MITSUBISHI ELECTRIC

<DIPIPM>

Super mini DIPIPM Ver.6 Series APPLICATION NOTE
PSS**S92E6-AG/ PSS**S92F6-AG

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CHAPTER 1 INTRODUCTION

1.1 Features of Super mini DIPIPM Ver.6

Super Mini DIPIPM Ver.6 (hereinafter called DIP Ver.6) is an ultra-small compact intelligent power module with transfer mold package favorable for larger mass production. Power chips, drive and protection circuits are integrated in the module, which make it easy for AC100-240V class low power motor inverter control.

DIP Ver.6 takes over the functions of conventional DIP Ver.5 (such as incorporating bootstrap diode with resistor, analog signal output), additionally, DIP Ver.6 is improved more.

Main features of DIP Ver.6 are as below.

- ***Newly developed 7th generation CSTBT are integrated for improving efficiency.***
- ***Wider overload operating range by improvement in accuracy of short circuit trip level.***
- ***Expanding line-up up to 35A.***
- ***Easy to replace from conventional Ver.5 due to high pin compatibility.***

About detailed differences, please refer Section 1.5. Fig.1-1-1 and Fig.1-1-2 show the outline and internal cross-section structure respectively.

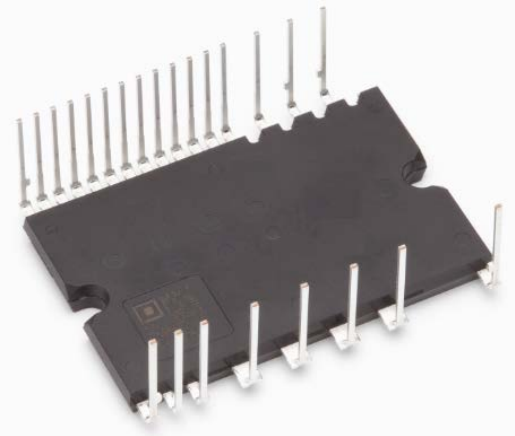


Fig.1-1-1 Package photograph

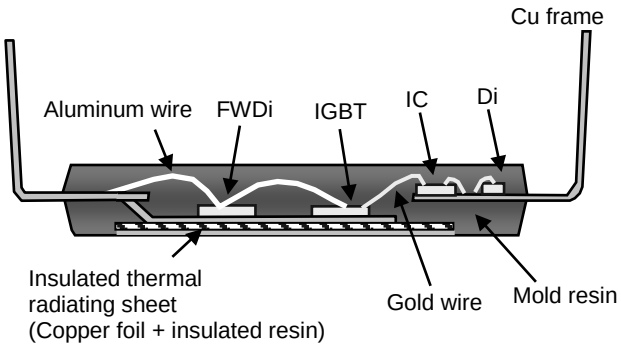


Fig.1-1-2 Internal cross-section structure

1.2 Functions

DIP Ver.6 has following functions and inner block diagram as described in Fig.1-2-1.

- For P-side IGBTs:
  - Drive circuit;
  - High voltage level shift circuit;
  - Control supply under voltage (UV) lockout circuit (without fault signal output).
  - Built-in bootstrap diode (BSD) with current limiting resistor
- For N-side IGBTs:
  -Drive circuit;
  -Short circuit (SC) protection circuit (by inserting external shunt resistor into main current path)
  -Control supply under voltage (UV) lockout circuit (with fault signal output)
  -Over temperature (OT) protection by monitoring LVIC temperature.(PSS**S92E6 series only)
  -Outputting LVIC temperature by analog signal (PSS**S92F6 series only)
- Fault Signal Output
  -Corresponding to N-side IGBT SC, N-side UV and OT protection. (OT:PSS**S92E6 series only)
- IGBT Drive Supply
  -Single DC15V power supply (in the case of using bootstrap method)
- Control Input Interface
  -Schmitt-triggered 3V, 5V input compatible, high active logic.
- UL recognized
  -UL 1557 File E323585

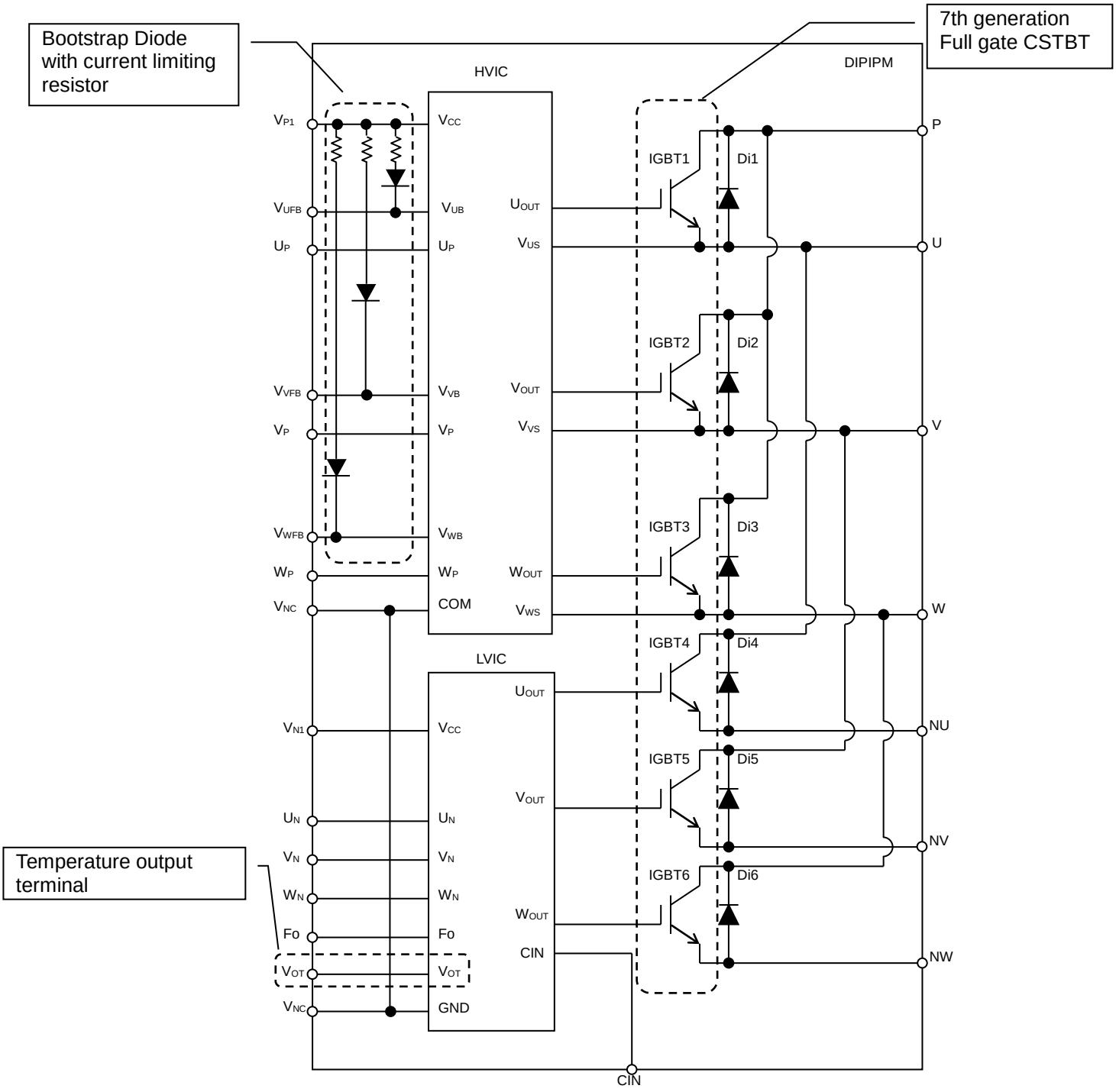


Fig.1-2-1 Inner block diagram

1.3 Target Applications

Motor drives for household electric appliances, such as air conditioners, washing machines, refrigerators
Low power industrial motor drive except automotive applications

1.4 Product Line-up

Table 1-4-1 DIP Ver.6 Line-up ***with temperature output function***

Type Name (Note 1)	IGBT Rating	Motor Rating (Note 1)	Isolation Voltage
PSS05S92F6-AG	5A/600V	0.4kW/220VAC	V_{iso} = 1500Vrms (Sine 60Hz, 1min All shorted pins-heat sink)
PSS10S92F6-AG	10A/600V	0.75kW/220VAC	
PSS15S92F6-AG	15A/600V	0.75kW/220VAC	
PSS20S92F6-AG	20A/600V	1.5kW/220VAC	
PSS30S92F6-AG	30A/600V	2.2kW/220VAC	
PSS35S92F6-AG	35A/600V	2.2kW/220VAC	

Table 1-4-2 DIP Ver.6 Line-up ***with over temperature protection function***

Type Name (Note 1)	IGBT Rating	Motor Rating (Note1)	Isolation Voltage
PSS05S92E6-AG	5A/600V	0.4kW/220VAC	V_{iso} = 1500Vrms (Sine 60Hz, 1min All shorted pins-heat sink)
PSS10S92E6-AG	10A/600V	0.75kW/220VAC	
PSS15S92E6-AG	15A/600V	0.75kW/220VAC	
PSS20S92E6-AG	20A/600V	1.5kW/220VAC	
PSS30S92E6-AG	30A/600V	2.2kW/220VAC	
PSS35S92E6-AG	35A/600V	2.2kW/220VAC	

Note 1: The motor ratings are simulation results under following conditions: V_{AC}=220V, V_D=V_{DB}=15V, Tc=100°C, Tj=125°C, f_{PWM}=5kHz, P.F=0.8, motor efficiency=0.75, current ripple ratio=1.05, motor over load 150% 1min.

1.5 The Differences between Previous Series and This Series (PSS**S92*6)

DIP Ver.6 has some differences against DIP Ver.4 (PS219A*) and DIP Ver.5 (PS219B*)
Main differences are described in Table 1-5-1, Table 1-5-2.

Table 1-5-1 Differences of functions and outlines

Items	Ver.4 with BSD	Ver.5	Ver.6	Ref.
Built-in bootstrap diodes 1)	Built-in	Built-in with current limiting resistor	←	Section 4.2
Temperature protection	OT (-T)	OT or VOT 2)	←	Section 2.2.4
Dummy terminal (Compare with PS2196*) 3)	Add one terminal (No. 1-B pin)	←	←	Section 2.3
N-side IGBT emitter terminal	Common / Open	Open3)	←	

(1) DIP Ver.5 and DIP Ver.6 have built-in bootstrap diodes (BSD) with current limiting resistors. So there aren't any limitation about bootstrap capacitance like PS219A* has (22μF or less in the case of one long pulse initial charging).

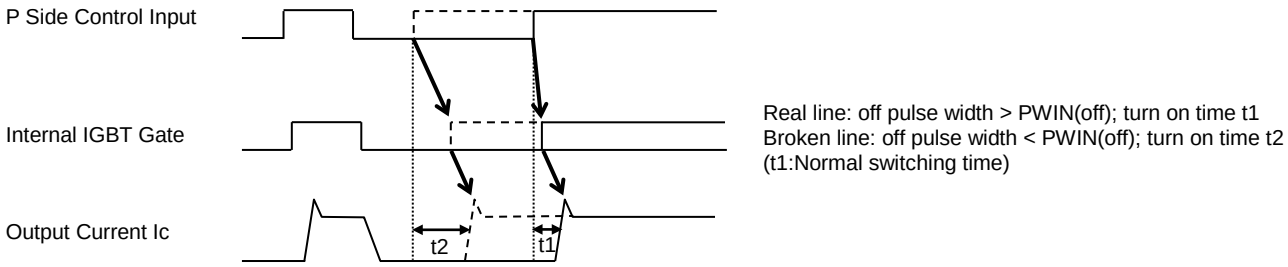
(2) Temperature protection function of both DIP Ver.5 and DIP Ver.6 is selectable from two functions. (They have different model numbers.) One is conventional over temperature protection (OT), and the other is LVIC temperature output function (V_{OT}). OT function shutdowns all N-side IGBTs automatically when LVIC temperature exceeds specified value (typ.120 °C). But V_{OT} function cannot shutdown by itself in that case. So it is necessary for system controller to monitor this V_{OT} output and shutdown when the temperature reaches the protection level.

(3) Because of incorporating bootstrap diodes, a part of package was changed. (Just one dummy terminal was added) But its package size, pin assignment and pin number weren't changed, so the same PCB can be used with small modification when replacing from Super min DIP Ver.4. (External bootstrap diodes and current limit resistors should be removed in the case of replacing from PS2196*. And also if N-side common emitter type was used in former PCB, it is necessary to change wiring from common emitter to open emitter wiring because of both DIP Ver.5 and DIP Ver.6 have open emitter type only.

Table 1-5-2 Differences of specifications and recommended operating conditions

Items	Symbol	Ver.4 with BSD	Ver.5	Ver.6	
				Current rating 5~20A	Current rating 30A, 35A
Circuit current for P-side driving	I_D	Max. 2.80mA	←	←	Max. 3.40mA
Circuit current for P-side driving	I_{DB}	Max. 0.10mA	←	←	Max. 0.30mA
Trip voltage for P-side control supply under voltage protection	UV_{DBt}	Min. 7.0V	←	←	Min. 10.0V
Reset voltage for P-side control supply under voltage protection	UV_{DBr}	Min. 7.0V	←	←	Min. 10.5V
Bootstrap Di forward voltage	V_F	Typ. 2.8V @100mA	Typ. 1.7V @10mA	←	Typ. 1.3V @10mA
Arm-shoot-through blocking time	t_{dead}	Min. 1.0μs	←	←	Min.2.0μs
Allowable minimum input pulse width	PWIN(on)	Min. 0.5μs	Min. 0.7μs	←	Min. 0.7μs
	PWIN(off)	Min. 0.5μs	Min. 0.7μs	←1)	Due to current rating1) Refer each datasheet
Short circuit trip level	$V_{SC(ref)}$	0.48V±0.05V	←	0.48V±0.025V 2)	

(1) IPM might make delayed response or no response for the input signal with off pulse width less than PWIN(off). Please refer below about delayed response. (Ver.6 30A, 35A products only. In the case of 5~20A products IPM might not make response. Refer the datasheet for each product.)
Delayed Response against Shorter Input Off Signal than PWIN(off) (30A and 35a products, P-side only)



(2) Short circuit trip level tolerance of DIP Ver.6 is improved to 0.48±5%. By this improvement, DIP Ver.6 has wider overload operating range.
If you use short circuit protection as a protection for degauss of motor, you can use at wider overload operating range due to improve trip level tolerance as in Fig.1-5-1.

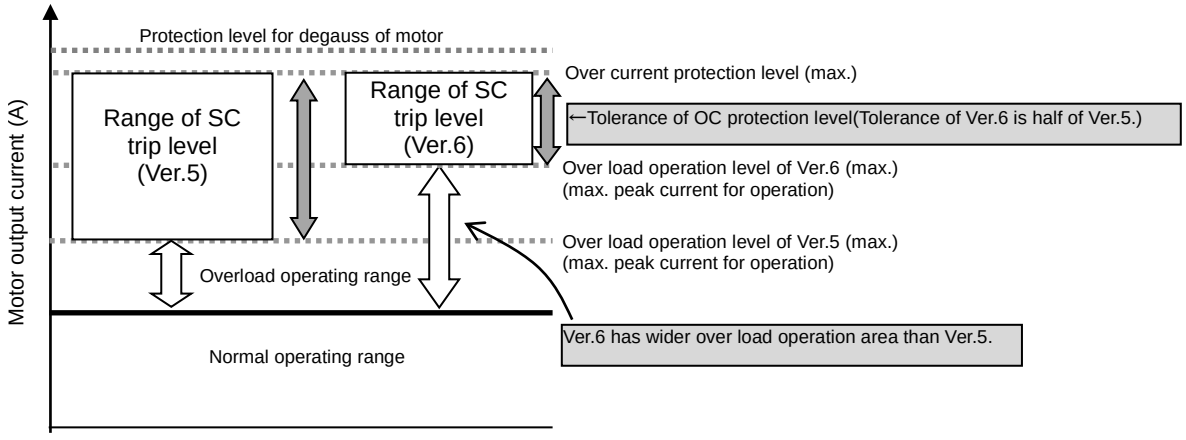


Fig.1-5-1 short circuit trip level

For more detail and the other characteristics, please refer the datasheet for each product.

CHAPTER 2 SPECIFICATIONS AND CHARACTERISTICS

2.1 Super Mini DIPIPM Ver.6 Specifications

DIP Ver.6 specifications are described below by using PSS15S92*6-AG (15A/600V) as an example. Please refer to respective datasheets for the detailed description of other types.

2.1.1 Maximum Ratings

The maximum ratings of PSS15S92*6-AG are shown in Table 2-1-1.

Table 2-1-1 Maximum Ratings

INVERTER PART

Symbol	Parameter	Condition	Ratings	Unit	
V_{CC}	Supply voltage	Applied between P-NU,NV,NW	450	V	(1)
$V_{CC(surge)}$	Supply voltage (surge)	Applied between P-NU,NV,NW	500	V	(2)
V_{CES}	Collector-emitter voltage		600	V	(3)
$\pm I_C$	Each IGBT collector current	T_C= 25°C (Note1)	15	A	(4)
$\pm I_{CP}$	Each IGBT collector current (peak)	T_C= 25°C, less than 1ms	30	A	
P_C	Collector dissipation	T_C= 25°C, per 1 chip	27.0	W	
T_j	Junction temperature	(Note2)	-30~+150	°C	(5)

Note1: Pulse width and period are limited due to junction temperature.
Note2: The maximum junction temperature rating of built-in power chips is 150°C(@Tc≤100°C).However, to ensure safe operation of DIPIPM, the average junction temperature should be limited to Tj(Ave)≤125°C (@Tc≤100°C).

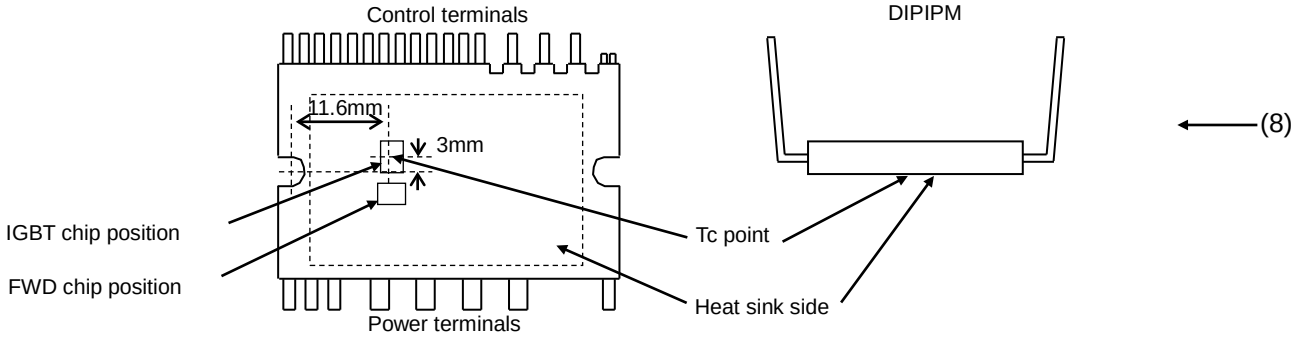
CONTROL (PROTECTION) PART

Symbol	Parameter	Condition	Ratings	Unit
V_D	Control supply voltage	Applied between V_{P1}-V_{NC}, V_{N1}-V_{NC}	20	V
V_{DB}	Control supply voltage	Applied between V_{UFB}-U, V_{VFB}-V, V_{WFB}-W	20	V
V_{IN}	Input voltage	Applied between U_P, V_P, W_P, U_N, V_N, W_N-V_{NC}	-0.5~V_D+0.5	V
V_{FO}	Fault output supply voltage	Applied between F_O-V_{NC}	-0.5~V_D+0.5	V
I_{FO}	Fault output current	F_O terminal sink current	1	mA
V_{SC}	Current sensing input voltage	Applied between CIN-V_{NC}	-0.5~V_D+0.5	V

TOTAL SYSTEM

Symbol	Parameter	Condition	Ratings	Unit	
$V_{CC(PROT)}$	Self protection supply voltage limit (Short circuit protection capability)	V_D = 13.5~16.5V, Inverter Part T_j = 125°C, non-repetitive, less than 2μs	400	V	(6)
T_C	Module case operation temperature	Measurement point of Tc is provided in the following figure	-30~+100	°C	
T_{stg}	Storage temperature		-40~+125	°C	
V_{iso}	Isolation voltage	60Hz, Sinusoidal, AC 1min, between connected all pins and heat sink plate	1500	V_{rms}	(7)

Tc measurement position



(1) Vcc **The maximum voltage can be biased between P-N. A voltage suppressing circuit such as a brake circuit is necessary if P-N voltage exceeds this value.**

(2) Vcc(surge) The maximum P-N surge voltage in switching state. If P-N voltage exceeds this voltage, a snubber circuit is necessary to absorb the surge under this voltage.

(3) V_{CES} The maximum sustained collector-emitter voltage of built-in IGBT and FWDi.

(4) +/-I_C The allowable current flowing into collect electrode (@Tc=25°C).Pulse width and period are limited due to junction temperature Tj.

(5) Tj The maximum junction temperature rating is 150°C. But for safe operation, it is recommended to limit the average junction temperature up to 125°C. Repetitive temperature variation ΔTj affects the life time of power cycle, so refer life time curves for safety design.

(6) Vcc(prot)

The maximum supply voltage for turning off IGBT safely in the case of an SC or OC fault. The power chip might be damaged if supply voltage exceeds this specification.

(7) Isolation voltage

Isolation voltage of Super mini DIPIPM is the voltage between all shorted pins and copper surface of DIPIPM. The maximum rating of isolation voltage of Super mini DIPIPM is 1500Vrms. But if such as convex shape heat radiation fin will be used for enlarging clearance between outer terminals and heat radiation fin (2.5mm or more is recommended), it is able to correspond isolation voltage 2500Vrms. Super mini DIPIPM is recognized by UL at the condition 2500Vrms with convex shape heat radiation fin.

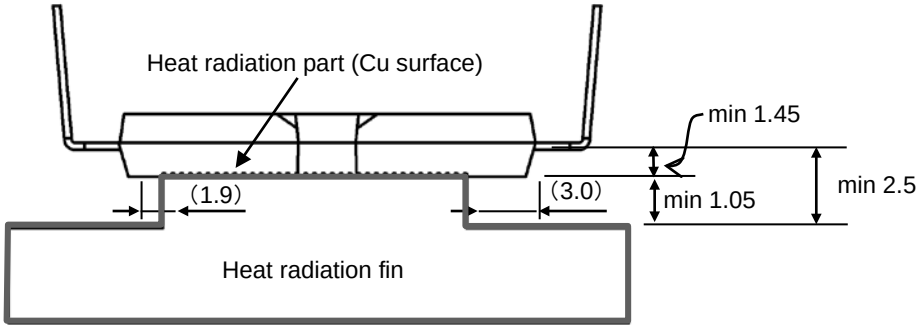


Fig.2-1-1 In the case of using convex fin (unit: mm)

(8) Tc position

Tc (case temperature) is defined to be the temperature just beneath the specified power chip. Please mount a thermocouple on the heat sink surface at the defined position to get accurate temperature information. Due to the control schemes such different control between P and N-side, there is the possibility that highest Tc point is different from above point. In such cases, it is necessary to change the measuring point to that under the highest power chip.

[Power chip position]

Fig.2-1-2 indicates the position of the each power chips. (This figure is the view from laser marked side.)

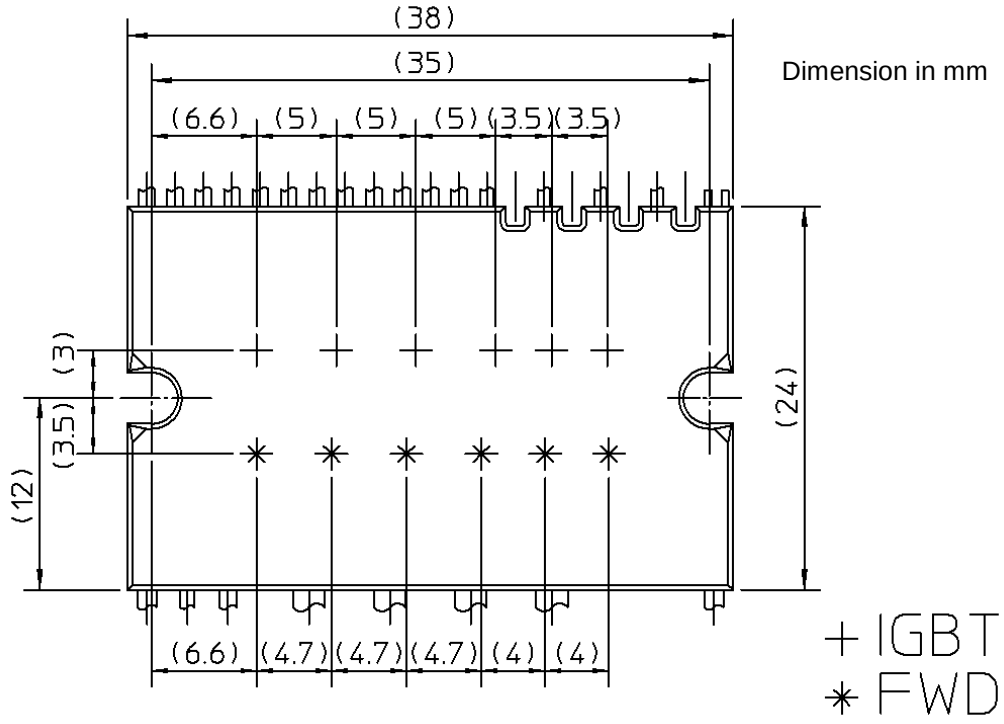


Fig.2-1-2 Power chip position

2.1.2 Thermal Resistance

Table 2-1-2 shows the thermal resistance of PSS15S92*6-AG.

Table 2-1-2 Thermal resistance of PSS15S92*6-AG

THERMAL RESISTANCE

Symbol	Parameter	Condition	Limits			Unit
			Min.	Typ.	Max.	
$R_{th(j-c)Q}$	Junction to case thermal resistance (Note)	Inverter IGBT part (per 1/6 module)	-	-	3.7	K/W
$R_{th(j-c)F}$		Inverter FWDi part (per 1/6 module)	-	-	4.5	K/W

Note : Grease with good thermal conductivity and long-term endurance should be applied evenly with about +100μm~+200μm on the contacting surface of DIPIPM and heat sink. The contacting thermal resistance between DIPIPM case and heat sink Rth(c-f) is determined by the thickness and the thermal conductivity of the applied grease. For reference, Rth(c-f) is about 0.3K/W (per 1/6 module, grease thickness: 20μm, thermal conductivity: 1.0W/m•K).

The above data shows the thermal resistance between chip junction and case at steady state. The thermal resistance goes into saturation in about 10 seconds. The unsaturated thermal resistance is called as transient thermal impedance which is shown in Fig.2-1-3. Zth(j-c)* is the normalized value of the transient thermal impedance. (Zth(j-c)*= Zth(j-c) / Rth(j-c)max)

For example, the IGBT transient thermal impedance of PSS15S92*6-AG in 0.3s is 3.7×0.8=3.0K/W.

The transient thermal impedance isn't used for constantly current, but for short period current (ms order). (E.g. In the cases at motor starting, at motor lock・・・)

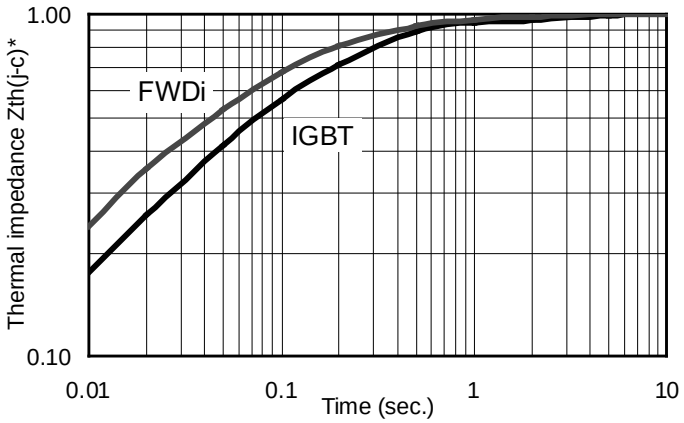


Fig.2-1-3 Typical transient thermal impedance

2.1.3 Electric Characteristics and Recommended Conditions

Table 2-1-3 shows the typical static characteristics and switching characteristics of PSS15S92*6-AG.

Table 2-1-3 Static characteristics and switching characteristics of PSS15S92*6-AG

INVERTER PART (T_j = 25°C, unless otherwise noted)

Symbol	Parameter	Condition		Limits			Unit
				Min.	Typ.	Max.	
$V_{CE(sat)}$	Collector-emitter saturation voltage	V_D=V_{DB} = 15V, V_{IN}= 5V	I_C= 15A , T_j= 25°C	-	1.70	2.05	V
			I_C= 15A , T_j= 125°C	-	1.90	2.25	
			I_C= 1.5A , T_j= 25°C	-	0.90	1.10	
V_{EC}	FWDi forward voltage	V_{IN}= 0V, -I_C= 15A		-	2.50	3.00	V
t_{on}	Switching times	V_{CC}= 300V, V_D= V_{DB}= 15V I_C= 15A, T_j= 125°C, V_{IN}= 0↔5V Inductive Load (upper-lower arm)		0.65	1.05	1.45	μs
$t_{C(on)}$				-	0.40	0.65	μs
t_{off}				-	1.15	1.60	μs
$t_{C(off)}$				-	0.15	0.30	μs
t_{rr}				-	0.30	-	μs
I_{CES}	Collector-emitter cut-off current	V_{CE}=V_{CES}	T_j= 25°C	-	-	1	mA
			T_j= 125°C	-	-	10	

Switching time definition and performance test method are shown in Fig.2-1-4 and 2-1-5.
Switching characteristics are measured by half bridge circuit with inductance load.

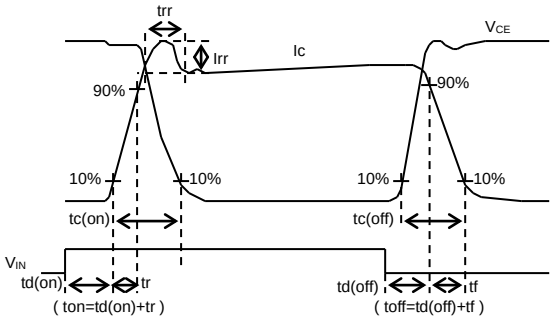


Fig.2-1-4 Switching time definition

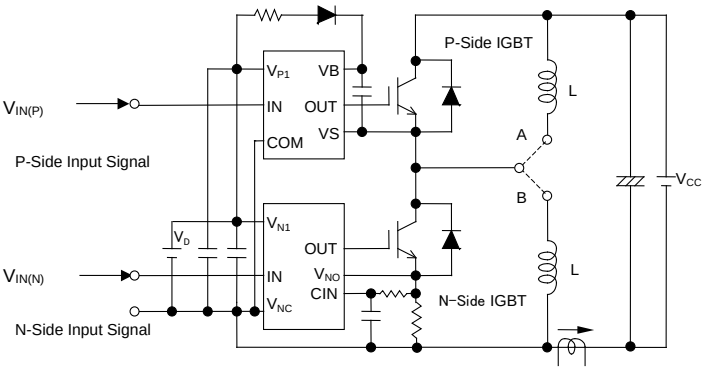


Fig.2-1-5 Evaluation circuit (inductive load)
Short A for N-side IGBT, and short B for P-side IGBT evaluation

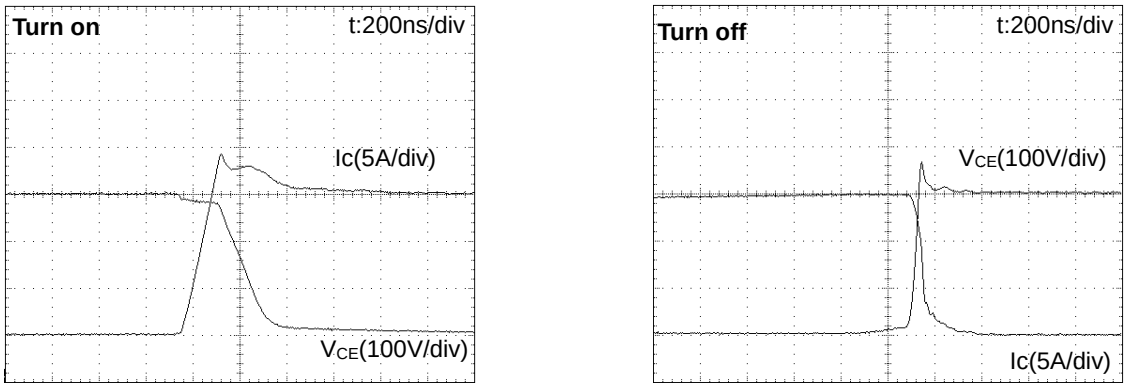


Fig.2-1-6 Typical switching waveform (PSS15S92*6-AG)
Conditions: V_{CC}=300V, V_D=V_{DB}=15V, Tj=125°C, Ic=15A, Inductive load half-bridge circuit

Table 2-1-4 shows the typical control part characteristics of PSS15S92*6-AG.

Table 2-1-4 Control (Protection) characteristics of PSS15S92*6-AG

CONTROL (PROTECTION) PART (T_j = 25°C, unless otherwise noted)*

Symbol	Parameter	Condition		Limits			Unit
				Min.	Typ.	Max.	
I_D	Circuit current	Total of V_{P1}-V_{NC}, V_{N1}-V_{NC}	V_D=15V, V_{IN}=0V	-	-	2.80	mA
			V_D=15V, V_{IN}=5V	-	-	2.80	
I_{DB}		Each part of V_{UFB}-U, V_{VFB}-V, V_{WFB}-W	V_D=V_{DB}=15V, V_{IN}=0V	-	-	0.10	
			V_D=V_{DB}=15V, V_{IN}=5V	-	-	0.10	
$V_{SC(ref)}$	Short circuit trip level	V_D = 15V (Note 1)		0.455	0.480	0.505	V
UV_{DBt}	P-side Control supply under-voltage protection(UV)	T_j ≤125°C	Trip level	7.0	10.0	12.0	V
UV_{DBr}			Reset level	7.0	10.0	12.0	V
UV_{Dt}	N-side Control supply under-voltage protection(UV)		Trip level	10.3	-	12.5	V
UV_{Dr}			Reset level	10.8	-	13.0	V
V_{OT}	Temperature output (PSS15S92F6-AG only) (Note5)	Pull down R=5kΩ (Note 2)	LVIC Temperature=90°C	2.63	2.77	2.91	V
			LVIC Temperature=25°C	0.88	1.13	1.39	V
OT_t	Overt temperature protection (PSS15S92E6-AG only) (Note3) (Note5)	V_D = 15V	Trip level	100	120	140	°C
OT_{rh}		Detect LVIC temperature	Hysteresis of trip-reset	-	10	-	°C
V_{FOH}	Fault output voltage	V_{SC} = 0V, F_O terminal pulled up to 5V by 10kΩ		4.9	-	-	V
V_{FOL}		V_{SC} = 1V, I_{FO} = 1mA		-	-	0.95	V
t_{FO}	Fault output pulse width	(Note 4)		20	-	-	μs
I_{IN}	Input current	V_{IN} = 5V		0.70	1.00	1.50	mA
$V_{th(on)}$	ON threshold voltage	Applied between U_P, V_P, W_P, U_N, V_N, W_N-V_{NC}		-	2.10	2.60	V
$V_{th(off)}$	OFF threshold voltage			0.80	1.30	-	
$V_{th(hys)}$	ON/OFF threshold hysteresis voltage			0.35	0.65	-	
V_F	Bootstrap Di forward voltage	I_F=10mA including voltage drop by limiting resistor		1.1	1.7	2.3	V
R	Built-in limiting resistance	Included in bootstrap Di		80	100	120	Ω

Note 1 : SC protection works only for N-side IGBT. Please select the external shunt resistance such that the SC trip-level is less than 1.7 times of the current rating.
2 : DIPIPM don't shutdown IGBTs and output fault signal automatically when temperature rises excessively. When temperature exceeds the protective level that user defined, controller (MCU) should stop the DIPIPM.
3 : When the LVIC temperature exceeds OT trip temperature level(OT_t), OT protection works and Fo outputs. In that case if the heat sink dropped off or fixed loosely, don't reuse that DIPIPM. (There is a possibility that junction temperature of power chips exceeded maximum Tj(150°C).
4 : Fault signal Fo outputs when SC, UV or OT protection works. Fo pulse width is different for each protection modes. At SC failure, Fo pulse width is a fixed width (=minimum 20μs), but at UV or OT failure, Fo outputs continuously until recovering from UV or OT state. (But minimum Fo pulse width is 20μs.)
5 : It is necessary to select from temperature output function or over temperature protection about temperature protection.
Their part numbers are different. (e.g. PSS15S92F6-AG is the type with temperature output function and PSS15S92E6-AG is the type with over temperature protection.)

***) Some specifications such as circuit current (I_D, I_{DB}), P-side Control supply under-voltage protection (UV_{DBt}, UV_{DBr}), characteristic of Bootstrap Di (V_F, R) are different between rated current 5A~20A and 30A, 35A. For more detail, please refer the datasheet for each product.**

Recommended operating conditions of PSS15S92*6-AG are given in Table 2-1-5.

Although these conditions are the recommended but not the necessary ones, it is highly recommended to operate the modules within these conditions so as to ensure DIPIPM safe operation.

Table 2-1-5 Recommended operating conditions of PSS15S92*6-AG

RECOMMENDED OPERATIONAL CONDITIONS

Symbol	Parameter	Condition		Limits			Unit
				Min.	Typ.	Max.	
V_{CC}	Supply voltage	Applied between P-NU, NV, NW		0	300	400	V
V_D	Control supply voltage	Applied between V_{P1}-V_{NC}, V_{N1}-V_{NC}		13.5	15.0	16.5	V
V_{DB}	Control supply voltage	Applied between V_{UFB}-U, V_{VFB}-V, V_{WFB}-W		13.0	15.0	18.5	V
ΔV_D, ΔV_{DB}	Control supply variation			-1	-	+1	V/μs
t_{dead}	Arm shoot-through blocking time	For each input signal, Tc≤100°C		1.0	-	-	μs
f_{PWM}	PWM input frequency	T_C ≤ 100°C, T_j ≤ 125°C		-	-	20	kHz
I_O	Allowable r.m.s. current	V_{CC} = 300V, V_D = V_{DB} = 15V, P.F = 0.8, Sinusoidal PWM T_C ≤ 100°C, T_j ≤ 125°C (Note1)	f_{PWM}= 5kHz	-	-	7.5	Arms
			f_{PWM}= 15kHz	-	-	4.5	
PWIN(on)	Minimum input pulse width	(Note 2)		0.7	-	-	μs
PWIN(off)				0.7	-	-	
V_{NC}	V_{NC} variation	Between V_{NC}-NU, NV, NW (including surge)		-5.0	-	+5.0	V
T_j	Junction temperature			-20	-	+125	°C

Note 1: Allowable r.m.s. current depends on the actual application conditions.
2: DIPIPM might not make response if the input signal pulse width is less than PWIN(on), PWIN(off).

***) Some specifications are different between rated current 5A~20A and 30A, 35A. For more detail, please refer the datasheet for each product**.

About Control supply variation
If high frequency noise superimposed to the control supply line, IC malfunction might happen and cause DIPIPM erroneous operation. To avoid such problem, line ripple voltage should meet the following specifications:

dV/dt ≤ +/-1V/μs, Vripple≤2Vp-p

2.1.4 Mechanical Characteristics and Ratings

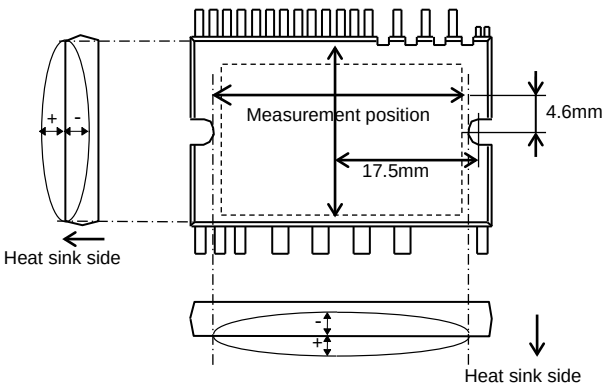
The mechanical characteristics and ratings are shown in Table 2-1-6.
Please refer to Section 2.4 for the detailed mounting instruction of DIP Ver.6.

Table 2-1-6 Mechanical characteristics and ratings of PSS15S92*6-AG

MECHANICAL CHARACTERISTICS AND RATINGS

Parameter	Condition		Limits			Unit
			Min.	Typ.	Max.	
Mounting torque	Mounting screw : M3 (Note 1)	Recommended 0.69N·m	0.59	0.69	0.78	N·m
Terminal pulling strength	Control terminal: Load 4.9N Power terminal: Load 9.8N	JEITA-ED-4701	10	-	-	s
Terminal bending strength	Control terminal: Load 2.45N Power terminal: Load 4.9N 90deg. bend	JEITA-ED-4701	2	-	-	times
Weight			-	8.5	-	g
Heat-sink flatness	(Note 2)		-50	-	100	μm

Note 1: Plain washers (ISO 7089~7094) are recommended.
Note 2: Measurement point of heat sink flatness



2.2 Protective Functions and Operating Sequence

DIP Ver.6 has Short circuit (SC), Under Voltage of control supply (UV), Over Temperature (OT) and temperature output (VOT) for protection function. The operating principle and sequence are described below.

2.2.1 Short Circuit Protection

1. General

DIP Ver.6 uses external shunt resistor for the current detection as shown in Fig.2-2-1. The internal protection circuit inside the IC captures the excessive large current by comparing the CIN voltage generated at the shunt resistor with the referenced SC trip voltage, and perform protection automatically. The threshold voltage trip level of the SC protection Vsc(ref) is typ. 0.48V.

In case of SC protection happens, all the gates of N-side three phase IGBTs will be interrupted together with a fault signal output. To prevent DIPIPM erroneous protection due to normal switching noise and/or recovery current, it is necessary to set an RC filter (time constant: 1.5μ ~ 2μs) to the CIN terminal input (Fig.2-2-1, 2-2-2). Also, please make the pattern wiring around the shunt resistor as short as possible.

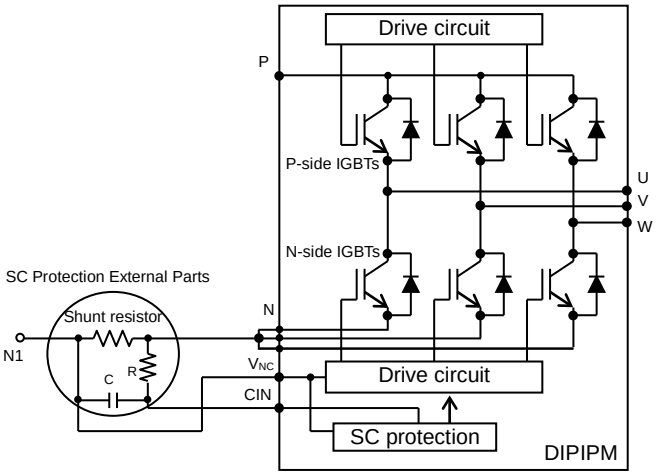


Fig.2-2-1 SC protecting circuit

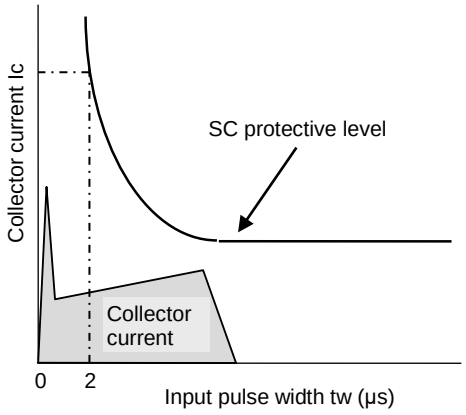


Fig.2-2-2 Filter time constant setting

2. SC protection Sequence

SC protection (N-side only with the external shunt resistor and RC filter)

a1. Normal operation: IGBT ON and carrying current.
a2. Short circuit current detection (SC trigger).
(It is recommended to set RC time constant 1.5~2.0μs so that IGBT shut down within 2.0μs when SC.)
a3. All N-side IGBTs gate are hard interrupted.
a4. All N-side IGBTs turn OFF.
a5. Fo outputs for t_{Fo}=minimum 20μs.
a6. Input = “L”. IGBT OFF
a7. Fo finishes output, but IGBTs don't turn on until inputting next ON signal (L→H).
(IGBT of each phase can return to normal state by inputting ON signal to each phase.)
a8. Normal operation: IGBT ON and outputs current.

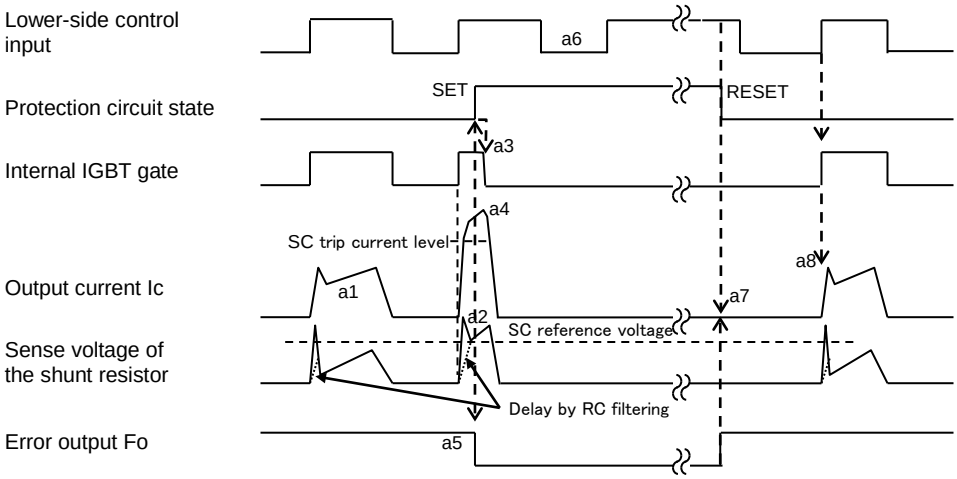


Fig.2-2-3 SC protection timing chart

3. Determination of Shunt Resistance

(1) Shunt resistance

The value of current sensing resistance is calculated by the following expression:

$$R_{Shunt} = V_{SC(ref)} / SC$$

where $V_{SC(ref)}$ is the referenced SC trip voltage.

The maximum SC trip level SC(max) should be set less than the IGBT minimum saturation current which is 1.7 times as large as the rated current. For example, the SC(max) of PSS15S92*6-AG should be set to 15x1.7=25.5A. The parameters ($V_{SC(ref)}$, R_{Shunt}) tolerance should be considered when designing the SC trip level.

For example of PSS15S92*6-AG, there is +/-0.025V tolerance in the spec of $V_{SC(ref)}$ as shown in Table 2-2-1.

Table 2-2-1 Specification for $V_{SC(ref)}$ (unit: V)

Condition	Min	Typ	Max
at T_j=25°C, V_D=15V	0.455	0.480	0.505

Then, the range of SC trip level can be calculated by the following expressions:

$R_{Shunt(min)}=V_{SC(ref)\ max}$ /SC(max)

$R_{Shunt(typ)}= R_{Shunt(min)}$ / 0.95* then SC(typ) = $V_{SC(ref)\ typ}$ / $R_{Shunt(typ)}$

$R_{Shunt(max)}= R_{Shunt(typ)}$ x 1.05* then SC(min)= $V_{SC(ref)\ min}$ / $R_{Shunt(max)}$

*)This is the case that shunt resistance tolerance is within +/-5%.

So the SC trip level range is described as Table 2-2-2.

Table 2-2-2 Operative SC Range (R_{Shunt}=19.8mΩ (min), 20.8mΩ (typ), 21.8mΩ(max)

Condition	min.	typ.	Max.
at T_j=25°C	20.9A	23.1A	25.5A

(e.g. 19.8mΩ ($R_{shunt(min)}$)= 0.505V (=$V_{SC(max)}$) / 25.5A(=SC(max))

There is the possibility that the actual SC protection level becomes less than the calculated value. This is considered due to the resonant signals caused mainly by parasitic inductance and parasitic capacity. It is recommended to make a confirmation of the resistance by prototype experiment.

(2) RC Filter Time Constant

It is necessary to set an RC filter in the SC sensing circuit in order to prevent malfunction of SC protection due to noise interference. The RC time constant is determined depending on the applying time of noise interference and the SCSOA of the DIPIPM.

When the voltage drop on the external shunt resistor exceeds the SC trip level, the time (t1) that the CIN terminal voltage rises to the referenced SC trip level can be calculated by the following expression:

$$V_{SC} = R_{shunt} \cdot I_c \cdot (1 - \varepsilon^{-\frac{t1}{\tau}})$$

$$t1 = -\tau \cdot \ln(1 - \frac{V_{SC}}{R_{shunt} \cdot I_c})$$

Vsc : the CIN terminal input voltage, Ic : the peak current, τ : the RC time constant

On the other hand, the typical time delay t2 (from Vsc voltage reaches Vsc(ref) to IGBT gate shutdown) of IC is shown in Table 2-2-3.

Table 2-2-3 Internal time delay of IC

Item		min	typ	max	Unit
IC transfer delay time	5A~20A	-	-	0.5	μs
	30A, 35A	-	-	0.6	μs

Therefore, the total delay time from an SC level current happened to the IGBT gate shutdown becomes:

t_{TOTAL}=t1+t2

2.2.2 Control Supply UV Protection

The UV protection is designed to prevent unexpected operating behavior as described in Table 2-2-4.

Both P-side and N-side have UV protecting function. However, fault signal (Fo) output only corresponds to N-side UV protection. Fo output continuously during UV state.

In addition, there is a noise filter (typ. 10μs) integrated in the UV protection circuit to prevent instantaneous UV erroneous trip. Therefore, the control signals are still transferred in the initial 10μs after UV happened.

Table 2-2-4 DIPIPM operating behavior versus control supply voltage

Control supply voltage	Operating behavior
0-4.0V (P, N)	In this voltage range, built-in control IC may not work properly. Normal operating of each protection function (UV, Fo output etc.) is not also assured. Normally IGBT does not work. But external noise may cause DIPIPM malfunction (turns ON), so DC-link voltage need to start up after control supply starts-up.
4.0-UV_{Dt} (N), UV_{DBt} (P)	UV function becomes active and output Fo (N-side only). Even if control signals are applied, IGBT does not work
UV_{Dt} (N)-13.5V UV_{DBt} (P)-13.0V	IGBT can work. However, conducting loss and switching loss will increase, and result extra temperature rise at this state.
13.5-16.5V (N) 13.0-18.5V (P)	Recommended conditions.
16.5-20.0V (N) 18.5-20.0V (P)	IGBT works. However, switching speed becomes fast and saturation current becomes large at this state, increasing SC broken risk.
20.0V- (P, N)	The control circuit will be destroyed.

Ripple Voltage Limitation of Control Supply

If high frequency noise superimposed to the control supply line, IC malfunction might happen and cause DIPIPM erroneous operation. To avoid such problem, line ripple voltage should meet the following specifications:

$dV/dt \leq +/-1V/\mu s$, $Vripple \leq 2Vp\text{-}p$

[N-side UV Protection Sequence]

a1. Control supply voltage V_D rising: After the voltage level reaches UV_{Dr}, the circuits start to operate when next input is applied (L→H). (IGBT of each phase can return to normal state by inputting ON signal to each phase.)

a2. Normal operation: IGBT ON and carrying current.

a3. V_D level dips to under voltage trip level. (UV_{Dt}).

a4. All N-side IGBTs turn OFF in spite of control input condition.

a5. Fo outputs for t_{Fo}=minimum 20μs, but output is extended during V_D keeps below UV_{Dr}.

a6. V_D level reaches UV_{Dr}.

a7. Normal operation: IGBT ON and outputs current.

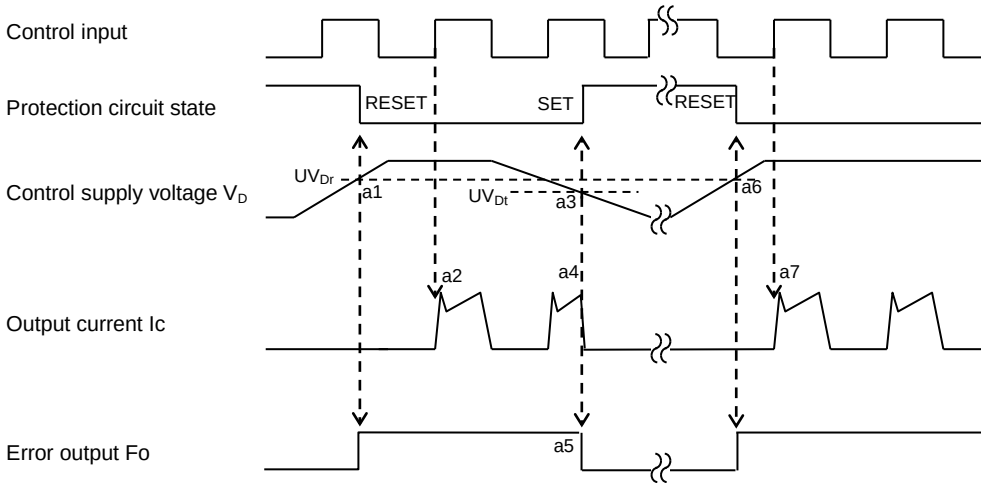


Fig.2-2-4 Timing chart of N-side UV protection

[P-side UV Protection Sequence]**(for rated current 5A~20A products)**

a1. Control supply voltage V_{DB} rises. After the voltage reaches UV_{DBr}, the circuits start to operate when next input is applied (L→H).
a2. Normal operation: IGBT ON and carrying current.
a3. V_{DB} level dips to under voltage trip level (UV_{DBt}).
a4. IGBT of corresponding phase only turns OFF in spite of control input signal level, but there is no F_O signal output.
a5. V_{DB} level reaches UV_{DBr}.
a6. Normal operation: IGBT ON and outputs current.

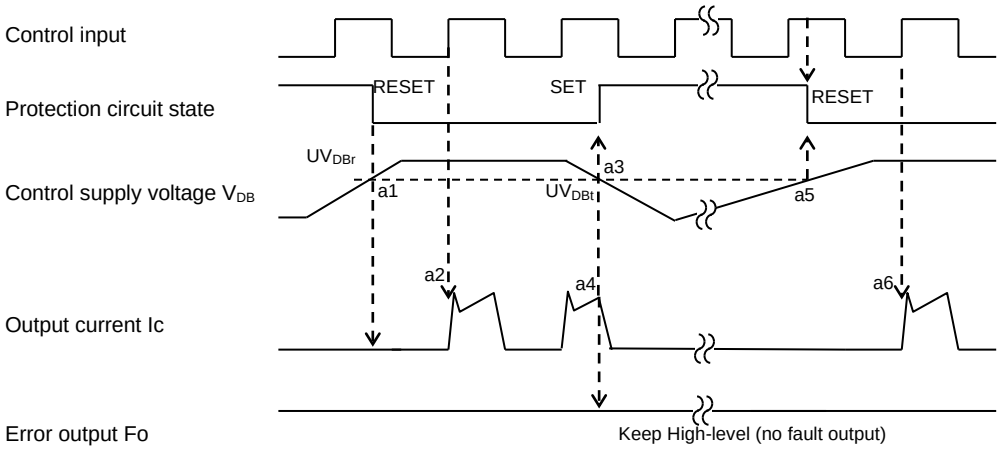


Fig.2-2-5 Timing Chart of P-side UV protection (Rated current 5A~20A)

[P-side UV Protection Sequence]**(for rated current 30A, 35A products)**

a1. Control supply voltage rises: After the voltage reaches UV_{DBr}, the circuits start to operate when next input is applied (L→H).
a2. Normal operation : IGBT ON and carrying current.
a3. V_{DB} level dips to under voltage trip level (UV_{DBt}).
a4. IGBT of corresponding phase only turns OFF in spite of control input signal level, but there is no Fo signal output.
a5. V_{DB} level reaches UV_{DBr}.
a6. Normal operation : IGBT ON and outputs current.

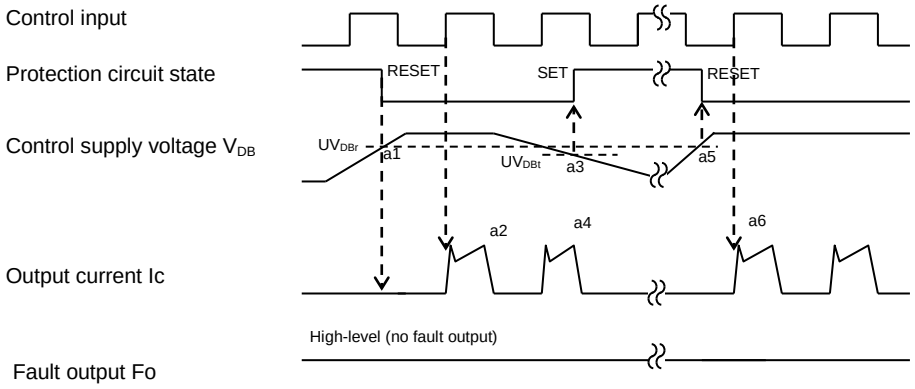


Fig.2-2-6 Timing Chart of P-side UV protection (Rated current 30A, 35A)

2.2.3 OT Protection (PSS**S92E6-AG only)

PSS**S92E6-AG series have OT (over temperature) protection function by monitoring LVIC temperature rise.
While LVIC temperature exceeds and keeps over OT trip temperature, error signal Fo outputs and all N-side IGBTs are shut down without reference to input signal. (P-side IGBTs are not shut down)
The specification of OT trip temperature and its sequence are described in Table 2-2-5 and Fig.2-2-7.

Table 2-2-5 OT trip temperature specification

Item	Symbol	Condition		Min.	Typ.	Max.	Unit
Over temperature protection	OT_t	V_D=15V, At temperature of LVIC	Trip level	100	120	140	°C
	OT_{rh}		Trip/reset hysteresis	-	10	-	

[OT Protection Sequence]
a1. Normal operation: IGBT ON and outputs current.
a2. LVIC temperature exceeds over temperature trip level(OT_t).
a3. All N-side IGBTs turn OFF in spite of control input condition.
a4. Fo outputs for t_{FO}=minimum 20μs, but output is extended during LVIC temperature keeps over OT_t.
a5. LVIC temperature drops to over temperature reset level.
a6. Normal operation: IGBT turns on by next ON signal (L→H).
(IGBT of each phase can return to normal state by inputting ON signal to each phase.)

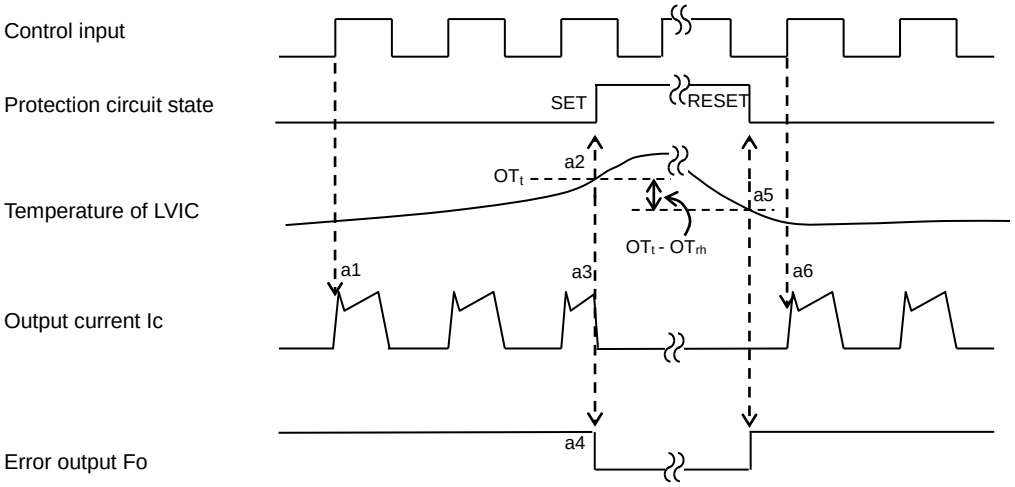


Fig.2-2-7 Timing Chart of OT protection

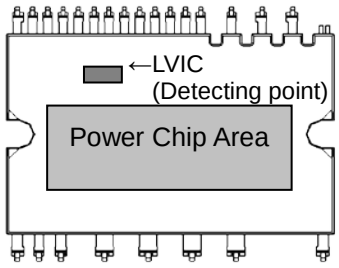


Fig.2-2-8 Temperature detecting point

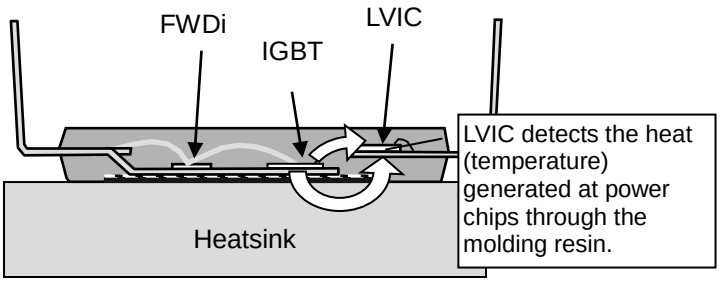


Fig.2-2-9 Thermal conducting from power chips

Precaution about this OT protection function

(1)This OT protection will not work effectively in the case of rapid temperature rise like motor lock or over current. (This protection monitors LVIC temperature, so it cannot respond to rapid temperature rise of power chips.)

(2)If the cooling system is abnormal state (e.g. heat sink comes off, fixed loosely, or cooling fun stops) when OT protection works, can't reuse the DIPIPM. (Because the junction temperature of power chips will exceeded the maximum rating of Tj(150°C).)

2.2.4 Temperature output function V_{OT} (PSS**S92F6-AG only)

(1) Usage of this function

This function measures the temperature of control LVIC by built in temperature sensor on LVIC. The heat generated at IGBT and FWDi transfers to LVIC through molding resin of package and outer heat sink. So LVIC temperature cannot respond to rapid temperature rise of those power chips effectively. (e.g. motor lock, short circuit) It is recommended to use this function for protecting from slow excessive temperature rise by such cooling system down and continuance of overload operation.（Replacement from the thermistor which was mounted on outer heat sink currently）

[Note]

In this function, DIPIPM cannot shutdown IGBT and output fault signal by itself when temperature rises excessively. When temperature exceeds the defined protection level, controller (MCU) should stop the DIPIPM.

(2) V_{OT} characteristics

V_{OT} output circuit, which is described in Fig.2-2-10, is the output of OP amplifier circuit. The current capability of V_{OT} output is described as Table 2-2-6. The characteristics of V_{OT} output vs. LVIC temperature is linear characteristics described in Fig.2-2-14. There are some cautions for using this function as below.

Table 2-2-6 Output capability

(Tc=-30°C ~100°C)

	min.
Source	1.7mA
Sink	0.1mA

Source: Current flow from V_{OT} to outside.

Sink : Current flow from outside to V_{OT}.

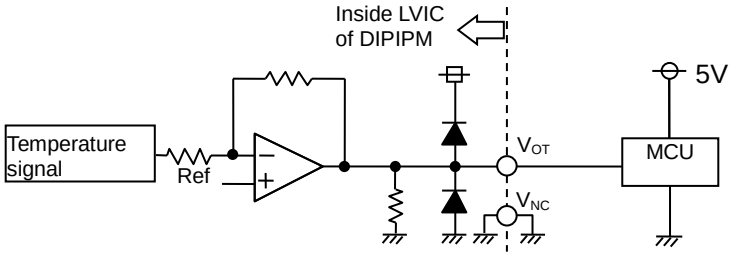


Fig.2-2-10 V_{OT} output circuit

• In the case of detecting lower temperature than room temperature

It is recommended to insert 5.1kΩ pull down resistor for getting linear output characteristics at lower temperature than room temperature. When the pull down resistor is inserted between V_{OT} and V_{NC}(control GND), the extra current calculated by V_{OT} output voltage / pull down resistance flows as LVIC circuit current continuously. In the case of only using V_{OT} for detecting higher temperature than room temperature, it isn't necessary to insert the pull down resistor.

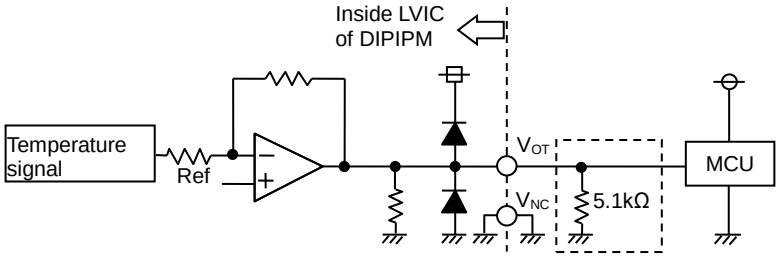


Fig.2-2-11 V_{OT} output circuit in the case of detecting low temperature

• In the case of using with low voltage controller(MCU)

In the case of using V_{OT} with low voltage controller (e.g. 3.3V MCU), V_{OT} output might exceed control supply voltage 3.3V when temperature rises excessively. If system uses low voltage controller, it is recommended to insert a clamp Di between control supply of the controller and this output for preventing over voltage.

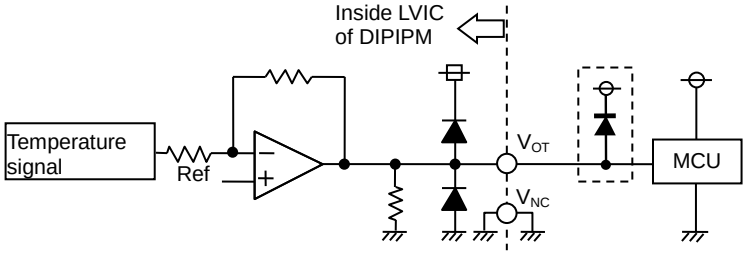


Fig.2-2-12 V_{OT} output circuit in the case of using with low voltage controller

- In the case that the protection level exceeds control supply of the controller

  In the case of using low voltage controller like 3.3V MCU, if it is necessary to set the trip V_{OT} level to control supply voltage (e.g. 3.3V) or more, there is the method of dividing the V_{OT} output by resistance voltage divider circuit and then inputting to A/D converter on MCU (Fig.2-2-13). In that case, sum of the resistances of divider circuit should be as much as 5kΩ. About the necessity of clamp diode, we consider that the divided output will not exceed the supply voltage of controller generally, so it will be unnecessary to insert the clump diode. But it should be judged by the divided output level finally.

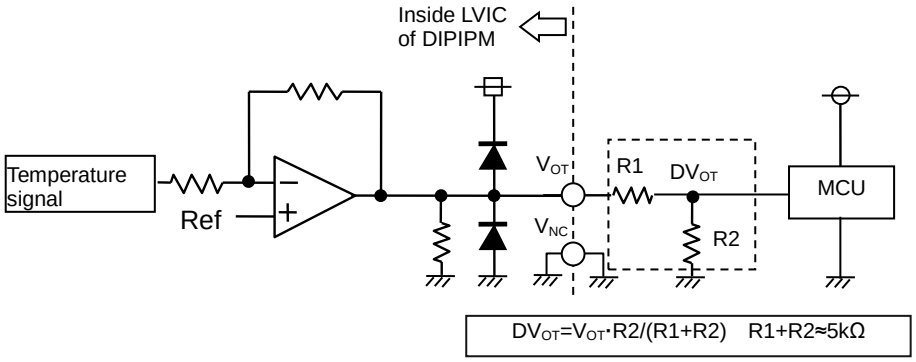


Fig.2-2-13 V_{OT} output circuit in the case with high protection level

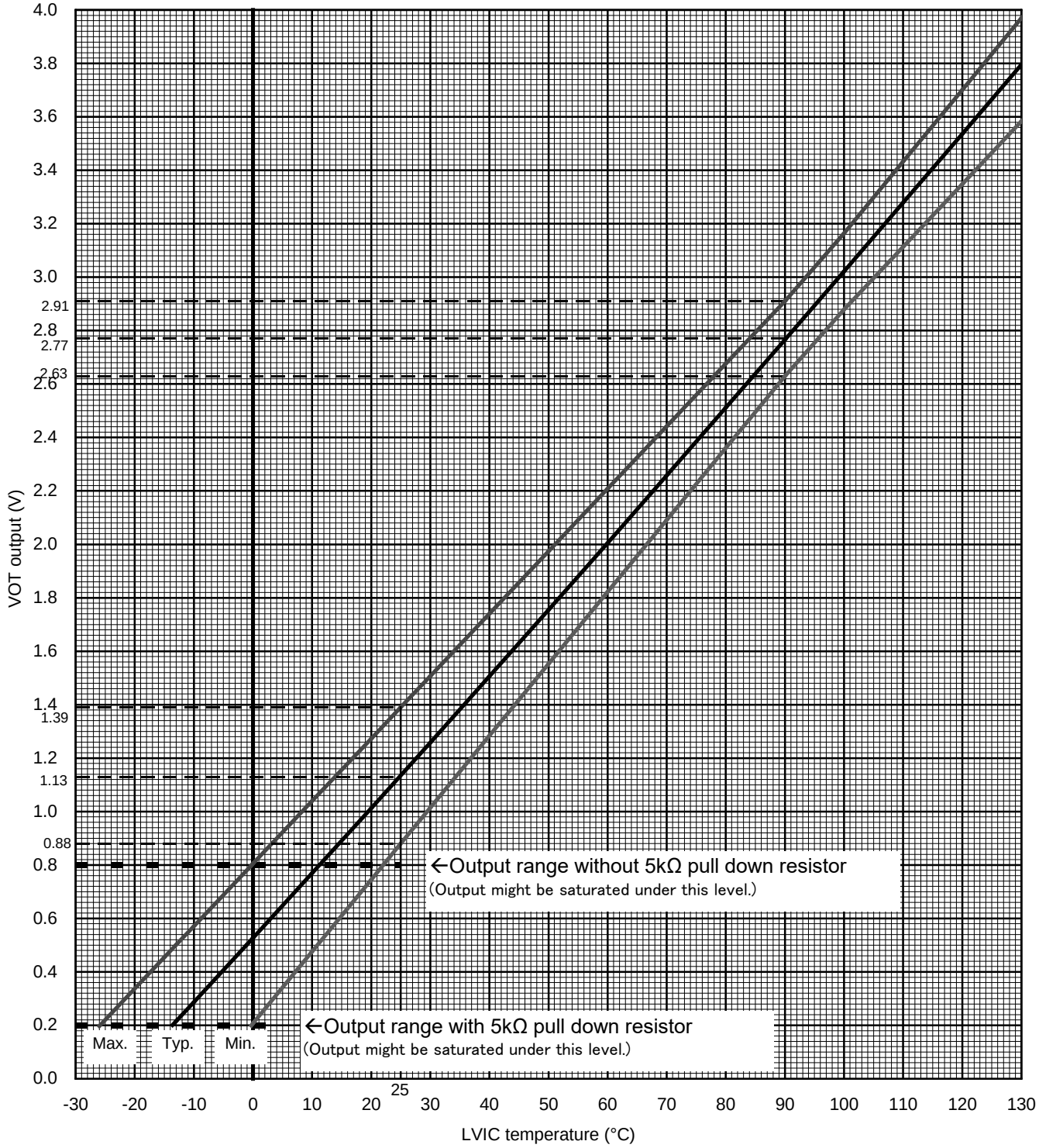
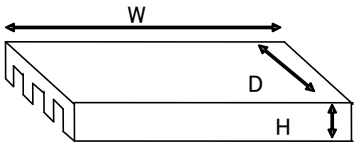


Fig.2-2-14 V_{OT} output vs. LVIC temperature

As mentioned above, the heat of power chips transfers to LVIC through the heat sink and package, so the relationship between LVIC temperature: Tic(=V_{OT} output), case temperature: Tc(under the chip defined on datasheet), and junction temperature: Tj depends on the system cooling condition, heat sink, control strategy, etc. For example, their relationship example in the case of using the heat sink (Table 2-2-7) is described in Fig.2-2-15. This relationship may be different due to the cooling conditions. So when setting the threshold temperature for protection, it is necessary to get the relationship between them on your real system. And when setting threshold temperature Tic, it is important to consider the protection temperature assures Tc≤100°C and Tj ≤150°C.

Table 2-2-7 Outer heat sink

Heat sink size (W x D x H)	Thermal resistance $R_{th(f-a)}$
100 x 88 x 40 mm	2.20K/W



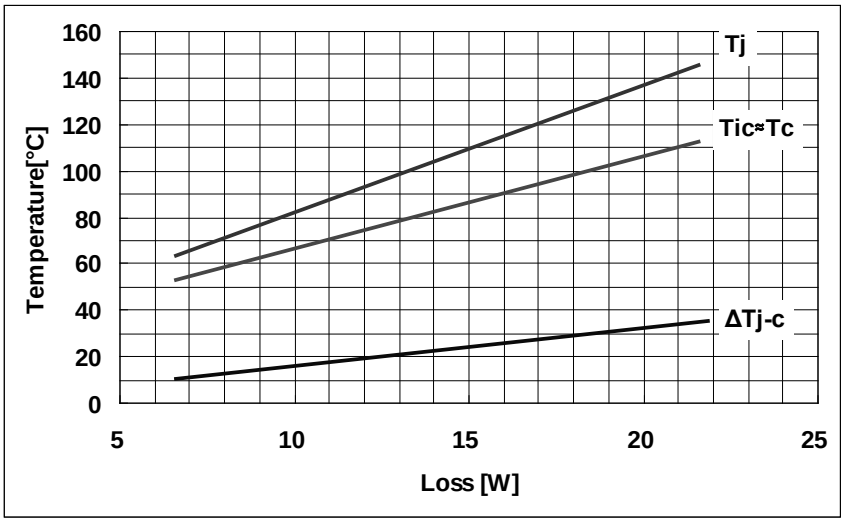


Fig.2-2-15 Example of relationship of Tj, Tc, Tic
(One IGBT chip turns on. DC current Ta=25°C, In this example, Tic and Tc are almost same temperature.)

Procedure about setting the protection level by using Fig.2-2-16 is described as below.

Table 2-2-8 Procedure for setting protection level

	Procedure	Setting value example
1)	Set the protection Tj temperature	Set Tj to 120°C as protection level.
2)	Get LVIC temperature Tic that matches to above Tj of the protection level from the relationship of Tj-Tic in Fig.2-2-16.	Tic=93°C (@Tj=120°C)
3)	Get V_{OT} value from the VOT output characteristics in Fig.2-2-17 and the Tic value which was obtained at phase 2) .	V_{OT}=2.84V (@Tic=93°C) is decided as the protection level.

As above procedure, the setting value for V_{OT} output is decided to 2.84V. But V_{OT} output has some data spread, so it is important to confirm whether the protection temperature fluctuation of Tj and Tc due to the data spread of V_{OT} output is Tj≤150°C and Tc≤100°C. Procedure about the confirmation of temperature fluctuation is described in Table 2-2-9.

Table 2-2-9 Procedure for confirmation of temperature fluctuation

	Procedure	Confirmation example
4)	Confirm the region of Tic fluctuation at above V_{OT} from Fig.2-2-17.	Tic=87°C~98.5°C (@V_{OT}=2.84V)
5)	Confirm the region of Tj and Tc fluctuation at above region of Tic from Fig.2-2-16.	Tj=113°C~126°C (≤150°C No problem) Tc=87°C~98.5°C (≤100°C No problem) In this example, Tic and Tc are almost same temperature, so Tc fluctuation is also same that of Tic

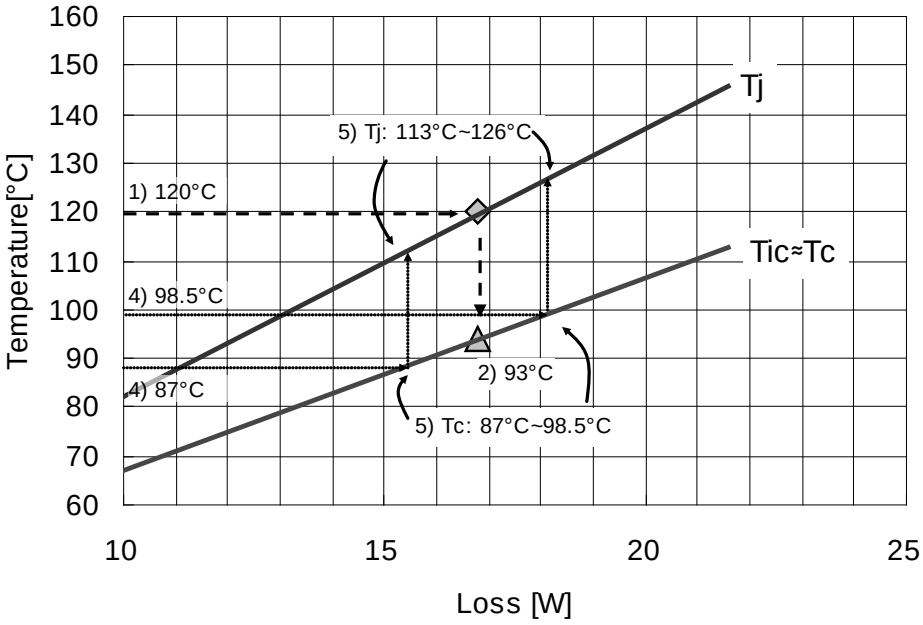


Fig.2-2-16 Relationship of Tj, Tc, Tic(Enlarged graph of Fig.2-2-15)

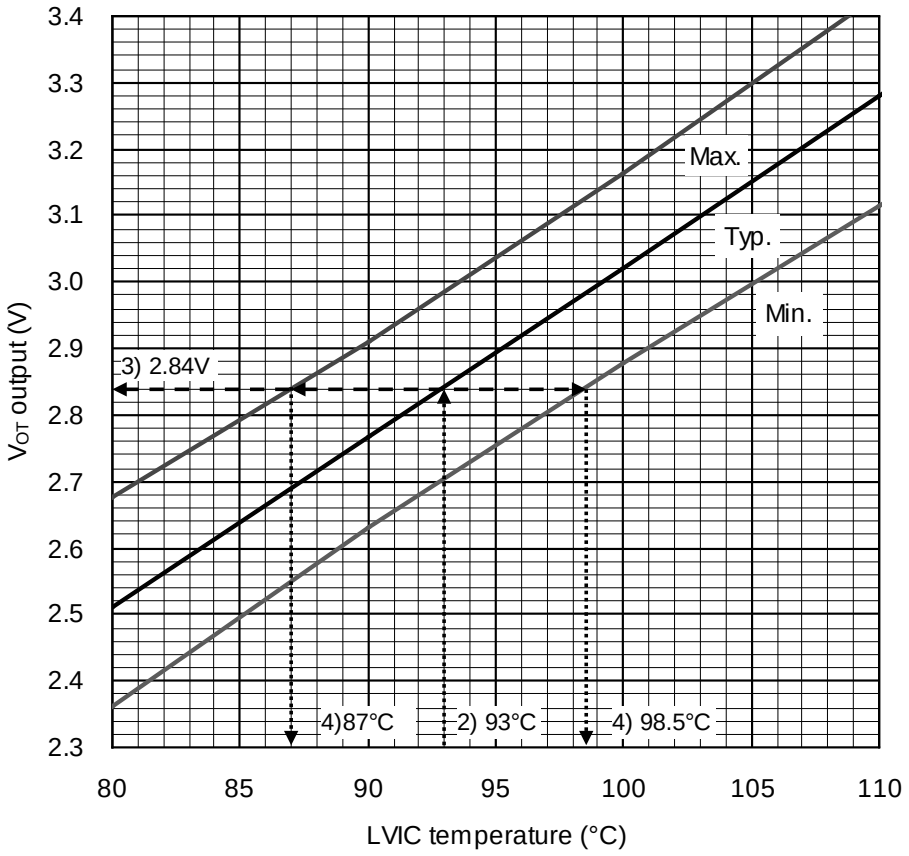


Fig.2-2-17 V_{OT} output vs. LVIC temperature (Enlarged graph of Fig.2-2-14)

As mentioned above, the relationship between Tic, Tc and Tj depends on the system cooling condition and control strategy, and so on. So please evaluate about these temperature relationship on your real system when considering the protection level.

If necessary, it is possible to ship the sample with the individual data of V_{OT} vs. LVIC temperature.

2.3 Package Outlines

2.3.1 Package outlines

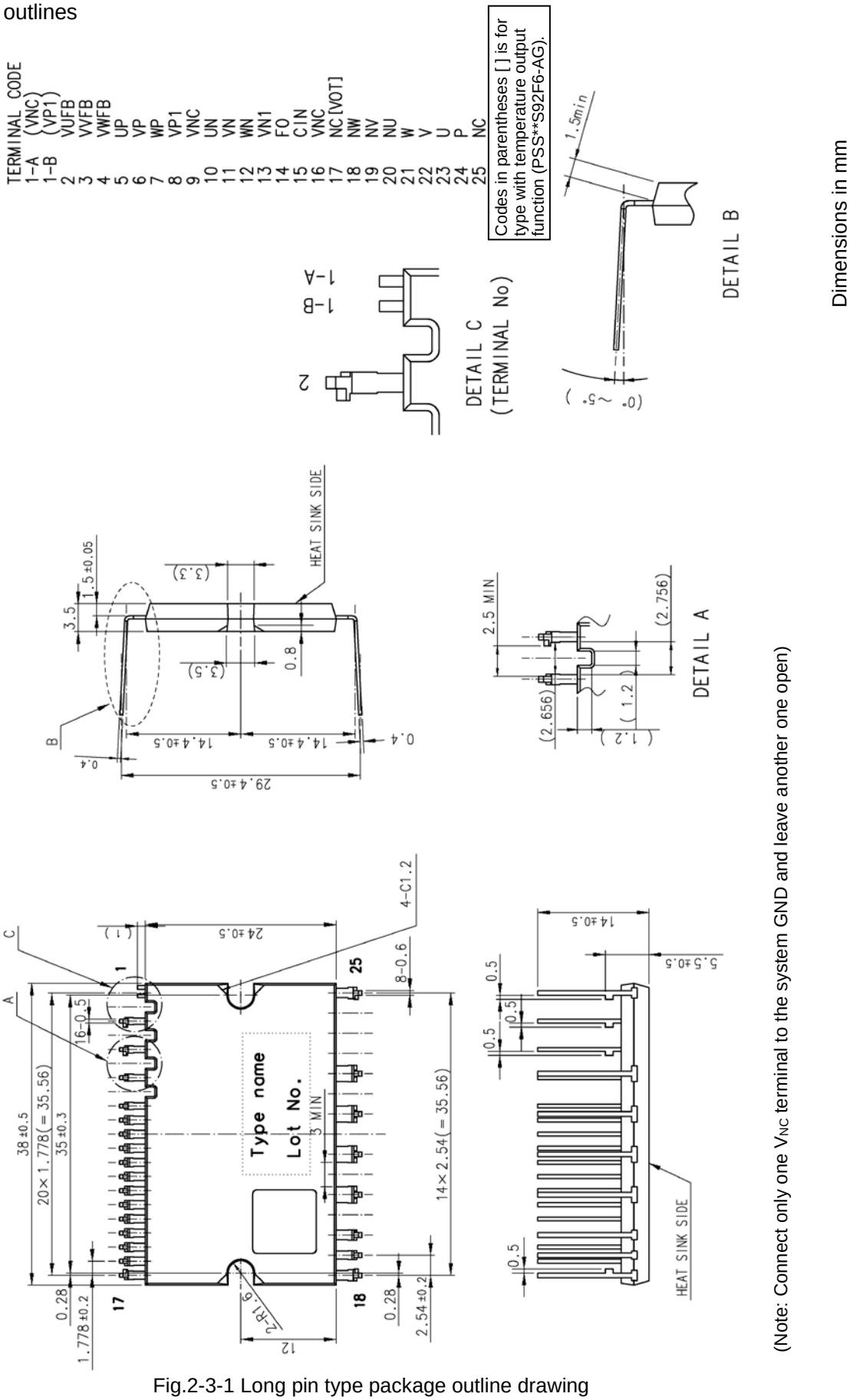


Fig.2-3-1 Long pin type package outline drawing

2.3.2 Marking

The laser marking specification of DIP Ver.6 is described in Fig.2-3-2. Company name, Type name, Lot number, Made of origin, and 2D code mark are marked in the upper side of module.

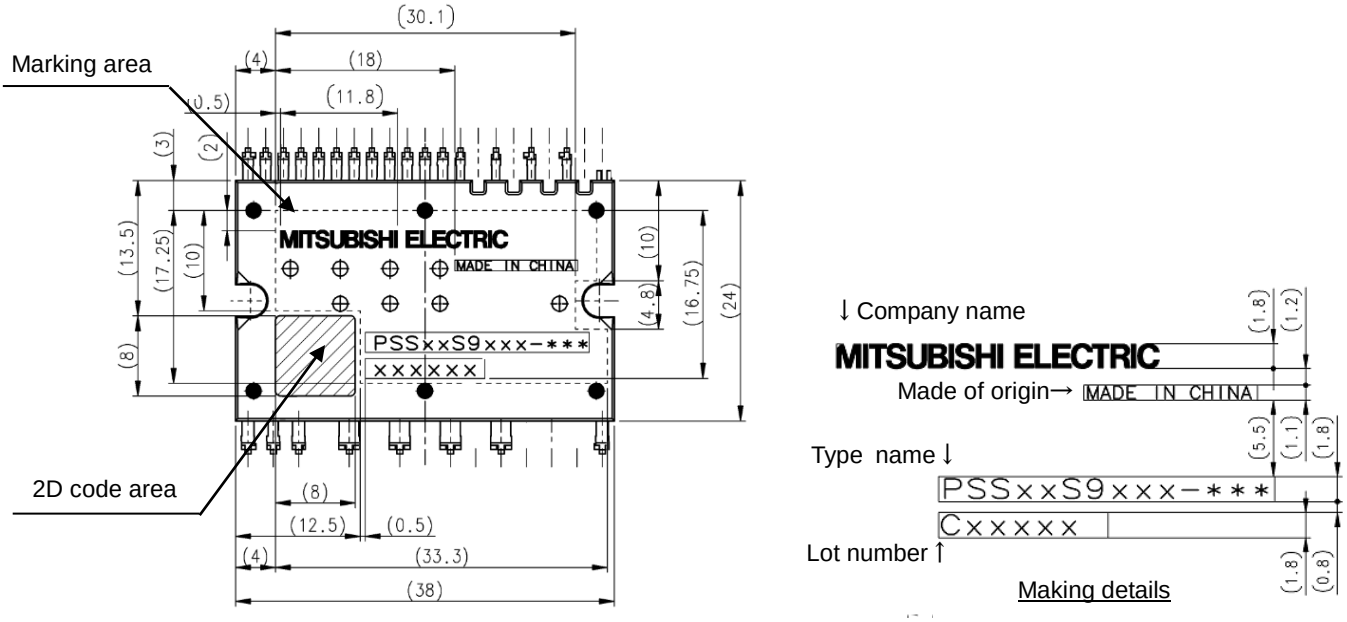


Fig.2-3-2 Laser marking view

The Lot number indicates production year, month, running number and country of origin.
The detailed is described as below.

(Example) H 4 9 AA1

- AA1 → Running number
- 9 → Product month (however O: October, N: November, D: December)
- 4 → Last figure of Product year (e.g. 2014)
- H → Factory identification
  - No mark : Manufactured at the factory in Japan
  - C : Manufactured at the factory A in China
  - H : Manufactured at the factory B in China

2.3.3 Terminal Description

Table 2-3-1 Terminal description

Pin	PSS**S92F6-AG(with temperature output function)		PSS**S92E6-AG(with OT protection function)	
	Name	Description	Name	Description
1-A	(V_{NC})*2	Inner used terminal. Keep no connection It has control GND potential.	(V_{NC})*2	Same as on the left
1-B	(V_{P1})*2	Inner used terminal. Keep no connection. It has control supply potential.	(V_{P1})*2	Same as on the left
2	V_{UFB}	U-phase P-side drive supply positive terminal	V_{UFB}	Same as on the left
3	V_{VFB}	V-phase P-side drive supply positive terminal	V_{VFB}	Same as on the left
4	V_{WFB}	W-phase P-side drive supply positive terminal	V_{WFB}	Same as on the left
5	U_P	U-phase P-side control input terminal	U_P	Same as on the left
6	V_P	V-phase P-side control input terminal	V_P	Same as on the left
7	W_P	W-phase P-side control input terminal	W_P	Same as on the left
8	V_{P1}	P-side control supply positive terminal	V_{P1}	Same as on the left
9	V_{NC}*1	P-side control supply GND terminal	V_{NC}*1	Same as on the left
10	U_N	U-phase N-side control input terminal	U_N	Same as on the left
11	V_N	V-phase N-side control input terminal	V_N	Same as on the left
12	W_N	W-phase N-side control input terminal	W_N	Same as on the left
13	V_{N1}	N-side control supply positive terminal	V_{N1}	Same as on the left
14	F_O	Fault signal output terminal	F_O	Same as on the left
15	CIN	SC trip voltage detecting terminal	CIN	Same as on the left
16	V_{NC}*1	N-side control supply GND terminal	V_{NC}*1	Same as on the left
17	V_{OT}	Temperature output	NC	No connection (There isn't any connection inside DIPIPM.)
18	NW	WN-phase IGBT emitter	NW	Same as on the left
19	NV	VN-phase IGBT emitter	NV	Same as on the left
20	NU	UN-phase IGBT emitter	NU	Same as on the left
21	W	W-phase output terminal(W-phase drive supply GND)	W	Same as on the left
22	V	V-phase output terminal (V-phase drive supply GND)	V	Same as on the left
23	U	U-phase output terminal (U-phase drive supply GND)	U	Same as on the left
24	P	Inverter DC-link positive terminal	P	Same as on the left
25	NC	No connection (There isn't any connection inside DIPIPM.)	NC	Same as on the left

*1) Connect only one V_{NC} terminal to the system GND and leave another one open.
*2) No.1-A,1-B are inner used terminals, so it is necessary to leave no connection.

Table 2-3-2 Detailed description of input and output terminals

Item	Symbol	Description
P-side drive supply positive terminal P-side drive supply GND terminal	V_{UFB}-U V_{VFB}-V V_{WFB}-W	• Drive supply terminals for P-side IGBTs. • By mounting bootstrap capacitor, individual isolated power supplies are not needed for the P-side IGBT drive. Each bootstrap capacitor is charged by the N-side V_D supply when potential of output terminal is almost GND level. • Abnormal operation might happen if the V_D supply is not aptly stabilized or has insufficient current capability due to ripple or surge. In order to prevent malfunction, a bypass capacitor with favorable frequency and temperature characteristics should be mounted very closely to each pair of these terminals. • Inserting a Zener diode (24V/1W) between each pair of control supply terminals is helpful to prevent control IC from surge destruction.
P-side control supply terminal N-side control supply terminal	V_{P1} V_{N1}	• Control supply terminals for the built-in HVIC and LVIC. • In order to prevent malfunction caused by noise and ripple in the supply voltage, a bypass capacitor with favorable frequency characteristics should be mounted very closely to these terminals. • Carefully design the supply so that the voltage ripple caused by noise or by system operation is within the specified minimum limitation. • It is recommended to insert a Zener diode (24V/1W) between each pair of control supply terminals to prevent surge destruction.
N-side control GND terminal	V_{NC}	• Control ground terminal for the built-in HVIC and LVIC. • Ensure that line current of the power circuit does not flow through this terminal in order to avoid noise influences. • Connect only one V_{NC} terminal (9 or 16pin) to the GND, and leave another one open.
Control input terminal	U_P,V_P,W_P U_N,V_N,W_N	• Control signal input terminals.Voltage input type. • These terminals are internally connected to Schmitt trigger circuit. • The wiring of each input should be as short as possible to protect the DIPIPM from noise interference. • Use RC filter in case of signal oscillation. (Pay attention to threshold voltage of input terminal, because input circuit has pull down resistor (min 3.3kΩ))
Short-circuit trip voltage detecting terminal	CIN	• For inverter part SC protection, input the potential of shunt resistor to CIN terminal through RC filter (for the noise immunity). • The time constant of RC filter is recommended to be up to 2μs.
Fault signal output terminal	F_O	• Fault signal output terminal. • Fo signal line should be pulled up to a 5V logic supply with over 5kΩ resistor (for limitting the Fo sink current I_{Fo} up to 1mA.) Normally 10kΩ is recommended.
Temperature output terminal	V_{OT}	• LVIC temperature is ouput by analog signal. • This terminal is connected ti the ouput of OP amplifer internally. • It is recommended to connect 5.1kΩ pulldown resistor if output linearlity is necessary under room temperature.
Inverter DC-link positive terminal	P	• DC-link positive power supply terminal. • Internally connected to the collectors of all P-side IGBTs. • To suppress surge voltage caused by DC-link wiring or PCB pattern inductance, smoothing capacitor should be located very closely to the P and N terminal of DIPIPM. It is also effective to add small film capacitor with good frequency characteristics.
Inverter DC-link negative terminal	NU,NV,NW	• Open emitter terminal of each N-side IGBT • Usually, these terminals are connected to the power GND through individual shunt resistor.
Inverter power output terminal	U, V, W	• Inverter output terminals for connection to inverter load (e.g. motor). • Each terminal is internally connected to the intermidiate point of the corresponding IGBT half bridge arm.

Note: Use oscilloscope to check voltage waveform of each power supply terminals and P&N terminals, the time division of OSC should be set to about 1μs/div. Please ensure the voltage (including surge) not exceed the specified limitation.

2.4 Mounting Method

This section shows the electric spacing and mounting precautions of DIP Ver.6.

2.4.1 Electric Spacing

The electric spacing specification of DIP Ver.6 is shown in Table 2-4-1

Table 2-4-1 Minimum insulation distance of DIP Ver.6

	Clearance (mm)	Creepage (mm)
Between live terminals with high potential	2.50	3.00
Between terminals and heat sink	1.45	1.50

2.4.2 Mounting Method and Precautions

When installing the module to the heat sink, excessive or uneven fastening force might apply stress to inside chips. Then it will lead to a broken or degradation of the chips or insulation structure. The recommended fastening procedure is shown in Fig.2-4-1. When fastening, it is necessary to use the torque wrench and fasten up to the specified torque. And pay attention to the foreign particle on the contact surface between the module and the heat sink. Even if the fixing of heatsink was done by proper procedure and condition, there is a possibility of damaging the package because of tightening by unexpected excessive torque or tucking particle. For ensuring safety it is recommended to conduct the confirmation test(e.g. insulation inspection) on the final product after fixing the DIPIPM with the heatsink.

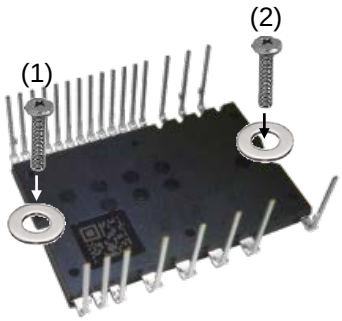


Fig.2-4-1 Recommended screw fastening order

Temporary fastening
(1)→(2)

Permanent fastening
(1)→(2)

Note: Generally, the temporary fastening torque is set to 20-30% of the maximum torque rating.
Not care the order of fastening (1) or (2), but need to fasten alternately.

Table 2-4-2 Mounting torque and heat sink flatness specifications

Item	Condition	Min.	Typ.	Max.	Unit
Mounting torque	Recommended 0.69N·m, Screw : M3	0.59	-	0.78	N·m
Flatness of outer heat sink	Refer Fig.2-4-2	-50	-	+100	μm

Note : Recommend to use plain washer (ISO7089-7094) in fastening the screws.

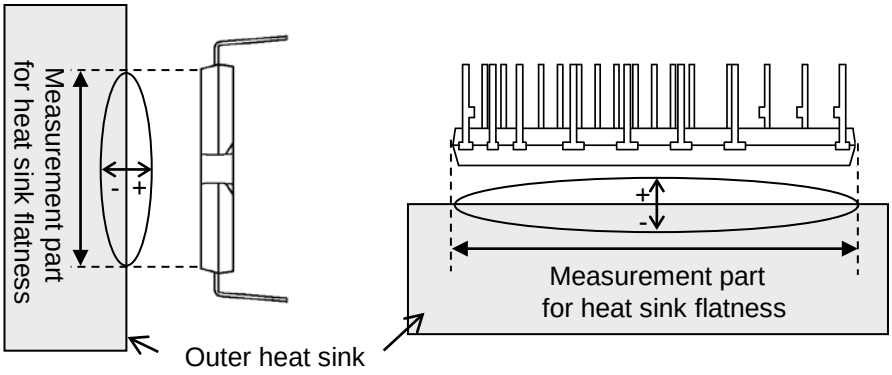


Fig.2-4-2 Measurement point of heat sink flatness

In order to get effective heat dissipation, it is necessary to enlarge the contact area as much as possible to minimize the contact thermal resistance. Regarding the heat sink flatness (warp/concavity and convexity) on the module installation surface, the surface finishing-treatment should be within Rz12.

Evenly apply thermally-conductive grease with 100μ-200μm thickness over the contact surface between a module and a heat sink, which is also useful for preventing corrosion. Furthermore, the grease should be with stable quality and long-term endurance within wide operating temperature range. The contacting thermal resistance between DIPIPM case and heat sink Rth(c-f) is determined by the thickness and the thermal conductivity of the applied grease. For reference, Rth(c-f) is about 0.3K/W (per 1/6 module, grease thickness: 20μm, thermal conductivity: 1.0W/m·k). When applying grease and fixing heat sink, pay attention not to take air into grease. It might lead to make contact thermal resistance worse or loosen fixing in operation.

Pay attention to the selection of thermal conductive grease. The grease thickness after fixing the heatsink may increase due to the properties of the grease (contained filler diameter, viscosity, amount of application and so on). And it may cause increase of contact thermal resistance or package crack. Please contact thermal conductive grease manufacturer for its detailed characteristics.

2.4.3 Soldering Conditions

The recommended soldering condition is mentioned as below.
(Note: The reflow soldering cannot be recommended for DIPIPM.)

(1) Flow (wave) Soldering

DIPIPM is tested on the condition described in Table 2-4-3 about the soldering thermostability, so the recommended conditions for flow (wave) soldering are soldering temperature is up to 265°C and the immersion time is within 11s. However, the condition might need some adjustment based on flow condition of solder, the speed of the conveyer, the land pattern and the through-hole shape on the PCB, etc.

It is necessary to confirm whether it is appropriate or not for your real PCB finally.

Table 2-4-3 Reliability test specification

Item	Condition
Soldering thermostability	260±5°C, 10±1s

(2) Hand soldering

Since the temperature impressed upon the DIPIPM may change based on the soldering iron types (wattages, shape of soldering tip, etc.) and the land pattern on PCB, the unambiguous hand soldering condition cannot be decided.

As a general requirement of the temperature profile for hand soldering, the temperature of the root of the DIPIPM terminal should be kept 150°C or less for considering glass transition temperature (Tg) of the package molding resin and the thermal withstand capability of internal chips. Therefore, it is necessary to check the DIPIPM terminal root temperature, solderability and so on in your real PCB, when configure the soldering temperature profile. (It is recommended to set the soldering time as short as possible.)

For reference, the evaluation example of hand soldering with 50W soldering iron is described as below.

[Evaluation method]
a. Sample: Super mini DIPIPM
b. Evaluation procedure
- Put the soldering tip of 50W iron (temperature set to 350/400°C) on the terminal within 1mm from the toe. (The lowest heat capacity terminal (=control terminal) is selected.)
- Measure the temperature rise of the terminal root part by the thermocouple installed on the terminal root.

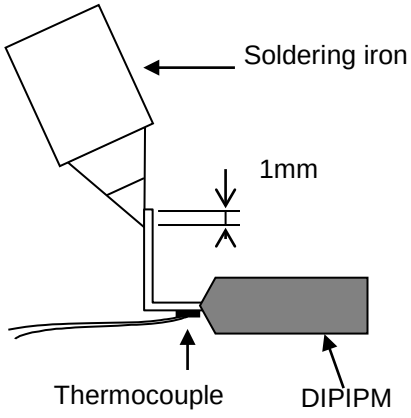


Fig.2-4-3 Heating and measuring point

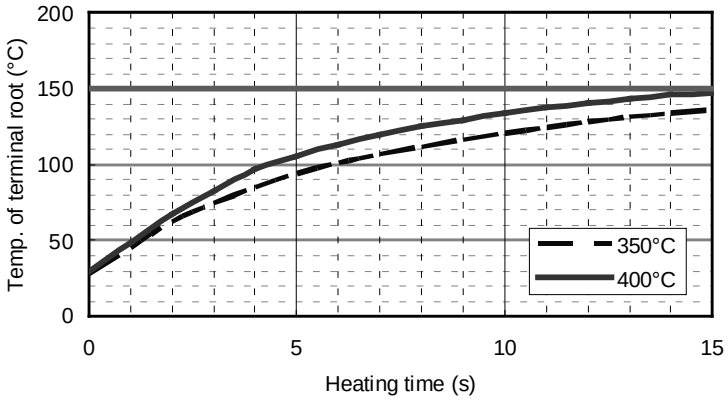


Fig.2-4-4 Temperature alteration of the terminal root (Example)

[Note]

For soldering iron, it is recommended to select one for semiconductor soldering (12~24V low voltage type, and the earthed iron tip) and with temperature adjustment function.

CHAPTER 3 SYSTEM APPLICATION GUIDANCE

3.1 Application Guidance

This chapter states the DIP Ver.6 application method and interface circuit design hints.

3.1.1 System connection

C1: Electrolytic type with good temperature and frequency characteristics.
Note: the capacitance also depends on the PWM control strategy of the application system
C2:0.22μ-2μF ceramic capacitor with good temperature, frequency and DC bias characteristics
C3:0.1μ-0.22μF Film capacitor (for snubber)
D1:Zener diode 24V/1W for surge absorber

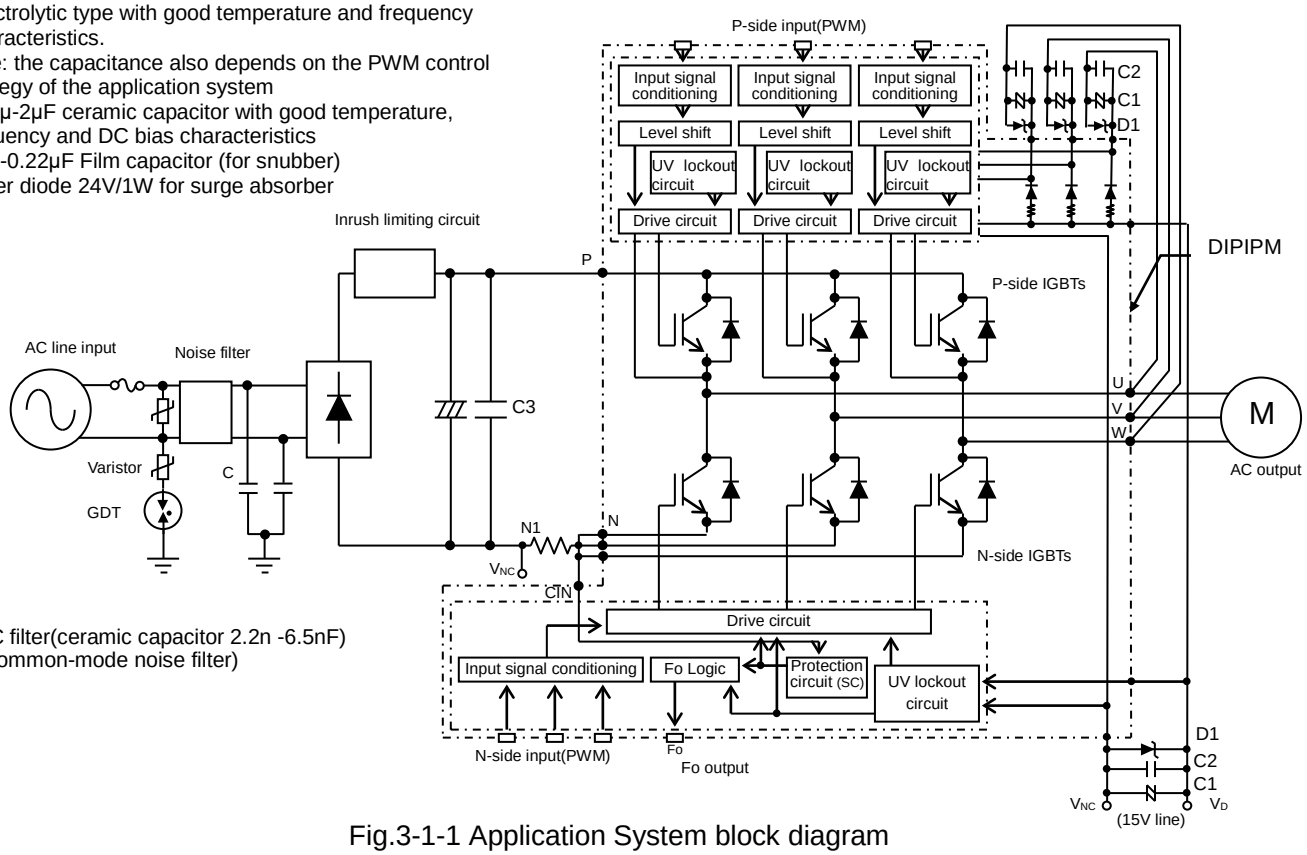


Fig.3-1-1 Application System block diagram

3.1.2 Interface Circuit (Direct Coupling Interface example for using one shunt resistor)

Fig.3-1-2 shows a typical application circuit of interface schematic, in which control signals are transferred directly input from a controller (e.g. MCU, DSP).

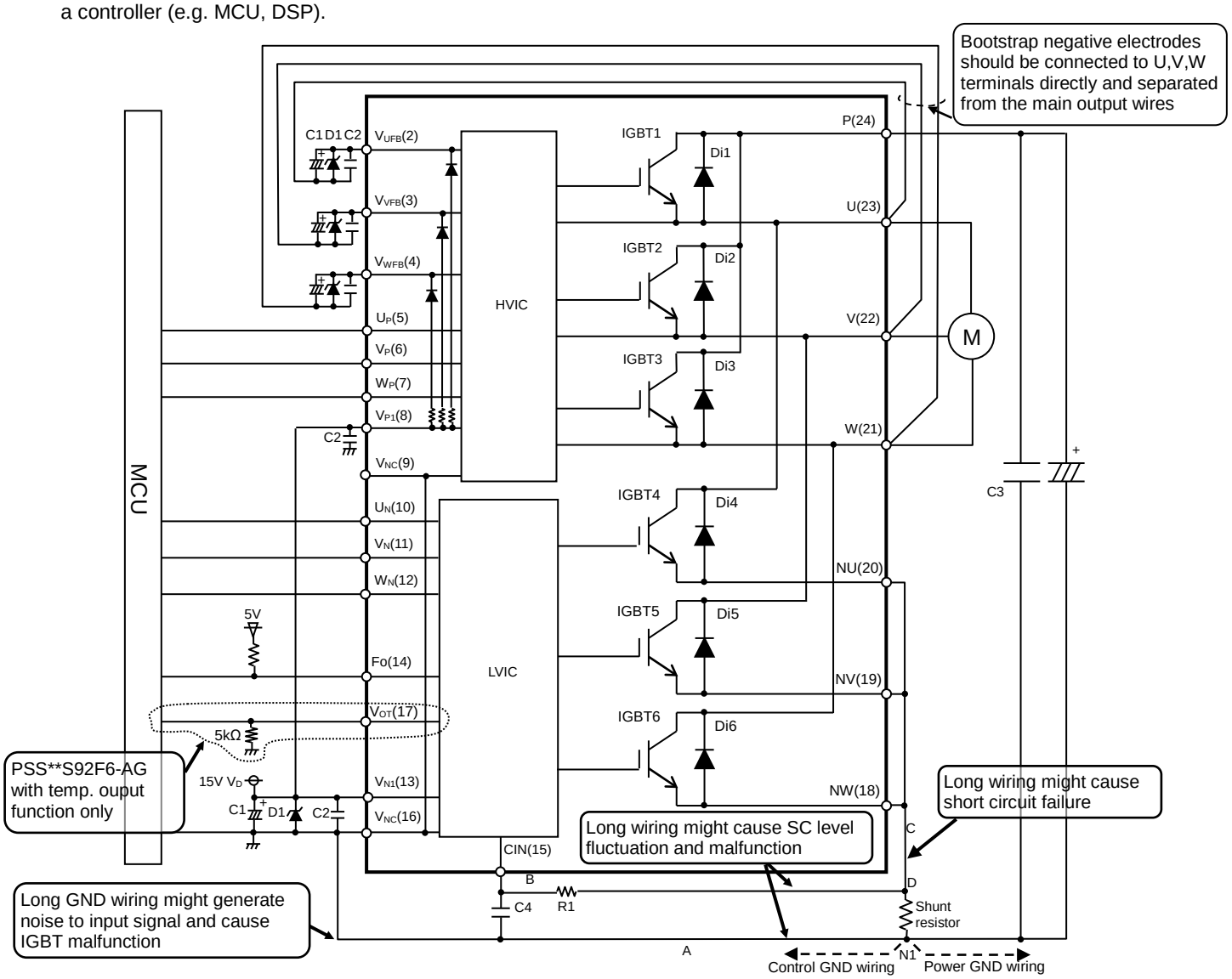


Fig.3-1-2 Interface circuit example in the case of using with one shunt resistor

(1) If control GND is connected with power GND by common broad pattern, it may cause malfunction by power GND fluctuation. It is recommended to connect control GND and power GND at only a point N1 (near the terminal of shunt resistor).

(2) It is recommended to insert a Zener diode D1(24V/1W) between each pair of control supply terminals to prevent surge destruction.

(3) To prevent surge destruction, the wiring between the smoothing capacitor and the P, N1 terminals should be as short as possible. Generally a 0.1-0.22μF snubber capacitor C3 between the P-N1 terminals is recommended.

(4) R1, C4 of RC filter for preventing protection circuit malfunction is recommended to select tight tolerance, temp-compensated type. The time constant R1C4 should be set so that SC current is shut down within 2μs. (1.5μs~2μs is general value.) SC interrupting time might vary with the wiring pattern, so the enough evaluation on the real system is necessary.

(5) To prevent malfunction, the wiring of A, B, C should be as short as possible.

(6) The point D at which the wiring to CIN filter is divided should be near the terminal of shunt resistor. NU, NV, NW terminals should be connected at near NU, NV, NW terminals.

(7) All capacitors should be mounted as close to the terminals as possible. (C1: good temperature, frequency characteristic electrolytic type and C2:0.22μ-2μF, good temperature, frequency and DC bias characteristic ceramic type are recommended.)

(8) Input drive is High-active type. There is a minimum 3.3kΩ pull-down resistor in the input circuit of IC. To prevent malfunction, the wiring of each input should be as short as possible. When using RC coupling circuit, make sure the input signal level meet the turn-on and turn-off threshold voltage.

(9) Fo output is open drain type. It should be pulled up to MCU or control power supply (e.g. 5V,15V) by a resistor that makes I_{Fo} up to 1mA. (I_{FO} is estimated roughly by the formula of control power supply voltage divided by pull-up resistance. In the case of pulled up to 5V, 10kΩ (5kΩ or more) is recommended.)

(10) Thanks to built-in HVIC, direct coupling to MCU without any optocoupler or transformer isolation is possible.

(11) Two V_{NC} terminals (9 & 16 pin) are connected inside DIPIPM, please connect either one to the 15V power supply GND outside and leave another one open.

(12) If high frequency noise superimposed to the control supply line, IC malfunction might happen and cause DIPIPM erroneous operation. To avoid such problem, line ripple voltage should meet dV/dt ≤+/-1V/μs, Vripple≤2Vp-p.

3.1.3 Interface Circuit (Example of Optocoupler Isolated Interface)

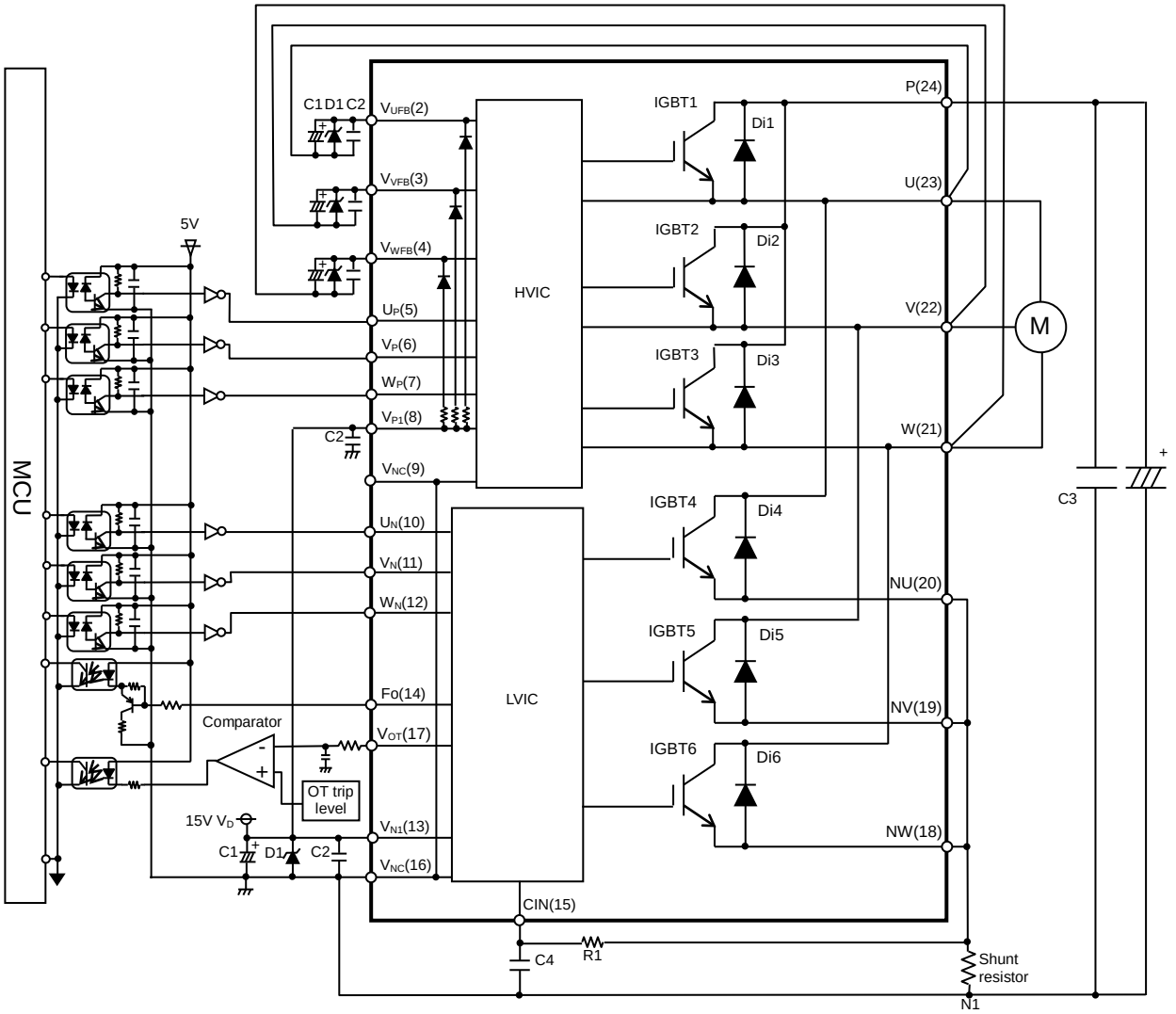


Fig.3-1-3 Interface circuit example with optocoupler

Note:

(1) High speed (high CMR) optocoupler is recommended.
(2) Fo terminal sink current for inverter part is max.1mA.
(3) About comparator circuit at V_{OT} output, it is recommended to design the input circuit with hysteresis because of preventing output chattering.

3.1.4 External SC Protection Circuit with Using Three Shunt Resistors

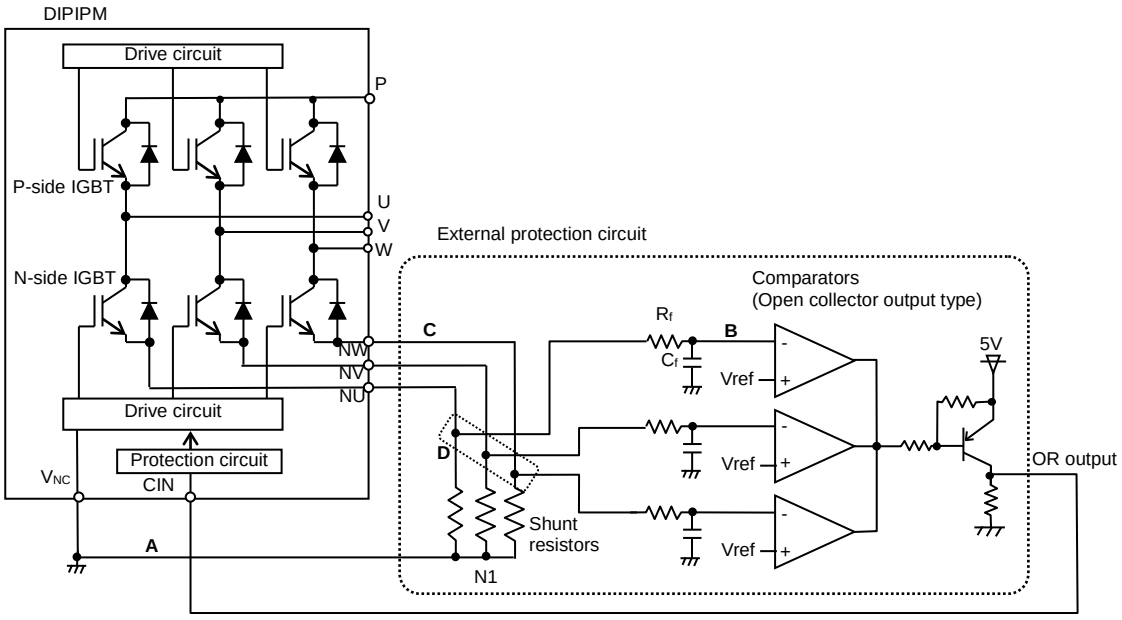


Fig.3-1-4 Interface circuit example

Note:

(1) It is necessary to set the time constant R_fC_f of external comparator input so that IGBT stop within 2μs when short circuit occurs. SC interrupting time might vary with the wiring pattern, comparator speed and so on.
(2) The threshold voltage Vref should be set up the same rating of short circuit trip level (Vsc(ref) typ. 0.48V).
(3) Select the external shunt resistance so that SC trip-level is less than specified value.
(4) To avoid malfunction, the wiring A, B, C should be as short as possible.
(5) The point D at which the wiring to comparator is divided should be near the terminal of shunt resistor.
(6) OR output high level should be over 0.505V (=maximum Vsc(ref)).
(7) GND of Comparator, Vref circuit and Cf should be not connected to noisy power GND but to control GND wiring.

3.1.5 Circuits of Signal Input Terminals and Fo Terminal

(1) Internal Circuit of Control Input Terminals

DIPIPM is high-active input logic.
A 3.3kΩ(min) pull-down resistor is built-in each input circuits of the DIPIPM as shown in Fig.3-1-5 , so external pull-down resistor is not needed.
Furthermore, by lowering the turn on and turn off threshold value of input signal as shown in Table 3-1-1, a direct coupling to 3V class microcomputer or DSP becomes possible.

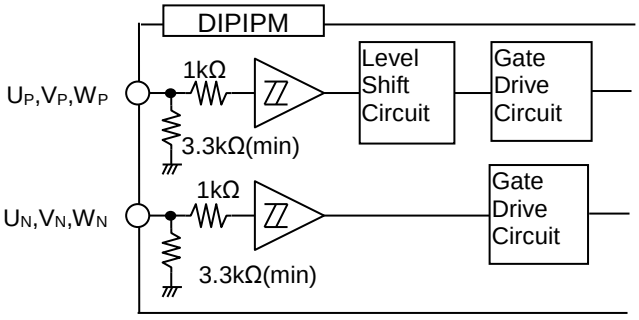


Fig.3-1-5 Internal structure of control input terminals

Table 3-1-1 Input threshold voltage ratings(Tj=25°C)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Turn-on threshold voltage	Vth(on)	U_P,V_P,W_P-V_{NC} terminals U_N,V_N,W_N-V_{NC} terminals	-	2.1	2.6	V
Turn-off threshold voltage	Vth(off)		0.8	1.3	-	
Threshold voltage hysterisis	Vth(hys)		0.35	0.65	-	

Note: There are specifications for the minimum input pulse width in DIPIPM Ver.6. DIPIPM might make no response if the input signal pulse width (both on and off) is less than the specified value. Please refer to the datasheet for the specification. (The specification of min. width is different due to the current rating.)

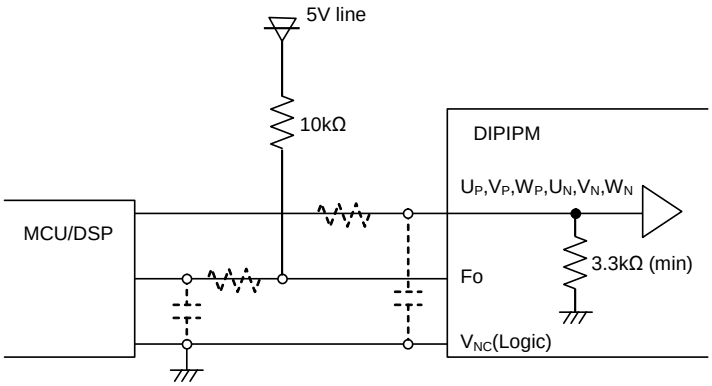


Fig.3-1-6 Control input connection

Note: The RC coupling (parts shown in the dotted line) at each input depends on user's PWM control strategy and the wiring impedance of the printed circuit board.
The DIPIPM signal input section integrates a 3.3kΩ(min) pull-down resistor. Therefore, when using an external filtering resistor, please pay attention to the signal voltage drop at input terminal.

(2) Internal Circuit of Fo Terminal

F_O terminal is an open drain type, it should be pulled up to a 5V supply as shown in Fig.3-1-6. Fig.3-1-7 shows the typical V-I characteristics of Fo terminal. The maximum sink current of Fo terminal is 1mA. If optocoupler is applied to this output, please pay attention to the optocoupler drive ability.

Table 3-1-2 Electric characteristics of Fo terminal

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Fault output voltage	V_{FOH}	V_{SC}=0V,Fo=10kΩ,5V pulled-up	4.9	-	-	V
	V_{FOL}	V_{SC}=1V,Fo=1mA	-	-	0.95	V

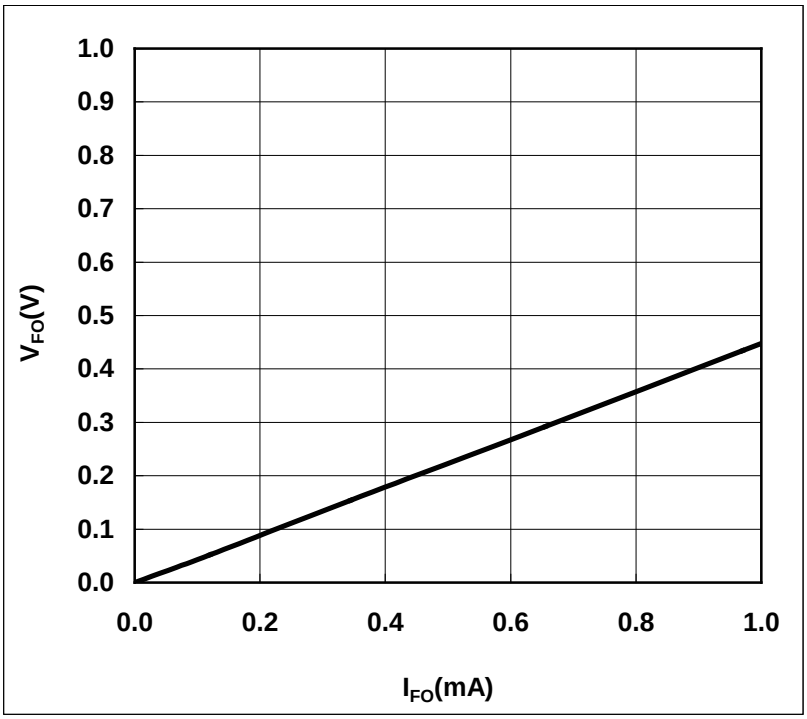


Fig.3-1-7 Fo terminal typical V-I characteristics (V_D=15V, T_j=25°C)

3.1.6 Snubber Circuit

In order to prevent DIPIPM from destruction by extra surge, the wiring length between the smoothing capacitor and DIPIPM P terminal – N1 points (shunt resistor terminal) should be as short as possible. Also, a 0.1μ~0.22μF/630V snubber capacitor should be mounted in the DC-link and near to P, N1.

There are two positions ((1)or(2)) to mount a snubber capacitor as shown in Fig.3-1-8. Snubber capacitor should be installed in the position (2) so as to suppress surge voltage effectively. However, the charging and discharging currents generated by the wiring inductance and the snubber capacitor will flow through the shunt resistor, which might cause erroneous protection if this current is large enough.

In order to suppress the surge voltage maximally, the wiring at part-A (including shunt resistor parasitic inductance) should be as small as possible. A better wiring example is shown in location (3).

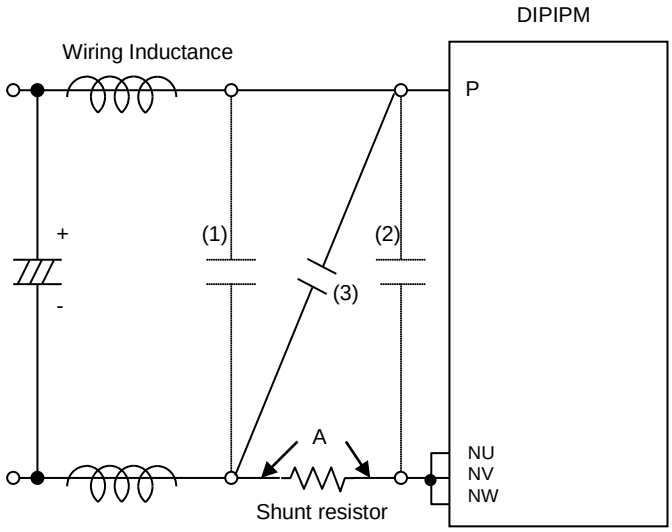


Fig.3-1-8 Recommended snubber circuit location

3.1.7 Recommended Wiring Method around Shunt Resistor

External shunt resistor is employed to detect short-circuit accident. A longer wiring between the shunt resistor and DIPIPM causes so much large surge that might damage built-in IC. To decrease the pattern inductance, the wiring between the shunt resistor and DIPIPM should be as short as possible and using low inductance type resistor such as SMD resistor instead of long-lead type resistor.

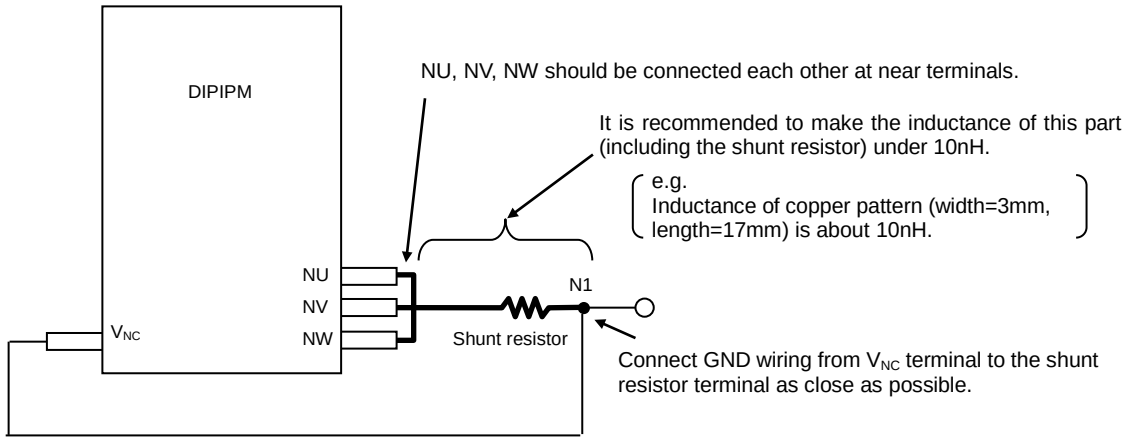


Fig.3-1-9 Wiring instruction (In the case of using with one shunt resistor)

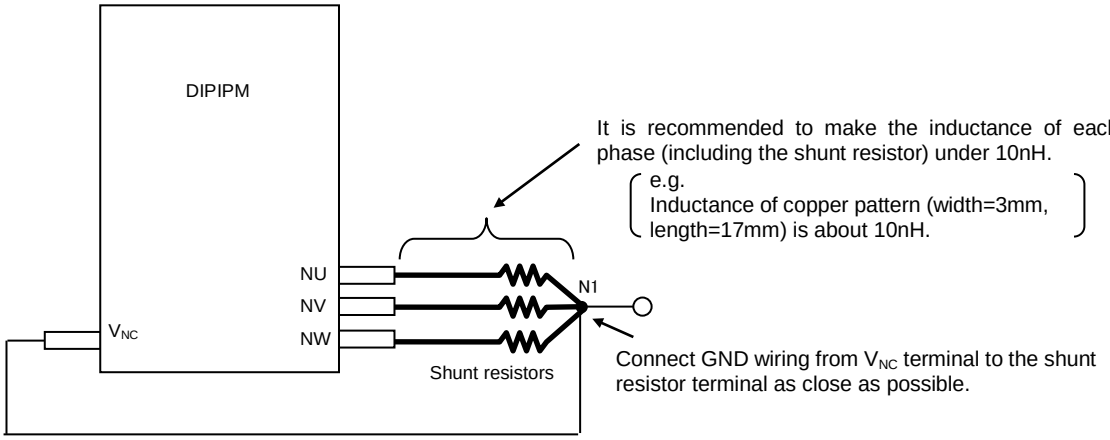


Fig.3-1-10 Wiring instruction (In the case of using with three shunt resistor)

Influence of pattern wiring around the shunt resistor is shown below.

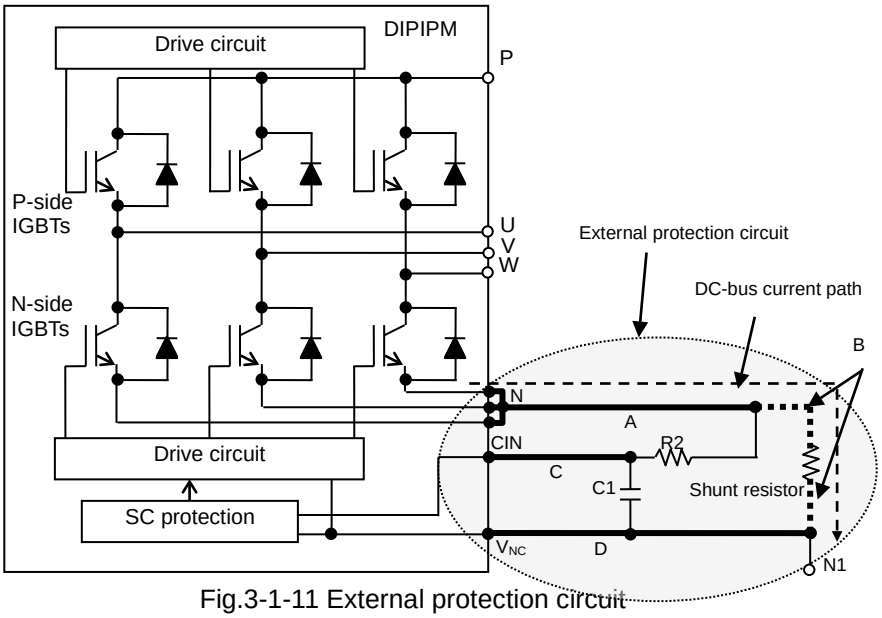


Fig.3-1-11 External protection circuit

(1) Influence of the part-A wiring

The ground of N-side IGBT gate is V_{NC}. If part-A wiring pattern in Fig.3-1-11 is too long, extra voltage generated by the wiring parasitic inductance will result the potential of IGBT emitter variation during switching operation. Please install shunt resistor as close to the N terminal as possible.

(2) Influence of the part-B wiring

The part-B wiring affects SC protection level. SC protection works by detecting the voltage of the CIN terminals. If part-B wiring is too long, extra surge voltage generated by the wiring inductance will lead to deterioration of SC protection level. It is necessary to connect CIN and V_{NC} terminals directly to the two ends of shunt resistor and avoid long wiring.

(3) Influence of the part-C wiring pattern

C1R2 filter is added to remove noise influence occurring on shunt resistor. Filter effect will dropdown and noise will easily superimpose on the wiring if part-C wiring is too long. It is necessary to install the C1R2 filter near CIN, V_{NC} terminals as close as possible.

(4) Influence of the part-D wiring pattern

Part-D wiring pattern gives influence to all the items described above, maximally shorten the GND wiring is expected.

3.1.8 Precaution for Wiring on PCB

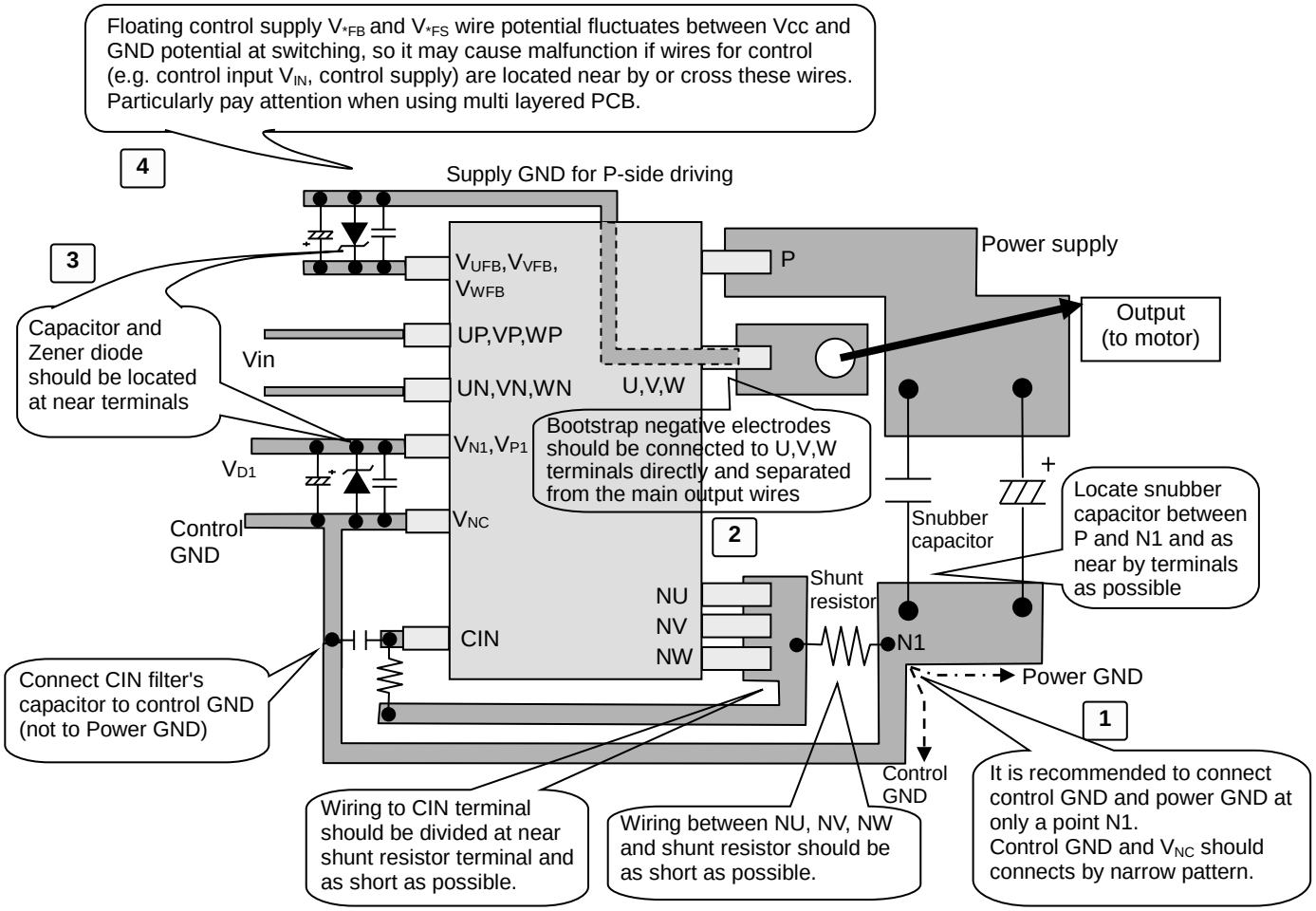


Fig.3-1-12 Precaution for wiring on PCB

The case example of trouble due to PCB pattern

	Case example	Matter of trouble
1	Control GND pattern overlaps power GND pattern	The surge, generated by the wiring pattern and di/dt of noncontiguous big current flows to power GND, transfers to control GND pattern. It causes the control GND level fluctuation, so that the input signal based on the control GND fluctuates too. Then the arm short might occur.
	Ground loop pattern exists	Stray current flows to GND loop pattern, so that the control GND level and input signal level (based on the GND) fluctuates. Then the arm short might occur.
	Control GND connects common broad pattern	Current flows to control GND pattern and the control GND level fluctuates. It leads the IPM malfunction or break.
2	Large inductance of wiring between N and N1 terminal	Long wiring pattern has big parasitic inductance and generates high surge when switching. This surge causes the matter as below. •HVIC malfunction due to VS voltage (output terminal potential) dropping excessively. •LVIC surge destruction
3	Capacitors or zener diodes are nothing or located far from the terminals	IC surge destruction or malfunction might occur.
4	The input lines are located parallel and close to the floating supply lines for P-side drive	Cross talk noise might be transferred through the capacitance between these floating supply lines and input lines to DIPIPM. Then incorrect signals are input to DIPIPM input, and arm short (short circuit) might occur.

3.1.9 Parallel operation of DIPIPM

Fig.3-1-13 shows the circuitry of parallel connection of two DIPIPMs. Route (1) and (2) indicate the gate charging path of low-side IGBT in DIPIPM No.1 & 2 respectively. In the case of DIPIPM 1, the parasitic inductance becomes large by long wiring and it might have a negative effect on DIPIPM's switching operation. (Charging operation of bootstrap capacitor for high-side might be affected too.) Also, such a wiring makes DIPIPM be affected by noise easily, then it might lead to malfunction. If more DIPIPMs are connected in parallel, GND pattern becomes longer and the influence to other circuit (protection circuit etc.) by the fluctuation of GND potential is conceivable, therefore parallel connection is not recommended.

Because DIPIPM doesn't consider the fluctuation of characteristics between each phase definitely, it cannot be recommended to drive same load by parallel connection with other phase IGBT or IGBT of other DIPIPM.

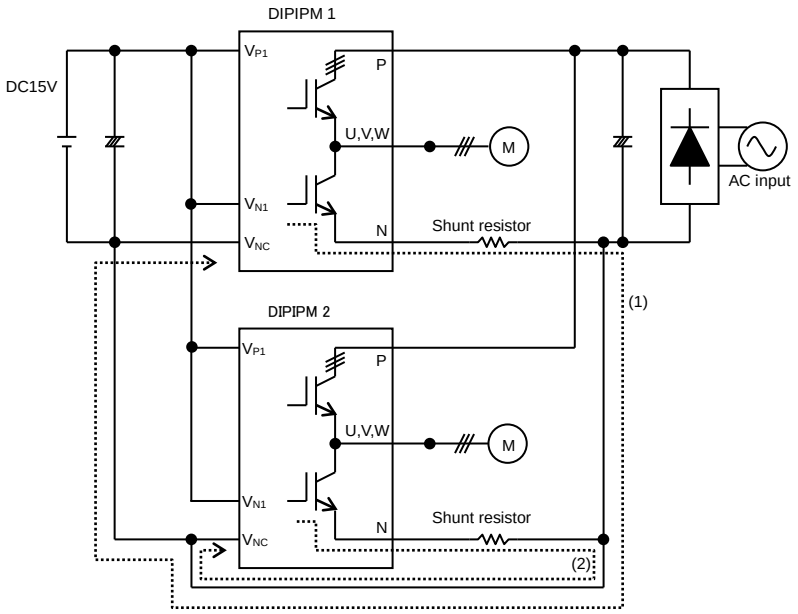


Fig.3-1-13 Parallel operation

3.1.10 SOA of DIP Ver.6

The following describes the SOA (Safety Operating Area) of the DIP Ver.6.

V_{CES} : Maximum rating of IGBT collector-emitter voltage

V_{CC} : Supply voltage applied on P-N terminals

$V_{CC(surge)}$: Total amount of V_{CC} and surge voltage generated by the wiring inductance and the DC-link capacitor.

$V_{CC(PROT)}$: DC-link voltage that DIPIPM can protect itself.

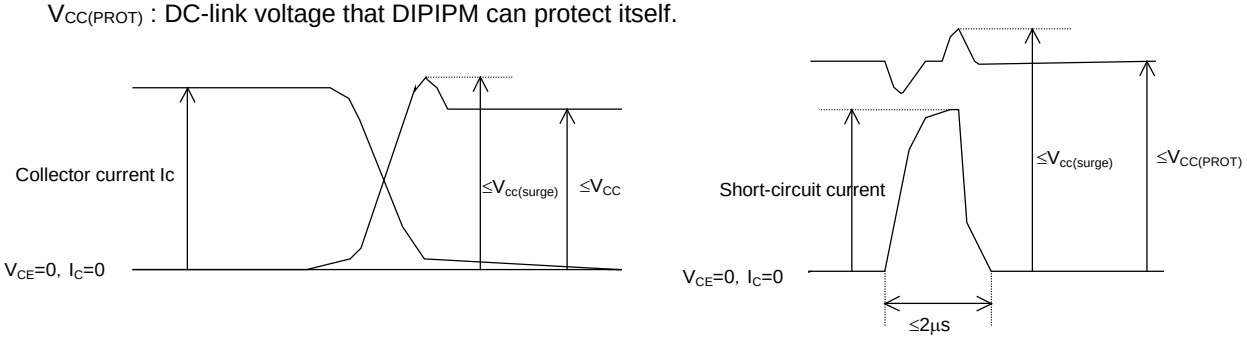


Fig.3-1-14 SOA at switching mode and short-circuit mode

In Case of switching

V_{CES} represents the maximum voltage rating (600V) of the IGBT. By subtracting the surge voltage (100V or less) generated by internal wiring inductance from V_{CES} is $V_{CC(surge)}$, that is 500V. Furthermore, by subtracting the surge voltage (50V or less) generated by the wiring inductor between DIPIPM and DC-link capacitor from $V_{CC(surge)}$ derives V_{CC}, that is 450V.

In Case of Short-circuit

V_{CES} represents the maximum voltage rating (600V) of the IGBT. By Subtracting the surge voltage (100V or less) generated by internal wiring inductor from V_{CES} is $V_{CC(surge)}$, that is, 500V. Furthermore, by subtracting the surge voltage (100V or less) generated by the wiring inductor between the DIPIPM and the electrolytic capacitor from $V_{CC(surge)}$ derives V_{CC}, that is, 400V.

3.1.11 SCSOA

Fig.3-1-15~18 shows the typical SCSOA performance curves of PSS05S92*6-AG, PSS10S92*6-AG, PSS15S92*6-AG and PSS20S92*6-AG.

(Conditions: Vcc=400V, Tj=125°C at initial state, Vcc(surge)≤500V(surge included), non-repetitive,2m load.)

In the case of PSS15S92*6-AG, it can shutdown safely an SC current that is about 5.8 times of its current rating under the conditions only if the IGBT conducting period is less than 2.7μs. Since the SCSOA operation area will vary with the control supply voltage, DC-link voltage, and etc, it is necessary to set time constant of RC filter with a margin.

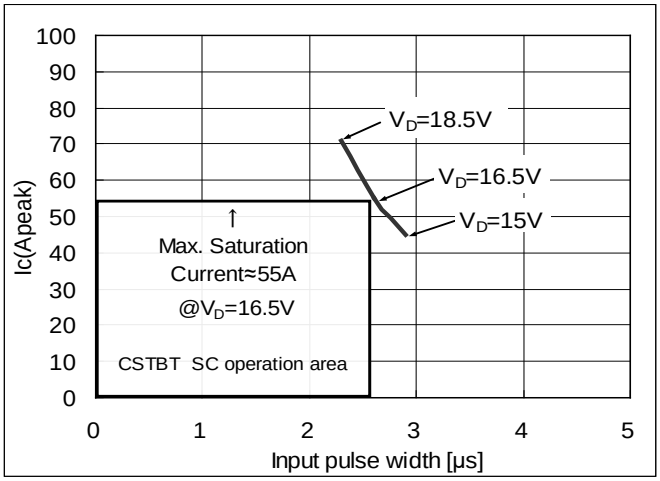


Fig.3-1-15 Typical SCSOA curve of PSS05S92*6-AG

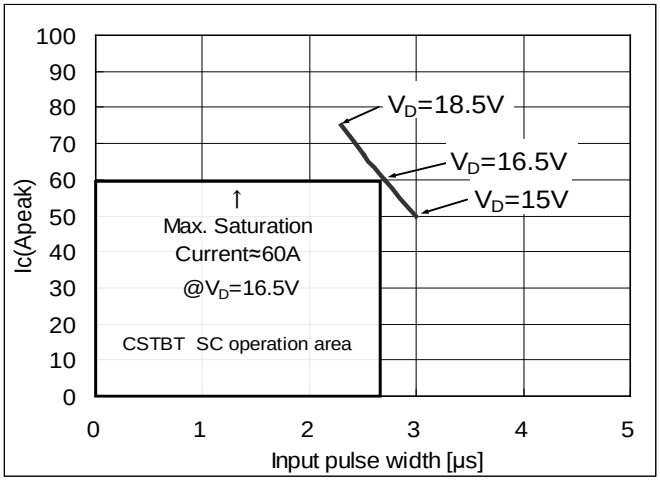


Fig.3-1-16 Typical SCSOA curve of PSS10S92*6-AG

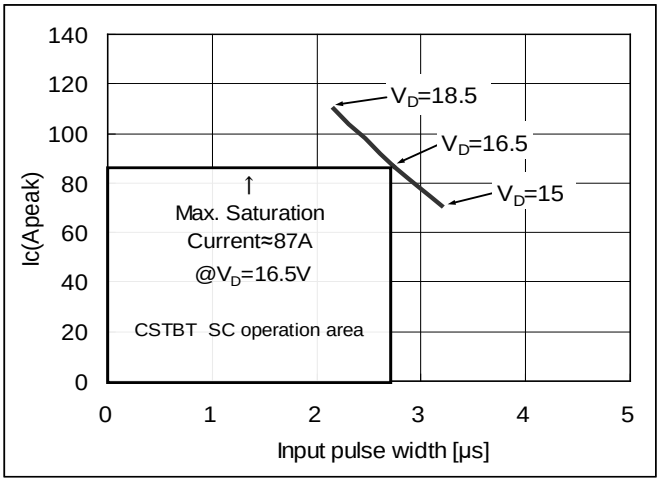


Fig.3-1-17 Typical SCSOA curve of PSS15S92*6-AG

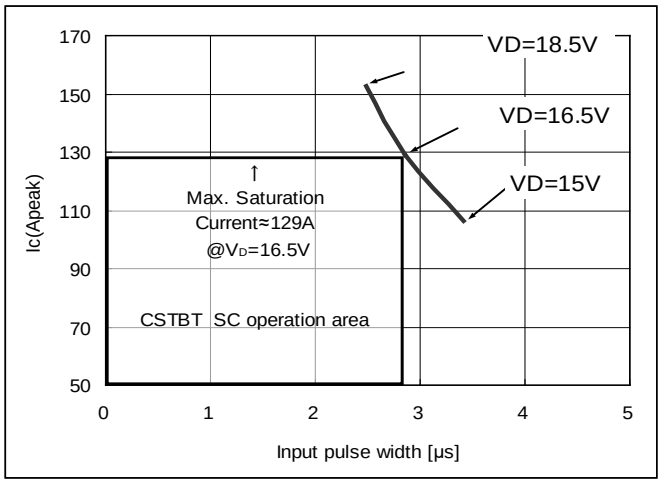


Fig.3-1-18 Typical SCSOA curve of PSS20S92*6-AG

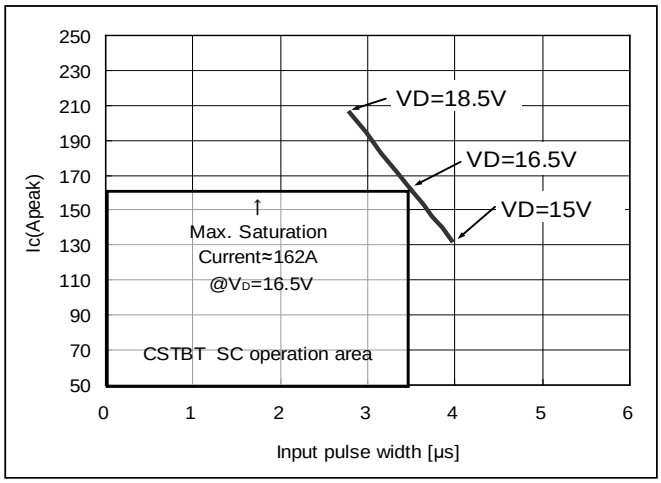


Fig.3-1-19 Typical SCSOA curve of PSS30S92*6-AG

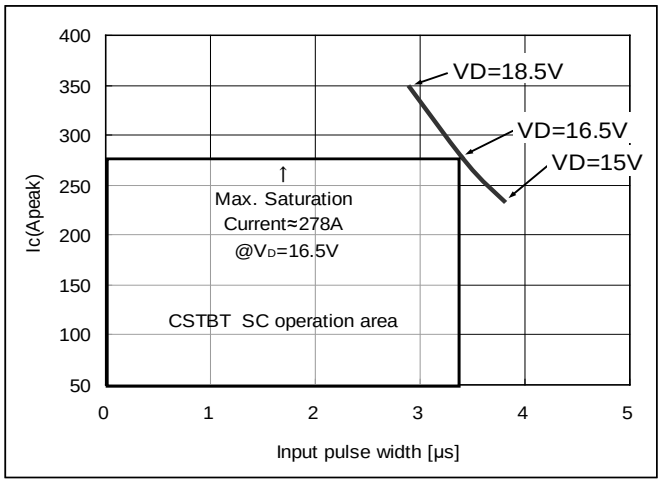


Fig.3-1-20 Typical SCSOA curve of PSS35S92*6-AG

3.1.12 Power Life Cycles

When DIPIPM is in operation, repetitive temperature variation will happens on the IGBT junctions (ΔTj). The amplitude and the times of the junction temperature variation affect the device lifetime.
Fig.3-1-19 shows the IGBT power cycle curve as a function of average junction temperature variation (ΔTj).
(The curve is a regression curve based on 3 points of ΔTj=46, 88, 98K with regarding to failure rate of 0.1%, 1% and 10%. These data are obtained from the reliability test of intermittent conducting operation)

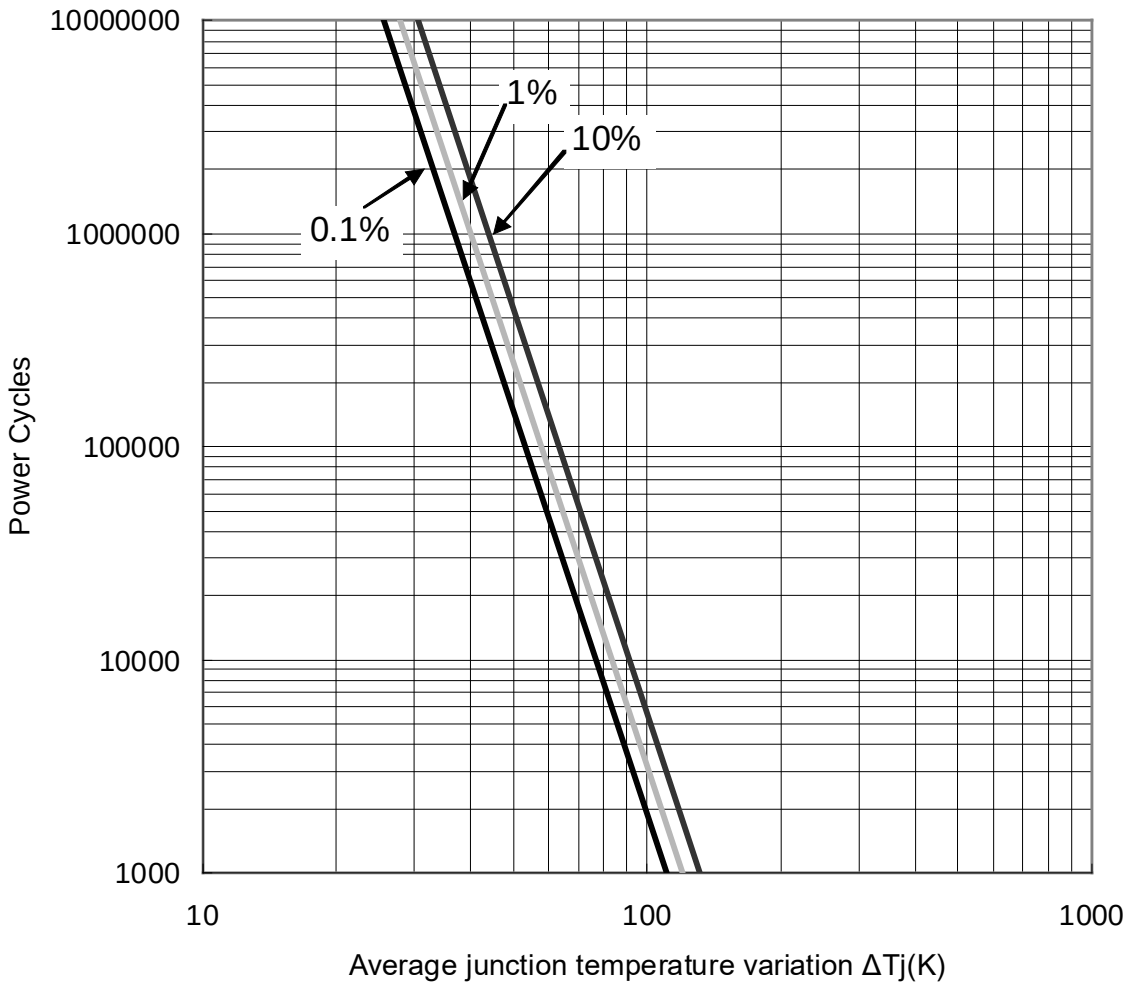


Fig.3-1-19 Power cycle curve

3.2 Power Loss and Thermal Dissipation Calculation

3.2.1 Power Loss Calculation

Simple expressions for calculating average power loss are given below:

● Scope

The power loss calculation intends to provide users a way of selecting a matched power device for their VVVF inverter application. However, it is not expected to use for limit thermal dissipation design.

● Assumptions

(1) PWM controlled VVVF inverter with sinusoidal output;
(2) PWM signals are generated by the comparison of sine waveform and triangular waveform.
(3) Duty amplitude of PWM signals varies between $\frac{1-D}{2} \sim \frac{1+D}{2}$ (%/100), (D: modulation depth).
(4) Output current various with Icp·sinx and it does not include ripple.
(5) Power factor of load output current is cosθ, ideal inductive load is used for switching.

● Expressions Derivation

PWM signal duty is a function of phase angle x as $\frac{1+\mathrm{D}\times\sin\mathrm{x}}{2}$ which is equivalent to the output voltage variation. From the power factor cosθ, the output current and its corresponding PWM duty at any phase angle x can be obtained as below:

$$Output\ \ current = Icp \times \sin x$$

$$PWM\ \ \ Duty = \frac{1 + D \times \sin(x + \theta)}{2}$$

Then, $V_{CE(sat)}$ and V_{EC} at the phase x can be calculated by using a linear approximation:

$$Vce(sat) = Vce(sat)(@\ Icp \times \sin x)$$
$$Vec = (-1) \times Vec(@\ Iecp(= Icp) \times \sin x)$$

Thus, the static loss of IGBT is given by:

$$\frac{1}{2\pi}\int_0^{\pi} (Icp \times \sin x) \times Vce(sat)(@\ Icp \times \sin x) \times \frac{1 + D\sin(x + \theta)}{2} \bullet dx$$

Similarly, the static loss of free-wheeling diode is given by:

$$\frac{1}{2\pi}\int_{\pi}^{2\pi} ((-1) \times Icp \times \sin x)((-1) \times Vec(@\ Icp \times \sin x) \times \frac{1 + D\sin(x + \theta)}{2} \bullet dx$$

On the other hand, the dynamic loss of IGBT, which does not depend on PWM duty, is given by:

$$\frac{1}{2\pi}\int_0^{\pi} (Psw(on)(@\ Icp \times \sin x) + Psw(off)(@\ Icp \times \sin x)) \times fc \bullet dx$$

FWDi recovery characteristics can be approximated by the ideal curve shown in Fig.3-2-1, and its dynamic loss can be calculated by the following expression:

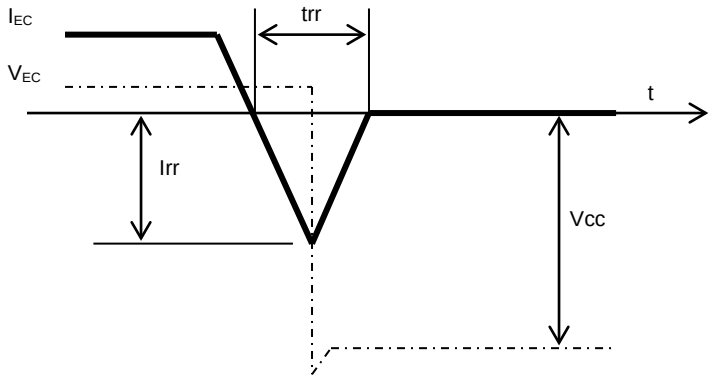


Fig.3-2-1 Ideal FWDi recovery characteristics curve

$$Psw = \frac{Irr \times Vcc \times trr}{4}$$

Recovery occurs only in the half cycle of the output current, thus the dynamic loss is calculated by:

$$\frac{1}{2}\int_{\pi}^{2\pi} \frac{Irr(@\ Icp \times \sin x) \times Vcc \times trr(@\ Icp \times \sin x)}{4} \times fc \bullet dx$$

$$= \frac{1}{8}\int_{\rho}^{2\pi} Irr(@\ Icp \times \sin x) \times Vcc \times trr(@\ Icp \times \sin x) \times fc \bullet dx$$

- Attention of applying the power loss simulation for inverter designs
  - Divide the output current period into fine-steps and calculate the losses at each step based on the actual values of PWM duty, output current, $V_{CE(sat)}$, V_{EC}, and Psw corresponding to the output current. The worst condition is most important.
  - PWM duty depends on the signal generating way.
  - The relationship between output current waveform or output current and PWM duty changes with the way of signal generating, load, and other various factors. Thus, calculation should be carried out on the basis of actual waveform data.
  - $V_{CE(sat)}$,V_{EC} and Psw(on, off) should be the values at Tj=125°C.

3.2.2 Temperature Rise Considerations and Calculation Example

Fig.3-2-2 shows the typical characteristics of allowable motor rms current versus carrier frequency under the following inverter operating conditions based on power loss simulation results.

Conditions: V_{CC}=300V, V_D=V_{DB}=15V, $V_{CE(sat)}$=Typ., Switching loss=Typ., Tj=125°C, Tf=100°C, Rth(j-c)=Max., Rth(c-f)=0.3°C/W (per 1/6 module), P.F=0.8, 3-phase PWM modulation, 60Hz sine waveform output

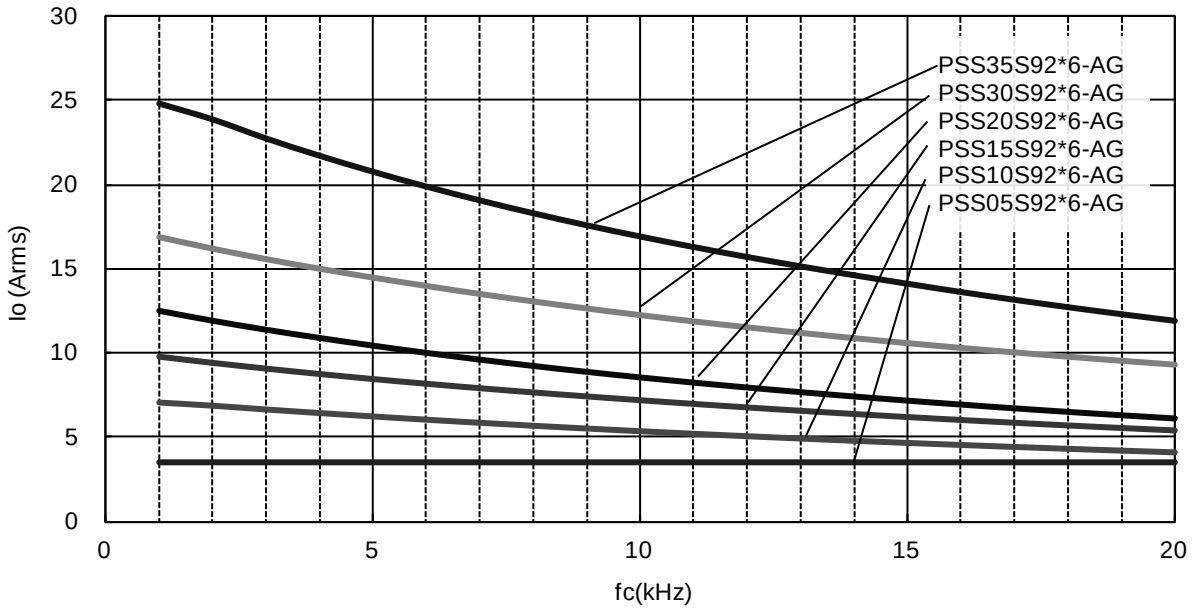


Fig.3-2-2 Effective current-carrier frequency characteristics

Fig.3-2-2 shows an example of estimating allowable inverter output rms current under different carrier frequency and permissible maximum operating temperature condition (Tf=100°C. Tj=125°C). The results may change for different control strategy and motor types. Anyway please ensure that there is no large current over device rating flowing continuously. The allowable motor current can also be obtained from the free power loss simulation software. The software can be downloaded at Mitsubishi Electric web site.
URL: http://www.mitsubishielectric.com/semiconductors/

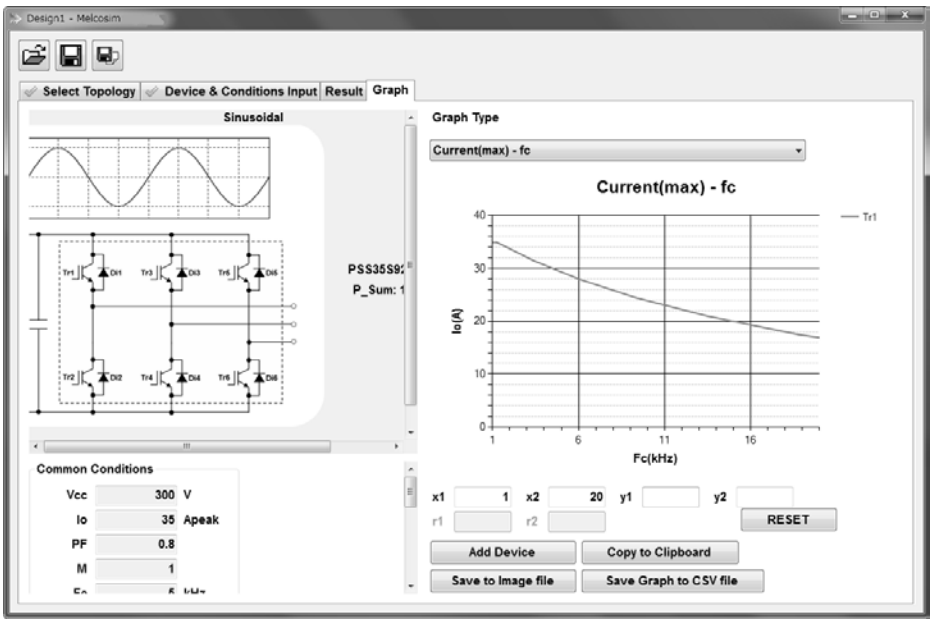


Fig.3-2-3 Loss simulator screen image

3.2.3 Installation of thermocouple

Installation of thermocouple for measurement of DIPIPM case temperature is shown below.

Point for installing thermocouple in heat sink is shown in Fig.3-2-4. In some control schemes, temperature measurement point at the following may not be highest case temperature. In such cases, it is necessary to change the measurement point to that under the highest power chip. (Refer previous figure of power chip position.)

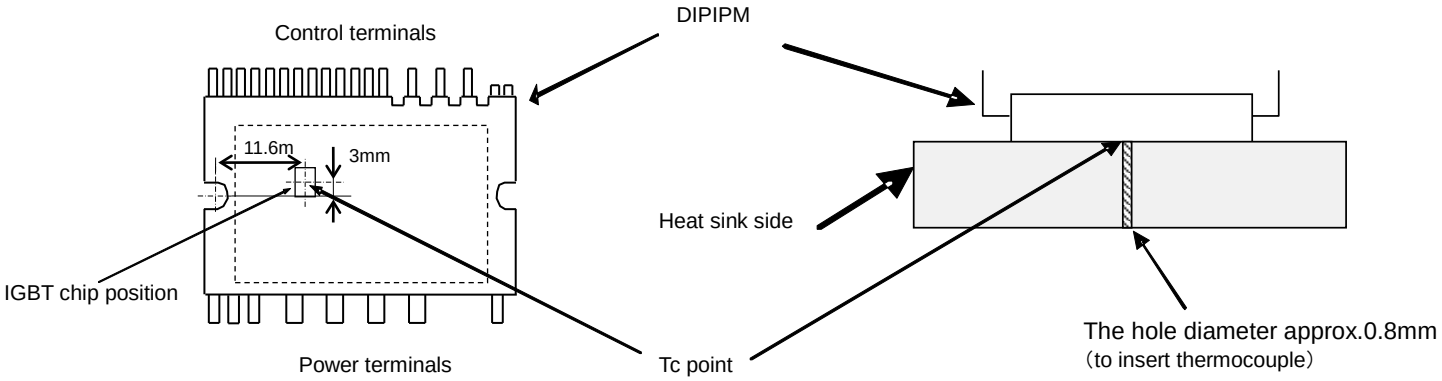


Fig. 3-2-4 Point for installing thermocouple in external heat sink

Installation of thermocouple is shown in Fig. 3-2-5. After making a hole under the chip with largest loss into the heat sink, the thermocouple is inserted in this hole and fixed by hammering around the hole with a centerpunch. After fixing the thermocouple, please sandpaper the thermocouple installing surface to make flat surface.

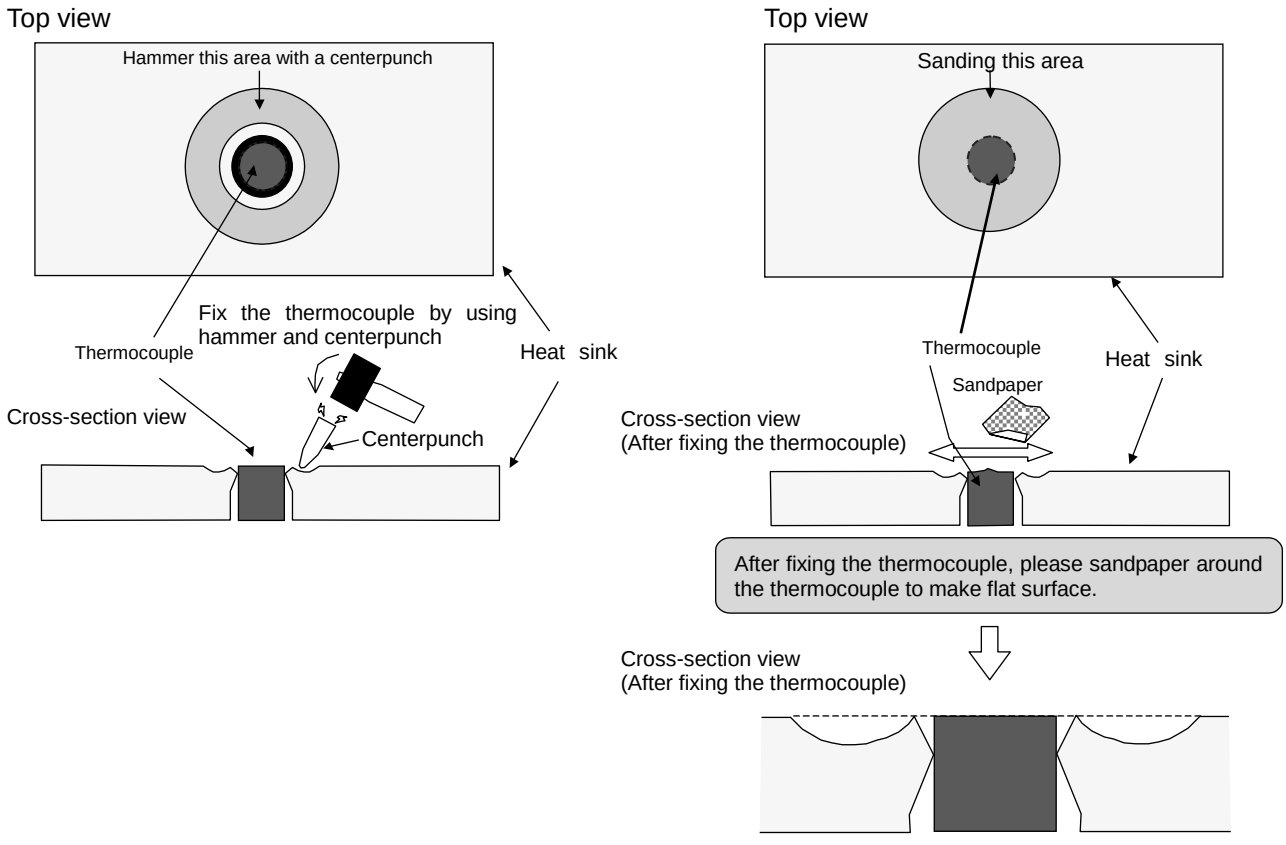


Fig. 3-2-5 Example of installation of thermocouple

3.3 Noise and ESD Withstand Capability

3.3.1 Evaluation Circuit of Noise Withstand Capability

DIP Ver.6 series have been confirmed to be with over +/-2.0kV noise withstand capability by the noise evaluation under the conditions shown in Fig.3-3-1. However, noise withstand capability greatly depends on the test environment, the wiring patterns of control substrate, parts layout, and other factors; therefore an additional confirmation on prototype is necessary.

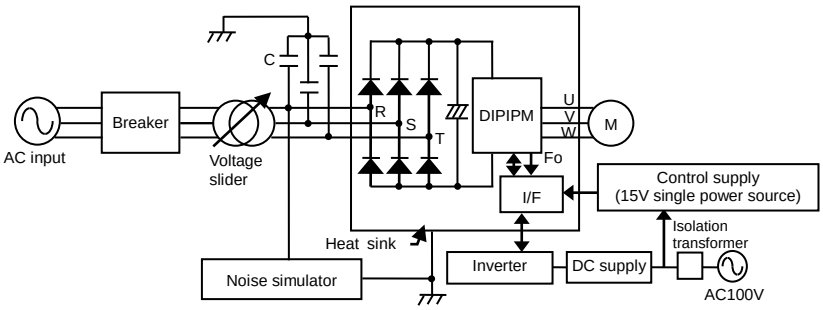


Fig.3-3-1 Noise withstand capability evaluation circuit

Note:

C1: AC line common-mode filter 4700pF, PWM signals are input from microcomputer by using optocouplers, 15V single power supply, Test is performed with IM

Test conditions

V_{CC}=300V, V_D=15V, Ta=25°C, no load

Scheme of applying noise: From AC line (R, S, T), Period T=16ms, Pulse width tw=0.05-1μs, input in random.

3.3.2 Countermeasures and Precautions

DIPIPM improves noise withstand capabilities by means of reducing parts quantity, lowering internal wiring parasitic inductance, and reducing leakage current. But when the noise affects on the control terminals of DIPIPM (due to wiring pattern on PCB), the short circuit or malfunction of SC protection may occur. In that case, below countermeasures are recommended.

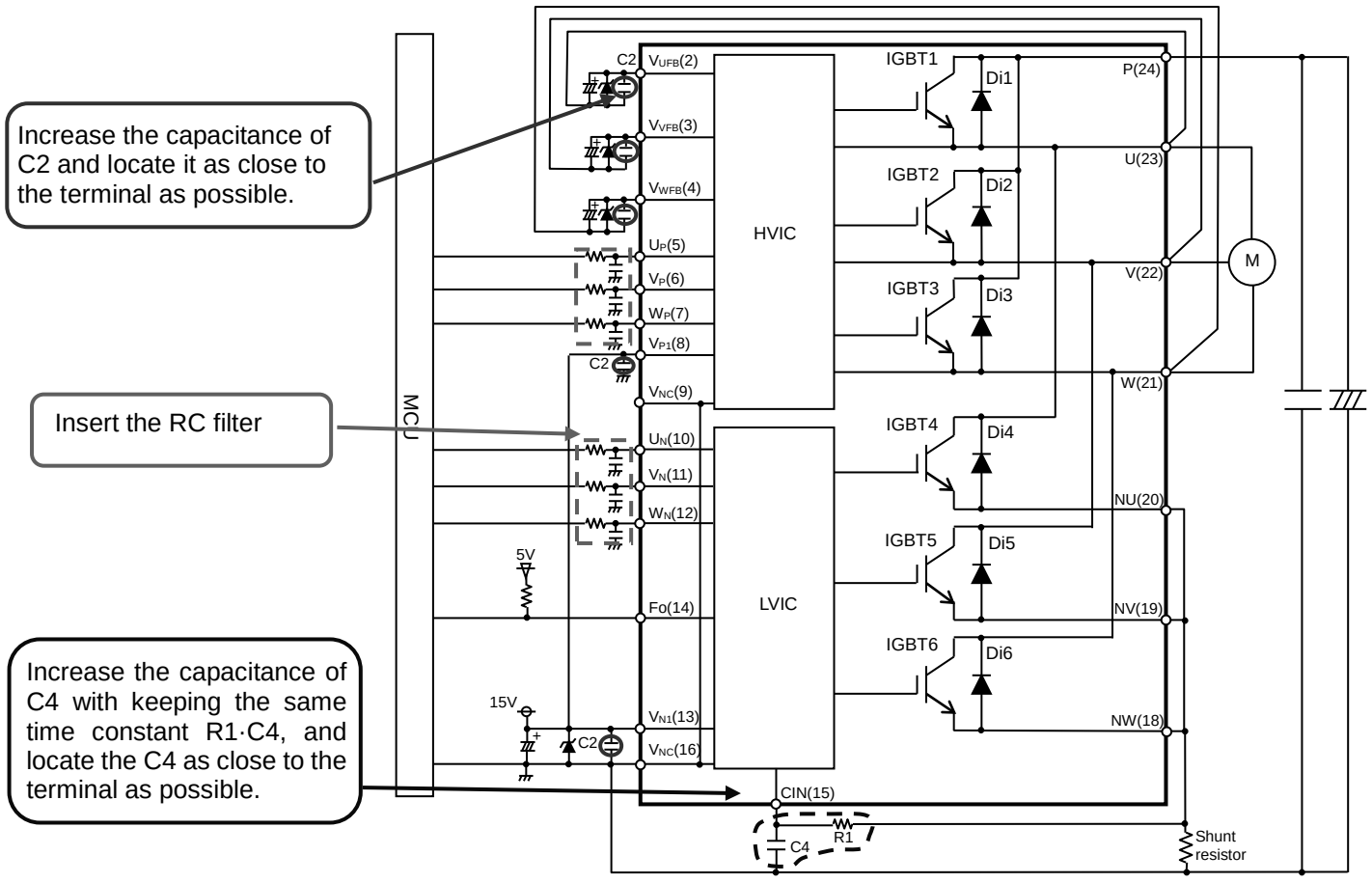


Fig.3-3-2 Example of countermeasures for inverter part

3.3.3 Static Electricity Withstand Capability

DIPIPM has been confirmed to be with +/-200V or more withstand capability against static electricity from the following tests shown in Fig.3-3-3, 4. The results (typical data) are described in Table 3-3-1.

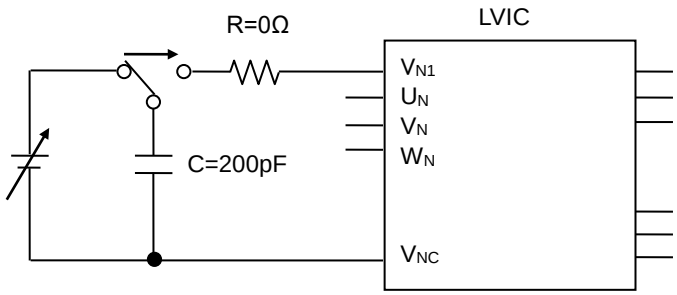


Fig.3-3-3 LVIC terminal Surge Test circuit

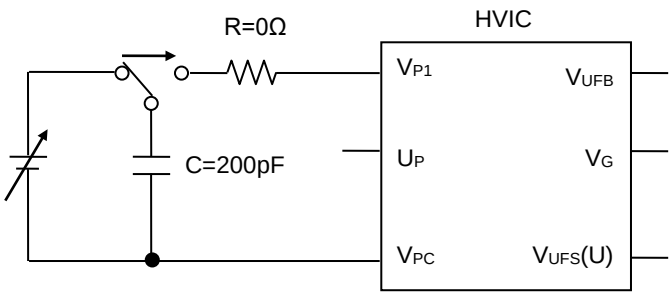


Fig.3-3-4 HVIC terminal Surge Test circuit

Conditions: Surge voltage increases by degree and only one-shot surge pulse is impressed at each surge voltage. (Limit voltage of surge simulator: ±4.0kV, Judgment method; change in V-I characteristic)

Table 3-3-1 Typical ESD capability

[Control terminal part] Common data for PSS**S92*6-AG

	Rated current 5A-20A		Rated current 30A, 35A	
Terminals	+	-	+	-
UP, VP, WP-V_{NC}	1.2	0.9	0.8	0.8
V_{P1} – V_{NC}	1.9	2.7	1.1	1.5
V_{UFB}-U, V_{VFB}-V,V_{WFB}-W	1.8	2.3	2.5	3.4
UN, VN, WN-V_{NC}	0.7	0.7	0.9	1.0
V_{N1}-V_{NC}	4.0 or more	2.9	4.0 or more	4.0 or more
CIN-V_{NC}	0.6	0.9	0.6	0.8
Fo-V_{NC}	0.6	1.1	0.6	1.0
V_{OT}-V_{NC}*	1.1	1.2	0.9	1.0

*) The type with temperature output only (PSS**S92F6-AG)

[Power terminal part]
PSS**S92*6-AG (All rated current)

Terminals	+	-
P-NU,NV,NW	4.0 or more	4.0 or more
U-NU, V-NV, W-NW	4.0 or more	4.0 or more

CHAPTER 4 Bootstrap Circuit Operation

4.1 Bootstrap Circuit Operation

For three phase inverter circuit driving, normally four isolated control supplies (three for P-side driving and one for N-side driving) are necessary. But using floating control supply with bootstrap circuit can reduce the number of isolated control supplies from four to one (N-side control supply).

Bootstrap circuit consists of a bootstrap diode(BSD), a bootstrap capacitor(BSC) and a current limiting resistor. (Super mini DIPIPM Ver.6 series integrates BSD and limiting resistor and can make bootstrap circuit by adding outer BSC only.) It uses the BSC as a control supply for driving P-side IGBT. The BSC supplies gate charge when P-side IGBT turning ON and circuit current of logic circuit on P-side driving IC (Fig.4-1-2). Since a capacitor is used as substitute for isolated supply, its supply capability is limited. This floating supply driving with bootstrap circuit is suitable for small supply current products like DIPIPM.

Charge consumed by driving circuit is re-charged from N-side 15V control supply to BSC via current limiting resistor and BSD when voltage of output terminal (U, V or W) goes down to GND potential in inverter operation. But there is the possibility that enough charge doesn't perform due to the conditions such as switching sequence, capacitance of BSC and so on. Deficient charge leads to low voltage of BSC and might work under voltage protection (UV). This situation makes the loss of P-side IGBT increase by low gate voltage or stop switching. So it is necessary to consider and evaluate enough for designing bootstrap circuit. For more detail information about driving by the bootstrap circuit, refer the DIPIPM application note "*Bootstrap Circuit Design Manual*"

The BSD characteristics for Super mini DIPIPM Ver.6 series and the circuit current characteristics in switching situation of P-side IGBT are described as below.

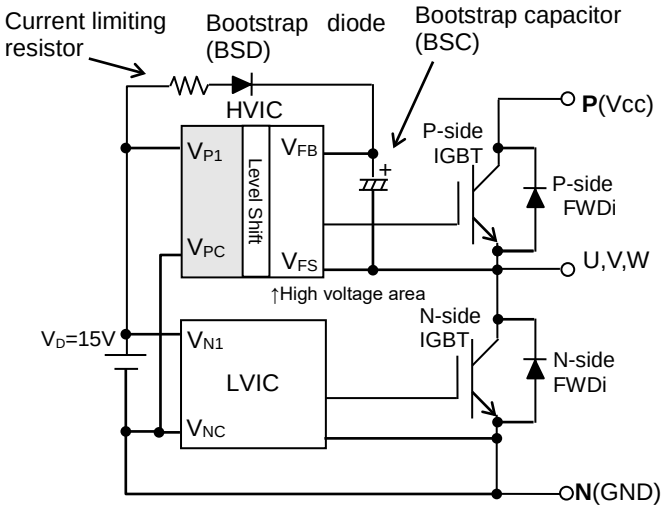


Fig.4-1-1 Bootstrap Circuit Diagram

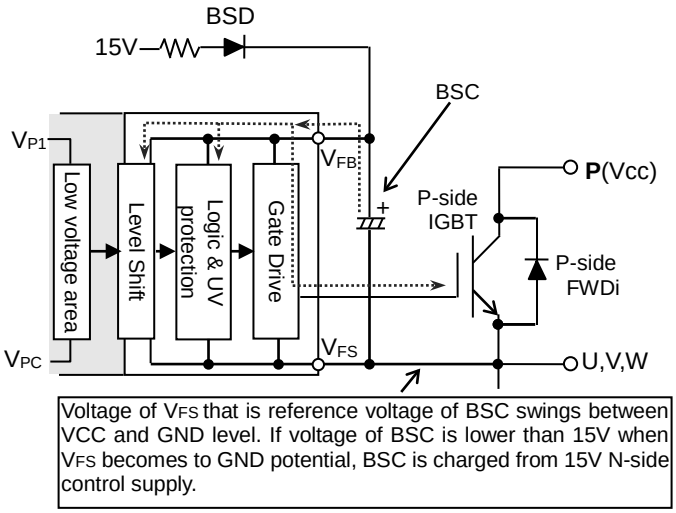


Fig.4-1-2 Bootstrap Circuit Diagram

4.2 Bootstrap Supply Circuit Current at Switching State

Bootstrap supply circuit current I_{DB} at steady state is maximum 0.1mA for PSS**S92*6-AG series (for rated current 5A~20A. I_{DB} specification of 30A and 35A product is maximum 0.3mA. For more detail, please refer the datasheet of each product.). But at switching state, because gate charge and discharge are repeated by switching, the circuit current exceeds 0.1mA (or 0.3mA) and increases proportional to carrier frequency. For reference, Fig.4-2-1~6 shows I_{DB} - carrier frequency fc characteristics for each current rating product.
(Conditions: V_D=V_{DB}=15V, Tj=125°C at which I_{DB} becomes larger, IGBT ON Duty=10, 30, 50, 70, 90%)

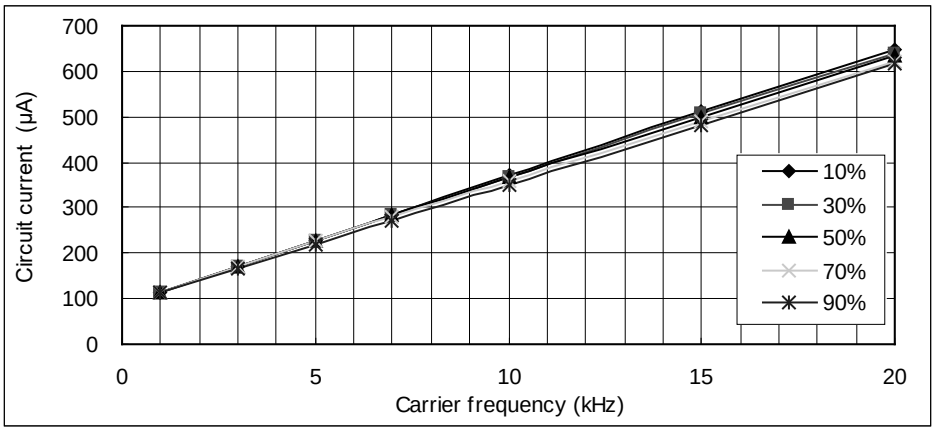


Fig.4-2-1 I_{DB} vs. Carrier frequency for PSS05S92*6-AG

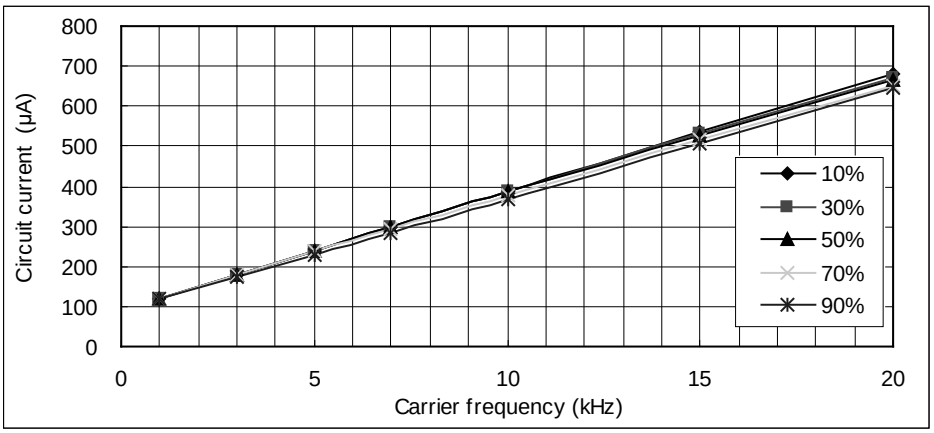


Fig.4-2-2 I_{DB} vs. Carrier frequency for PSS10S92*6-AG

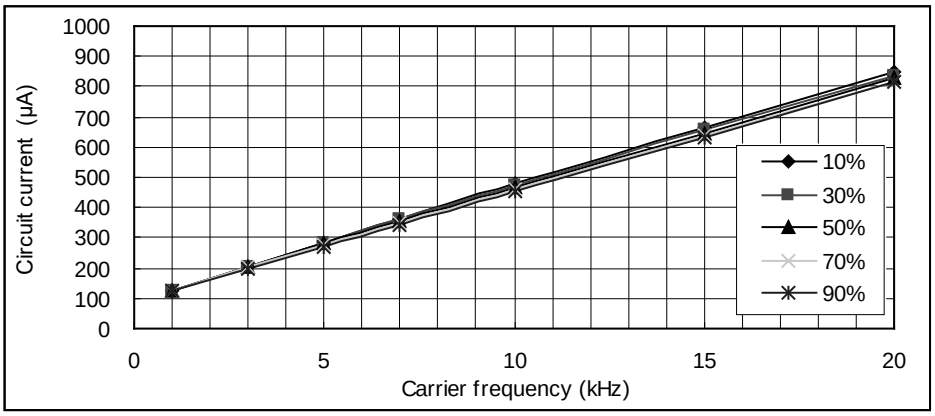


Fig.4-2-3 I_{DB} vs. Carrier frequency for PSS15S92*6-AG

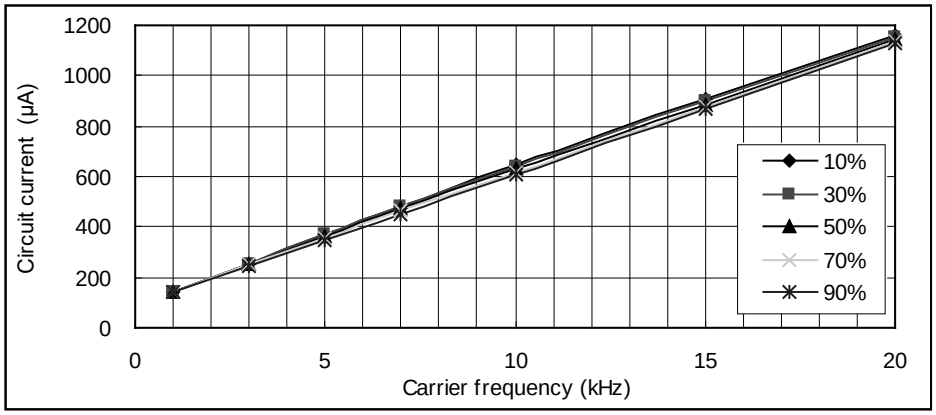


Fig.4-2-4 I_{DB} vs. Carrier frequency for PSS20S92*6-AG

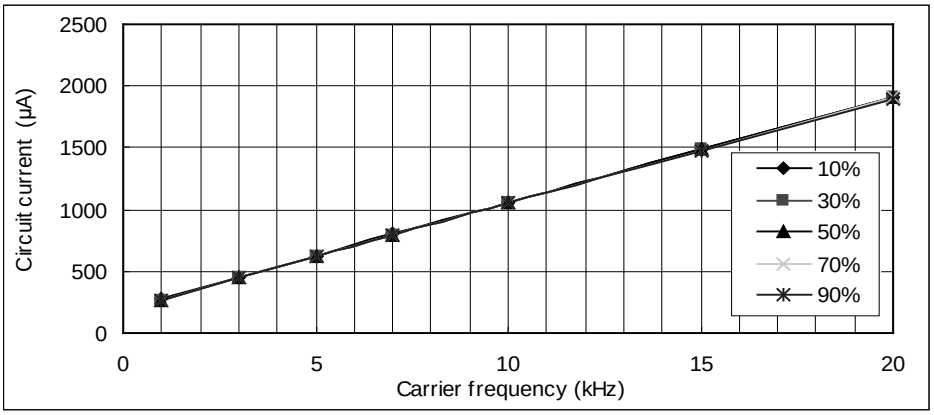


Fig.4-2-5 I_{DB} vs. Carrier frequency for PSS30S92*6-AG

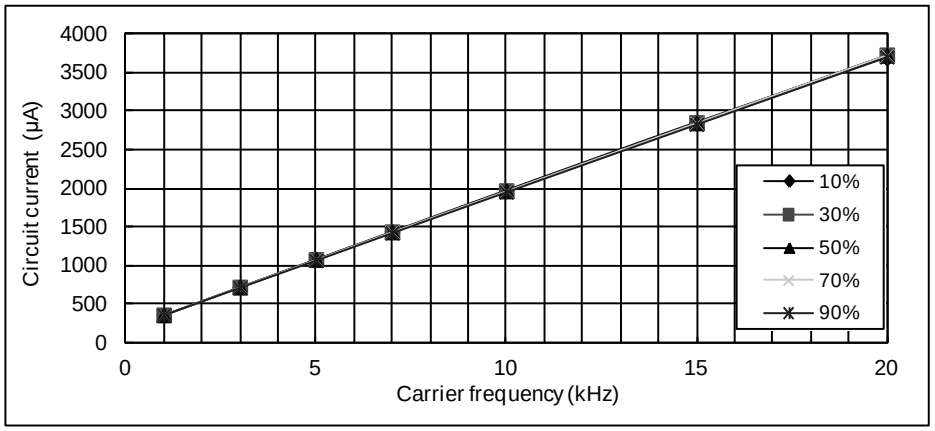


Fig.4-2-6 I_{DB} vs. Carrier frequency for PSS35S92*6-AG

4.3 Note for designing the bootstrap circuit

When each device for bootstrap circuit is designed, it is necessary to consider various conditions such as temperature characteristics, change by lifetime, variation and so on. Note for designing these devices are listed as below. For more detail information about driving by the bootstrap circuit, refer the DIPIPM application note "*Bootstrap Circuit Design Manual*"

(1) Bootstrap capacitor

Electrolytic capacitors are used for BSC generally. And recently ceramic capacitors with large capacitance are also applied. But DC bias characteristic of the ceramic capacitor when applying DC voltage is considerably different from that of electrolytic capacitor. (Especially large capacitance type) Some differences of capacitance characteristics between electrolytic and ceramic capacitors are listed in Table 4-3-1.

Table 4-3-1 Differences of capacitance characteristics between electrolytic and ceramic capacitors

	Electrolytic capacitor	Ceramic capacitor (large capacitance type)
Temperature characteristics (Ta:-20~ 85°C)	• Aluminum type: Low temp.: -10% High temp: +10% • Conductive polymer aluminum solid type: Low temp.: -5% High temp: +10%	Different due to temp. characteristics rank Low temp.: -5%~0% High temp.: -5%~-10% (in the case of B,X5R,X7R ranks)
DC bias characteristics (Applying DC15V)	Nothing within rating voltage	Different due to temp. characteristics, rating voltage, package size and so on **-70%**~-15%

DC bias characteristic of electrolytic capacitor is not matter. But it is necessary to note ripple capability by repetitive charge and discharge, life time which is greatly affected by ambient temperature and so on. Above characteristics are just example data which are obtained from the WEB, please refer to the capacitor manufacturers about detailed characteristics.

(2) Bootstrap diode

DIP Ver.6 integrates bootstrap diode for P-side driving supply. This BSD incorporates current limiting resistor. So there isn't any limitation about bootstrap capacitance like former PS219A* has (22μF or less in the case of one long pulse initial charging). The VF-IF characteristics (rated current 5A~20A, and rated current 30A, 35A including voltage drop by built-in current limiting resistor) is shown in Fig.4-3-1, Fig.4-3-2, Table 4-3-2 and Table 4-3-3.

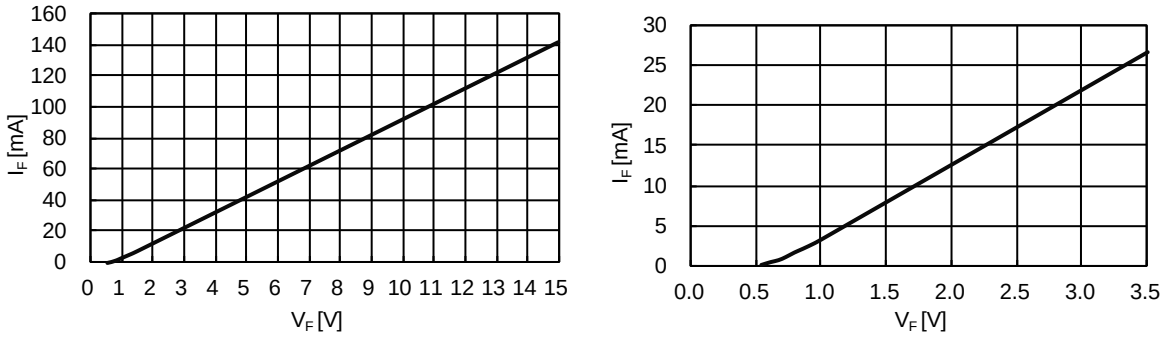


Fig.4-3-1 V_F-I_F curve for bootstrap Diode (rated current 5A~20A, the right figure is enlarged view)

Table 4-3-2 Electric characteristics of built-in bootstrap diode (rated current 5A~20A)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Bootstrap Di forward voltage	V_F	I_F=10mA including voltage drop by limiting resistor	1.1	1.7	2.3	V
Built-in limiting resistance	R	Included in bootstrap Di	80	100	120	Ω

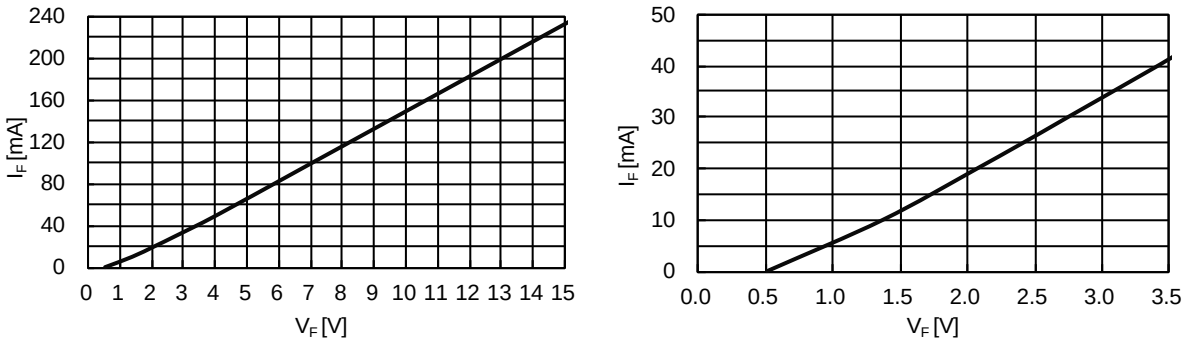


Fig.4-3-2 V_F-I_F curve for bootstrap Diode (rated current 30A, 35A, the right figure is enlarged view)

Table 4-3-3 Electric characteristics of built-in bootstrap diode (rated current 30A, 35A)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Bootstrap Di forward voltage	V_F	I_F=10mA including voltage drop by limiting resistor	0.9	1.3	1.7	V
Built-in limiting resistance	R	Included in bootstrap Di	48	60	72	Ω

4.4 Initial charging in bootstrap circuit

In the case of applying bootstrap circuit, it is necessary to charge to the BSC initially because voltage of BSC is 0V at initial state or it may go down to the trip level of under voltage protection after long suspending period (even 1s). BSC charging is performed by turning on all N-side IGBT normally. When outer load (e.g. motor) is connected to the DIPIPM, BSC charging may be performed by turning on only one phase N-side IGBT since potential of all output terminals will go down to GND level through the wiring in the motor. But its charging efficiency might become lower due to some cause. (e.g. wiring resistance of motor)

There are mainly two procedures for BSC charging. One is performed by one long pulse, and another is conducted by multiple short pulses. Multi pulse method is used when there are some restriction like control supply capability and so on.

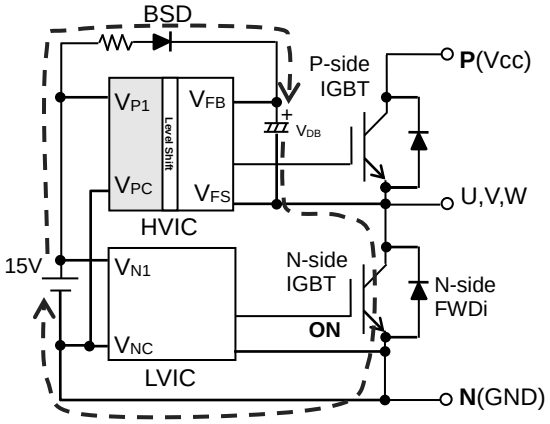


Fig.4-4-1 Initial charging root

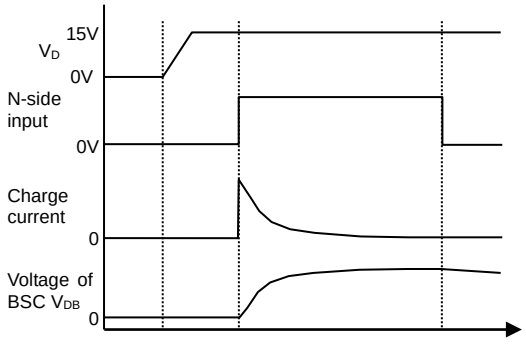


Fig.4-4-2 Example of waveform by one charging pulse

Initial charging needs to be performed until voltage of BSC exceeds recommended minimum supply voltage 13V. (It is recommended to charge as high as possible with consideration for voltage drop between the end of charging and start of inverter operation.)

After BSC was charged, it is recommended to input one ON pulse to the P-side input for reset of internal IC state before starting system. Input pulse width is needed to be longer than allowable minimum input pulse width PWIN(on). (e.g. 0.7μs or more for Super mini DIPIPM Ver.6. Refer the datasheet for each product.)

CHAPTER 5 Interface Demo Board

5.1 Super mini DIPIPM Ver.6 Interface Demo Board

This chapter describes the interface demo board of Super mini DIPIPM Ver.6 as a reference for the design of user application PCB with Super mini DIPIPM Ver.6.

(1) Demo Board Outline EVA11-SDIP

The demo board can mount the minimum necessary components of Super mini DIPIPM Ver.6 interface shown in Fig.5-1-1.

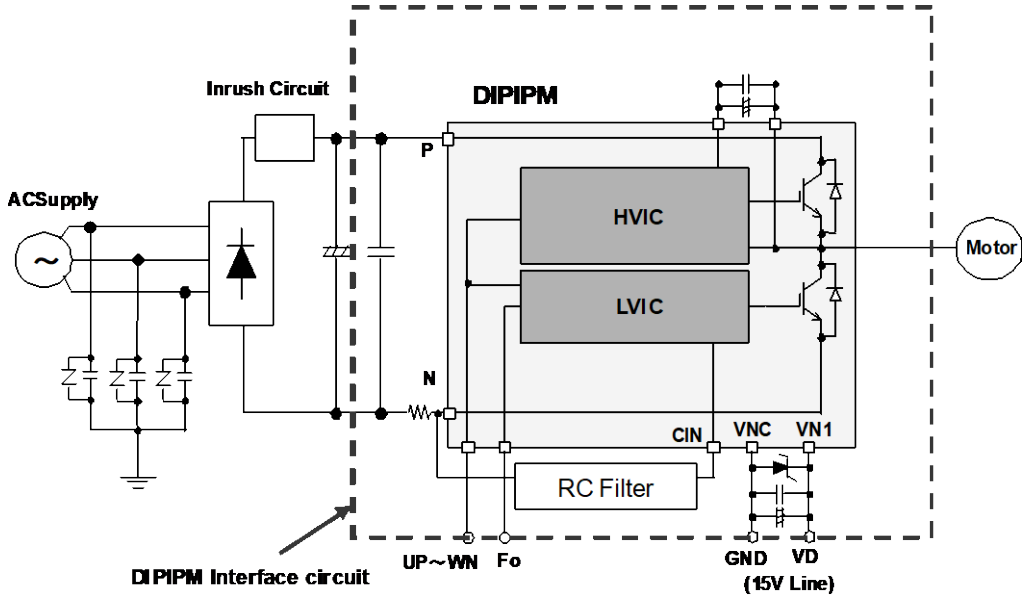


Fig.5-1-1 Demo board interface circuit

(2) Caution

- This interface board is designed to evaluate our all Super Mini DIPIPM series, so requires some changes for its wiring and component parts before the evaluation. Please refer its user manual for the details.

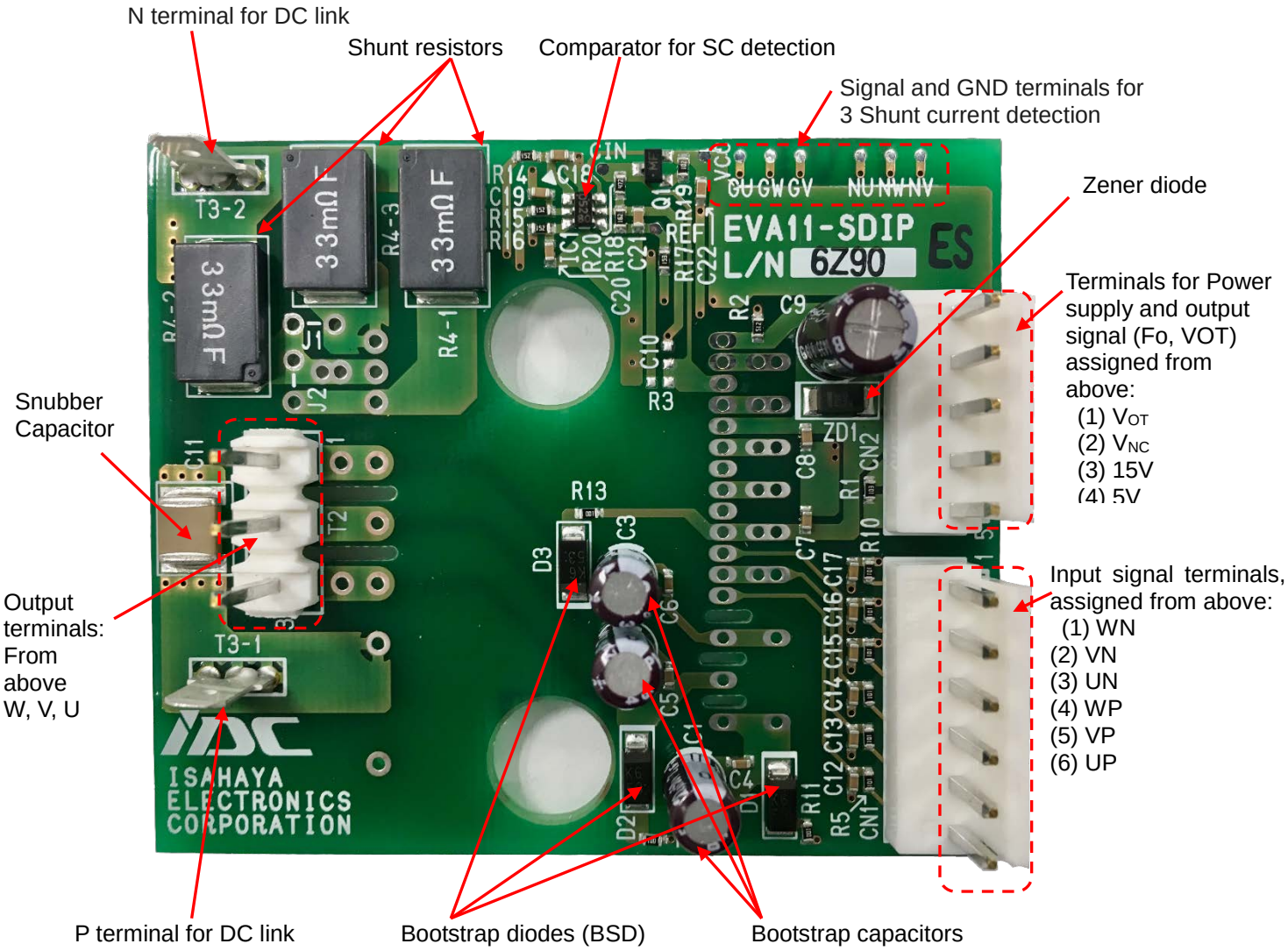
- This interface board hires three shunt resistors for the current detection and comparator (IC1) for the SC protection circuit. Please set shunt SC trip level less than the IGBT minimum saturation current (Super Mini DIPIPM Ver.6 series are 1.7 times as large as the rated current). For one shunt resistor operation, please insert jumper wires J1 and J2 to connect UN, VN, and WN patterns.

- Super Mini DIPIPM ver.6 series include bootstrap diodes (BSD), so please remove initial bootstrap diodes (D1~D3) from the evaluation board.

- Please connect the evaluation board and signal source (e.g. MCU board) as short as possible.

- This evaluation board is made for your quick and temporary evaluation and above patterns and parts list are examples. We cannot guarantee the proper operation of this PCB in all case. When selecting parts and design patterns for your PCB, please comply with your design standard and consider life time, reliability and so on.

(3) Demo Board Photo (Board dimension: 60mm×72mm, pattern thickness: 70μm)



(Note) Mounted circuit parts and printing contents on the board are subject to be changed without notice.

Fig.5-1-2 Interface demo board photo EVA11-SDIP

5.2 Interface demo board pattern

(1) Circuit Schematic

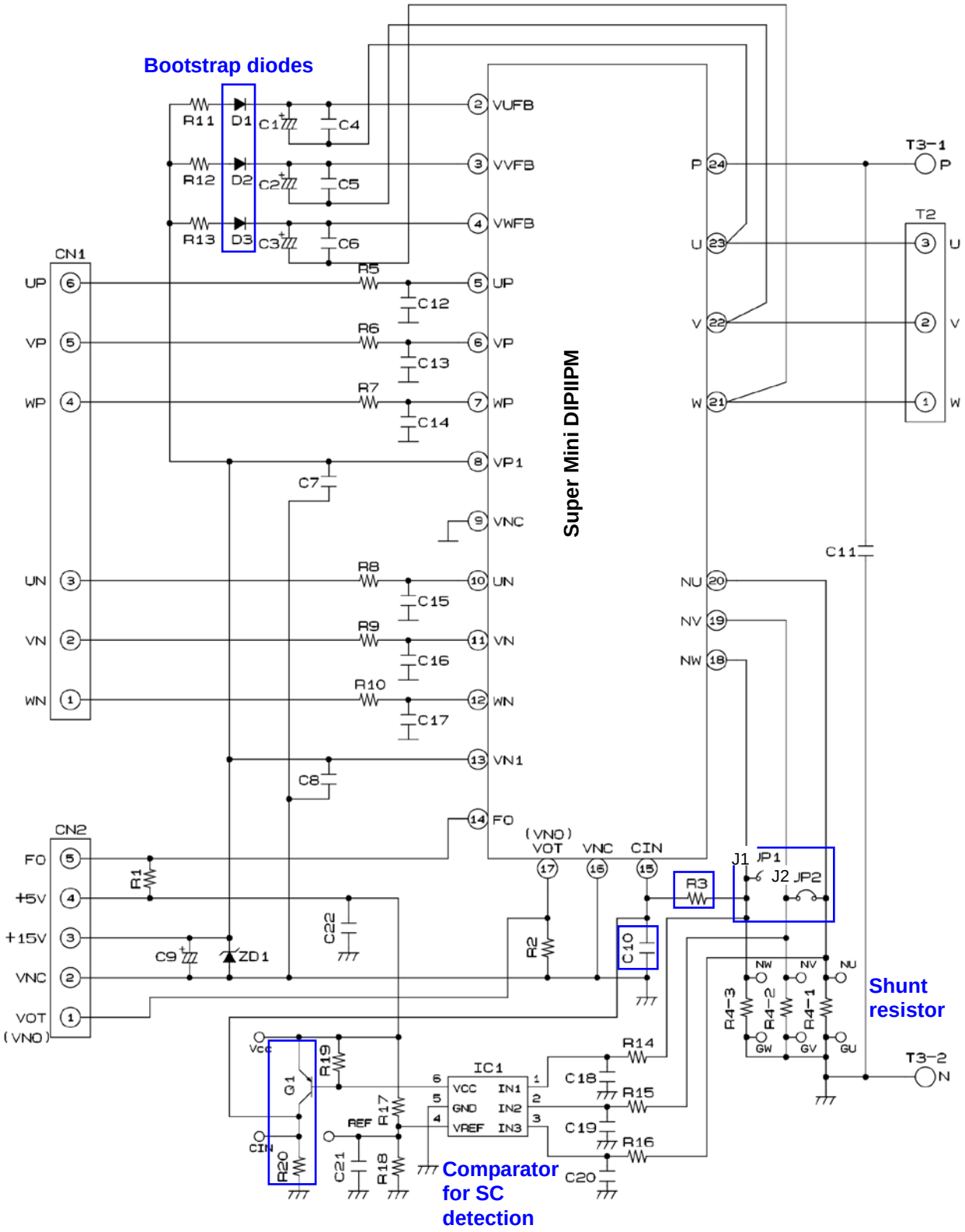


Fig.5-2-1 Demo board circuit schematic

Note: Although Zener diodes are not installed to P-side three floating drive supplies (between V_{UFB}-U, V_{VFB}-V, V_{WFB}-W) on this demo board, it is highly recommend to add these zener diodes in actual system board.

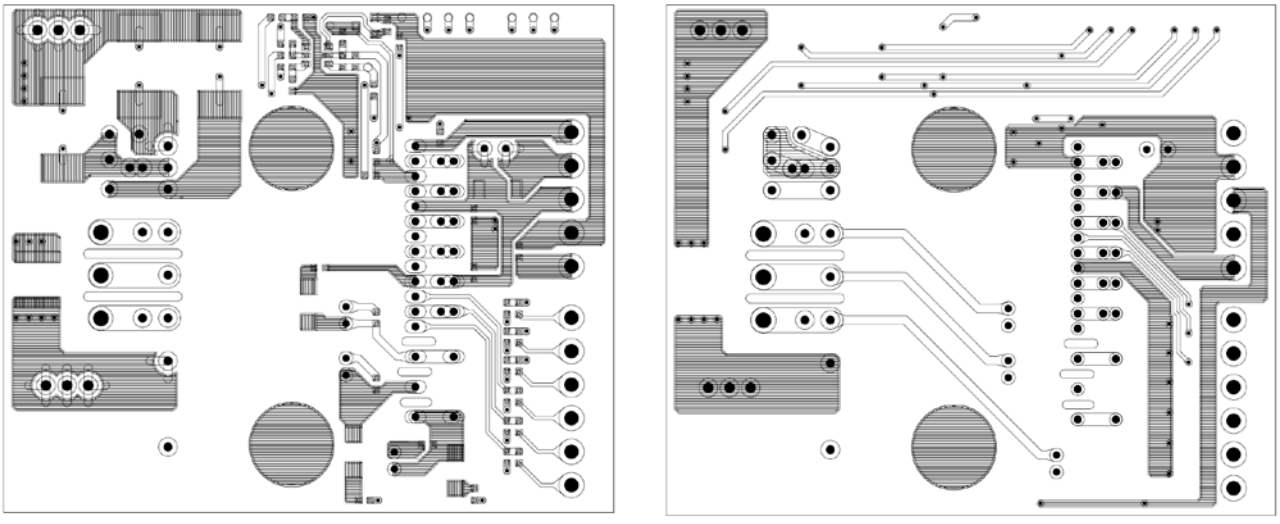
(2) I/F board parts list

Table5-2-1 Parts list (only for reference)

Symbol	Type Name	Description	Note
IC1	RT8H052C	Overcurrent protection IC	ISAHAYA
Q1	ISA1235AC1	-0.2A -50V Transistor	ISAHAYA
ZD1	CMZB24	24V 1W Zener Diode	Toshiba
D1~3	D1FK60	0.8A 600V Diode	Shindengen
C1~3	UPW1H220MDD	22μF 50V Al electrolytic capacitor	Nichicon
C4~8,10	GRM188R71H102K	1000pF 50V ceramic capacitor	Murata
C9	UPW1E101MED	100μF 25V Al electrolytic capacitor	Nichicon
C11	GRJ55DR72J224KWJ1	0.22μF 630V snubber capacitor	Murata
C12~20	GRM188R71H102K	1000pF 50V ceramic capacitor	Murata
C21,22	GRM188R71H104K	0.1μF 50V ceramic capacitor	Murata
R1	CR1/16W103F	1/16W 10KΩ	Hokuriku Denko
R2	CR1/16W512F	1/16W 5.1KΩ	Hokuriku Denko
R3	CR1/16W202F	1/16W 2KΩ	Hokuriku Denko
R4-1,2,3	SL2TTE33L0F	2W 33mΩ Current sensing resistor	KOA
R5~10	CR1/16W101F	1/16W 100Ω	Hokuriku Denko
R11~13	CR1/16W100F	1/16W 10Ω	Hokuriku Denko
R14~16	CR1/16W152F	1/16W 1.5kΩ	Hokuriku Denko
R17	CR1/16W153F	1/16W 15kΩ	Hokuriku Denko
R18	CR1/16W162F	1/16W 1.6kΩ	Hokuriku Denko
R19	CR1/16W102F	1/16W 1kΩ	Hokuriku Denko
R20	CR1/16W472F	1/16W 4.7kΩ	Hokuriku Denko
CN1	B6P-VH	6pin Socket	JST
CN2	B5P-VH	5pin Socket	JST
T2	B3P-VB-2	3-terminal connector	JST
T3-1,2	TP42097-21	Tab	Rhythm Kyoushin
J1,2		Jumper 3.5mm pitch	
DIPIPM	PS*	Super Mini DIPIPM Ver.4~6	Mitsubishi

(Note) The evaluation board does not mount initially either C10, R3, J1, J2 or DIPIPM.
These mounted parts are subject to be changed without notice.

(3) PCB pattern layout

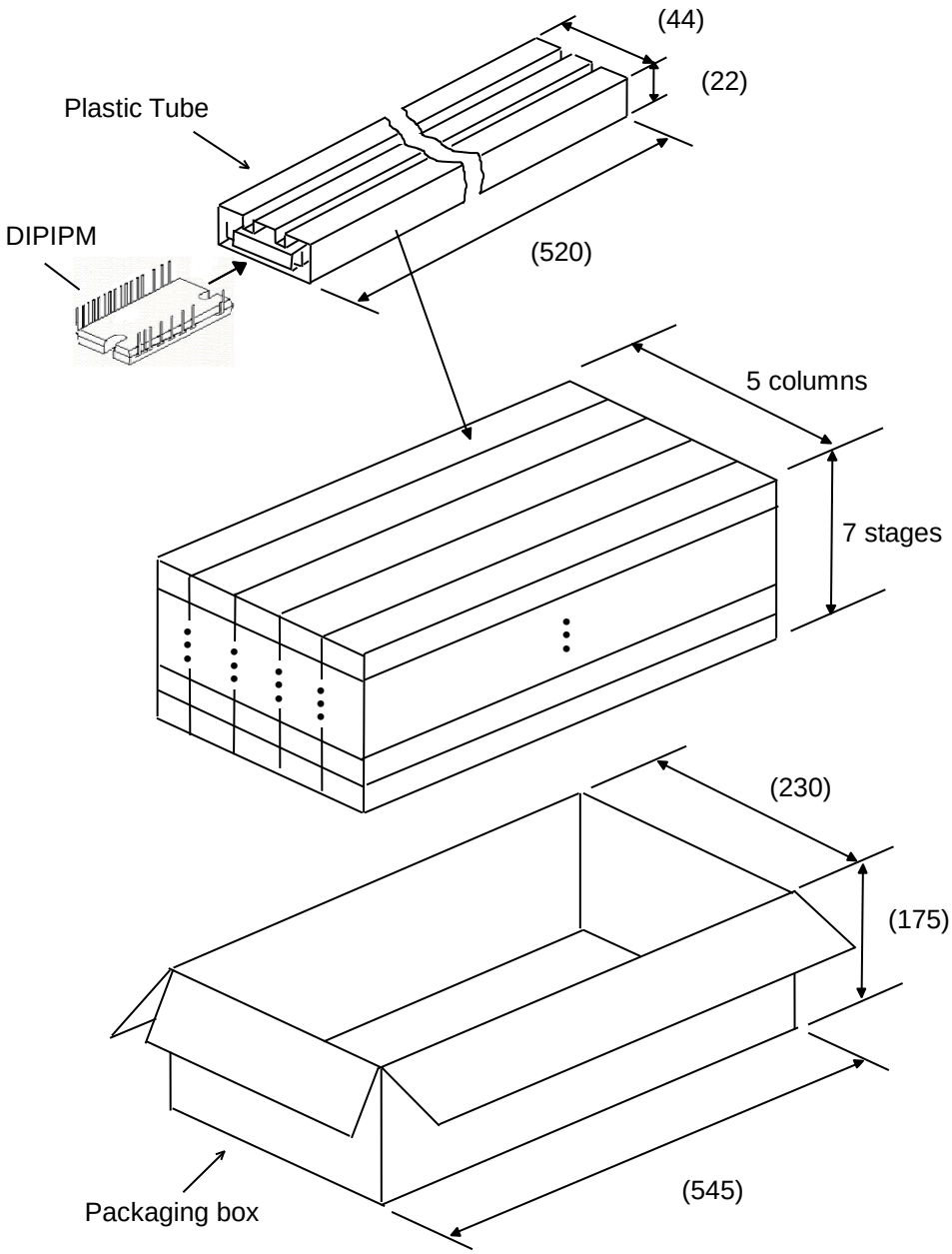


Component side　　Back side (The view from the component side)

Fig.5-2-2 Demo board PCB pattern layout

CHAPTER 6 PACKAGE HANDLING

6.1 Packaging Specification



Quantity:

12pcs per 1 tube

Total amount in one box (max):

Tube Quantity: 5 × 7=35pcs
IPM Quantity: 35 × 12=420pcs

When it isn't fully filled by tubes at top stage, cardboard spacers or empty tubes are inserted for filling the space of top stage.

Weight (max):

About 8.5g per 1pcs of DIPIPM
About 200g per 1 tube
About 8.3kg per 1 box

Spacers are put on the top and bottom of the box. If there is some space on top of the box, additional buffer materials are also inserted.

Fig.6-1-1 Packaging Specification

6.2 Handling Precautions

⚠ Cautions	
Transportation	・Put package boxes in the correct direction. Putting them upside down, leaning them or giving them uneven stress might cause electrode terminals to be deformed or resin case to be damaged. ・Throwing or dropping the packaging boxes might cause the devices to be damaged. ・Wetting the packaging boxes might cause the breakdown of devices when operating. Pay attention not to wet them when transporting on a rainy or a snowy day.
Storage	・We recommend temperature and humidity in the ranges 5-35°C and 45-75%, respectively, for the storage of modules. The quality or reliability of the modules might decline if the storage conditions are much different from the above.
Long storage	・When storing modules for a long time (more than one year), keep them dry. Also, when using them after long storage, make sure that there is no visible flaw, stain or rust, etc. on their exterior.
Surroundings	・Keep modules away from places where water or organic solvent may attach to them directly or where corrosive gas, explosive gas, fine dust or salt, etc. may exist. They might cause serious problems.
Flame resistance	・The epoxy resin and the case materials are flame-resistant type (UL standard 94-V0), but they are not noninflammable.
Static electricity	・ICs and power chips with MOS gate structure are used for the DIPIPM power modules. Please keep the following notices to prevent modules from being damaged by static electricity. (1) Precautions against the device destruction caused by the ESD When the ESD of human bodies, packaging and etc. are applied to terminal, it may damage and destroy devices. The basis of anti-electrostatic is to inhibit generating static electricity possibly and quick dissipation of the charged electricity. ・Containers that charge static electricity easily should not be used for transit and for storage. ・Terminals should be always shorted with a carbon cloth or the like until just before using the module. Never touch terminals with bare hands. ・Should not be taking out DIPIPM from tubes until just before using DIPIPM and never touch terminals with bare hands. ・During assembly and after taking out DIPIPM from tubes, always earth the equipment and your body. It is recommended to cover the work bench and its surrounding floor with earthed conductive mats. ・When the terminals are open on the printed circuit board with mounted modules, the modules might be damaged by static electricity on the printed circuit board. ・If using a soldering iron, earth its tip. (2)Notice when the control terminals are open ・When the control terminals are open, do not apply voltage between the collector and emitter. It might cause malfunction. ・Short the terminals before taking a module off.

Revision Record

Rev.	Date	Points
-	15/ 3/2014	New
1	1/ 5/2014	· Add circuit current I_{DB} specification of 30, 35A products in section 4.2 · Add section 4.4
2	3/ 12/2019	· Change Package photograph in section 1.1 · JEITA was EIAJ in section 2.1.4 · Change marking specification in section 2.3.2 · Revise information to the latest interface demo board in chapter 5

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