Three-Phase Full-Bridge Intelligent Power Module

1、 Summary

The SPB10CDG is a three-phase IGBT inverter module featuring an integrated IGBT and its gate driver chip, designed for driving brushless DC motors and permanent magnet brushless motors. The gate driver chip is optimized for IGBTs to minimize switching losses and electromagnetic interference (EMI), while incorporating multiple protection functions including undervoltage lockout, overcurrent protection, and fault reporting. A built-in thermistor provides temperature monitoring. The high-side IGBT's drive circuit utilizes a self-boost power supply design requiring only a single power supply. Each low-side IGBT's emitter is individually routed, enabling three-phase current sampling and support for various control algorithms. The circuit is packaged in a DIP-24H package with heat sinks.

Characteristic

600V/10A three-phase IGBT inverter module with built-in IGBT, FWD, BSD, HVIC, LVIC

The high side drive circuit uses the bootstrap method to generate a floating power supply and has a bootstrap diode with a current limiting resistor built in

The gate driver chip has a variety of protection functions, including under voltage protection, over current protection, over temperature protection

Fully compatible with the interface of 3.3V,5V and 15V MCU

The negative end of the three-phase is drawn separately for current detection

Fault status report output

Linear temperature sensing output

Encapsulation: HDIP24 with heat sink

2、 Function Block Diagram and Pin Description

2. 1. Function Block Diagram

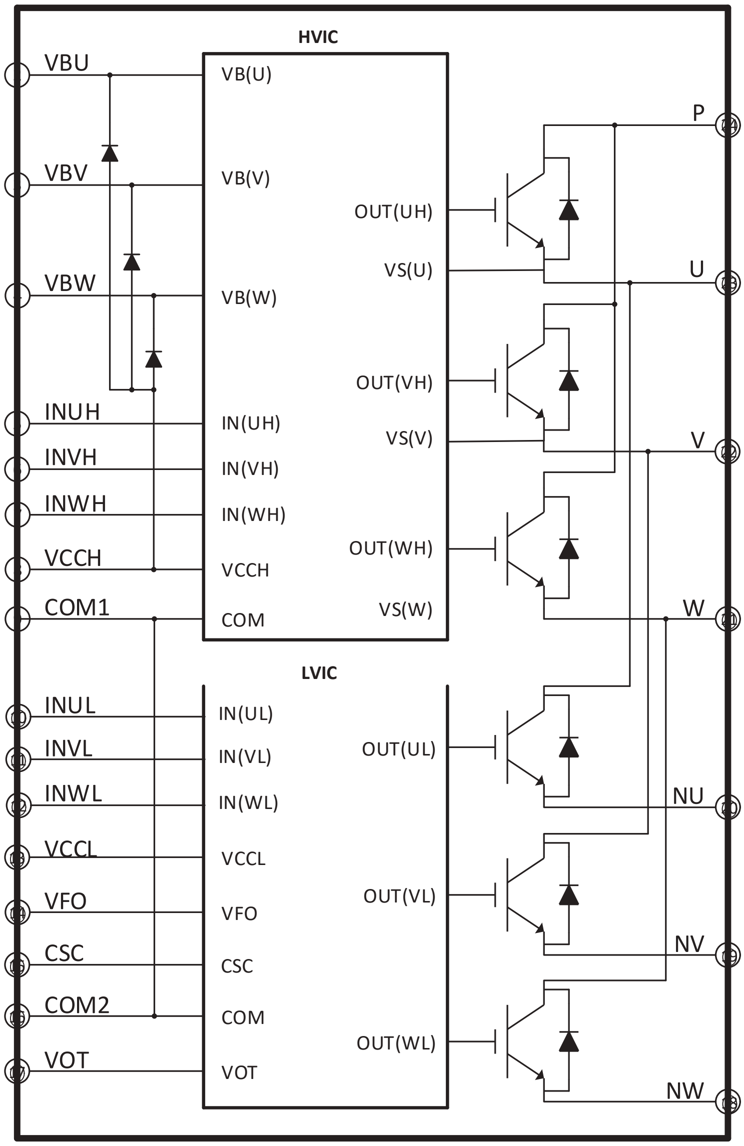

Figure 1 SPB10CDG Functional Block Diagram

2. 2. Functional Description

The SPB10CDG circuit integrates high-voltage ICs (HVIC), low-voltage ICs (LVIC), power devices (IGBT), freewheeling diodes (FRD), and bootstrap diodes (BSD), significantly enhancing integration density. Multiple protection features are incorporated to further improve circuit reliability. The emitter terminals of the three low-side IGBTs are separately routed, enabling independent sampling of three-phase currents for diverse drive configurations. The high-side IGBT's driver circuit employs a bootstrap method to generate floating power supply, with integrated bootstrap diodes requiring minimal external components. All three-phase floating power supplies incorporate undervoltage protection to prevent IGBT operation under high-power states. The SPB10CDG offers comprehensive protection mechanisms including undervoltage, overtemperature, and overcurrent safeguards. Additionally, it integrates a temperature sensing module that outputs an analog voltage proportional to temperature, facilitating MCU monitoring of IPM module thermal performance.

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2. 3. Pin Arrangement Diagram

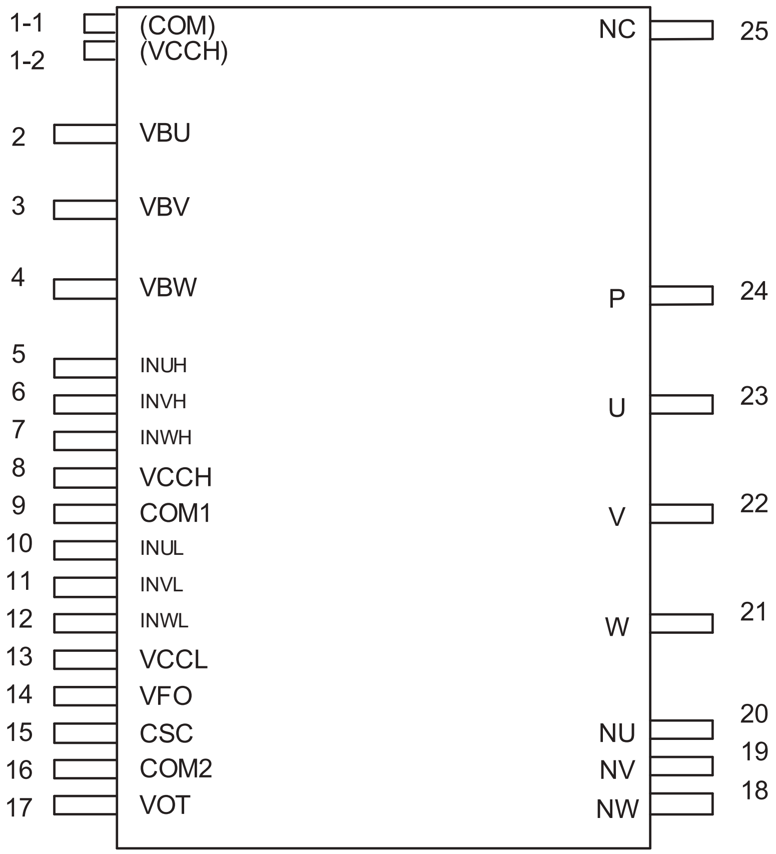

Figure 2 Pin Arrangement

2. 4. Pin Description

pin	Title	Description of the function of the leg
1-1	(COM)	Internal public ground terminal, no connection
1-2	(VCCH)	Internal power terminals, no connection
2	VBU	U phase high side IGBT drive suspension supply voltage
3	VBV	V phase high side IGBT drive suspension power supply voltage
4	VBW	V phase high side IGBT drive suspension supply voltage
5	INUH	U phase high side signal input
6	INVH	V Phase high side signal input
7	INWH	W phase high side signal input
8	VCCH	High side gate drive power supply voltage
9	COM1	Common to all modules
10	INUL	U phase low side signal input
11	INVL	V phase low side signal input
12	INWL	W phase low side signal input

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pin	Title	Description of the function of the leg
13	VCCL	Low side gate drive power supply voltage
14	VFO	Fault outputs
15	CSC	External capacitor, used for short circuit current detection input and low pass filter
16	COM2	Common to all modules
17	VOT	Temperature output terminal
18	NW	W phase DC negative end
19	NV	V phase DC negative end
20	NU	U phase DC negative terminal
21	W	W-phase output
22	V	V-phase output
23	U	U phase output
24	P	DC positive
25	NC	connectionless

3、 Electrical Characteristics

3. 1. Limiting Parameters (note 1)

Parameter Name	symbol	Scope of parameters	unit
IGBT part			
supply voltage	V_{PN}	450	V
Power supply voltage surge voltage	$V_{PN（SURGE）}$	500	V
Cathode-emitter voltage	V_{CES}	600	V
The continuous collector current of a single IGBT, T_C=25℃, T_J<150℃	I_C	10	A
The collector peak current of a single IGBT, T_C= 25℃, T_J<150℃, pulse width <1ms	I_{CP}	20	A
Maximum power dissipation of collector electrode for a single IGBT, T_C=25 ℃	P_C	20	W
control section			
Control the power supply voltage	V_{CC}	20	V
Voltage of floating power supply	V_{BS}	20	V
Input signal voltage	V_{IN}	-0.5~V_{CC}+0.5	V
Fault output voltage	V_{FO}	-0.5~V_{CC}+0.5	
Fault output current, VFO terminal injection current	I_{FO}	1	mA
Input voltage to current detection terminal	V_{SC}	-0.5~V_{CC}+0.5	V

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Parameter Name	symbol	Scope of parameters	unit
Self-oscillating diode section			
Maximum repeated reverse voltage	V_{RRM}	600	V
Forward current, T_C= 25℃, T_J<150℃	I_F	0.5	A
Positive peak current, T3=25℃, T4 <150℃ pulse width <1ms	I_{FP}	1.5	A
junction temperature	T_J	-40~150	
overall unit			
Short circuit protection limit voltage, V_{CC}=V_{BS}=13.5V~16.5V, T_J=150℃, single time and less than 2μs	$V_{PN（PROT）}$	400	V
Working shell temperature range, -40℃ ≤T_J≤150℃ (Note 2)	T_C	-20~100	
Storage temperature range	T_{STG}	-40~125	
IGBT shell thermal resistance	$R_{\theta JCQ}$	3.0	/W
FRD Shell thermal resistance	$R_{\theta JCF}$	3.9	/W
Insulated voltage 60Hz, sine wave, 1 minute connection of pins to heat sink	V_{ISO}	1500	Vrms
Installation twist Installation screw: -M 3, recommended value 0.62N.m	T	0.5~0.8	N.m

Note 1: The maximum limit value refers to the condition beyond which the chip may be damaged. The electrical parameters define the specifications of DC and AC parameters of the device within the operating range and under test conditions that guarantee specific performance indicators;

Note 2: The maximum junction temperature of the power chip is 150℃. In order to ensure the safe operation of the IPM, it is recommended that the average junction temperature T_J≤130℃ (@Tc ≤100℃)

3. 2. Recommended Working Conditions

Parameter Name	symbol	Regulatory values			unit
		minimum	typical case	maximum	
Bus voltage between PN	V_{PN}	-	300	400	V
Control the power supply voltage	V_{CC}	13.5	15	16.5	V
High side control voltage	V_{BS}	13.5	15	16.5	V
Control voltage fluctuations	dV_{CC}/dt dV_{BS}/dt	-1	-	1	V/μs
Input turn-on threshold voltage	$V_{IN（ON）}$	3.0	-	V_{CC}	V
Input turn-off threshold vol age	$V_{IN（OFF）}$	0	-	0.6	V
Prevent dead time when	T_{DEAD}	1.0	-	-	μs

bridge arms are straight through					
PWM switching freque-ncy	f_{PWM}	-	-	20	KHz
COM variations (between COM -N U , N V , and N W)	V_{COM}	-5	-	5	V

3. 3. Electrical Properties

Unless otherwise specified, Tamb = 25℃, $V_{CC}=V_{BS}=15V$

Parameter Name		symbol	test condition	Regulatory values: minimum	Regulatory values: typical case	Regulatory values: maximum	unit
IGBT part							
Cathode-emitter saturation voltage		$V_{CE(SAT)}$	$V_{CC}=V_{BS}=15V$ $V_{IN}=5V$, $I_C=10A$ $T_J=25$	-	2.0	2.3	V
Collector-emitter leakage current		I_{CES}	$V_{CE}=V_{CES}$	-	-	1	mA
FRD direct voltage		V_F	$V_{IN}=0V$, $I_F=10A$ $T_J=25$	-	-	2.5	V
switching time	High side	t_{ON}	$V_{PN}=300V$ $V_{CC}=V_{BS}=15V$ $I_C=10A$ $V_{IN}=0V\sim5V$	-	0.95	-	μs
		$t_{C(ON)}$		-	0.35	-	μs
		t_{OFF}		-	0.95	-	μs
		$t_{C(OFF)}$		-	0.13	-	μs
		t_{RR}		-	0.06	-	μs
	low side	t_{ON}		-	0.85	-	μs
		$t_{C(ON)}$		-	0.35	-	μs
		t_{OFF}		-	0.85	-	μs
		$t_{C(OFF)}$		-	0.13	-	μs
		t_{RR}		-	0.06	-	μs
control section							
VCC static current (ON)		I_{QCC_ON}	$V_{CC}=15V$, $V_{IN}=5V$	-	-	2.8	mA
VCC static current (OFF)		I_{QCC_OFF}	$V_{CC}=15V$, $V_{IN}=0V$	-	-	2.8	mA
VBS quiescent current		I_{QBS}	$V_{CC}=V_{BS}=15V$ $V_{INH(UVW)}=0V$	-	-	80	μA
The fault output has a high voltage		V_{FOH}	$V_{CSC}=0V$, VFO pull-up 10kΩ resis-	4.9		-	V

		tor to 5V				
The fault outputs a low voltage	V_{FOL}	V_{CSC}=1V, I_{FO}=1mA	-	-	0.95	
Fault outputs pulse length	T_{FO}	V_{CC}=15V	20	60	-	
short-circuit protection trigger voltage	V_{CS}	V_{CC}=15V	0.43	0.48	0.53	

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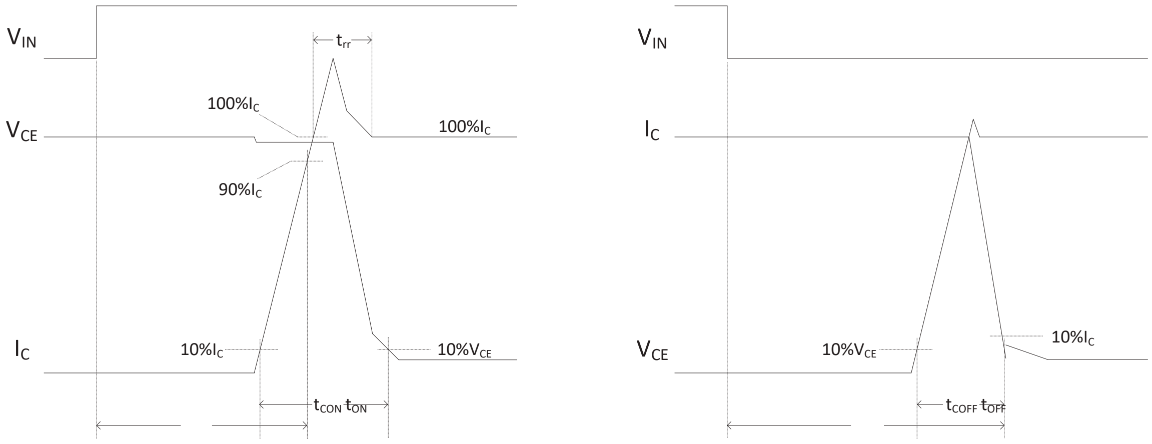
Parameter Name	symbol	test condition	Regulatory values			unit
			minimum	typical case	maximum	
Overtemperature protection	T_{SD}	V_{CC}=15V	110	130	150	
Overtemperature protection hysteresis	T_{SD}	V_{CC}=15V	-	10	-	
Temperature outputs	V_{OT}	T_A=25	0.88	1.13	1.39	
		T_A=90	2.63	2.77	2.91	
VCC under-voltage protection action voltage	UV_{CCD}	-	10.5	11.5	12.5	
VCC under-voltage protection recovery voltage	UV_{CCR}	-	11.0	12.0	13.0	
VBS under-protected action voltage	UV_{BSD}	-	9	10	11	
VBS Under-Pressure Protection Recovery Voltage	UV_{BSR}	-	9.5	10.5	11.5	
Input start voltage	V_{IH}	V_{CC}=15V	-	2.4	2.9	
Input cutoff voltage	V_{IL}	V_{CC}=15V	0.8	1.3	-	
Self-oscillating diode section						
direct voltage	V_F	I_F=0.1A, T_C=25	-	10.7	-	
reverse recovery time	t_{RR}	I_F=0.1A, T_C=25	-	80	-	



(1) Definition of Activation Time

(2) Definition of off Time

Figure 3 Switching Time Definition

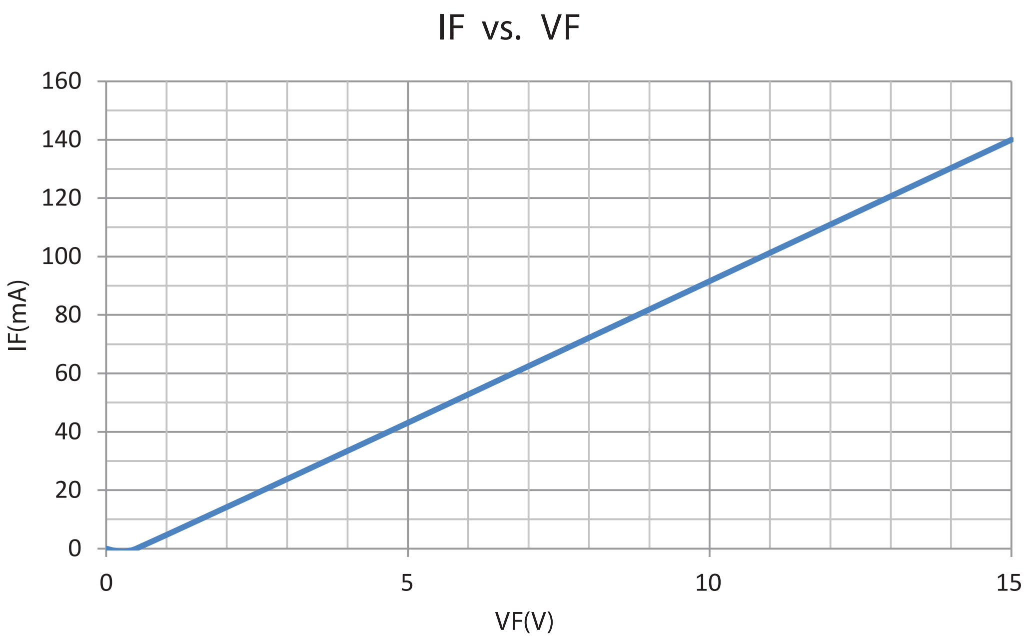


FIG. 4 Self-举二极管 Characteristic Curve

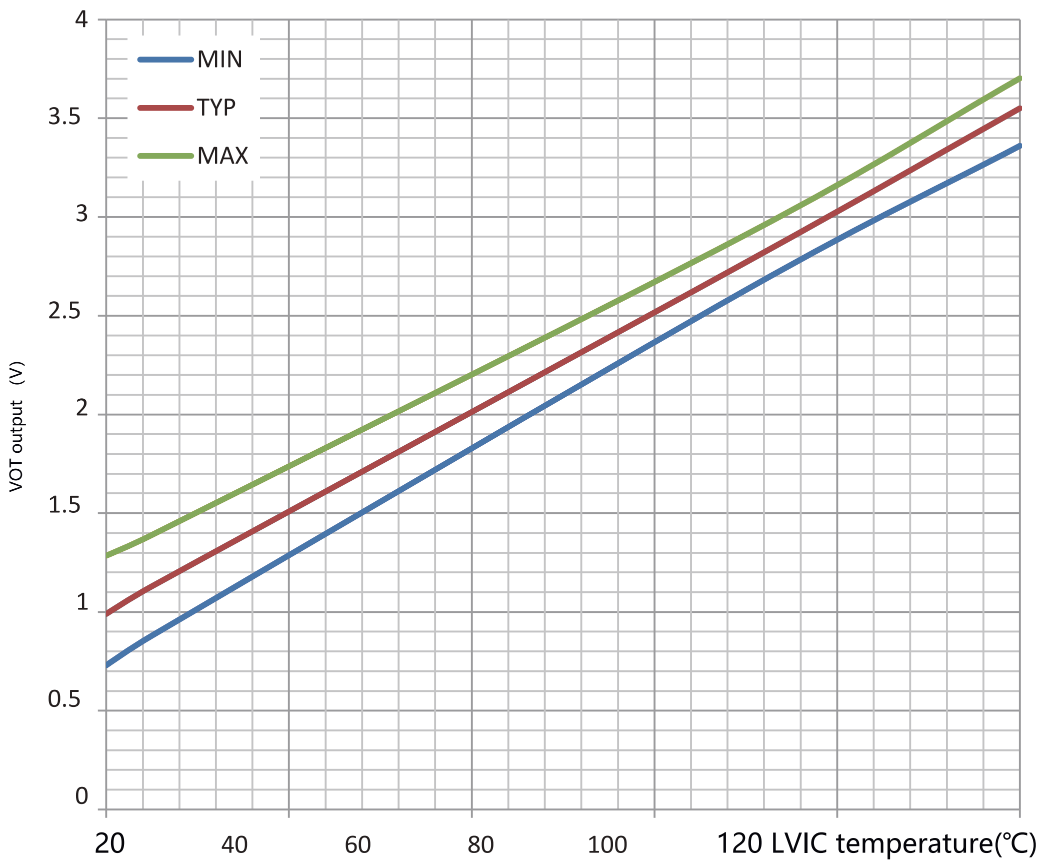


Figure 5 Output Characteristics of V_{OT}

4、 Functional Description

4. 1. Description of Overtemperature Protection Function

The low side LVIC has overtemperature protection function, and its working sequence is as follows:

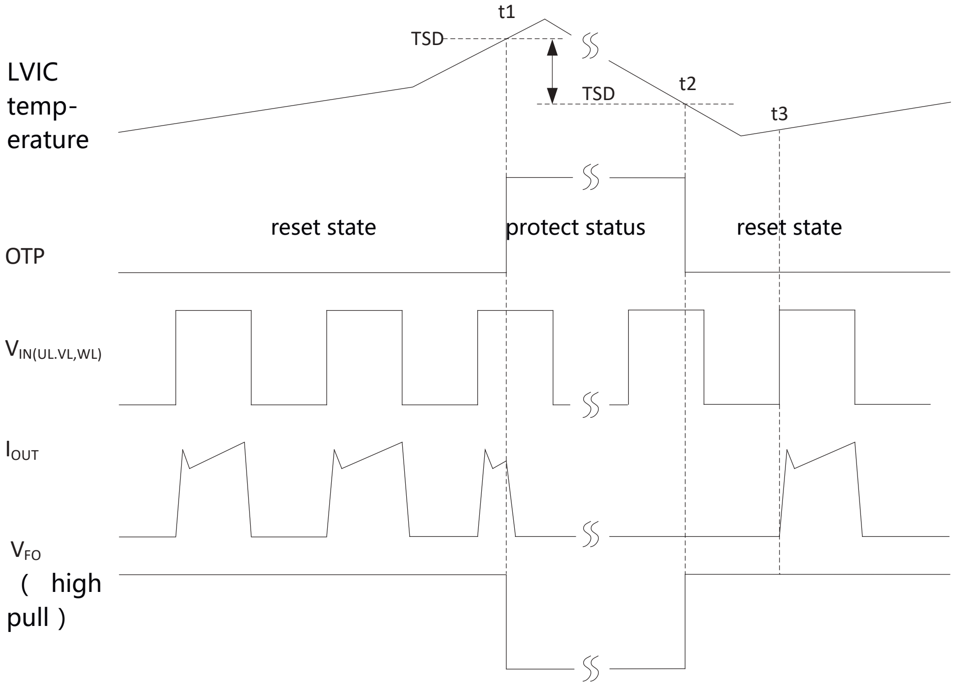


Figure 6 LVIC Overtemperature Protection Function Timing Diagram

0~t1: Before the temperature of LVIC rises to the overtemperature protection point, the circuit works normally. At this time, the current is provided to the load and V_{FO} outputs a high level, that is, the fault-free state;

t1~t2: After the temperature of LVIC rises to the overtemperature protection point, the circuit will not respond to the input signal, all low-side IGBT are turned off, and the VFO outputs a low level to report the fault status;

t2~t3: After the temperature of LVIC drops to the overtemperature protection recovery point, the circuit will not respond to the input signal immediately, but will wait for the next on signal of the input signal. At this time, the VFO outputs a high level, that is, the fault-free state;

t3: The circuit works normally, the IGBT is on, and the current is provided to the load.

(TSD and △TSD parameter values are shown in the electrical characteristics section of Chapter 3)

4. 2. Description of Low Side Undervoltage Protection Function

The low side control power supply V_{CCL} has undervoltage lockout protection function, and its working timing is as follows:

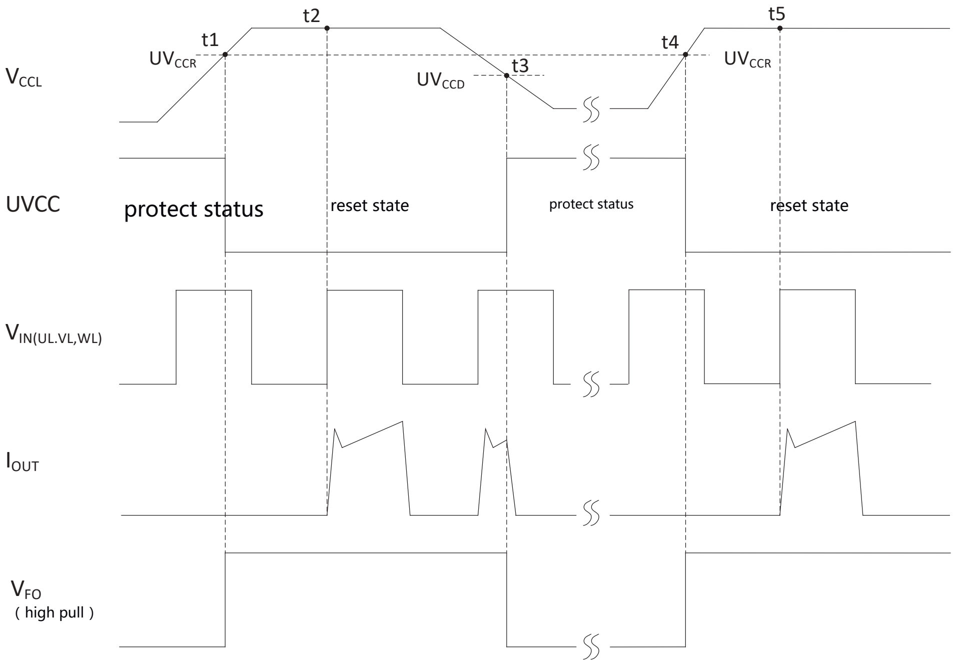


Figure 7 Schematic Diagram of Control Power Supply Under-Voltage Lockout Function

0~t1: Before V_{CCL} rises to the UV_{CCR} threshold, the UVCC is in the protection state and the circuit does not respond to the input signal. At this time, V_{FO} outputs a low level and reports the fault status;

t1~t2: When V_{CCL} rises above UV_{CCR}, the circuit does not respond to the input signal immediately, but waits for the next — on signal of the input signal. At this time, V_{FO} outputs a high level, that is, no fault state;

t2~t3: the circuit works normally;

t3~t4: When V_{CCL} drops to the UV_{CCD} threshold, the circuit enters the under-voltage lockout protection state and the output is immediately turned off. In the protection state, V_{FO} outputs a low level to report the fault status;

t4: When V_{CCL} rises above UV_{CCR}, UVCC enters the reset state, and the circuit works normally from the next on signal of the input signal;

t5: The circuit works normally, and the IGBT is on to provide current to the load.

(See chapter 3, electrical characteristics section for parameter values of <UV> 15</UV> and <UV>16</UV>)

4. 3. Description of High Side Undervoltage Protection Function

The floating power supply of the three channels on the high side has undervoltage lockout protection function (no V_{FO} fault report), and its working sequence is as follows:

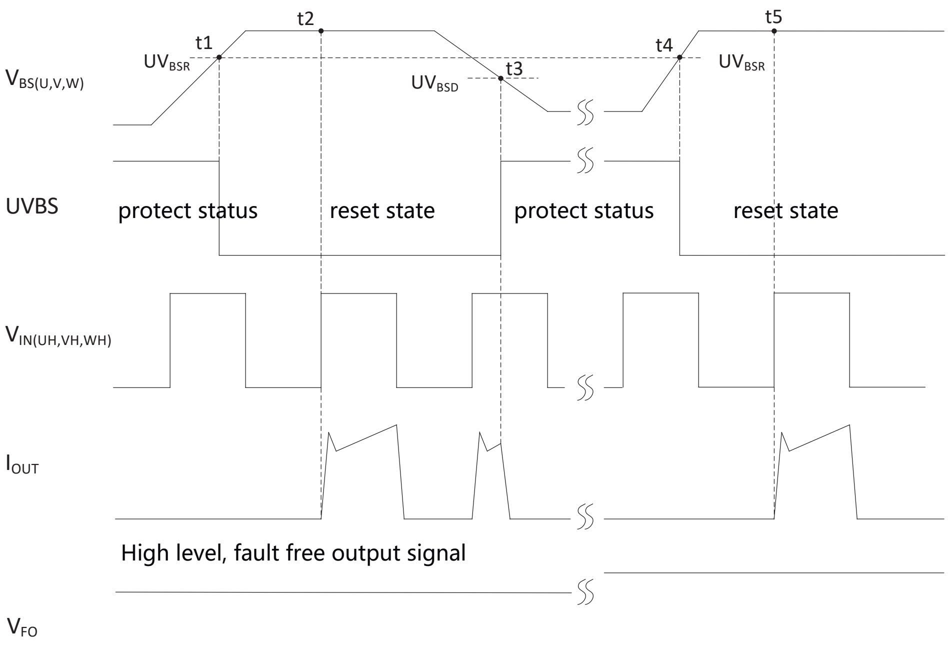


Figure 8 Floating Power Supply Under Voltage Lock Function Timing Diagram

0~t1: Before V_{BS} rises to UV_{BSR} threshold, UVBS is in the protection state, and the circuit does not respond to the input signal;

t1~t2: When V_{BS} rises above UV_{BSR}, the circuit does not respond to the input signal immediately, but waits for the next on signal of the input signal;

t2~t3: normal operation of the circuit;

t3~t4: When V_{BS} drops to UV_{BSD} threshold, the circuit enters the undervoltage lockout protection state, and the output is immediately turned off;

t4: When V_{BS} recovers to above UV_{BSR}, UVBS enters the reset state, and the circuit works normally from the next on signal of the input signal;

t5: The circuit works normally, the IGBT is on, and the current is provided to the load;

0 ¯t5: Since V_{FO} only outputs the fault signal of the control power supply undervoltage lock, no fault signal is output no matter whether the floating power supply is in the protection state or not. V_{FO} always stays at a high level.

(See chapter 3, electrical characteristics section for parameter values of UV_{BSD} and UV_{BSR})

4. 4. Description of Overcurrent Protection Function

The LVIC integrates short-circuit protection functionality. By sampling the IGBT's operating current through external current sampling resistor R_{CS}, the voltage is filtered via RC and connected to port C_{SC}. When a short circuit occurs, if the sampled voltage at port C_{SC} exceeds its protection threshold (0.48V), the LVIC activates short-circuit protection. Port V_{FO} outputs a low-level signal indicating a fault condition. The gate signal of the low-side IGBT enters soft shutdown mode to prevent circuit failure caused by excessive dI/d_T. After complete IGBT shutdown, the short-circuit protection remains active for a duration (no less than 60μs), during which the LVIC remains in inactive state.

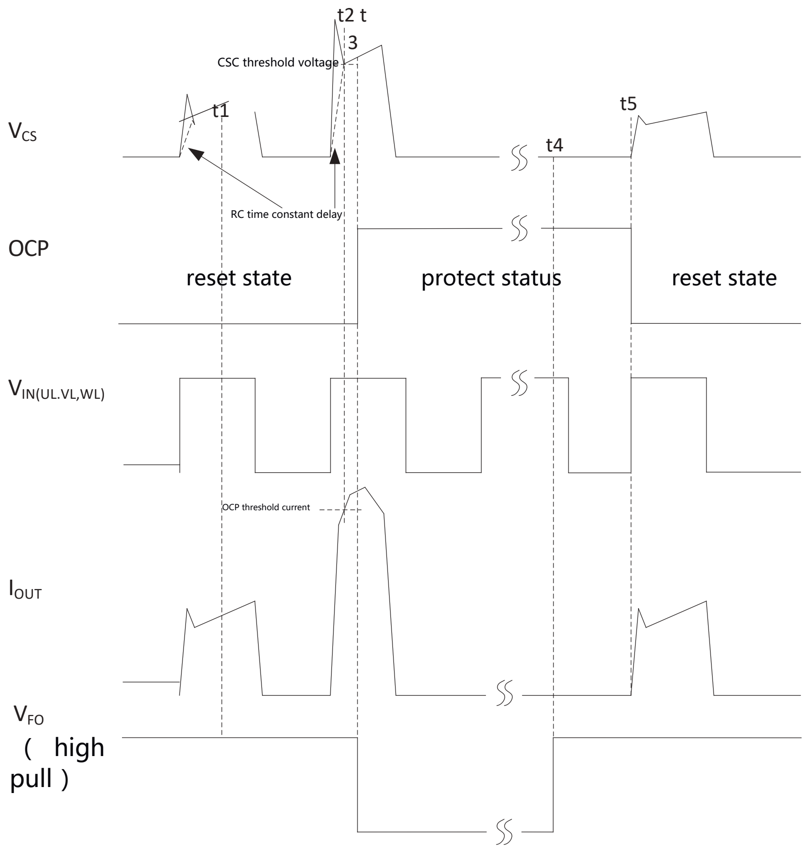


Figure 9 Current Protection Function Timing Diagram

0~t1: The circuit works normally, the IGBT is on, the current is provided to the load, V_{FO} is always in a high level, and no fault signal is output;

t1~t2: When the OCP voltage monitored on V_{CS} exceeds the threshold voltage, the overcurrent protection is triggered, but at this time, V_{FO} is still in a high level and no fault signal is output;

t2~t3: The fault protection module detects the overcurrent fault, V_{FO} is set to low level, all the gate of the low-side IGBT is hard interrupted, the output is immediately shut down, and the output fault signal is sent;

t3~t4: The fault protection state is maintained for at least 60μs. When the OCP enters the reset state, the circuit starts to work normally from the next on signal of the input signal;

t5: The circuit works normally, the IGBT is on, and the current is provided to the load;

(The V_{CS} OCP threshold voltage parameter value is shown in Chapter 3, electrical characteristics)

5、 Typical Application Lines and Application Instruc-tions

5. 1. Application Lines

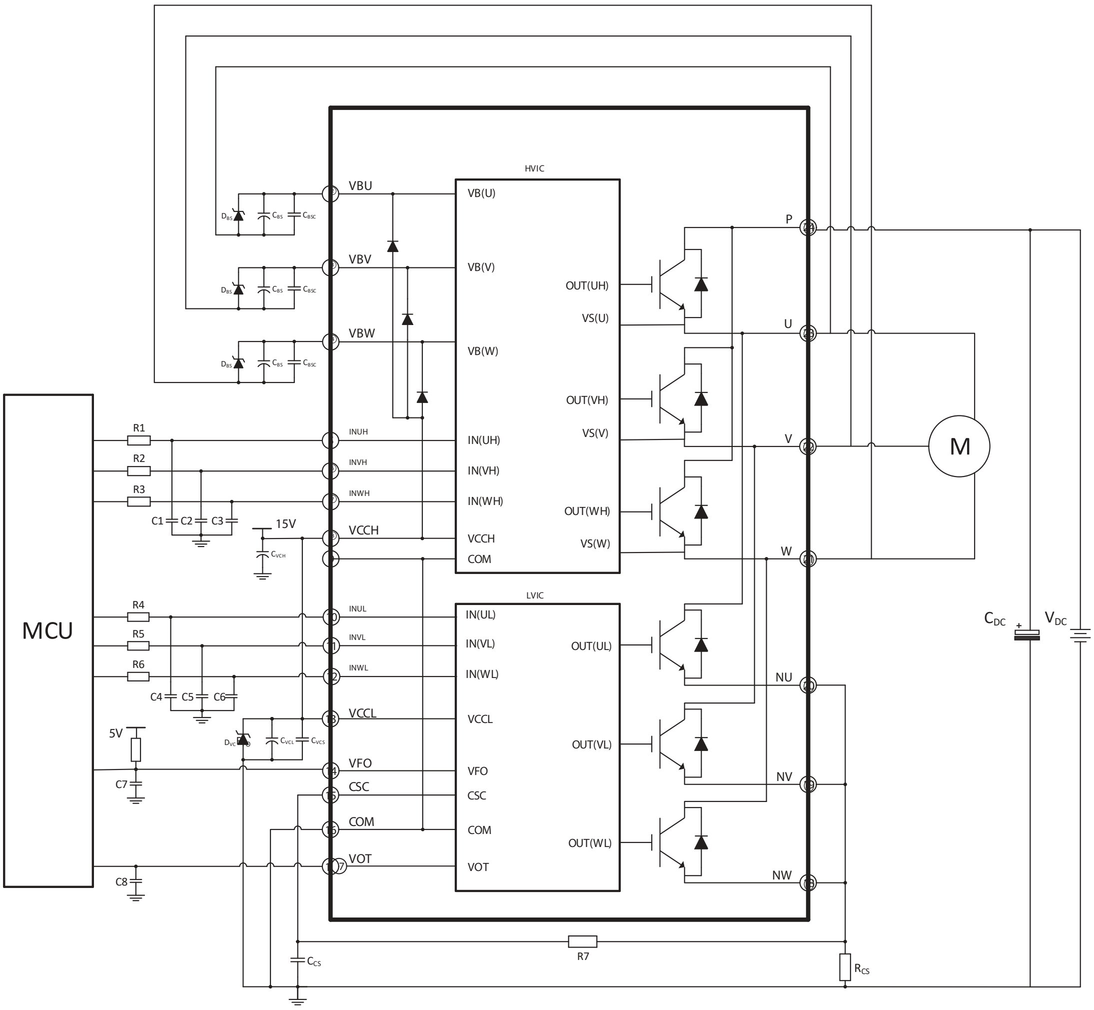


Figure 10 SPB10CDG Typical Application Circuit

5. 2. Application Note

Note 1: the wiring of each input pin should be as short as possible, otherwise it may cause false action;

Note 2: The input signal is high level effective. There is a 5KΩ pull-down resistor connected to ground at the input of each channel in HVIC. In addition, an RC filter circuit can be added at the input end to prevent surge noise caused by incorrect input;

Note 3: In order to prevent surge damage, it is recommended to add a high frequency non-inductive smoothing capacitor (0.1μF~0.22μF) between PN, and the connection of the capacitor should be as short as possible;

Note 4: The connection between the current detection resistor and the IPM should be as short as possible, otherwise the large surge voltage generated by the connecting inductor may cause damage;

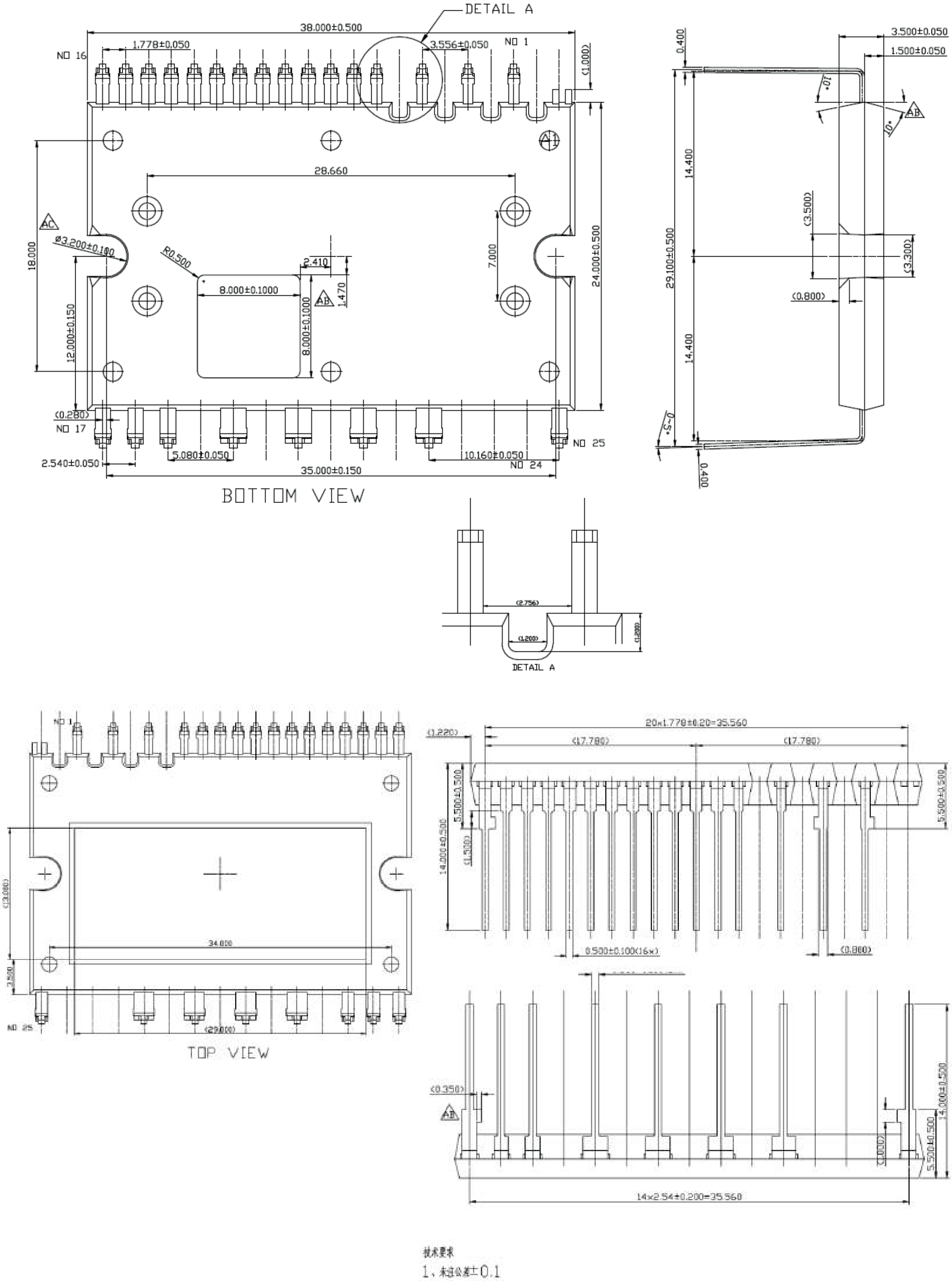
Note 5: The filter capacitor at the 15V power input is recommended to be at least 7 times the self-elevation capacitor CBS;

Note 6: Each external capacitor should be placed as close as possible to the IPM pin;

Note 7: VFO is an open drain output pin, which should be pulled up to 5V power supply through RFO resistor, so that I_{FO} is 1mA. Do not use it when not in use;

Note 8: In the short circuit protection circuit, please select RCS and CCS with a time constant in the range of 1.5μs to 2 μs, and the wiring around RCS and CCS should be as short as possible, and the wiring of RCS should be close to the shunt resistor.

6、 Encapsulation Size and Shape Diagram (unit: Mm)



Description of Toxic and Harmful Substances or Elements in the Product

Name and content of toxic or harmful substances or elements in the product

Part name	Toxic and harmful substances or elements					
	lead (Pb)	mercury (Hg)	cadmium (Cd)	hexavalent chromium (Cr^{+6})	Polybrominated biphenyl (PBB)	Polychlorinated biphenyls (PBDE)
lead frame						
Resin molding						
slug						
intraconnection track						
Film packaging						
explain	: indicates that the content of the toxic and harmful substance is below the limit requirements of GBT26572-2011 standard. ×: indicates that the content of the toxic and harmful substance exceeds the limit requirements of GBT26572-2011 standard.					