

## 1FSD08110 Data Sheet

### Abstract

The 1FSD08110 is a high-performance digital gate driver with optical fiber interface developed for high-voltage and high-power IGBT, which is suitable for 2-level and multi-level converters. The digital can optimize the switching performance of IGBTs, which provides optimal protection for IGBTs. Its good EMC characteristics is suitable for harsh electromagnetic field environment. Now it has been widely used in various fields such as new energy, rail, industrial transmission and smart grid.

The 1FSD08110 is a plug-and-play gate driver developed for modules in 140×190mm and 140×130mm IGBT packages, such as Infineon IHM and ABB HiPak. It is suitable for IGBTs in the same package from different manufacturers.



Fig.1 1FSD08110

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**System block diagram**

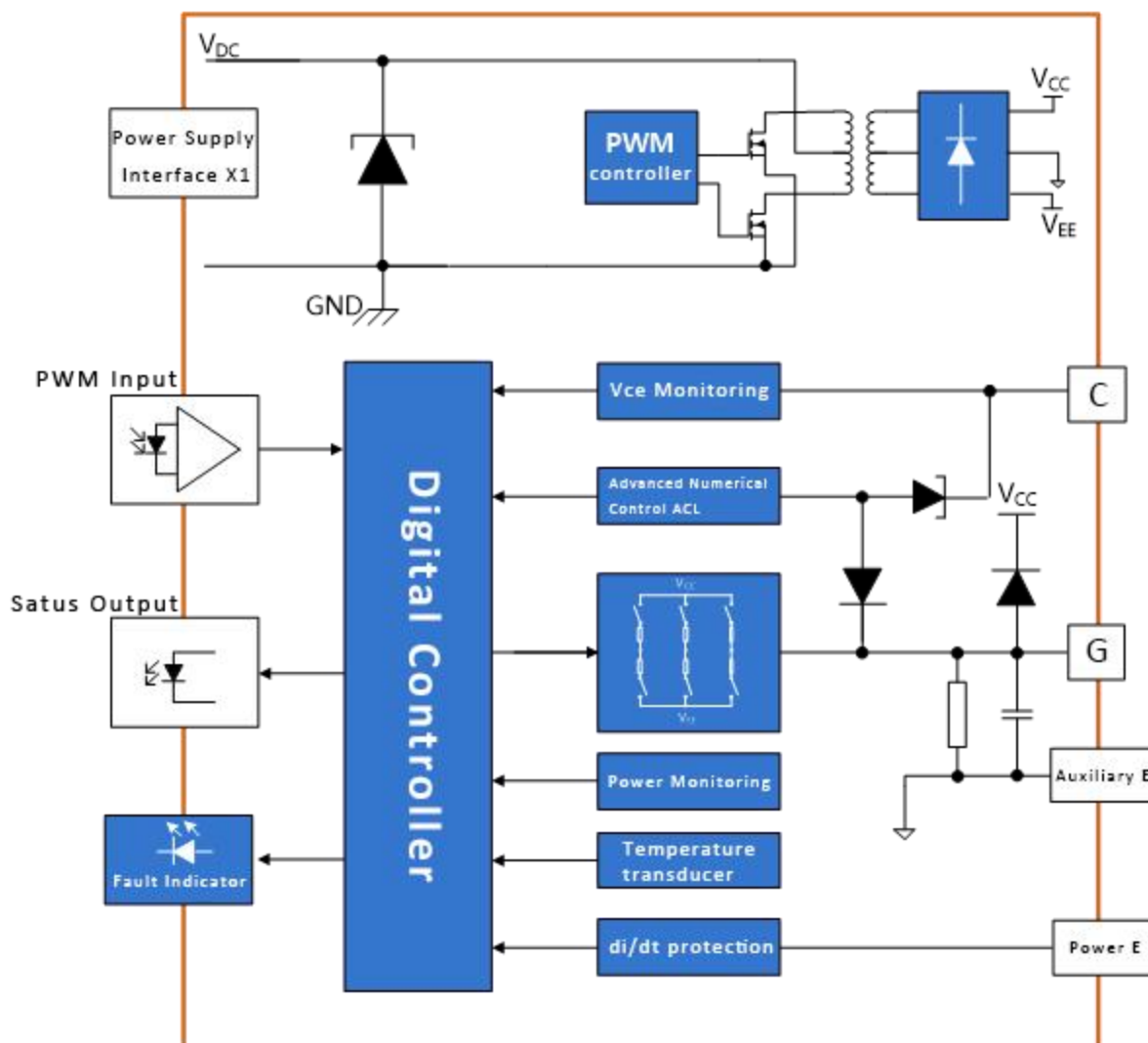


Fig.2 System block diagram (di/dt protection reserved)

The primary side power supply inputs a DC voltage of 15V, and the power supply voltage required by the system is obtained through the relevant circuit, which ensures the energy source of the system; the PWM signal is transmitted directly to the secondary side through the optical fiber, and the driving signal of the semiconductor device IGBT is obtained through the processing of the relevant unit circuit.

When the gate is turned on, if no short-circuit fault occurs, the main power device is saturated and turned on, the voltage across the IGBT-CE is close to zero, the IGBT-CE detection is reset, and the corresponding soft shut down circuit does not start; if a short-circuit fault occurs,

during the gate opening process, the main power device exits saturation, the voltage across IGBT-CE is close to the bus voltage, the IGBT-CE detection is set, and the corresponding soft shut down circuit is activated to protect the main power device from damage. At the same time, the fault signal is transmitted to the master computer through the optical fiber; when there is no PWM signal input, the gate is always in the negative pressure turn-off state.

## 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 model of the IGBT module that the gate driver is adapted to. It is invalid for non-designated IGBT modules. Improper use may cause the drive and the module failure.

### 2. Install the gate driver on the IGBT module

Any treatment of IGBT modules or gate drivers should follow the general specifications for the protection of electrostatic sensitive devices required by the international standard IEC 60747-1, Chapter IX or European standard EN 100015 (which means 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

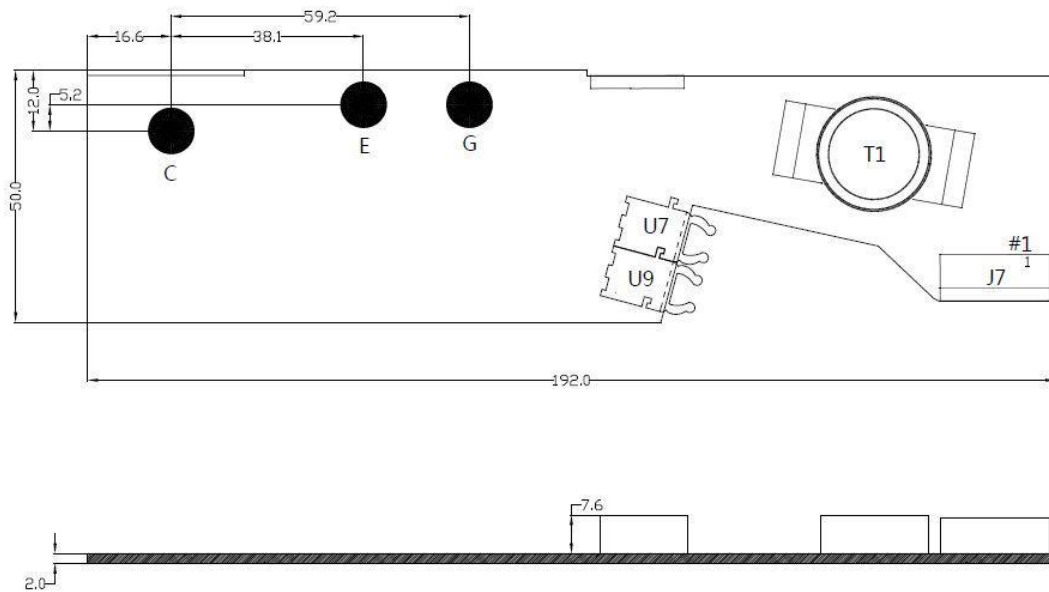
Check the gate voltage: for the turn-off state, the rated gate voltage is given in the corresponding data sheet, for the turn-on state, the voltage is 15V. Please also check the input current of the gate driver with and without a control signal. For Firstack's digital gate driver, the gate driver status 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 or double pulse test method. In particular, Firstack recommends that users ensure that the IGBT module does not exceed the operating range specified by SOA even under the worst conditions, as this is strongly dependent on the specific converter configuration.

## Mechanical dimensions



unit: mm

Fig.3 Mechanical dimensions

Note:

1. The thickness tolerance of the board is  $\pm 10\%$ ;
2. Other dimensional tolerances refer to GB/T1804-m.

### Connector Manufacturer and Part Number

Number	Ref	Manufacturer	Part Number	Recommended Matching Terminals
1	J7	WÜRTH	691325310003	691364300003
2	U7	AVAGO	HFBR-1521Z	
3	U9	AVAGO	HFBR-2521Z	

## Pin functional description

Pin	Ref	Note	Pin	Ref	Note
1	GND	Ground of Input	2	NC	Not Connect
3	V <sub>IN</sub>	Input Voltage			

**LED status indicator**

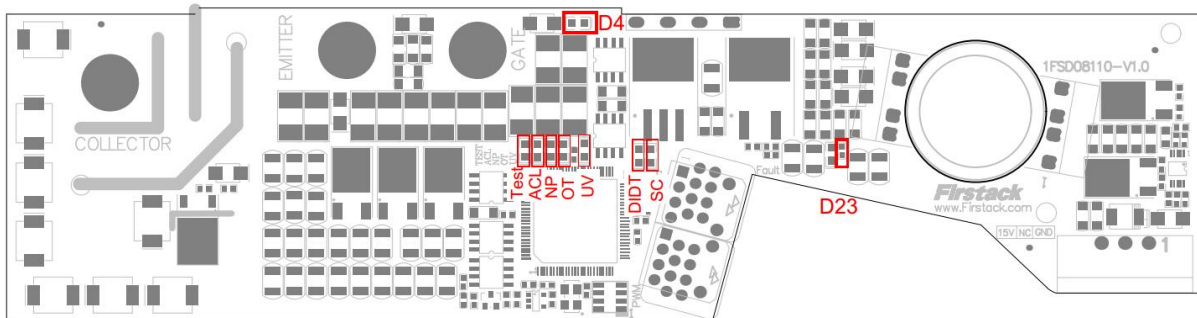


Fig.4 LED status indicator

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

**LED Status Indicator**

Number	Ref	Interface	Note
1	D23	D23	Power indicator
2	D4	D4	GE indicator. Light up when it is turned on, otherwise off
3	D7	TEST	Light up when the power supply is normal and there is no fault, otherwise off
4	D9	SC	Once triggered by a short-circuit, it is always on, unless restarted
5	D10	NP	This indicator is not enabled
6	D11	OT	Once triggered by overheating, it is always on, unless restarted
7	D13	ACL	Once the ACL is triggered, it is always on, unless restarted
8	D14	DIDT	Once triggered by a short-circuit, it is always on, unless restarted
9	D15	UV	Once triggered by undervoltage, it is always on, unless restarted



## Driving parameters

### Absolute Maximum Ratings

Parameter	Note	Min.	Max.	Unit
V <sub>IN</sub>	V <sub>IN</sub> to GND		16	V
Gate Peak Current			110	A
Output Power	T <sub>A</sub> ≤85°C		8	W
Test Voltage(50Hz/1min)		6		kV <sub>RMS</sub>
Operating Temperature		-40	85	°C
Storage Temperature		-40	85	°C

### Recommended Operating Conditions

Parameter	Note	Min.	Typ.	Max.	Unit
V <sub>IN</sub>		14.5	15	15.5	V

### Electrical Characteristics

Power	Note	Min.	Typ.	Max.	Unit
Power Supply Current	Without Load, Note 1		0.15		A
Coupling Capacitance	Primary to Secondary Side		9.5		pF

### Power Supply Monitoring

Threshold		12.7		V
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### Short-circuit Protection

V<sub>CE</sub> Protection

V <sub>CE</sub> Threshold		10.2		V
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Response Time	Note 2	8		us
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didt Protection

Response Time		3		us
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### Timing Characteristics

Turn-on Delay	Note 3	500		ns
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Turn-off Delay	Note 4	500	ns
Rise Time	Note 5	15	ns
Fall Time	Note 6	12	ns
Fault Hold Time		30	us
Fault Blocking Time		90	ms

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Unless otherwise specified, all data are based on +25°C and  $V_{IN}=15V$ .

**Note:**

- 1. Power Supply Current:** gate driver core connected to IGBT, no PWM input;
- 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) without connecting the IGBT;
- 6. Fall Time:** the amount of time from 90% of the gate turn-on voltage(+15V) to the gate turn-off voltage(-10V).

**Functional description**

◆ **Short-circuit protection— $V_{CE}$  monitoring**

The driving circuit judges whether the IGBT is in a short-circuit state by detecting the collector 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.

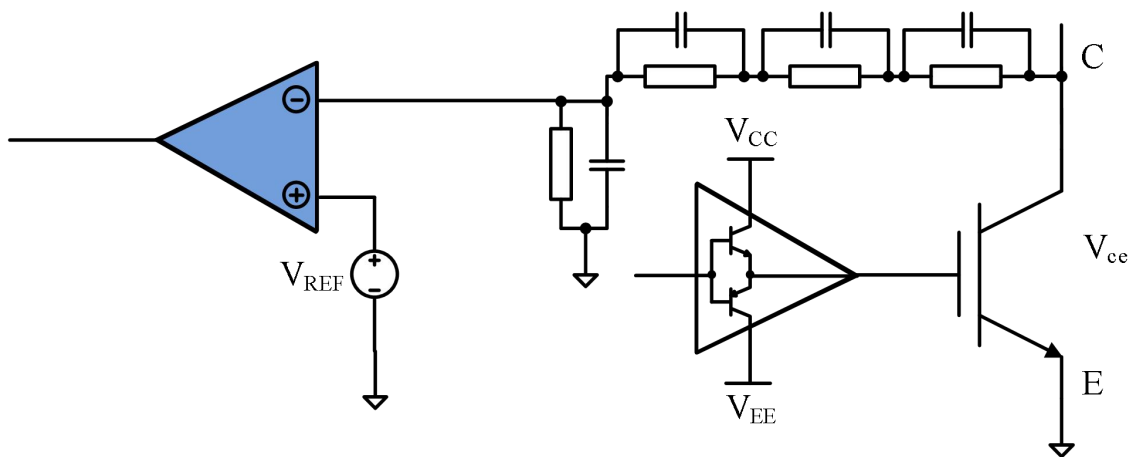


Fig.5  $V_{CE}$  monitoring circuit

◆ **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.

For IGBT bridge arms, Firststack intelligent gate driver strongly suggests that any IGBT 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 a slight turn-on of 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 under 10 $\mu$ s, 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, which ensures the safety of the IGBT.

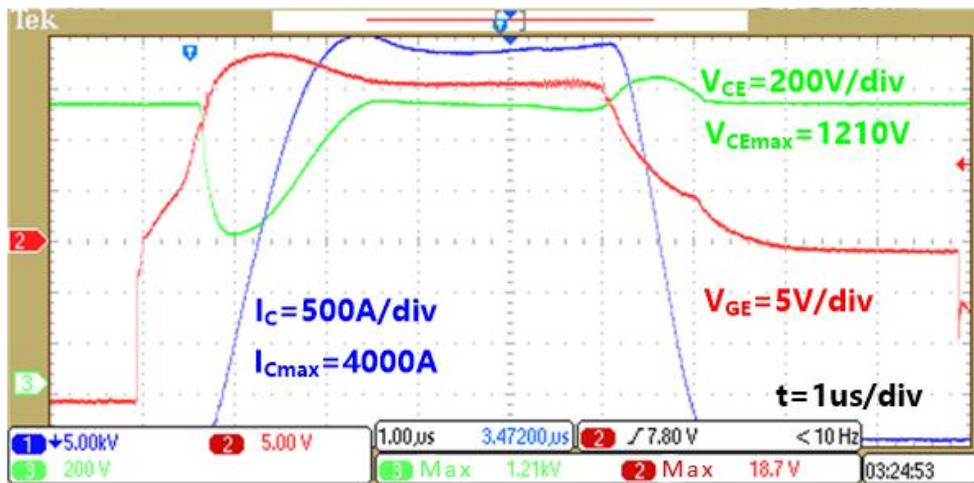


Fig.6 Short-circuit waveform of FF1400R17IP4 at 1100V

Fig.6 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 IGBT is safely turned off.

◆ **Digitally dynamic advanced active clamping D<sup>2</sup>A<sup>2</sup>C technology**

When the system is in an overload or short-circuit state 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.

In order to improve the clamping effect, Firststack introduces a digitally controlled active clamping and added a "digitally controlled current source" to the gate. When the current  $I_Z$  flowing through the TVS is larger than a certain threshold, the N transistor is turned off and the "digitally controlled current source" is started at the same time. At this time,  $I_Z = I_G + I_D$ , keeping  $I_Z$  at a low value by the digitally controlled current source, and the TVS will be in a weak breakdown state until the end of the turn-off.

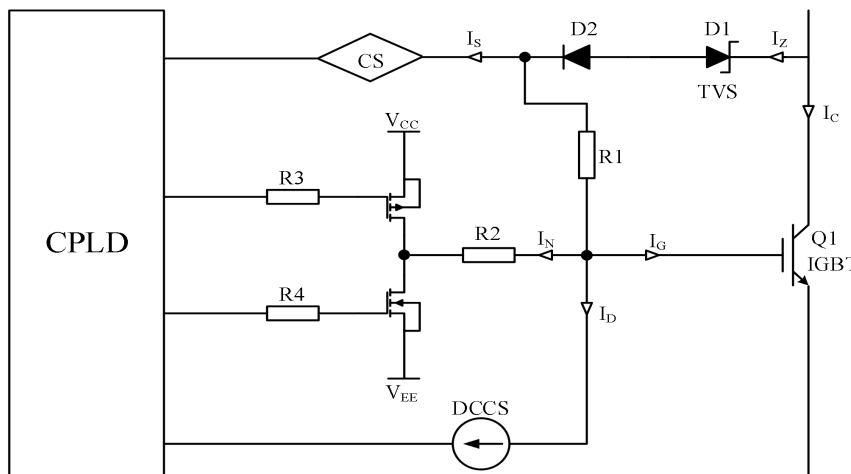


Fig.7 Schematic diagram of active clamping principle

The following Fig.8 is the short-circuit test waveform of intelligent gate driver products based on Infineon FF1000R17IP4 module. The turn-off moment  $V_{ce}$  voltage is basically clamped at 1380V, and the turn-off process is very smooth with no violent oscillation.

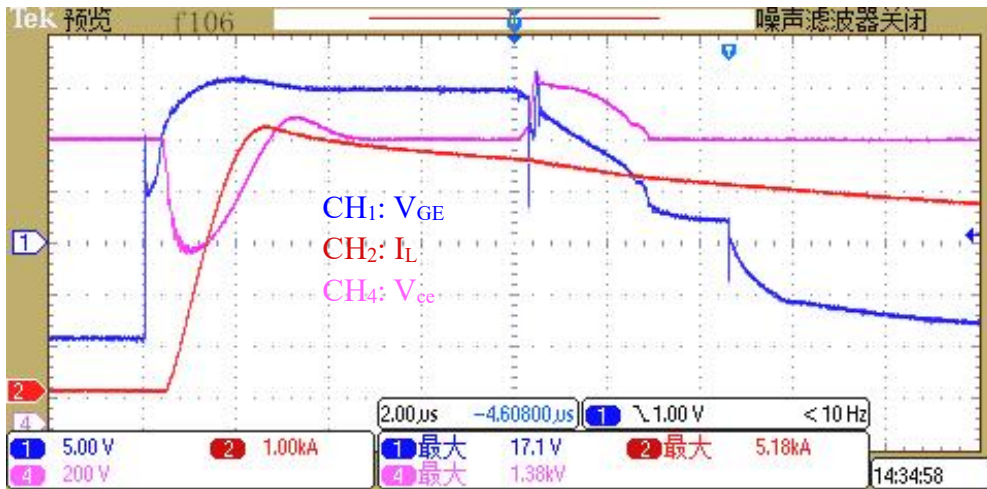


Fig.8 Digitally controlled active clamping waveform

In the picture above, CH1:  $V_{GE}$ (blue); CH2: $I_L$ (red); CH4:  $V_{ce}$ (pink)

◆ **Muti-level turn-off**

In some applications with large stray inductances, such as NPC I-type 3-level large commutation circuit, each time the IGBT is turned off, it will face the risk of excessive turn-off spikes. Due to the limitation of the thermal capacitance of TVS, active clamping technology is not suitable for these occasions, and the muti-level turn-off technology can play a significant role at this time. By using different turn-off resistances during the turn-off process, the entire turn-off process is optimized to suppress the turn-off spike.

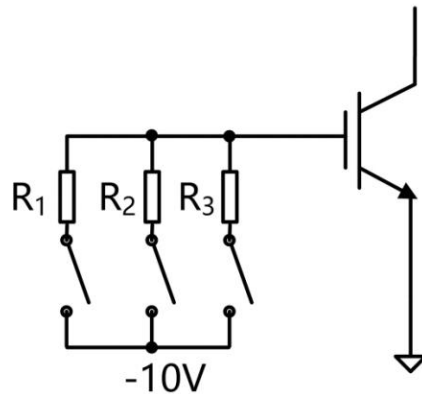


Fig.9 Muti-level turn-off schematic diagram

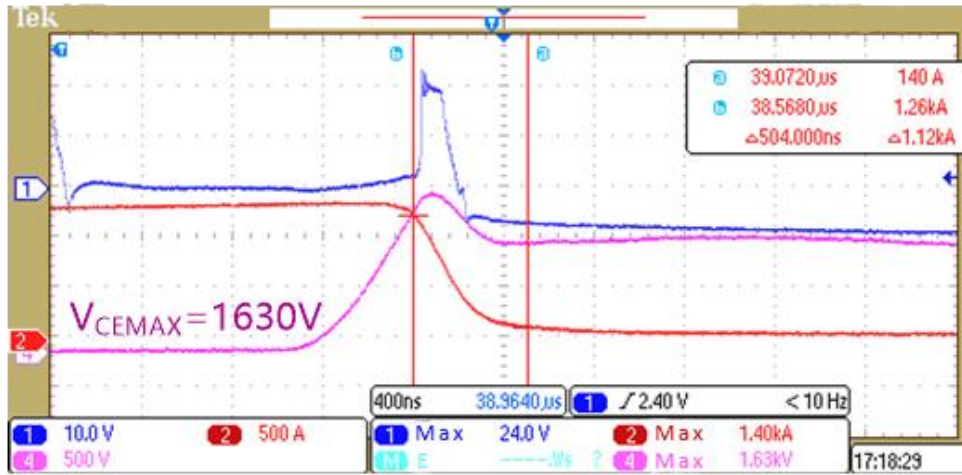


Fig.10a Without muti-level turn-off

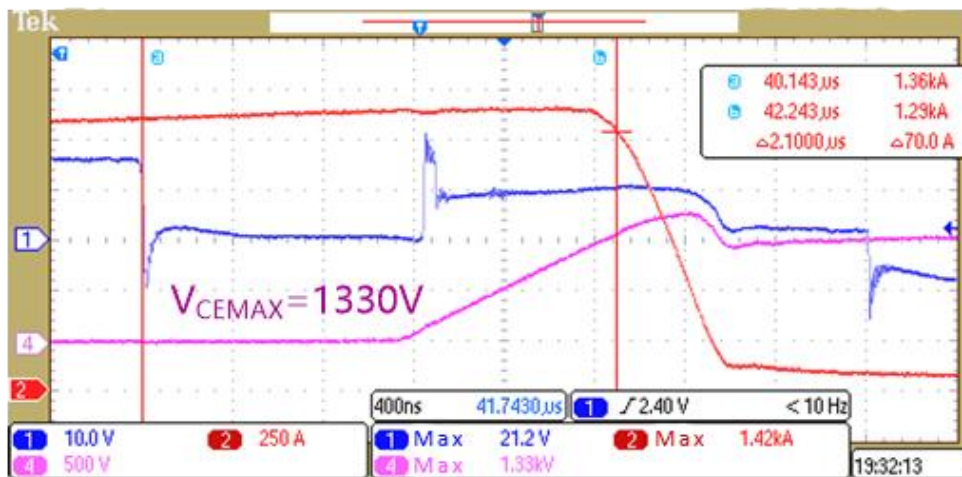


Fig.10b With muti-level turn-off



◆ **Highly robust DC/DC**

Since the built-in DC/DC of the gate driver needs to reduce the coupling capacitance  $C_{PS}$  of the primary and secondary side as much as possible, it generally adopts an open-loop form, so it is difficult to integrate functions such as overcurrent protection, which also leads to the anti-overload of the built-in DC/DC ability very poor. When counting gate driver failures, almost all of them are related to DC/DC failures.

In order to improve the reliability of the gate driver, Firststack puts forward the concept of "highly robust DC/DC", the gate driver can withstand a GE short-circuit of any length of time.

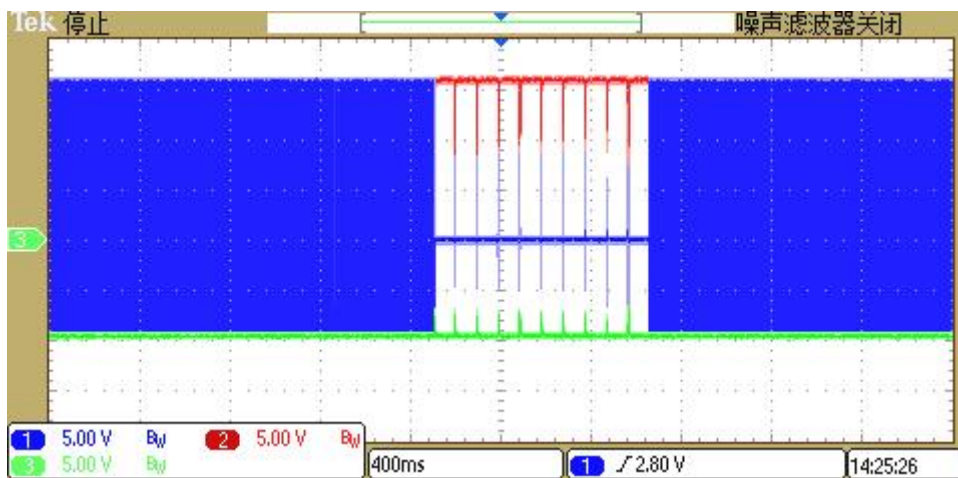


Fig.11 GE waveform

In the picture above, CH1:  $V_{GE}$ (blue); CH2:  $I_C$ (red)= +15V(secondary side); CH3:  $V_{CE}$  (green)= -10V(secondary side)

When an overload occurs, the gate driver will block the PWM signal and report a fault signal to the master computer at the same time. When the overload is removed, the gate driver will return to its normal state.

◆ **Optical fiber port notification signal**

In the process of using optical fiber, there are phenomena such as the buckle of optical fiber port 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 Firststack intelligent gate driver is configured with the fiber port response function, as follows:

1. When the driver board operates normally, every time a PWM command is received, the



light of the returning fibre optic head will go out for a short time of 700ns at the rising edge and falling edge of the PWM command as a response to receiving the command.

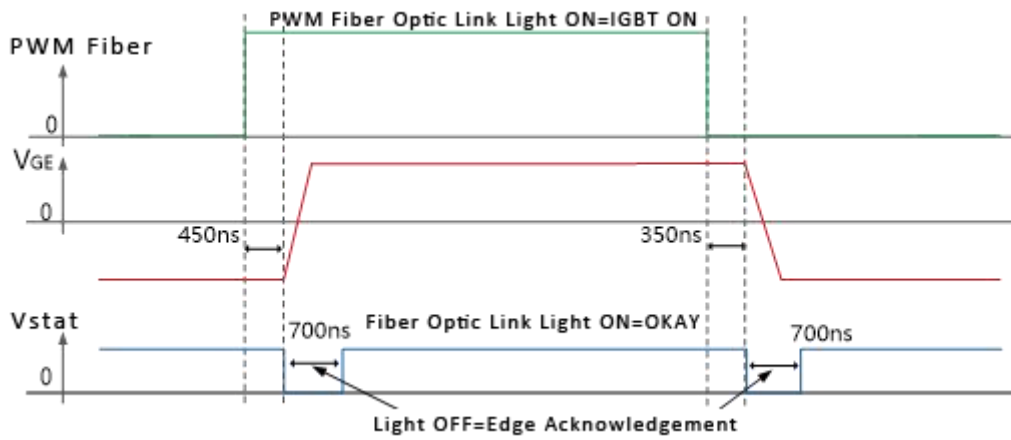


Fig.12a Normal condition

2. When the fault is detected by the driver board, the light of the return fibre optic head will go out for more than 30us, which will be used as a fault signal to inform the master computer.

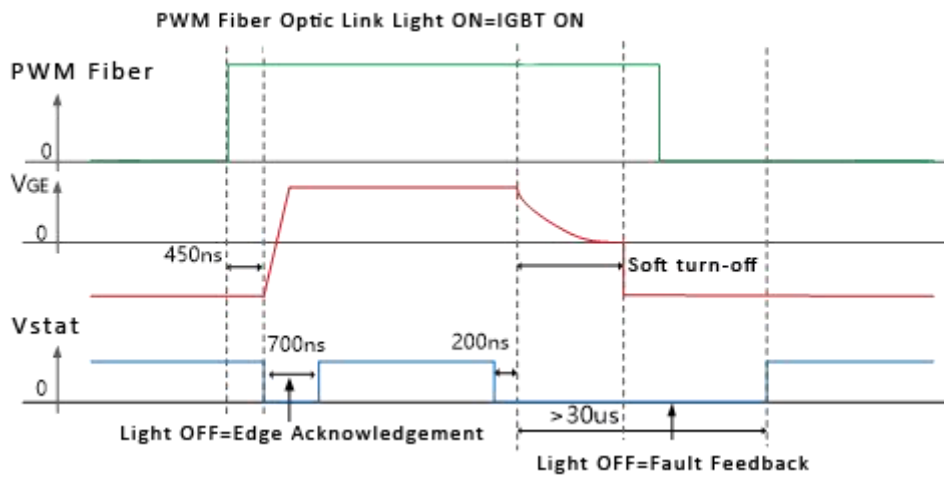


Fig.12b Fault condition

The master computer can accurately distinguish the response information from the fault information by the length of time for the light of the returning optical fiber head going out.

**Gate resistor indication**

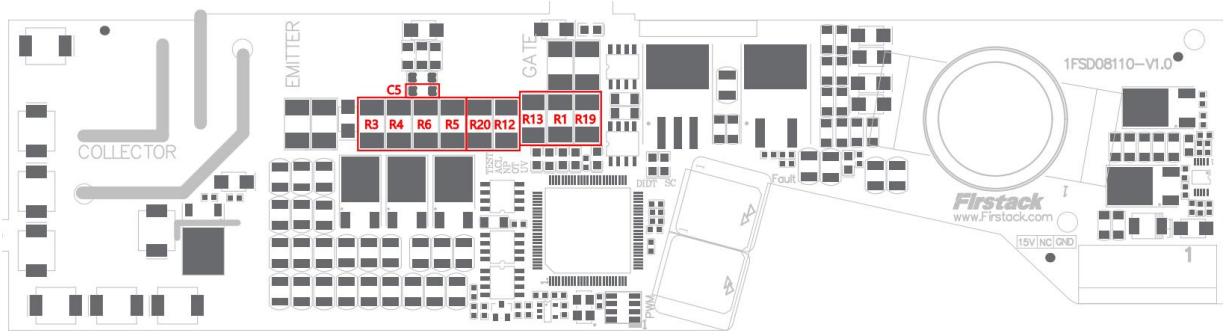


Fig.13 Gate resistor indication

**Calculation formula of gate resistor**

	<b>Rgon</b>	<b>Rgoff</b>	<b>Cge</b>
Single IGBT	<b>R3 // R4 // R5 // R6</b>	<b>R1 // R12 // R13 // R19 // R20</b>	<b>C5</b>

**Gate driver model selection of common IGBT modules**

IGBT model	Gate driver model selection	Cge(nF)	Rgon(Ω)	Rgoff(Ω)
ALL 1700V model	1FSD08110-17-A1	NC	NC	NC
ALL 3300V model	1FSD08110-33-A2	NC	NC	NC
TIM2400ESM17-TSA000	1FSD08110Y01	NC	0.8	1.7
FD1200R17HP4-K_B2	1FSD08110Y02	NC	2	2.2
5SNA1500E330305	1FSD08110-5SNA1200E330100	330	1.5	≈3*
5SNA1200E330100	1FSD08110-5SNA1200E330100	330	1.5	≈3*
5SNA1000N330300	1FSD08110-5SNA1200E330100	330	1.5	≈3*
FZ1200R33HE3	1FSD08110-FZ1200R33HE3	330	1.5	≈4*
FZ1000R33HE3	1FSD08110-FZ1200R33HE3	330	1.5	≈4*
FZ1500R33HE3	1FSD08110-FZ1500R33HE3	330	1.5	≈5*
CM1200HC-66H	1FSD08110-CM1200HC-66H	330	1.5	≈4*
TIM1000ECM33-PSA011	1FSD08110-TIM1000NSM33	330	1.5	≈4*
TIM1000NSM33-PSA011	1FSD08110-TIM1000NSM33	330	1.5	≈4*
DIM1000NSM33-TS000	1FSD08110-TIM1000NSM33	330	1.5	≈4*
TIM1500ESM33-PSA012	1FSD08110-TIM1500ESM33-PSA012	330	1.5	≈5*

Note:

1. We strongly recommend that customers prioritize these models and the corresponding gate parameters, which have been fully validated, ships in large quantities and has significant advantages in delivery time.

2. \* is equivalent gate turn-off resistance, these drive models use multi-level turn-off technology, the specific turn-off characteristics are subject to actual testing.
3. The application of the above gate parameters requires a busbar inductance of less than 300nH;
4. Recommended dead time of inverter controller for normal operation  $\geq 4\mu\text{s}$ ;
5. If the customer thinks that an IGBT module parameter is not suitable in our recommended list, we recommend customers to use models without resistor, including the test phase and batch phase, which has significant advantages both in price and delivery time. They are 1FSD08110-17-A1 and 1FSD08110-33-A2. These models require the customer to weld the gate resistance and apply three proof paint themselves. For details, please refer to our company's instruction manual "IGBT Driver General Model SMT Gate Resistance Welding Instruction Manual".

## Ordering information

The 1FSD8110 can support 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

Firststack'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.

Firststack reserves the right to modify technical data and product specifications at any time without prior notice. Firststack's general terms and conditions of delivery apply.

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