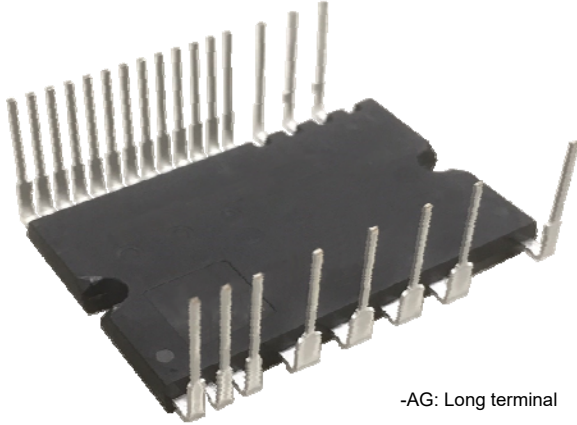


< DIIPM >

# PSS40S93F6-AG PSS40S93E6-AG

TRANSFER MOLDING TYPE  
INSULATED TYPE

## OUTLINE



-AG: Long terminal

## MAIN FUNCTION AND RATINGS

- 3 phase DC/AC inverter
- 600V / 40A (Low noise CSTBT)
- N-side IGBT open emitter
- Built-in bootstrap diodes with current limiting resistor

## APPLICATION

- AC 100~240Vrms(DC voltage:400V or below) class low power motor control

## TYPE NAME

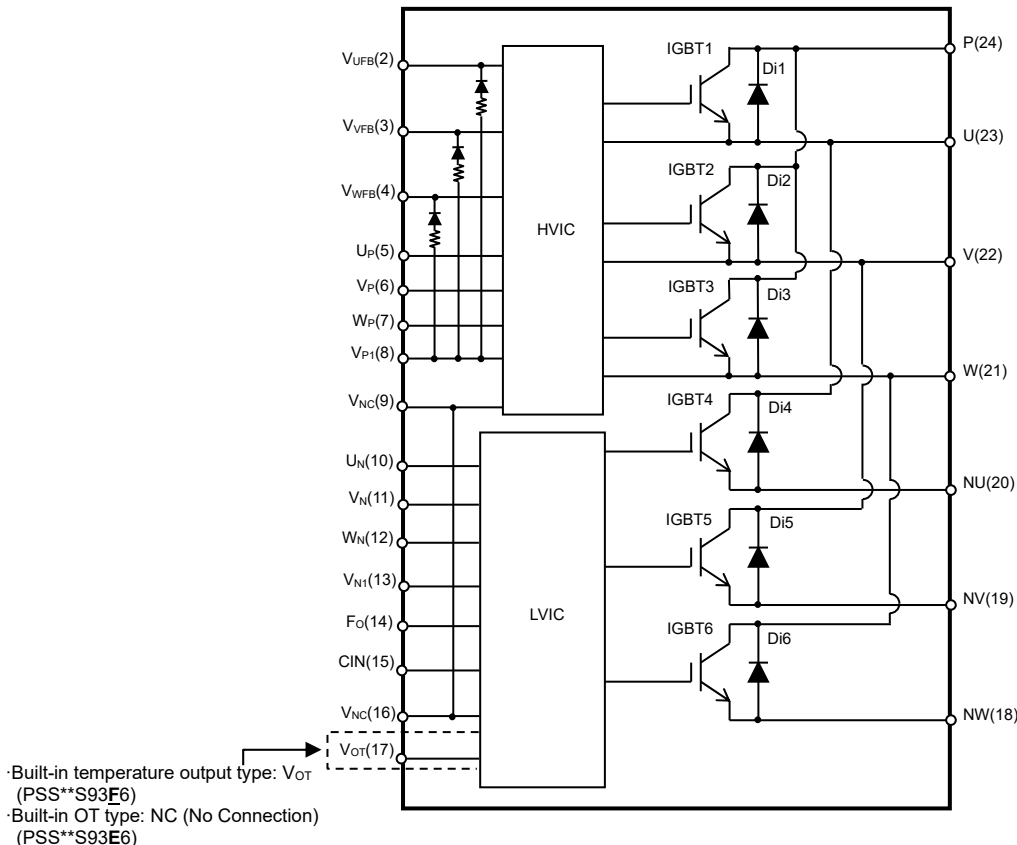
PSS40S93F6-AG	With temperature output function
PSS40S93E6-AG	With OT protection function

-AG: Long terminal

## INTEGRATED DRIVE, PROTECTION AND SYSTEM CONTROL FUNCTIONS

- For P-side : Drive circuit, High voltage high-speed level shifting, Control supply under-voltage (UV) protection
- For N-side : Drive circuit, Control supply under-voltage protection (UV), Short circuit protection (SC), Over temperature protection (OT, PSS40S93E6-AG only)
- Fault signaling : Corresponding to SC fault (N-side IGBT), UV fault (N-side supply) and OT fault
- Temperature output: Outputting LVIC temperature by analog signal (PSS40S93F6-AG only)
- Input interface : 3, 5V line, Schmitt trigger receiver circuit (High Active)
- UL Recognized : UL1557 File E323585

## INTERNAL CIRCUIT



# PSS40S93F6-AG, PSS40S93E6-AG

TRANSFER MOLDING TYPE  
INSULATED TYPE

## MAXIMUM RATINGS (T<sub>j</sub> = 25°C, unless otherwise noted)

### INVERTER PART

Symbol	Parameter	Condition	Ratings	Unit
V <sub>CC</sub>	Supply voltage	Applied between P-NU, NV, NW	450	V
V <sub>CC(surge)</sub>	Supply voltage (surge)	Applied between P-NU, NV, NW	500	V
V <sub>CEs</sub>	Collector-emitter voltage		600	V
±I <sub>C</sub>	Each IGBT collector current	T <sub>C</sub> = 25°C (Note 1)	40	A
±I <sub>CP</sub>	Each IGBT collector current (peak)	T <sub>C</sub> = 25°C, less than 1ms	80	A
T <sub>job</sub>	Operation junction temperature	Continuous operation (Note 2)	-30~+150	°C
T <sub>jmax</sub>	Maximum junction temperature	Temporally operation (e.g. overload)	175	°C

Note1: Pulse width and period are limited due to junction temperature.

Note2: The maximum junction temperature rating of built-in power chips is 175°C(@T<sub>c</sub>≤125°C). However, to ensure safe operation of DIIPM, the average junction temperature should be limited to T<sub>j(Ave)</sub> ≤ 150°C (@T<sub>c</sub> ≤ 125°C).

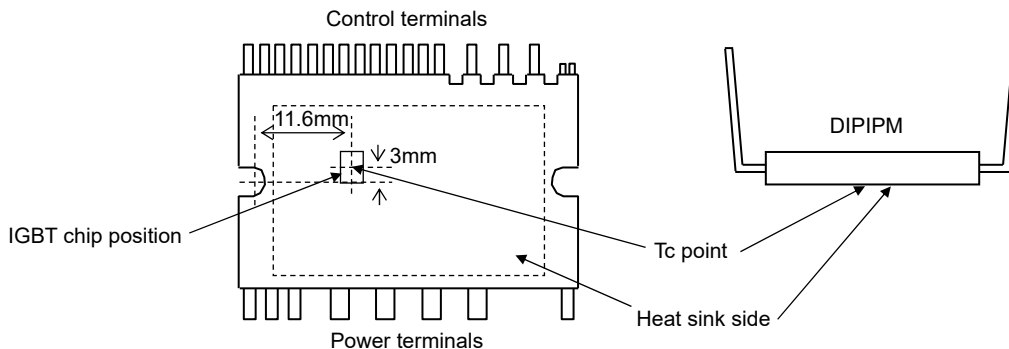
### CONTROL (PROTECTION) PART

Symbol	Parameter	Condition	Ratings	Unit
V <sub>D</sub>	Control supply voltage	Applied between V <sub>P1</sub> -V <sub>NC</sub> , V <sub>N1</sub> -V <sub>NC</sub>	20	V
V <sub>DB</sub>	Control supply voltage	Applied between V <sub>UFB-U</sub> , V <sub>VFB-V</sub> , V <sub>WFB-W</sub>	20	V
V <sub>IN</sub>	Input voltage	Applied between U <sub>P</sub> , V <sub>P</sub> , W <sub>P</sub> , U <sub>N</sub> , V <sub>N</sub> , W <sub>N</sub> -V <sub>NC</sub>	-0.5~V <sub>D</sub> +0.5	V
V <sub>FO</sub>	Fault output supply voltage	Applied between F <sub>O</sub> -V <sub>NC</sub>	-0.5~V <sub>D</sub> +0.5	V
I <sub>FO</sub>	Fault output current	Sink current at F <sub>O</sub> terminal	5	mA
V <sub>SC</sub>	Current sensing input voltage	Applied between CIN-V <sub>NC</sub>	-0.5~V <sub>D</sub> +0.5	V

### TOTAL SYSTEM

Symbol	Parameter	Condition	Ratings	Unit
V <sub>CC(PROT)</sub>	Self protection supply voltage limit (Short circuit protection capability)	V <sub>D</sub> = 13.5~16.5V, Inverter Part T <sub>j</sub> = 150°C, non-repetitive, less than 2μs	400	V
T <sub>C</sub>	Module case operation temperature	Measurement point of T <sub>C</sub> is provided in Fig.1	-30~+125	°C
T <sub>stg</sub>	Storage temperature		-40~+125	°C
V <sub>iso</sub>	Isolation voltage	60Hz, Sinusoidal, AC 1min, between connected all pins and heatsink plate	1500	V <sub>rms</sub>

Fig. 1: T<sub>C</sub> MEASUREMENT POINT



### THERMAL RESISTANCE

Symbol	Parameter	Condition	Limits			Unit
			Min.	Typ.	Max.	
R <sub>th(j-c)Q</sub>	Junction to case thermal resistance (Note 3)	Inverter IGBT part (per 1/6 module)	-	-	1.5	K/W
R <sub>th(j-c)F</sub>		Inverter FWDi part (per 1/6 module)	-	-	2.6	K/W

Note 3: Grease with good thermal conductivity and long-term endurance should be applied evenly with about +100μm~+200μm on the contacting surface of DIIPM and heatsink. The contacting thermal resistance between DIIPM case and heat sink R<sub>th(c-f)</sub> is determined by the thickness and the thermal conductivity of the applied grease. For reference, R<sub>th(c-f)</sub> is about 0.3K/W (per 1/6 module, grease thickness: 20μm, thermal conductivity: 1.0W/m·K).

**ELECTRICAL CHARACTERISTICS** ( $T_j = 25^\circ\text{C}$ , unless otherwise noted)**INVERTER PART**

Symbol	Parameter	Condition	Limits			Unit	
			Min.	Typ.	Max.		
$V_{CE(sat)}$	Collector-emitter saturation voltage	$V_D=V_{DB} = 15\text{V}, V_{IN} = 5\text{V}$	$I_C = 40\text{A}, T_j = 25^\circ\text{C}$	-	1.50	1.80	V
			$I_C = 40\text{A}, T_j = 125^\circ\text{C}$	-	1.65	2.00	
			$I_C = 4.0\text{A}, T_j = 25^\circ\text{C}$	-	0.80	1.00	
$V_{EC}$	FWDi forward voltage	$V_{IN} = 0\text{V}, -I_C = 40\text{A}$	-	1.90	2.40	V	
$t_{on}$	Switching times	$V_{CC} = 300\text{V}, V_D = V_{DB} = 15\text{V}$ $I_C = 40\text{A}, T_j = 125^\circ\text{C}, V_{IN} = 0 \leftrightarrow 5\text{V}$ Inductive Load (upper-lower arm)		1.10	1.65	2.35	$\mu\text{s}$
$t_{C(on)}$				-	0.40	0.65	$\mu\text{s}$
$t_{off}$				-	1.80	2.50	$\mu\text{s}$
$t_{C(off)}$				-	0.15	0.30	$\mu\text{s}$
$t_{tr}$				-	0.35	-	$\mu\text{s}$
$I_{CES}$	Collector-emitter cut-off current	$V_{CE} = V_{CES}$	$T_j = 25^\circ\text{C}$	-	-	1	mA
			$T_j = 125^\circ\text{C}$	-	-	10	

**CONTROL (PROTECTION) PART**

Symbol	Parameter	Condition	Limits			Unit	
			Min.	Typ.	Max.		
$I_D$	Circuit current	Total of $V_{P1}-V_{NC}, V_{N1}-V_{NC}$	$V_D = 15\text{V}, V_{IN} = 0\text{V}$	-	-	3.40	mA
			$V_D = 15\text{V}, V_{IN} = 5\text{V}$	-	-	3.40	
$I_{DB}$		Each part of $V_{UFB}-U,$ $V_{VFB}-V, V_{WFB}-W$	$V_D = V_{DB} = 15\text{V}, V_{IN} = 0\text{V}$	-	-	0.30	mA
			$V_D = V_{DB} = 15\text{V}, V_{IN} = 5\text{V}$	-	-	0.30	
$V_{SC(ref)}$	Short circuit trip level	$V_D = 15\text{V}$ (Note 4)	0.455	0.480	0.505	V	
$UV_{DBt}$	P-side Control supply under-voltage protection(UV)	$T_j \leq 125^\circ\text{C}$	Trip level	10.0	-	12.0	V
$UV_{DBr}$			Reset level	10.5	-	12.5	V
$UV_{Dt}$	N-side Control supply under-voltage protection(UV)	$T_j \leq 125^\circ\text{C}$	Trip level	10.3	-	12.5	V
$UV_{Dr}$			Reset level	10.8	-	13.0	V
$V_{OT}$	Temperature Output (PSS**S93F6)	Pull down R=5.1k $\Omega$ (Note 5)	LVIC Temperature=90 $^\circ\text{C}$	2.63	2.77	2.91	V
$OT_t$	Over temperature protection (OT, PSS**S93E6) (Note6)	$V_D = 15\text{V}$ Detect LVIC temperature	Trip level	130	140	150	$^\circ\text{C}$
$OT_{th}$			Hysteresis of trip-reset	-	10	-	$^\circ\text{C}$
$V_{FOH}$	Fault output voltage	$V_{SC} = 0\text{V}, F_O$ terminal pulled up to 5V by 10k $\Omega$	4.9	-	-	V	
$V_{FOL}$		$V_{SC} = 1\text{V}, I_{FO} = 1\text{mA}$	-	-	0.95	V	
$t_{FO}$	Fault output pulse width	(Note 7)	20	-	-	$\mu\text{s}$	
$I_{IN}$	Input current	$V_{IN} = 5\text{V}$	0.70	1.00	1.50	mA	
$V_{th(on)}$	ON threshold voltage	Applied between $U_P, V_P, W_P, U_N, V_N, W_N-V_{NC}$	-	1.70	2.35	V	
$V_{th(off)}$	OFF threshold voltage		0.70	1.20	-		
$V_{th(hys)}$	ON/OFF threshold hysteresis voltage		0.25	0.50	-		
$V_F$	Bootstrap Di forward voltage	$I_F = 10\text{mA}$ including voltage drop by limiting resistor (Note 8)	0.9	1.3	1.7	V	
R	Built-in limiting resistance	Included in bootstrap Di	48	60	72	$\Omega$	

Note 4 : 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.

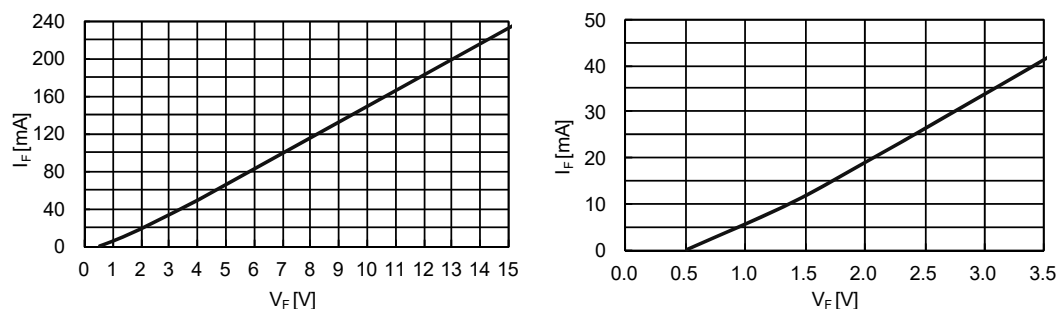
5 : For temperature output type, DIIPM don't shutdown IGBTs and output fault signal automatically when temperature rises excessively. When temperature exceeds the protective level that user defined, controller (MCU) should stop the DIIPM. Temperature of LVIC vs. VOT output characteristics is described in Fig. 3.

6 : When the LVIC temperature exceeds OT trip temperature level(OT<sub>t</sub>), OT protection works and Fo outputs. In that case if the heatsink dropped off or fixed loosely, don't reuse that DIIPM. (There is a possibility that junction temperature of power chips exceeded the maximum junction temperature (175 $^\circ\text{C}$ ).

7 : 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 20 $\mu\text{s}$ ), but at UV or OT failure, Fo outputs continuously until recovering from UV or OT state. (But minimum Fo pulse width is 20 $\mu\text{s}$ .)

8 : The characteristics of bootstrap Di is described in Fig.2.

Fig. 2 Characteristics of bootstrap Di  $V_F$ - $I_F$  curve (@ $T_a = 25^\circ\text{C}$ ) including voltage drop by limiting resistor (Right chart is enlarged chart.)



< DIPIPM >  
**PSS40S93F6-AG, PSS40S93E6-AG**  
 TRANSFER MOLDING TYPE  
 INSULATED TYPE

Fig. 3 Temperature of LVIC vs.  $V_{OT}$  output characteristics

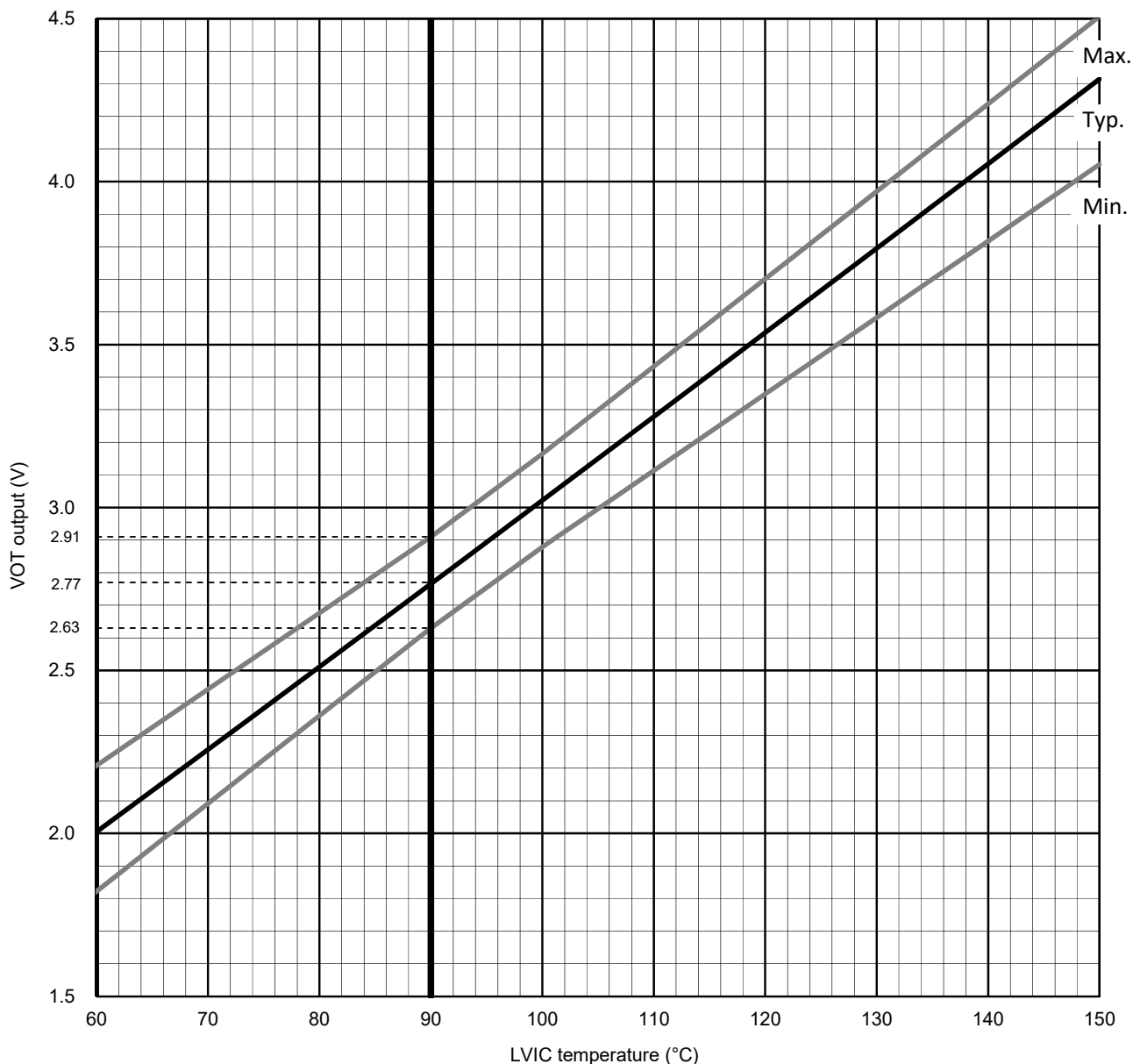
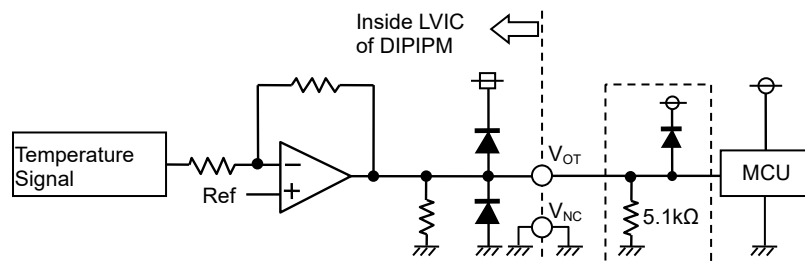


Fig. 4  $V_{OT}$  output circuit



- (1) It is recommended to insert 5kΩ (5.1kΩ is recommended) pull down resistor for getting linear output characteristics at low temperature below room temperature. When the pull down resistor is inserted between  $V_{OT}$  and  $V_{NC}$ (control GND), the extra circuit current, which is calculated approximately by  $V_{OT}$  output voltage divided by pull down resistance, flows as LVIC circuit current continuously. In the case of using  $V_{OT}$  for detecting high temperature over room temperature only, it is unnecessary to insert the pull down resistor.
- (2) In the case of using  $V_{OT}$  with low voltage controller like 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  $V_{OT}$  output for preventing over voltage destruction.
- (3) In the case of not using  $V_{OT}$ , leave  $V_{OT}$  output NC (No Connection).

Refer the application note about the usage of  $V_{OT}$ .

# PSS40S93F6-AG, PSS40S93E6-AG

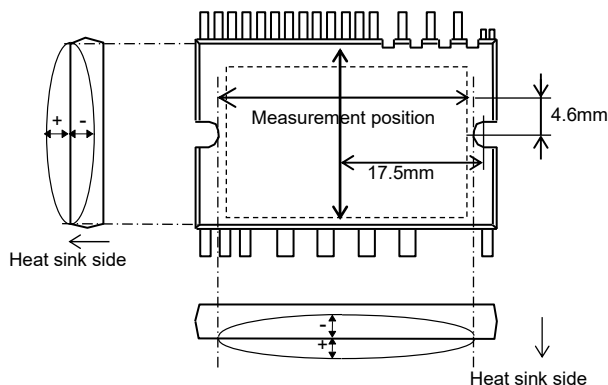
TRANSFER MOLDING TYPE  
INSULATED TYPE

## MECHANICAL CHARACTERISTICS AND RATINGS

Parameter	Condition	Reference	Limits			Unit
			Min.	Typ.	Max.	
Mounting torque	Mounting screw : M3 (Note 9)	JEITA-ED-4701 402 method II	0.59	0.69	0.78	N·m
Terminal strength pulling	Control terminal: Load 5N Power terminal: Load 10N	JEITA-ED-4701 401 method I	10	-	-	s
Terminal strength bending	Control terminal: Load 2.5N Power terminal: Load 5 90deg. bend	JEITA-ED-4701 401 method III	2	-	-	times
Weight		-	-	8.5	-	g
Heat radiation part flatness	(Note 10)	-	-50	-	100	μm

Note 9: Plain washers (ISO 7089-7094) are recommended.

Note 10: Measurement positions of heat radiation part flatness are as below.



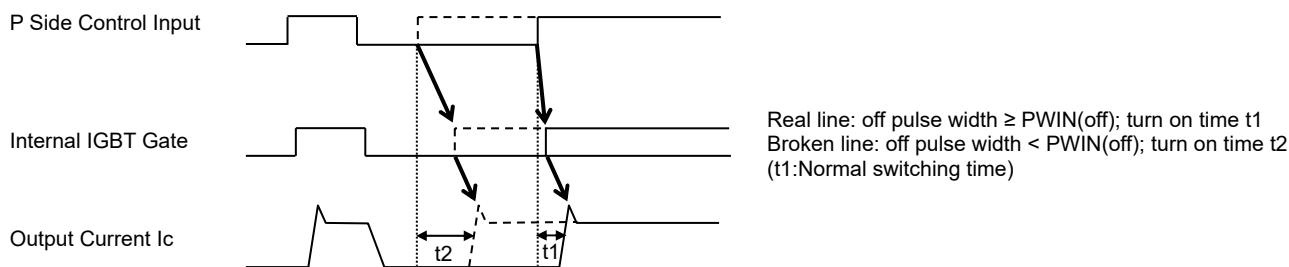
## RECOMMENDED OPERATION CONDITIONS

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
$\Delta V_D, \Delta V_{DB}$	Control supply variation		-1	-	+1	V/μs
$t_{dead}$	Arm shoot-through blocking time	For each input signal	1.5	-	-	μs
$f_{PWM}$	PWM input frequency	$T_C \leq 125^\circ C$ , $T_J \leq 150^\circ C$	-	-	20	kHz
PWIN(on)	Minimum input pulse width	(Note 11)	0.7	-	-	μs
PWIN(off)		(Note 12)	1.5	-	-	
$V_{NC}$	$V_{NC}$ variation	Between $V_{NC}-NU$ , NV, NW (including surge)	-5.0	-	+5.0	V
$T_J$	Junction temperature		-30	-	150	°C

Note 11: When inputting shorter pulse than PWIN(on), DIIPM might not make response.

12: DIIPM might make delayed response or no response for the input signal with off pulse width less than PWIN(off). Moreover, in case of rated current or more, DIIPM might make delayed response even for input signal with off pulse more than PWIN(off), Please refer below about delayed response.

### Delayed Response against Shorter Input Off Signal than PWIN(off) (P-side only)



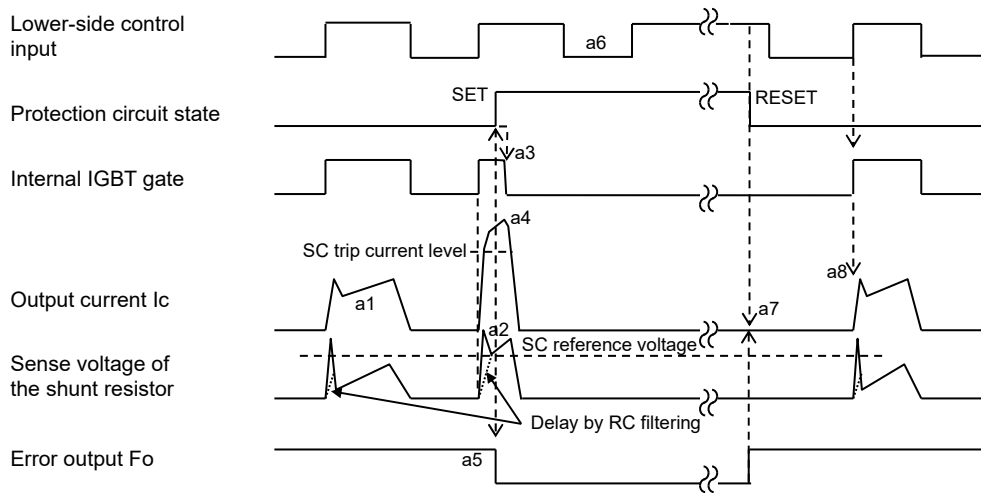
# PSS40S93F6-AG, PSS40S93E6-AG

TRANSFER MOLDING TYPE  
INSULATED TYPE

Fig. 5 Timing Charts of The DIIPM Protective Functions

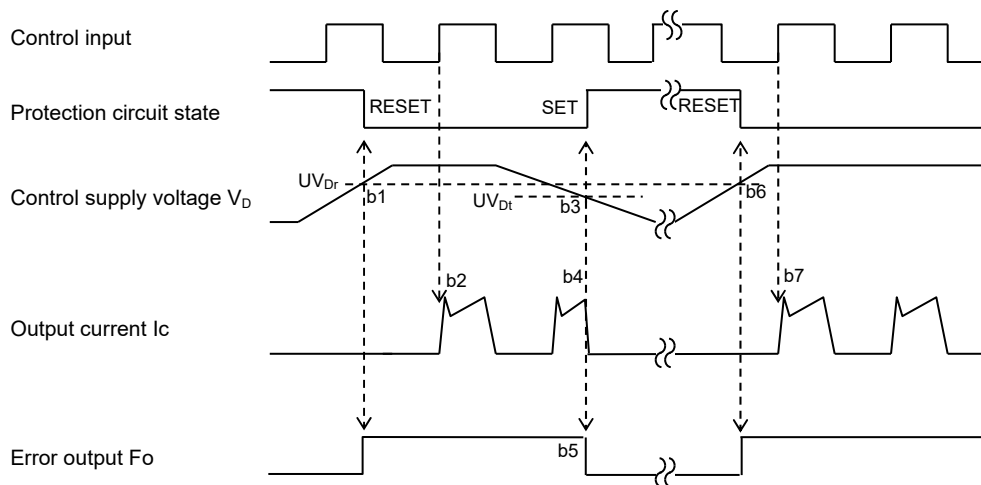
[A] Short-Circuit Protection (N-side only with the external shunt resistor and RC filter)

- a1. Normal operation: IGBT ON and outputs current.
- a2. Short circuit current detection (SC trigger)  
(It is recommended to set RC time constant 1.5~2.0 $\mu$ s so that IGBT shut down within 2.0 $\mu$ s when SC.)
- a3. All N-side IGBT's gates are hard interrupted.
- a4. All N-side IGBTs turn OFF.
- a5.  $F_o$  outputs for  $t_{Fo}$ =minimum 20 $\mu$ s.
- a6. Input = "L": IGBT OFF
- a7.  $F_o$  finishes output, but IGBTs don't turn on until inputting next ON signal (L $\rightarrow$ 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.



[B] Under-Voltage Protection (N-side, UV<sub>D</sub>)

- b1. Control supply voltage  $V_D$  exceeds under voltage reset level ( $UV_{Dr}$ ), but IGBT turns ON by next ON signal (L $\rightarrow$ H).  
(IGBT of each phase can return to normal state by inputting ON signal to each phase.)
- b2. Normal operation: IGBT ON and outputs current.
- b3.  $V_D$  level drops to under voltage trip level. ( $UV_{Dt}$ ).
- b4. All N-side IGBTs turn OFF in spite of control input condition.
- b5.  $F_o$  outputs for  $t_{Fo}$ =minimum 20 $\mu$ s, but output is extended during  $V_D$  keeps below  $UV_{Dr}$ .
- b6.  $V_D$  level reaches  $UV_{Dr}$ .
- b7. Normal operation: IGBT ON and outputs current.

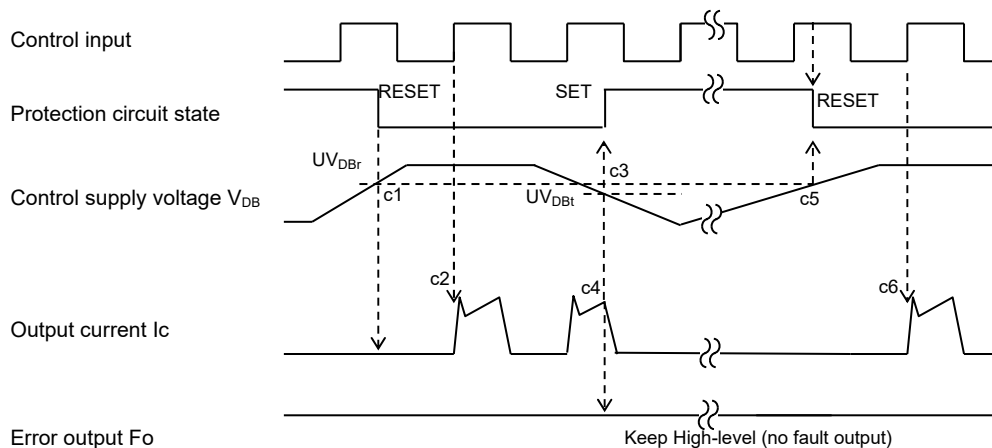


# PSS40S93F6-AG, PSS40S93E6-AG

TRANSFER MOLDING TYPE  
INSULATED TYPE

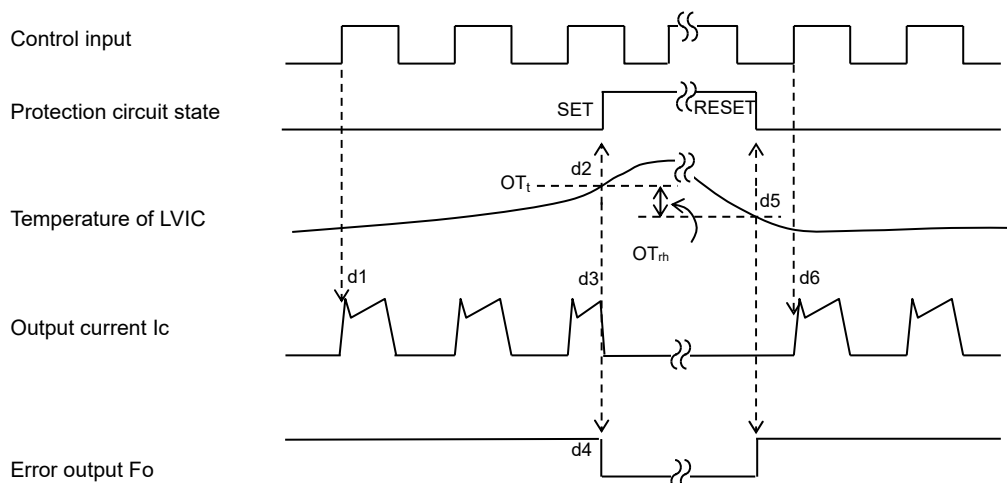
## [C] Under-Voltage Protection (P-side, $UV_{DB}$ )

- c1. Control supply voltage  $V_{DB}$  rises. After the voltage reaches under voltage reset level  $UV_{DBr}$ , IGBT turns on by next ON signal (L→H).
- c2. Normal operation: IGBT ON and outputs current.
- c3.  $V_{DB}$  level drops to under voltage trip level ( $UV_{DBt}$ ).
- c4. IGBT of the correspond phase only turns OFF in spite of control input signal level, but there is no  $F_o$  signal output.
- c5.  $V_{DB}$  level reaches  $UV_{DBr}$ .
- c6. Normal operation: IGBT ON and outputs current.



## [D] Over Temperature Protection (N-side, Detecting LVIC temperature)

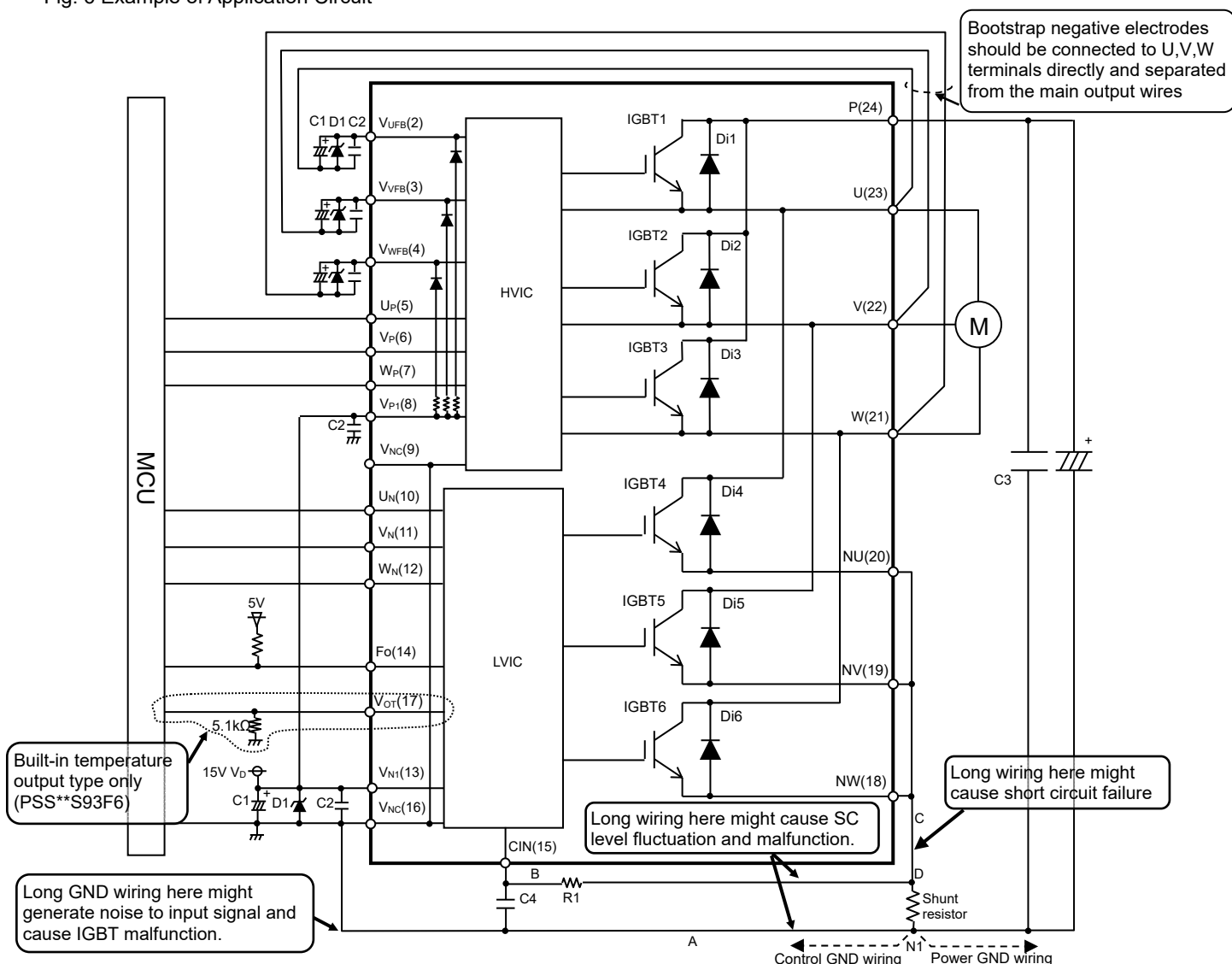
- d1. Normal operation: IGBT ON and outputs current.
  - d2. LVIC temperature exceeds over temperature trip level ( $OT_t$ ).
  - d3. All N-side IGBTs turn OFF in spite of control input condition.
  - d4.  $F_o$  outputs for  $t_{Fo}$ =minimum 20 $\mu$ s, but output is extended during LVIC temperature keeps over  $OT_t$ .
  - d5. LVIC temperature drops to over temperature reset level.
  - d6. 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.)



# PSS40S93F6-AG, PSS40S93E6-AG

TRANSFER MOLDING TYPE  
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Fig. 6 Example of Application Circuit

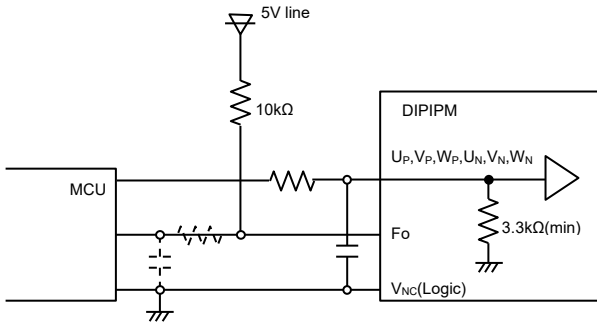


- (1) If control GND is connected with power GND by common broad pattern, it may cause malfunction by power GND fluctuation. It is recommended to connect control GND and power GND at only a point N1 (near the terminal of shunt resistor).
- (2) It is recommended to insert a Zener diode D1(24V/1W) between 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 0.1-0.22 $\mu$ F 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 2 $\mu$ s. (1.5-2 $\mu$ s 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 C2:0.22 $\mu$ -2 $\mu$ F, good temperature, frequency and DC bias characteristic ceramic type are recommended.)
- (8) Input drive is High-active type. There is a minimum 3.3k $\Omega$  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. Fo output will be max 0.95V(@I<sub>FO</sub>=1mA,25°C), so it should be pulled up to MCU or control power supply (e.g. 5V,15V) by a resistor that makes I<sub>FO</sub> up to 1mA. (In the case of pulled up to 5V, 10k $\Omega$  is recommended.) About driving opto coupler by Fo output, please refer the application note of this series.
- (10) Thanks to built-in HVIC, direct coupling to MCU without any opto-coupler or transformer isolation is possible.
- (11) Two V<sub>NC</sub> terminals (9 & 16 pin) are connected inside DIIPM, 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 DIIPM erroneous operation. To avoid such problem, line ripple voltage should meet dV/dt  $\leq$  +/-1V/ $\mu$ s, V<sub>ripple</sub>  $\leq$  2Vp-p.
- (13) For DIIPM, it isn't recommended to drive same load by parallel connection with another phase IGBT or other DIIPM.



< DIIPIM >  
**PSS40S93F6-AG, PSS40S93E6-AG**  
 TRANSFER MOLDING TYPE  
 INSULATED TYPE

Fig. 7 MCU I/O Interface Circuit



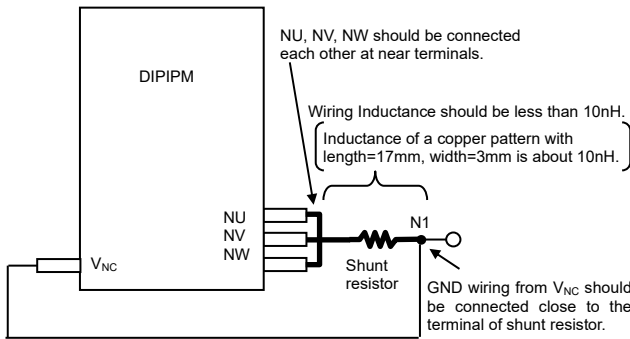
Note)

Design for input RC filter depends on PWM control scheme used in the application and wiring impedance of the printed circuit board.

DIIPIM input signal interface integrates a minimum 3.3kΩ pull-down resistor. Therefore, when inserting RC filter, it is necessary to satisfy turn-on threshold voltage requirement.

Fo output is open drain type. It should be pulled up to the positive side of 5V or 15V power supply with the resistor that limits Fo sink current  $I_{Fo}$  under 1mA. In the case of pulling up to 5V supply, over 5.1kΩ is needed. (10kΩ is recommended.)

Fig. 8 Pattern Wiring Around the Shunt Resistor



Low inductance shunt resistor like surface mounted (SMD) type is recommended.

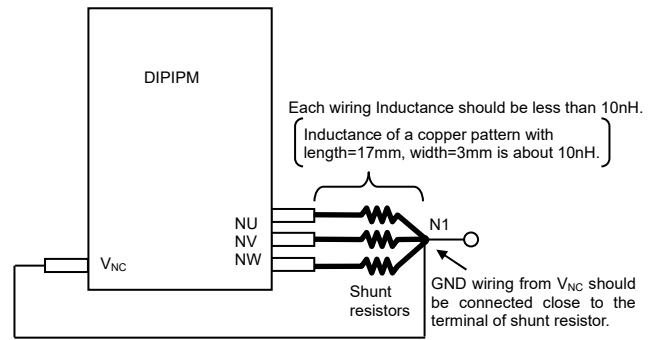
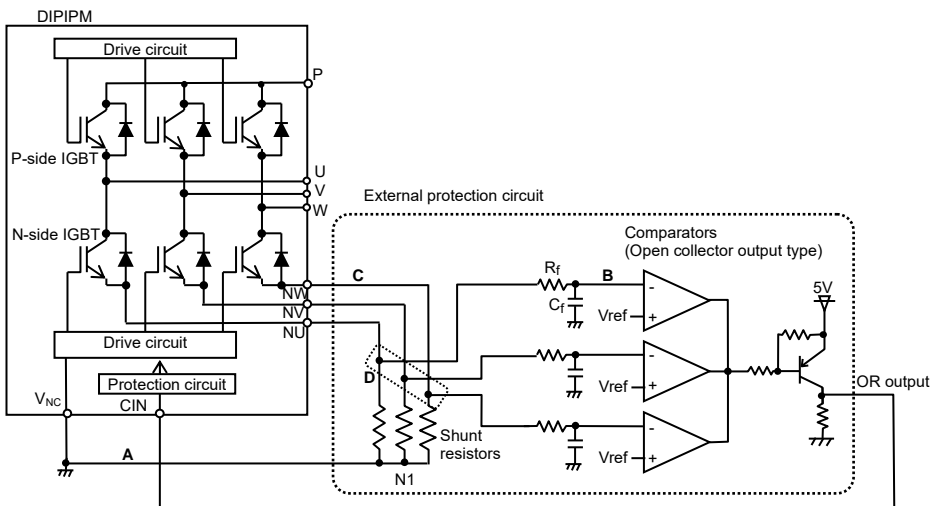


Fig. 9 Pattern Wiring Around the Shunt Resistor (for the case of open emitter)

When DIIPIM is operated with three shunt resistors, voltage of each shunt resistor cannot be input to CIN terminal directly. In that case, it is necessary to use the external protection circuit as below.

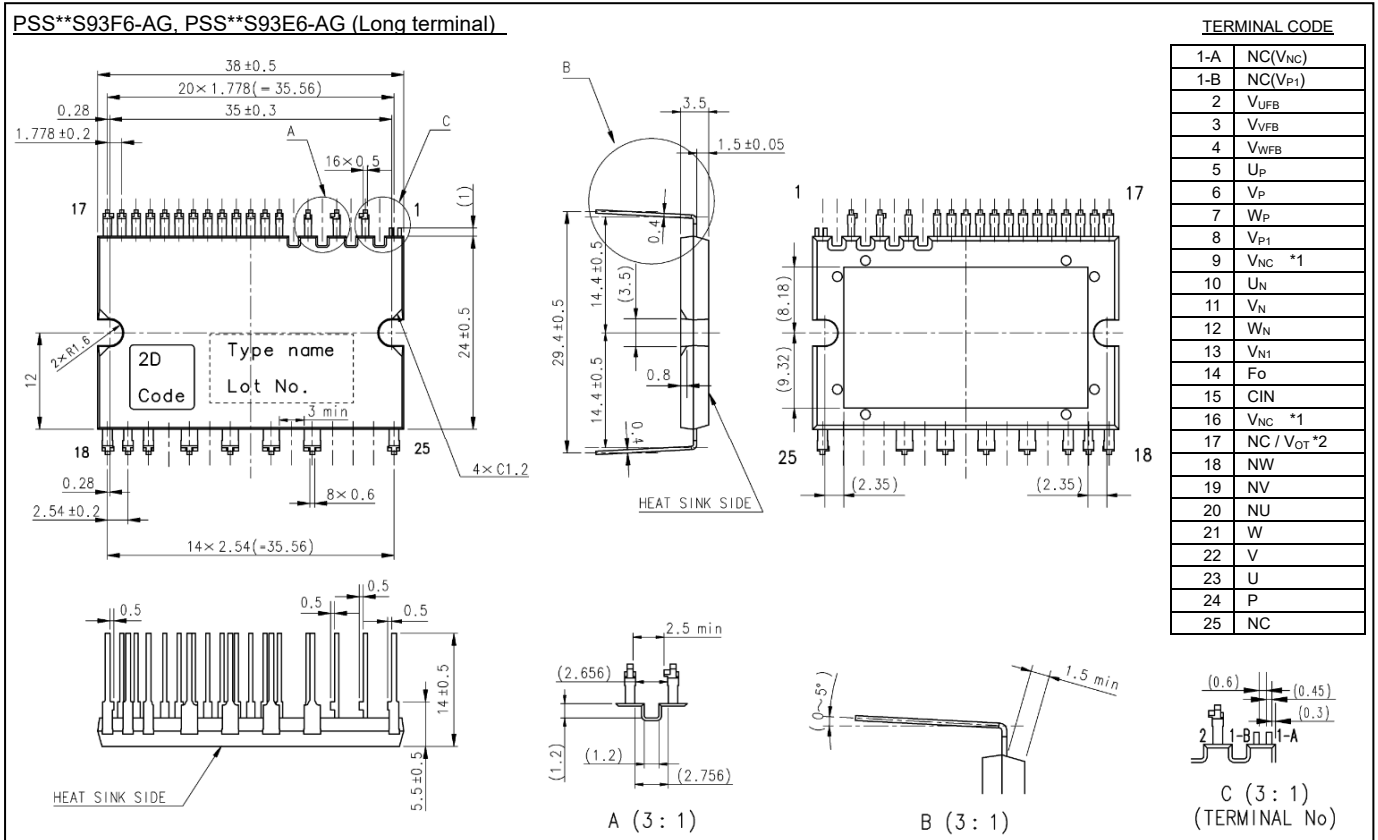


- (1) It is necessary to set the time constant  $R_f C_f$  of external comparator input so that IGBT stops within  $2\mu s$  when short circuit occurs. SC interrupting time might vary with the wiring pattern, comparator speed and so on.
- (2) It is recommended for the threshold voltage  $V_{ref}$  to set to the same rating of short circuit trip level ( $V_{sc(ref)}$ : typ. 0.48V).
- (3) Select the external shunt resistance so that SC trip-level is less than specified value (=1.7 times of rating current).
- (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 close to the terminal of shunt resistor.
- (6) OR output high level when protection works should be over 0.505V (=maximum  $V_{sc(ref)}$  rating).

< DIIPM >  
**PSS40S93F6-AG, PSS40S93E6-AG**  
 TRANSFER MOLDING TYPE  
 INSULATED TYPE

Fig. 10 Package Outlines

Dimensions in mm



- 1) 9 & 16 pins (V<sub>NC</sub>) are connected inside DIIPM, please connect either one to the control power supply GND outside and leave another one open.  
 2) No.17 is V<sub>OT</sub> for built-in temperature output function type (PSS\*\*S93F6) and NC (No Connection) for built-in OT protection function type (PSS\*\*S93E6).

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