detecting the master computer voltage V_{CE} when the IGBT is turned on.

The V_{CE} voltage is detected by resistance division. When the V_{CE} voltage exceeds the set threshold, the gate driver determines that the IGBT is in a short-circuit state and returns the fault to the master computer.

According to different operating modes, in the 2-level mode, soft shut down will be started to turn off IGBT slowly; in the 3-level mode, the IGBT will be kept in the turn-on state, and the master computer will give the turn-off command.

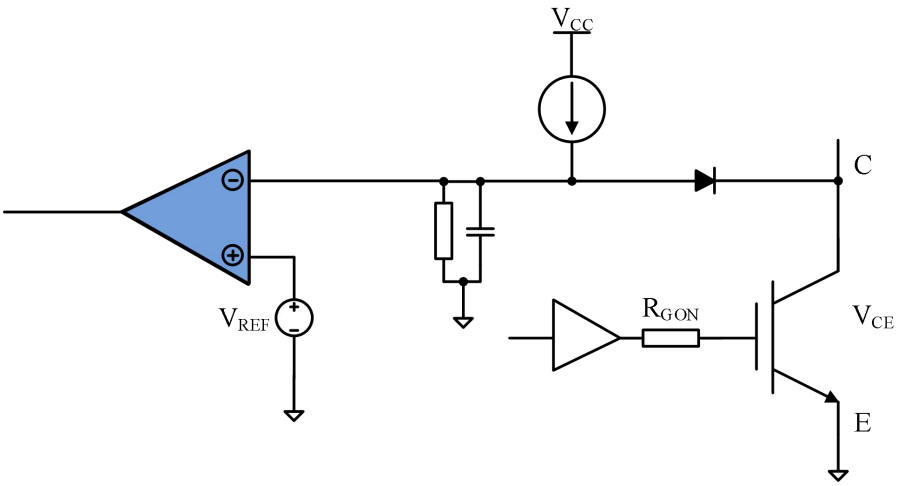


Fig.7 Short-circuit protection detection circuit

◆ Undervoltage protection

The driver board monitors the positive and negative power supply of the secondary side at the same time. When the absolute value of the positive or negative voltage of the secondary side is lower than the threshold voltage, the driving circuit determines that an undervoltage fault has occurred and will feed back a fault signal to the master computer.

Mode	State at the time of failure	Solution
2-level	On	Soft shut down
	Off	Keep off

3-level	On	Keep it open, and wait for the instructions from the master computer
	Off	Keep it down, and wait for the instructions from the master computer

Firstack intelligent gate driver strongly suggests that any IGBT in IGBT bridge arm should not operate undervoltage. Because of the existence of C_{GC}, when an IGBT in the bridge arm is turned on, its high dv/dt can be coupled to another IGBT through C_{GC}, which leads to the micro-conduction of the IGBT. At the same time, low gate voltage will increase the switching loss of IGBT.

◆ Soft shut down

When a direct short-circuit occurs, IGBT will quickly desaturate, and the voltage V_{CE} at both terminals will reach the DC bus voltage; while the current I_C flowing through IGBT will reach 4 times or more of the rated current (depending on IGBT type and gate voltage). At this time, the power consumed by IGBT will instantly reach megawatt level. If the short-circuit current cannot be reduced in a short time, the IGBT will be burned down due to overheating of the chip. However, if the turn-off speed during short-circuit is as fast as normal turn-off, a large di/dt will be generated. Due to the existence of parasitic inductance, this di/dt will bring a large voltage spike at both terminals of IGBT, which will cause IGBT overvoltage breakdown.

In order to suppress the turn-off spike in short-circuit, the Firstack intelligent driving circuit introduces soft shut down technology. In case of direct short-circuit of IGBT, on the premise of ensuring that the short-circuit time is under 10us, by slowly reducing the gate voltage V_{GE}, the IGBT chip will not be burned down due to overheating, and the di/dt will be effectively reduced, thus avoiding the voltage spike when the IGBT is turned off and ensuring the safety of IGBT.

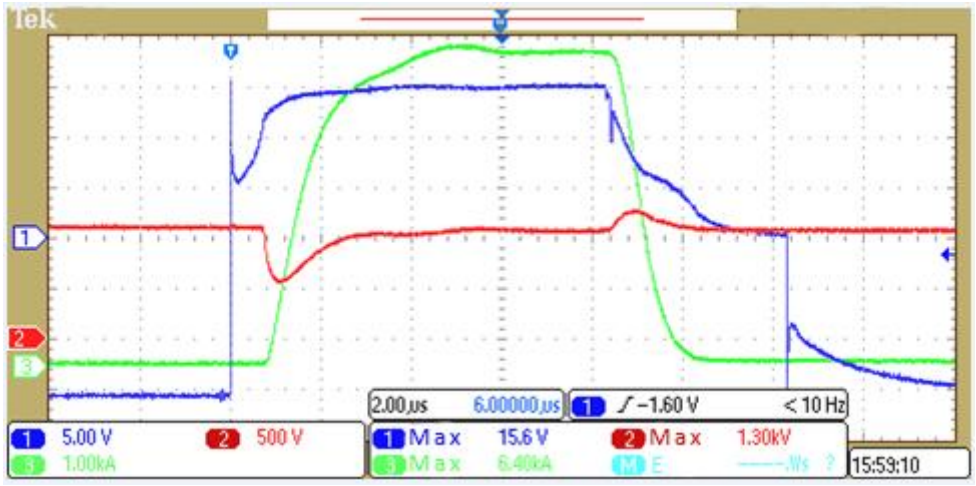


Fig.8 Short-circuit waveform of FF1400R17IP4 at 1100V

In the picture above, CH1: V_{GE}(blue); CH2: V_{CE}(red); CH3: I_C(green)

Fig.8 shows the short-circuit waveform of the 1700V/1400A IGBT(FF1400R17IP4) controlled by the Firstack IGBT driving circuit when the DC bus is 1100V. The peak value of short-circuit current is 6400A(4.5 times of rated current). Under the action of soft shut down, I_C drops slowly, V_{CE} has almost no overshoot, and the IGBT is safely turned off.

◆ Active clamping

When the system has a fault of overload or short-circuit on the load side, the turn-off current of the IGBT will increase significantly. Under these conditions, active clamping can protect the IGBT and avoid failures caused by turn-off overvoltage.

When the V_{CE} voltage exceeds the TVS threshold, the TVS is broken down and the current sinks into the gate, which makes the V_{GE} rise and the IGBT enters the linear region, thereby limiting the turn-off voltage within a safe range. **(TVS on the adapter board)**

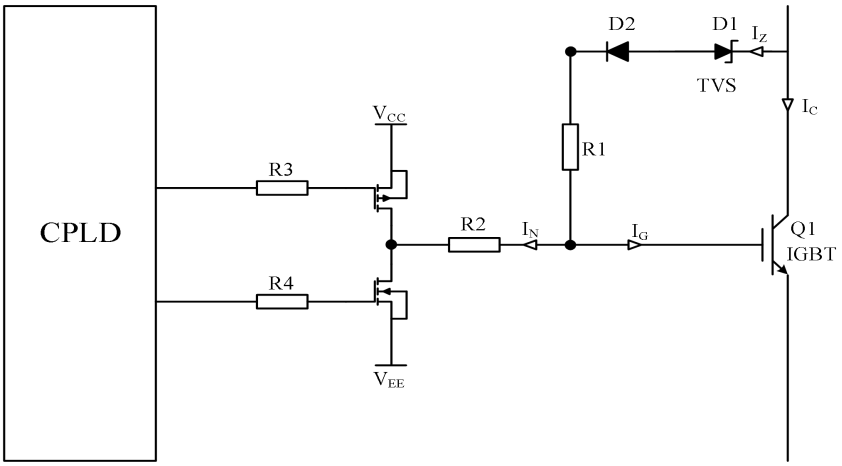


Fig.9 Schematic diagram of active clamping principle

◆ Impulse anomaly protection (reserved)

Optical fiber communication has the advantages of strong anti-interference ability and high insulation grade. At the same time, when using optical fiber, there are some problems, such as the fiber buckle is not firm, the turning radius of optical fiber line is not enough, which easily leads to light leakage, light attenuation and so on, and a large number of stray and high-frequency narrow pulses are generated at the receiving end of the optical fiber head. These narrow pulses will cause IGBT to turn on and off quickly, resulting in great loss, which is extremely harmful to high-voltage and high-power IGBT, and needs strict prevention.

The Firstack intelligent gate driver adopts two methods to guard against these abnormal pulses:

- Monitor the PWM pulse width in real time, but when the PWM pulse width is less than a certain preset value, the gate driver will filter out the narrow pulse and not report the fault;
- Monitor the frequency of PWM in real time, but after the time interval of several consecutive rising edges is shorter than a certain preset value, it is judged that there is an abnormal pulse and a fault is reported.

◆ Optical fiber port acknowledge signal

In the process of using optical fiber, there are some phenomena, such as the buckle of optical fiber mouth is not firm/falling off, and the turning radius of optical fiber line is not enough. In order to ensure the normal optical fiber communication, the Firstack intelligent gate driver is configured with the fiber port response function. It's compatible with two modes, as follows:

Mode 1: Compatible with Power Integrations fault protocol

1. When the driver board operates normally, every time a PWM command is received, the return-signal optical fiber head will turn off for 700ns at the rising edge and falling edge of the PWM command as a response to receiving the command.

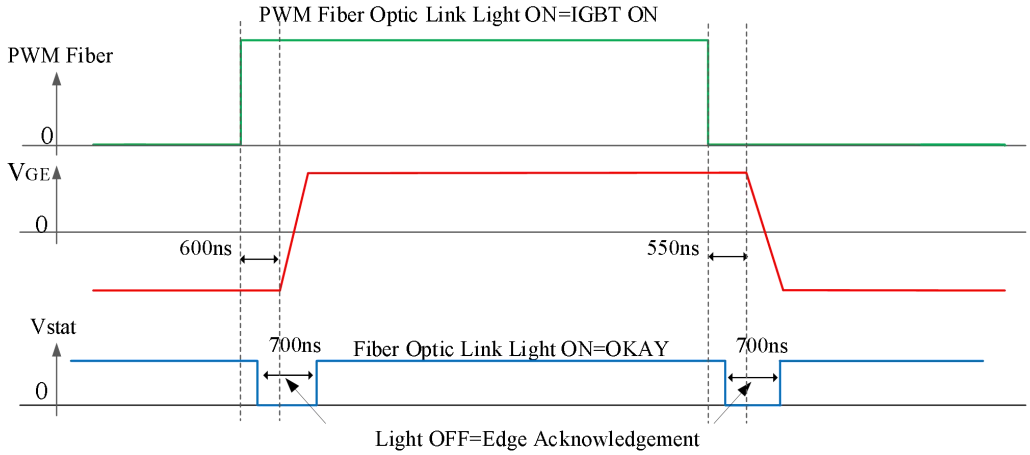


Fig.10a Normal condition in mode 1

2. When the fault is detected by the driver board, the return-signal optical fiber head will be extinguished for more than 30μs, which will be used as a fault signal to inform the master computer.

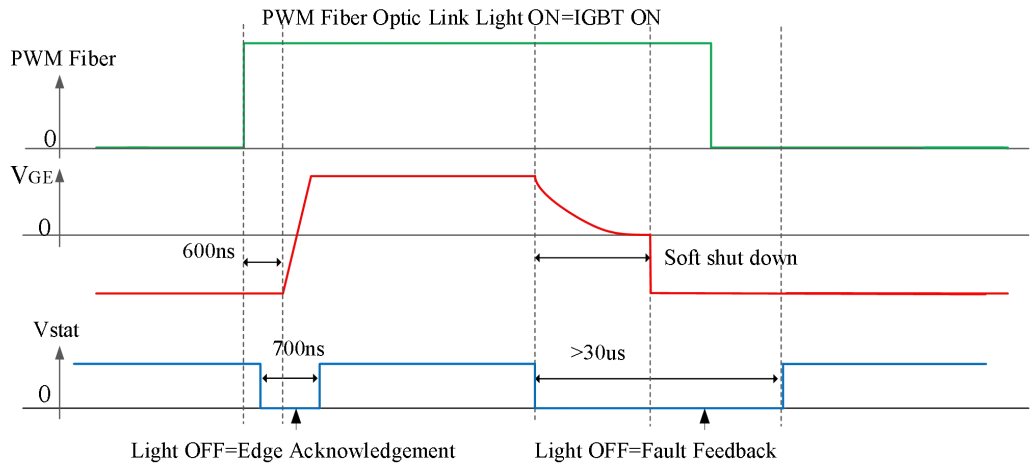


Fig.10b In case of failure

The master computer can accurately distinguish the response information from the fault information by the length of the light-off time of the optical fiber head.

Mode 2: Compatible with Inpower fault protocol

1. When the driver board operates normally, every time a PWM command is received, the return-signal optical fiber head will turn off for 1μs at the rising edge and falling edge of the PWM command as a response to receiving the command.

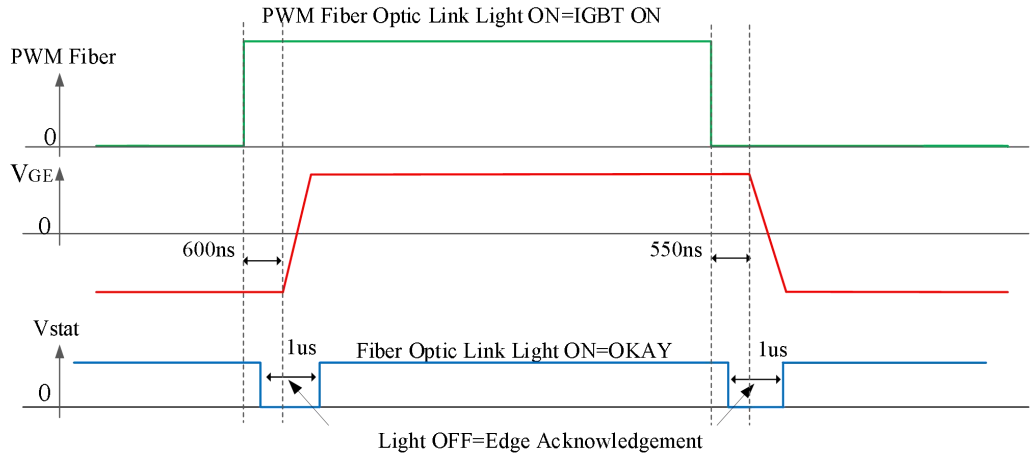


Fig.10c Normal condition in mode 2

2. When the OC1 fault is detected by the driver board, the return-signal optical fiber head will send a low-level pulse for about 4.1μs, and a low-level narrow pulse for about 0.8μs, which will be used as the fault signal to inform the master computer.

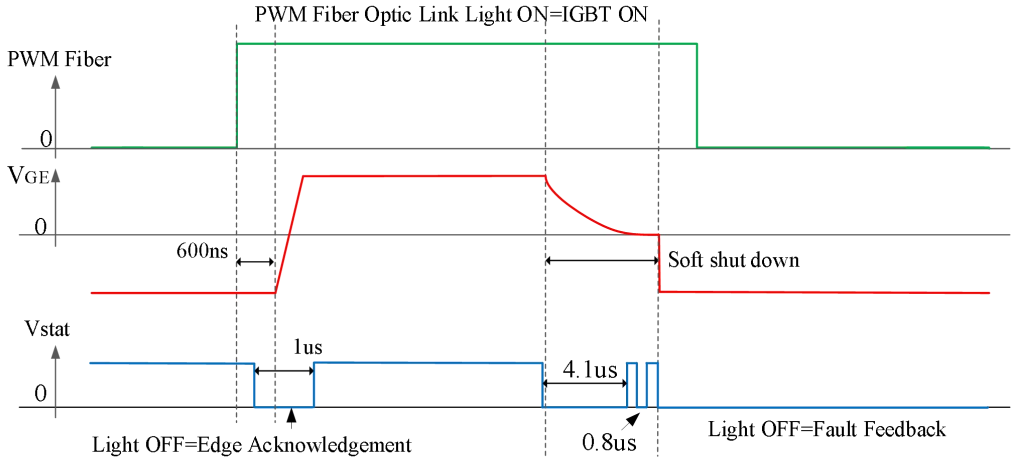


Fig.10d OC1 fault condition

3. When the OC2 fault is detected by the driver board, the return-signal optical fiber head will send a low-level pulse for about 4.1μs, and two low-level narrow pulse for about 0.8μs, which will be used as the fault signal to inform the master computer.

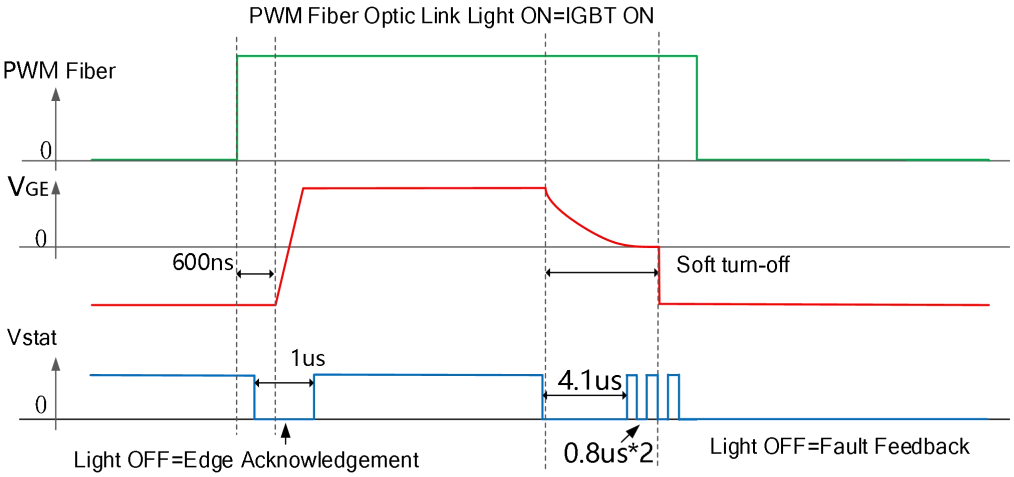


Fig.10e OC2 fault condition

4. When the di/dt fault is detected by the driver board, the return-signal optical fiber head will send a low-level pulse for about 4.1μs, which will be used as the fault signal to inform the master computer.

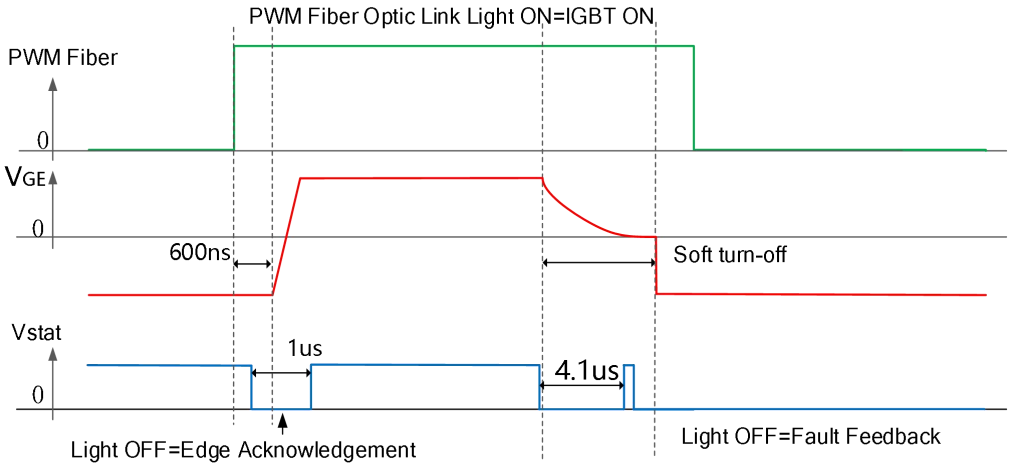


Fig.10f di/dt fault condition

Gate resistor indication

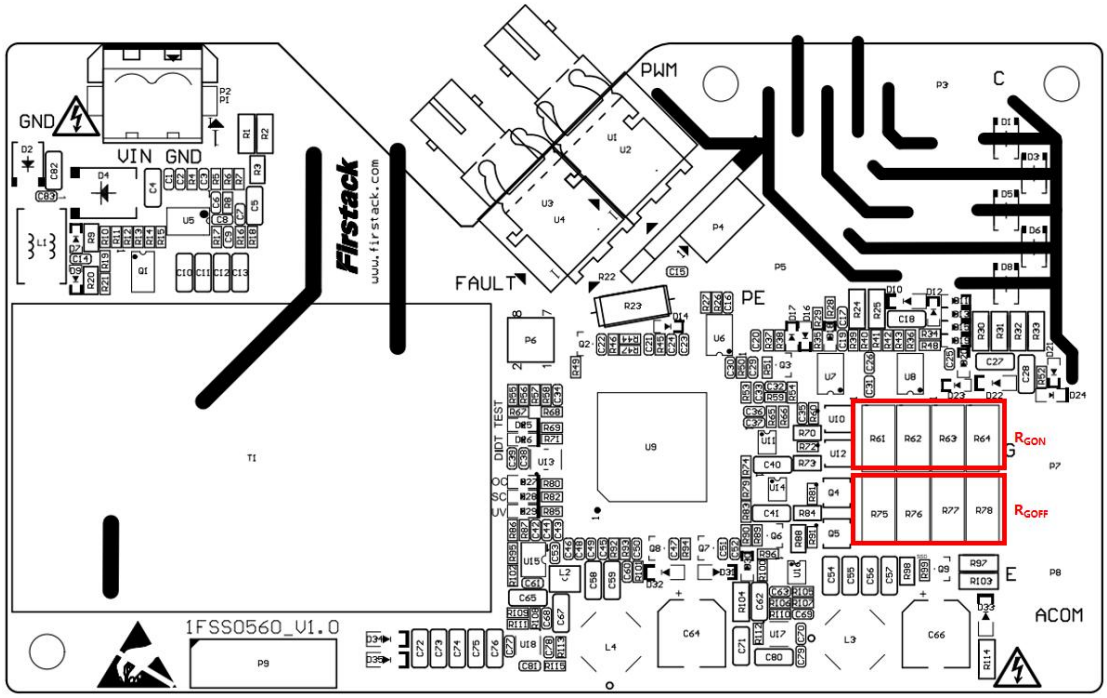


Fig.11 Gate resistor indication

Calculation formula of gate resistor

R_{GON}	R_{GOFF}
R63//R64	R77//R78

Note: For different IGBT models, the program of gate driver board is different.

Please do not change the gate resistor parameter at will.

Product selection

IGBT model: FZ1200R45HL3

Core Board:

Model	Faulty memory card	Faulty protocol	Fiber type	R_{GON}	R_{GOFF}
1FSS0560V45A3C-Y0100	Not have	Compatible with Inpower protocol	2 plastic optical fibers	2.55Ω	8Ω

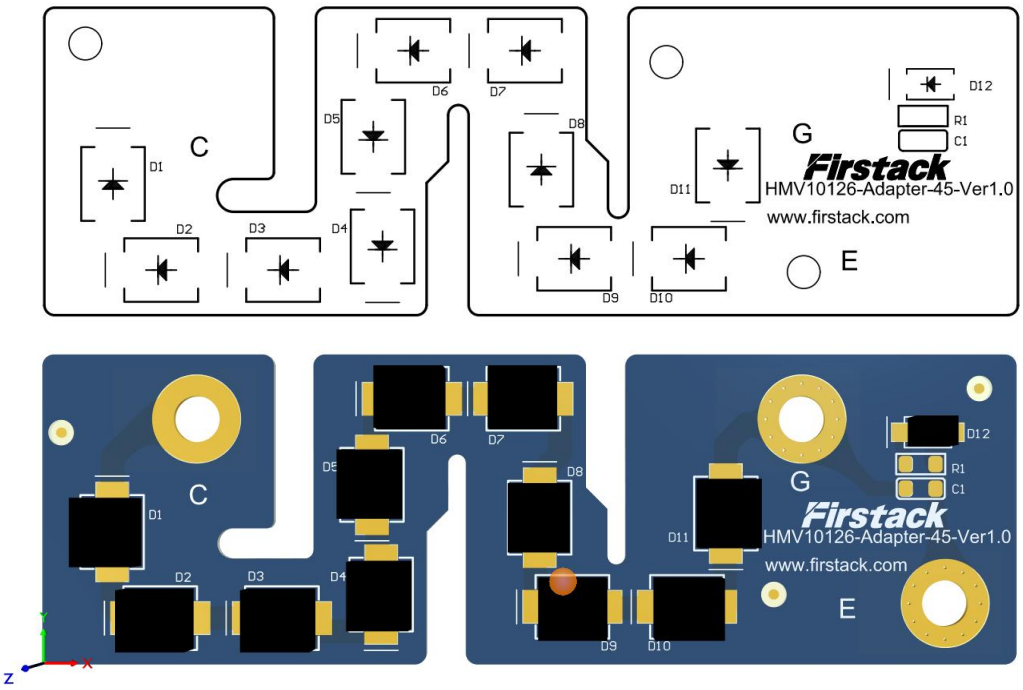
Adapter board:

Model	C_{GE}
A-HMV10126-45-IP-A1	100nF

Adapter board scheme: A-HMV10126-45-IP-A1

A-HMV10126-45-IP-A1 is suitable for IGBT modules with similar packaging such as IHV. The parameters and screen printing of this adapter board are as follows.

Parameters of Adapter Board	C_{GE}(nF)
A-HMV10126-45-IP-A1	100nF



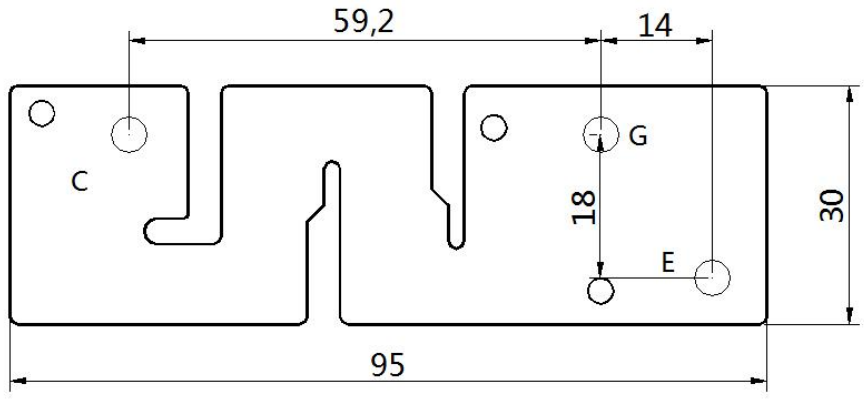


Fig.12 Mechanical dimensions of adapter board (unit: mm)

Note:

1. The thickness tolerance of the board is ±10%;

2. Other dimensional tolerances refer to GB/T1804-m.

Ordering information

The 1FSS0560 can support IHV and IHM modules of different models from multiple manufacturers. If you have a purchase request, please contact us, and we can provide the gate driver that best meets your needs.

Technical support

Firstack's professional team will provide you with business consultation, technical support, product selection, price, lead time and other related information, and guarantee to answer your questions within 48 hours.

Legal disclaimer

This manual gives a detailed introduction to the product, but cannot promise to provide specific parameters for the delivery, performance or applicability of the product. This article does not provide any express or implied warranties or guarantees. Firstack reserves the right to modify technical data and product specifications at any time without prior notice. Firstack's general terms and conditions of delivery apply.

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