6FHS0660MC1G15V-Y0101 Data Sheet

Abstract

The 6FHS0660MC1G15V-Y0101 is a high-performance digital driver core developed by Firstack for ANPC 3-level system. The driver adopts CPLD as the digital control core, with complete protection functions and built-in fault management system, which uploads the converter's operating state to the master computer in real time, providing support for "big data management" for the failed converter site. Perfectly solving the two major problems of "turn-off timing sequence" and "large commutation circuit turn-off peak" in NPC I-type topology, the reliability of NPC topology can be comparable to 2-level, allowing customers to use NPC I-type /ANPC 3-level as same as 2-level.

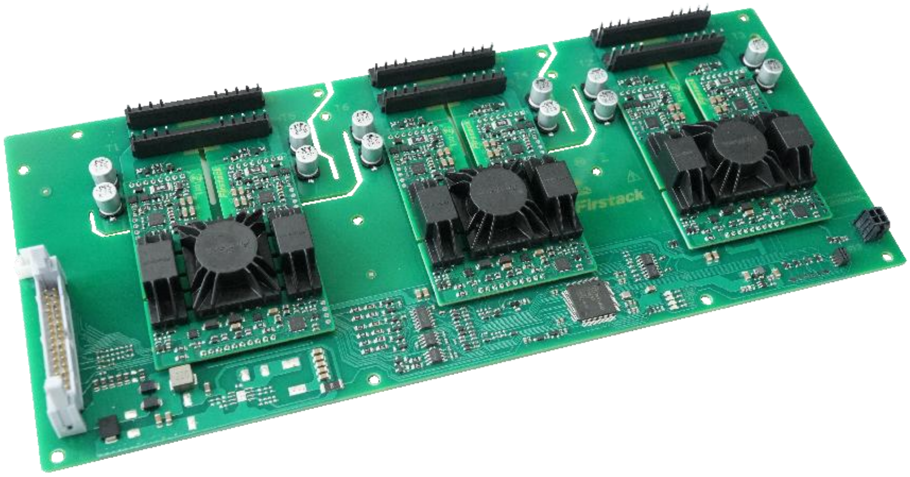


Fig.1 6FHS0660MC1G15V-Y0101

Highlights:

√ Output 6W per channel/peak current 60A

√ Support up to 2300V XHP module

√ Short-circuit protection (soft shut down) UVLO

√ Fault timing sequence protection

Applications:

√ PV

√ ESS

√ Medium Voltage AC Drive

√ Wind power

Contents

Functional block diagram

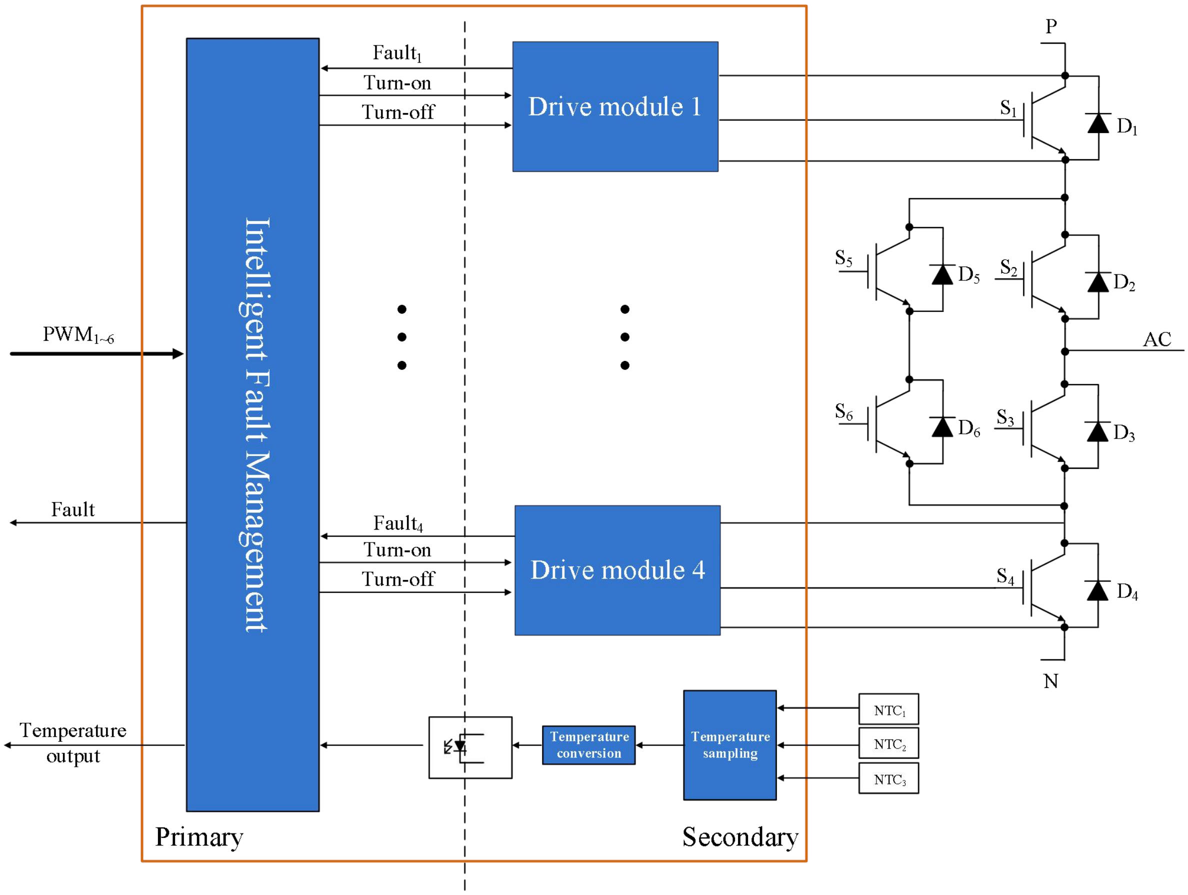


Fig.2 Functional block diagram

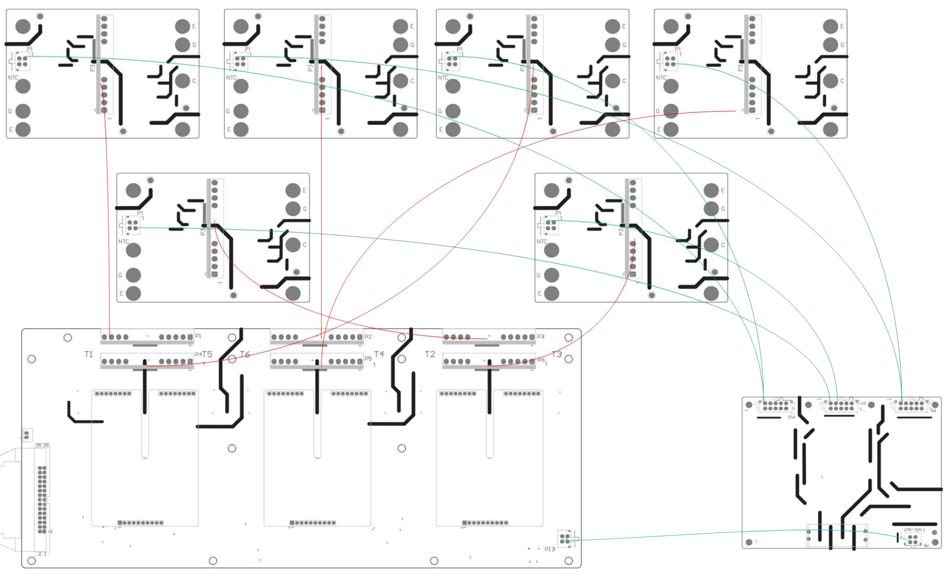


Fig.3 Connection schematic

Use steps and matters needing attention

Simple use steps of the gate driver are as follows::

1. Choose suitable gate driver

When use 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 gate driver 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 61340-5-1.

If these specifications were ignored, both the IGBT and the gate driver might be damaged.

3. Connect the gate driver to the control unit

Connect the gate driver connector 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. These tests should be performed prior to installation, as the gate terminals 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 single pulse and double pulse test method separately. 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 architecture.

Mechanical dimensions

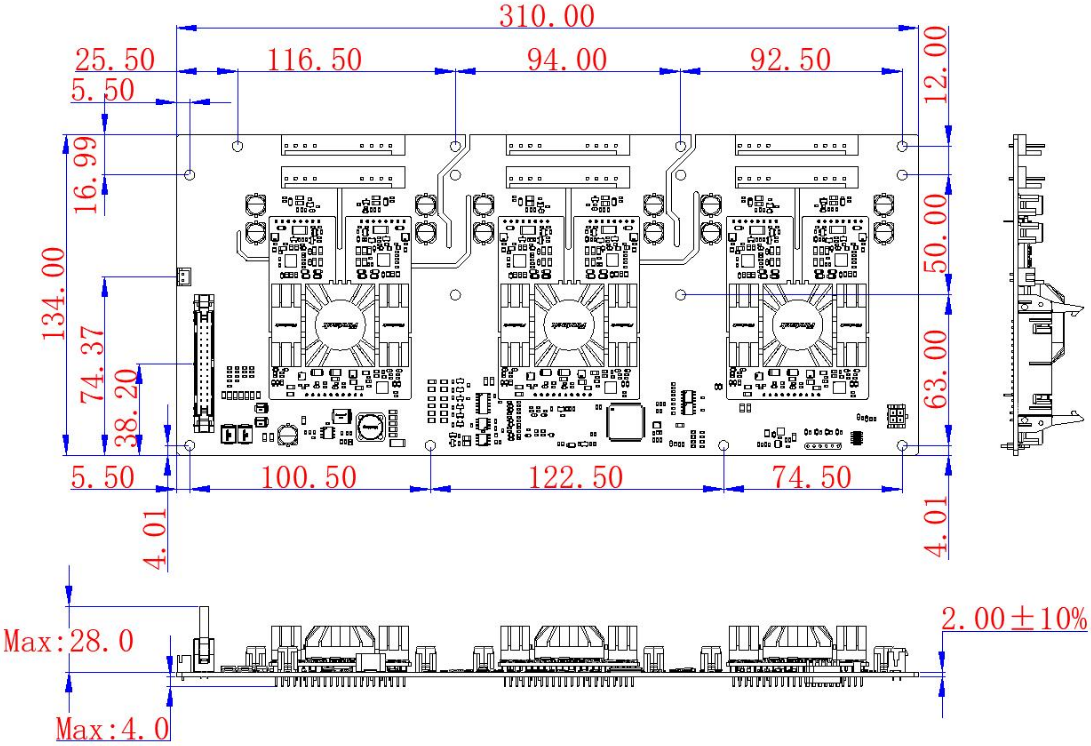


Fig.4 Mechanical dimensions (unit: mm)

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

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

3.All mounting holes in the diagram must be used as a fixing, otherwise the connector is likely to cause damage to the gate driver due to excessive insertion and extraction stress. At the same time, the mounting holes must be fixed with plastic studs or other insulating material studs, otherwise there is a risk of safety issue.

4. In the following table, only one connector can be selected between No.1 and No.2, Serial No.1 for the input interface perpendicular to the board, Serial No.2 for the input interface parallel to the board is serial number 2.

Connector Manufacturer and Part Number

No.	Label	Manufacturer	Part Number	Recommended Matching Terminals
1	P10	Nextron	Z-230010830209 (vertical)	FC-30P
2	P11	Nextron	Z-230011820209 (horizontal)	FC-30P
3	P1, P2, P3, P4, P5, P6	WCON	WF3963-WSH13B02	WF3963-H13B01W
4	P9	JST	B2B-XH-A	XHP-2
5	P13	CJT	C3030WV-2x2P	C3030HF-2x2P

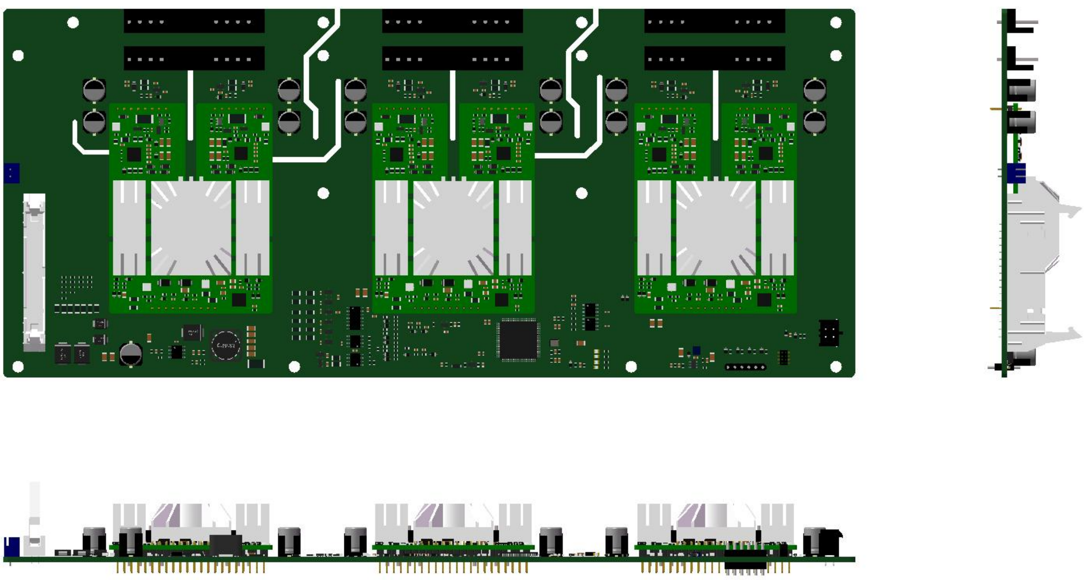


Fig.5 3D diagram

Pin definition

15V supply input P10 or P11 pin definition:

Pin	Name	Description	Pin	Name	Description
1	V_{DC}	+15V supply voltage	2	V_{DC}	+15V supply voltage
3	V_{DC}	+15V supply voltage	4	V_{DC}	+15V supply voltage
5	GND	Primary side ground	6	SO	Fault summary
7	GND	Primary side ground	8	GND	Primary side ground
9	GND	Primary side ground	10	IN1	T1 PWM signal
11	GND	Primary side ground	12	V_{DC}	+15V supply voltage
13	V_{DC}	+15V supply voltage	14	V_{DC}	+15V supply voltage
15	GND	Primary side ground	16	IN2	T2 PWM signal
17	GND	Primary side ground	18	V_{DC}	+15V supply voltage
19	GND	Primary side ground	20	V_{DC}	+15V supply voltage
21	GND	Primary side ground	22	IN3	T3 PWM signal
23	GND	Primary side ground	24	IN4	T4 PWM signal
25	GND	Primary side ground	26	IN5	T5 PWM signal
27	GND	Primary side ground	28	IN6	T6 PWM signal
29	GND	Primary side ground	30	FOUT	Frequency output

P1, P4 pin definition:

Pin	Name	Description	Pin	Name	Description
1	T5_GATE	T5 gate signal	8	NC	Free
2	10N-T5	T5_-10V	9	NC	Free
3	ACOM-T5	T5 reference ground	10	Vcesat-T1	T1 detection signal
4	15V-T5	T5_15V	11	15V-T1	T1_15V
5	Vcesat-T5	T5 detection signal	12	ACOM-T1	T1 reference ground
6	NC	Free	13	T1_GATE	T1 gate signal
7	NC	Free			

P2, P5 pin definition:

Pin	Name	Description	Pin	Name	Description
1	T4_GATE	T4 gate signal	8	NC	Free
2	10N-T4	T4_-10V	9	NC	Free
3	ACOM-T4	T4 reference ground	10	Vcesat-T6	T6 detection signal

4	15V-T4	T4_15V	11	15V-T6	T6_15V
5	Vcesat-T4	T4 detection signal	12	ACOM-T6	T6 reference ground
6	NC	Free	13	T6_GATE	T6 gate signal
7	NC	Free			

P3, P6 pin definition:

Pin	Name	Description	Pin	Name	Description
1	T3_GATE	T3 gate signal	8	NC	Free
2	10N-T3	T3_-10V	9	NC	Free
3	ACOM-T3	T3 reference ground	10	Vcesat-T2	T2 detection signal
4	15V-T3	T3_15V	11	15V-T2	T2_15V
5	Vcesat-T3	T3 detection signal	12	ACOM-T2	T2 reference ground
6	NC	Free	13	T2_GATE	T2 gate signal
7	NC	Free			

P13 pin definition:

Pin	Name	Description	Pin	Name	Description
1	GND	Primary ground signal	3	GND	Primary ground signal
2	NTC_OUT	Temperature output signal	4	NTC_OUT	Temperature output signal

P9 pin definition:

Pin	Name	Description	Pin	Name	Description
1	PT2-1	External PT2 pin1	2	PT2-2	External PT2 pin2

*The gate driver samples the temperature signals of 12 modules.
*NTCx is the temperature signal of module x.

LED status indication

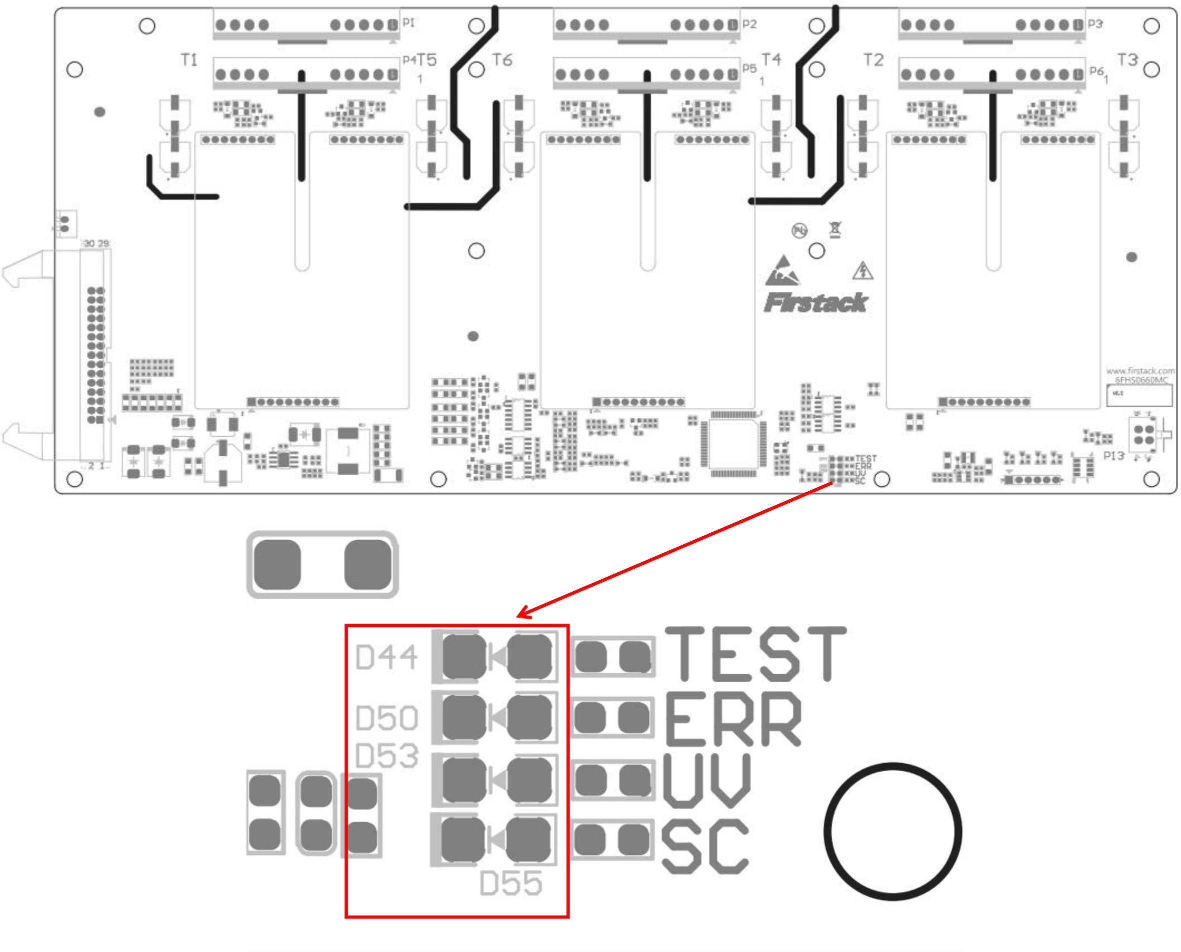


Fig.6 Status indicator

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:

Status Indicator

Number	Label	Interface	Note	Colour
1	D44	TEST	Light on when the primary power supply is normal and there are no faults, otherwise off	Green
2	D50	ERR	Fault triggered is always on except for undervoltage, short-circuit, unless restarted	Red
3	D53	UV	Once undervoltage trigger is always on, unless restarted.	Red
4	D55	SC	Once short-circuit trigger is always on, unless restarted.	Red

Driving parameters

Absolute Maximum Ratings

Parameter	Note	Min.	Max.	Unit
V_{DC}	V_{DC} to GND		15	V
Logic input and output voltages	Primary side, to GND	0	15.5	V
SO output	Fault condition		500	mA
Gate peak current			60	A
Output power per channel	T_A=85℃		6	W
Test voltage (50Hz/1min)	Primary to secondary side	9100		V_{RMS}
	Secondary to secondary side	6000		V_{RMS}
Operating temperature		-40	85	℃
Gate resistance derating	40%@118℃		2	W
Storage temperature		-40	85	℃

Recommended Operating Conditions

Parameters	Note	Min.	Typ.	Max.	Unit
V_{DC}			15		V
IN_X			15		V

Electrical Characteristics

Power supply	Note	Min.	Typ.	Max.	Unit
Power supply current	Without load, Note 1		0.4		A
Coupling capacitance	Primary to secondary side, Note 2		15		pF
Primary side power monitoring					
Threshold			12		V
Secondary side power monitoring					
Positive undervoltage threshold			12		V
Negative undervoltage threshold			-5		V
Input and output logic					
Input impedance			3.5		kΩ
Turn-on threshold	15V PWM input, high turn on		7.5		V
Turn-off threshold	15V PWM input, high turn on		4.8		V
NTC output level			15		V
SOx output potential	High normal, low fault (pulse)		15		V

Short-circuit protection					
V_{CE} monitoring threshold			12		V
Response time	T1, NoteT4, Note 3		11		µs
	T2, NoteT3, Note 3		11		µs
	T5, NoteT6, Note 3		11		µs
Blocking time			200		ms
Timing characteristics					
Turn-on delay	T1, NoteT4, Note 4		8200		ns
	T2, NoteT3, Note 4		8200		ns
	T5, NoteT6, Note 4		8200		ns
Turn-off delay	T1, NoteT4, Note 5		8300		ns
	T2, NoteT3, Note 5		8300		ns
	T5, NoteT6, Note 5		8300		ns
Rise time	T1, NoteT4, Note 6		50		ns
	T2, NoteT3, Note 6		50		ns
	T5, NoteT6, Note 6		50		ns
Fall time	T1, NoteT4, Note 7		50		ns
	T2, NoteT3, Note 7		50		ns
	T5, NoteT6, Note 7		50		ns
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, Note 8		40		mm
Clearance distance	Primary to secondary side		30.5		mm
Creepage distance	Secondary to secondary side		16		mm
Clearance distance	Secondary to secondary side		9		mm
NTC sampling					
NTC sampling range		-40		150	℃
Fault output					
Fault signal indication time	Note 9		100		ms
Dead time					
(T1&T3) (T2&T4)Dead time (T1&T5) (T4&T6)Dead time	Note 10		4		µs
Short pulse suppression					
Short pulse filtering time	Note 11		7000		ns

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

Note:

1. **Power supply current: no PWM input, but connected to IGBT;**

2. **Coupling capacitance: the values of coupling capacitance are within the range of values given in the table;**
3. **Response time: the time from the occurrence of the fault to the start of soft shut down;**
4. **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 gate driver of the secondary side;**
5. **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 gate driver of the secondary side;**
6. **Rise Time: the amount of time from 10% of the gate turn-off voltage(-10V) to 90% of the gate turn-on voltage(+15V);**
7. **Fall Time: the amount of time from 90% of the gate turn-on voltage(+15V) to the gate turn-off voltage(-10V);**
8. **Creepage distance: refer to IEC61800-5-1-2007;**
9. **Fault signal indication time: the Fault signal is high when normal, if the gate driver detects a fault, the Fault signal first waits for low level for 100ms, then outputs the fault code;**
10. **Dead time: when the time set by the control board has no deadband or is less than 4μs, the driver board itself will have a 4μs deadband; when the time set by the control board is more than 4μs, it will be executed according to the control board time;**
11. **Short pulse filtering time: the maximum short pulse that can be filtered out is 400ns, which may be less than this value in practice.**

Function description

◆ Short-circuit protection

The driving circuit determines whether the IGBT is in a short-circuit state by detecting the collector voltage V_{CE} when the IGBT turns on.

The V_{CE} voltage is detected by high-voltage diodes. 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 at the same time. The gate driver will turn off the IGBT according to the order of turning off the transistor outside first and then the transistor inside.

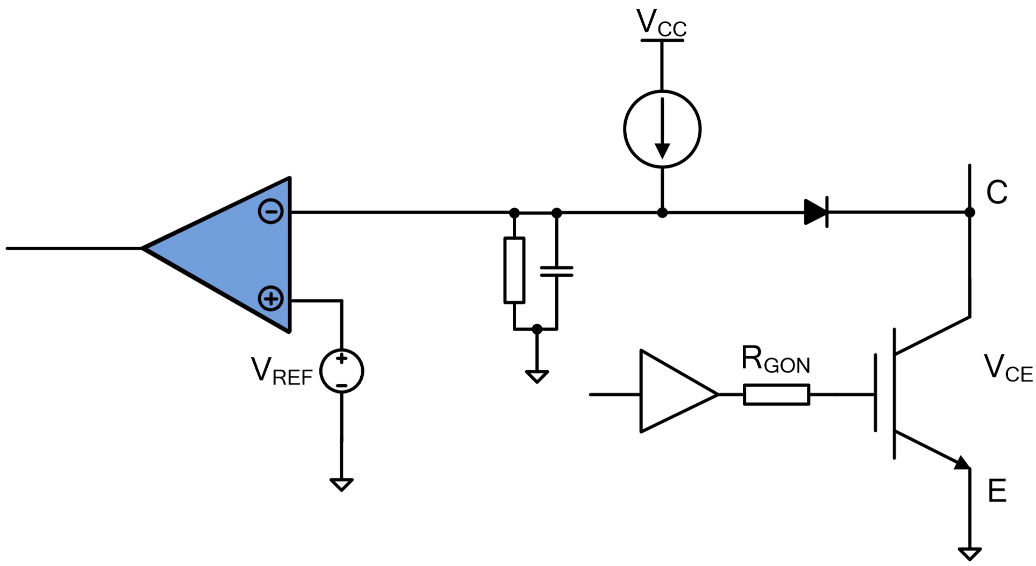


Fig.7 V_{CE} desaturation detection circuit

◆ 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. The gate driver will turn off the IGBT according to the order of turning off the transistor outside first and then the transistor inside.

For IGBT bridge arms, Firstack intelligent gate driver strongly suggests that any IGBT should not work 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.

◆ Disconnection detection

The driver connects the input Pin1 and Pin20, which allows for cable break detection. The following is the recommended test circuit, if the ejector header cable plugged firmly tight, the test point detected voltage is 0V; if the ejector header cable has a certain end which is not plugged tight, the test point detected voltage is the voltage of V_{CC}.

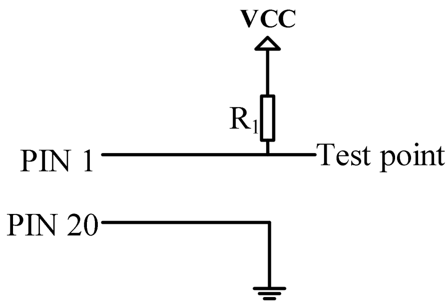


Fig.8 Disconnection detection

◆ Short pulse suppression

In many applications, the module may encounter a short pulse situation, and the IGBT will face the risk of too high turn-off peaks every time the IGBT is turned off by a short pulse. We detect the time of the input signal, when the time is less than 400ns, the signal will be filtered out directly, which needs to be verified according to the actual test situation.

◆ NTC sampling

With the advancement of module packaging technology, more and more modules begin to integrate temperature sensors internally, and NTC is one of these ways. Modules like PrimePACK^{TM}, EconoDUAL^{TM} and so on have NTC integrated internally.

The Firstack intelligent gate driver integrates a temperature monitoring circuit that converts the temperature signal into a frequency signal via a voltage-to-frequency conversion circuit, and informs the master computer of the frequency signal via an isolation device.

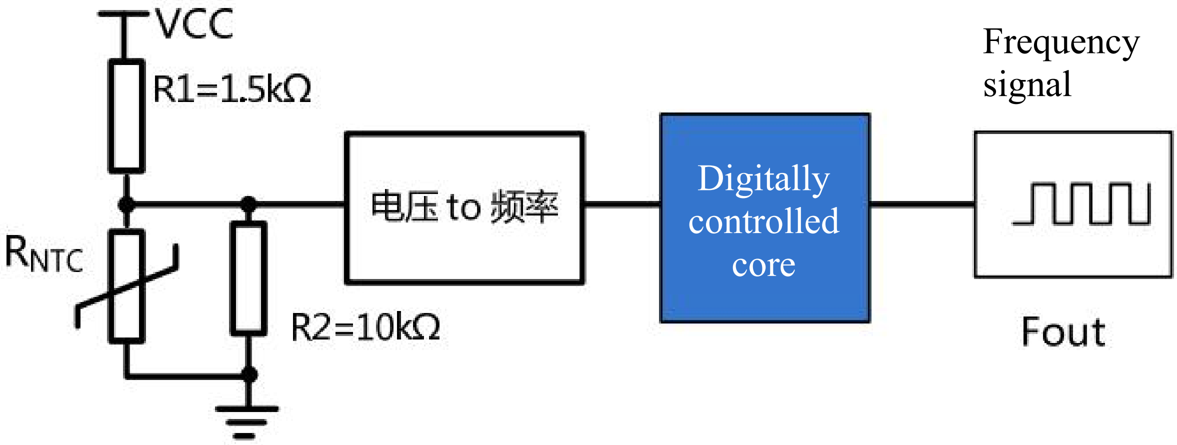


Fig.9 Temperature monitoring schematic

The 6FHS0660MC1G15V-Y0101 outputs the NTC with the highest temperature among the 12-channel IGBTs to the main control via a frequency signal.

*F_{OUT}=0.1*f_{CLKIN}+0.8*(V_{IN}/V_{REF})* f_{CLKIN}

*f_{CLKIN}=32.768kHz

*V_{IN}=V_{CC}*R/(R+1.5KΩ)

*R=R_{NTC}//10KΩ; Vcc=5V; V_{REF}=5V

◆ Fault code return

As large-scale grid integration of new energy sources becomes more and more common, the requirements for converter reliability are becoming higher and higher. The statistics of the types and frequency of failures occurring during field operation and the analysis of the causes after serious failures are also becoming more and more important.

The traditional gate driver design, which only informs the master computer that a fault has occurred when a fault occurs, is becoming less and less able to meet customers' needs. In order to provide more fault information to the customers, on the basis of the original 0/1, we have added a fault communication function, which informs the master computer of the fault category and the timing of the fault occurrence by coding.

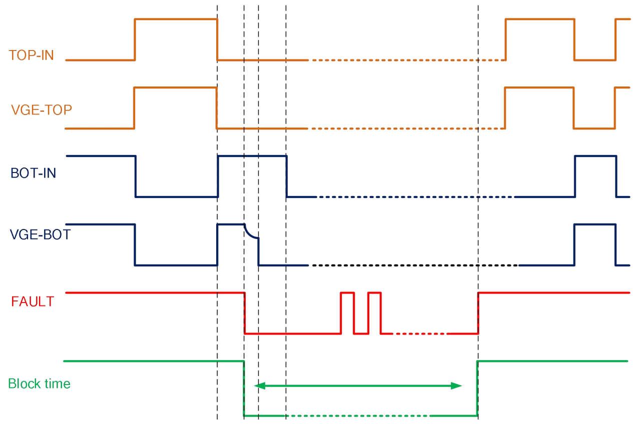
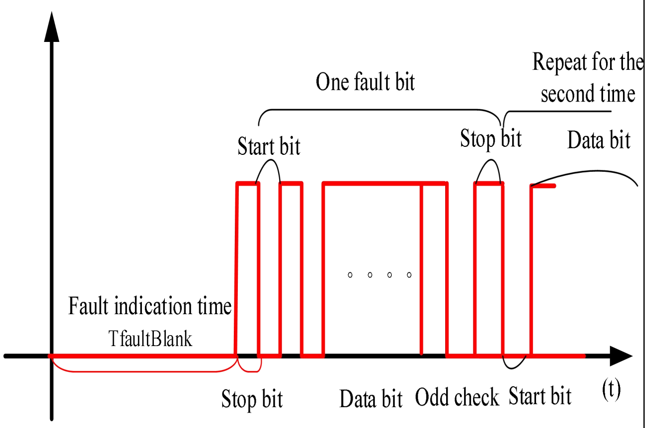


Fig.10 Fault communication schematic

The specific fault codes are shown below:

Symbol	Conditions	Min	Type	Max	Unit
Fault					
TfaultBlank	FAULT signal fault indication time		100		ms
Fault Bit	note: 0 – 15 If fault is Free, the fault bit holds default high '1'				
0	IGBT 1 (top IGBT) short-circuit; 1 for normal; 0 for fault		Bool		
1	IGBT 1 (top IGBT) power supply undervoltage; 1 for normal; 0 for fault		Bool		
2	IGBT 2 (bottom IGBT) short-circuit; 1 for normal; 0 for fault		Bool		
3	IGBT 2 (bottom IGBT) power supply undervoltage; 1 for normal; 0 for fault		Bool		
4	IGBT 3 short-circuit; 1 for normal; 0 for fault		Bool		
5	IGBT 3 power supply undervoltage; 1 for normal; 0 for fault		Bool		
6	IGBT 4 short-circuit; 1 for normal; 0 for fault		Bool		
7	IGBT 4 power supply undervoltage; 1 for normal; 0 for fault		Bool		
8	IGBT 5 short-circuit fault; 1 for normal; 0 for fault		Bool		
9	IGBT 5 power supply undervoltage; 1 for normal; 0 for fault		Bool		
10	IGBT 6 short-circuit; 1 for normal; 0 for fault		Bool		
11	IGBT 6 power supply undervoltage; 1 for normal; 0 for fault		Bool		
12	Primary side undervoltage; 1 for normal; 0 for fault		Bool		

13(Reserved)	Gate monitoring; 1 for normal; 0 for fault		Bool		
14(Reserved)	Overheating fault; 1 for normal; 0 for fault		Bool		
15(Reserved)	Other faults; 1 for normal; 0 for fault		Bool		



1. Fault signal indication time TfaultBlank=100ms
2. Fault signal communication protocol is serial interface.
   - Baud: 19200 (each roughly 52μs)
   - Start bit: 1 bit
   - Data bit: 16 bits
   - Odd check: 1 bit
   - Stop bit: 1 bit
3. A single fault needs to be repeated and reported 3 times in 10 consecutive groups.
4. The Fault signal is considered to have a cable fault if no data is output after pulling down TfaultBlank.

Fig.11 Fault communication timing diagram

◆ Intelligent fault management system

In NPC I-type 3-level, the DC bus voltage $V_{DC\text{-}LINK}$ is higher than the withstand voltage value of any IGBT, so whether in normal operation or fault condition, it must be ensured that the IGBT outside S_4(S_1) is turned off before the IGBT outside S_3(S_2), otherwise S_3(S_2) will be damaged because of withstanding the full DC bus voltage $V_{DC\text{-}LINK}$ alone.

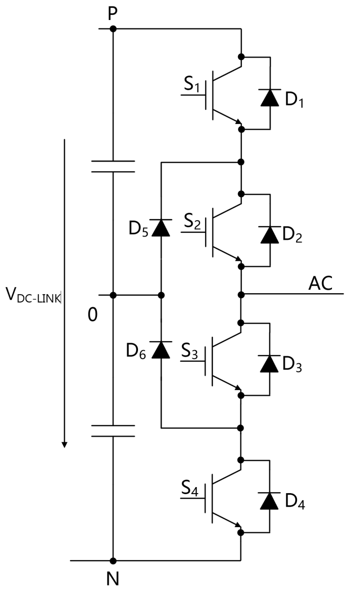


Fig. 12 NPC I-type 3-level topology

In the traditional I-type 3-level gate driver design, the correct turn-off timing is generally ensured by the master computer, for example, when a short-circuit fault occurs in S_3, the driver board first informs the master computer of the fault signal of S_3, and then the master computer will unify and coordinate the turn-off timing, and thus there are also several risks as follows:

1, Short-circuit protection time exceeds the maximum withstand time of IGBT: S_3 itself short-circuit detection time is generally about 8μs, plus the fault communication time, the master computer filtering time, as well as the turn-off time of S_4 (high-voltage high-power module turn-off time is generally longer, in the range of 4~6μs), the entire protection time will be more than 10μs, which also exceeds the short-circuit safety of the IGBT operating range;

2, Protection is dependent on the master computer: from the single point of failure analysis, when the master computer fails, the protection can not be completed properly, there are security risks.

Another risk is that traditional driver IC and even the vast majority of plug-and-play drivers tend to directly turn off the IGBT in the event of an undervoltage fault, which is not applicable to the NPC I-type 3-level scheme, resulting in a significant safety risk.

Based on the analysis above, Firstack has developed a drive solution specifically for NPC

I-type 3-levels: by integrating Firstack's unique "intelligent fault management system" on the primary side, it ensures the correct turn-off timing under any operating conditions.

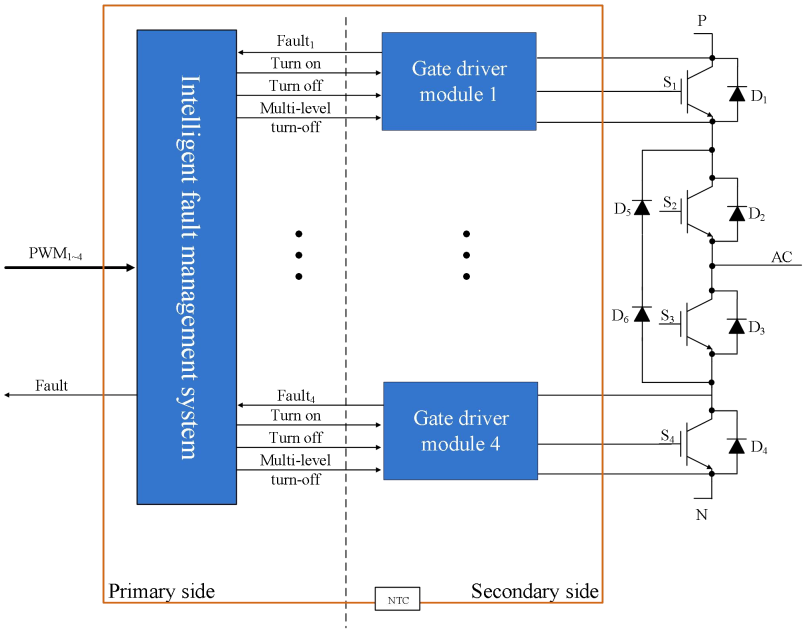


Fig. 13 Intelligent fault management system

The intelligent fault management system will monitor all six PWM signals and all six IGBT status in real time, and then give the optimal operation instruction through Firstack's unique control algorithm. When the whole machine is in continuous operation and the following faults occur, safety can be ensured:

1: PWM command fault: when the master computer is disturbed and sends wrong commands, or the PWM transmission path is disturbed and wrong commands appear on the gate driver side;

2: Connector disconnection: in the operation of the whole machine, the connector is disconnected due to vibration and other factors, resulting in uncontrolled PWM command status;

3: Gate driver power supply abnormality: in the operation of the whole machine, because of the failure of the power supply terminal, causing the gate driver power supply abnormality.

4: Short-circuit/undervoltage fault.

Change information

Date	Description	Note
2025-4-11	First version of data sheet	

Ordering information

The 6FHS0660MC1G15V-Y0101 supports different models of modules 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 and technical support. Please contact the Firstack technical sales team if you require the application manual for further information of the technical application.

Legal disclaimer

This manual gives a detailed introduction about the product, but cannot promise to provide specific parameters. No warranty or guarantee, express or implied, is given herein as to the delivery, performance or applicability of the product.

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