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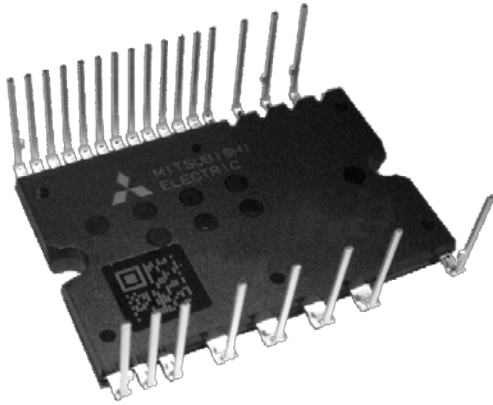


< Dual-In-Line Package Intelligent Power Module >

# PSM05S93E5-A

TRANSFER MOLDING TYPE  
INSULATED TYPE

## OUTLINE



## MAIN FUNCTION AND RATINGS

- 3 phase DC/AC inverter
- 500V / 5A (MOSFET)
- N-side MOSFET open source
- Built-in bootstrap diodes with current limiting resistor

## APPLICATION

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

## TYPE NAME

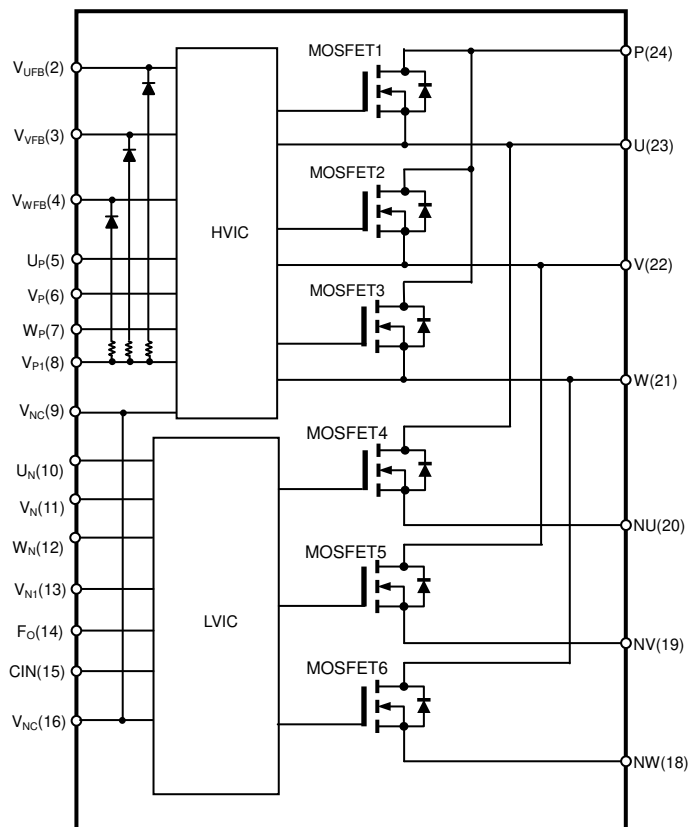
PSM05S93E5-A

With over temperature protection

## 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)
- Fault signaling : Corresponding to SC fault (N-side MOSFET), UV fault (N-side supply) and OT fault
- Input interface : 3, 5V line, Schmitt trigger receiver circuit (High Active)
- UL Recognized : UL1557 File E323585

## INTERNAL CIRCUIT



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**MAXIMUM RATINGS** ( $T_{ch} = 25^{\circ}\text{C}$ , unless otherwise noted)

**INVERTER PART**

Symbol	Parameter	Condition	Ratings	Unit
$V_{DD}$	Supply voltage	Applied between P-NU,NV,NW	400	V
$V_{DD(surge)}$	Supply voltage (surge)	Applied between P-NU,NV,NW	450	V
$V_{DSS}$	Drain-source voltage		500	V
$\pm I_D$	Each MOSFET drain current	$T_C = 25^{\circ}\text{C}$ (Note 1)	5	A
$\pm I_{DP}$	Each MOSFET drain current (peak)	$T_C = 25^{\circ}\text{C}$ , less than 1ms	10	A
$P_D$	Drain dissipation	$T_C = 25^{\circ}\text{C}$ , per 1 chip	35.7	W
$T_{ch}$	Channel temperature	(Note 2)	-20~+150	$^{\circ}\text{C}$

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

Note2: The maximum junction temperature rating of built-in power chips is  $150^{\circ}\text{C}$  ( $T_C \leq 100^{\circ}\text{C}$ ). However, to ensure safe operation of DIPIPM, the average channel temperature should be limited to  $T_{ch(Ave)} \leq 125^{\circ}\text{C}$  ( $T_C \leq 100^{\circ}\text{C}$ ).

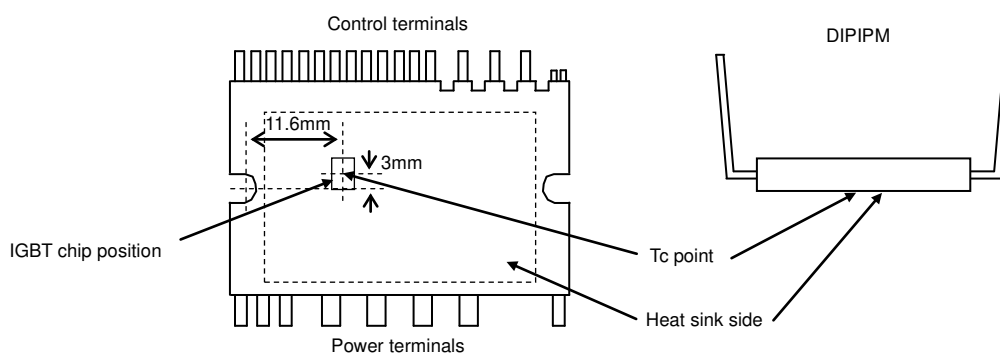
**CONTROL (PROTECTION) PART**

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	Sink current at $F_O$ terminal	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
$V_{DD(PROT)}$	Self protection supply voltage limit (Short circuit protection capability)	$V_D = 13.5\sim 16.5\text{V}$ , Inverter Part $T_{ch} = 125^{\circ}\text{C}$ , non-repetitive, less than 2 $\mu\text{s}$	400	V
$T_C$	Module case operation temperature	Measurement point of $T_C$ is provided in Fig.1	-20~+100	$^{\circ}\text{C}$
$T_{sig}$	Storage temperature		-40~+125	$^{\circ}\text{C}$
$V_{iso}$	Isolation voltage	60Hz, Sinusoidal, AC 1min, between connected all pins and heat sink plate	1500	$V_{rms}$

Fig. 1:  $T_C$  MEASUREMENT POINT



**THERMAL RESISTANCE**

Symbol	Parameter	Condition	Limits			Unit
			Min.	Typ.	Max.	
$R_{th(ch-c)Q}$	Channel to case thermal resistance (Note3)	1/6 module	-	-	2.8	K/W

Note 3: Grease with good thermal conductivity and long-term endurance should be applied evenly with about +100 $\mu\text{m}$ ~+200 $\mu\text{m}$  on the contacting surface of DIPIPM and heat sink. The contacting thermal resistance between DIPIPM case and heat sink  $R_{th(c-f)}$  is determined by the thickness and the thermal conductivity of the applied grease. For reference,  $R_{th(c-f)}$  is about 0.3K/W (per 1/6 module, grease thickness: 20 $\mu\text{m}$ , thermal conductivity: 1.0W/m $\cdot$ k).

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## ELECTRICAL CHARACTERISTICS (T<sub>ch</sub> = 25°C, unless otherwise noted)

### INVERTER PART

Symbol	Parameter	Condition	Limits			Unit	
			Min.	Typ.	Max.		
V <sub>DS(on)</sub>	Drain-source on-state resistance	V <sub>D</sub> =V <sub>DB</sub> = 15V, V <sub>IN</sub> = 5V, I <sub>D</sub> = 5A	T <sub>ch</sub> = 25°C	-	0.60	0.80	Ω
			T <sub>ch</sub> = 125°C	-	1.30	1.70	
V <sub>SD</sub>	Source-drain voltage drop	V <sub>IN</sub> = 0V, -I <sub>D</sub> = 5A	-	0.90	1.30	V	
t <sub>on</sub>	Switching times	V <sub>DD</sub> = 300V, V <sub>D</sub> = V <sub>DB</sub> = 15V I <sub>D</sub> = 5A, T <sub>ch</sub> = 125°C, V <sub>IN</sub> = 0→5V Inductive Load (upper-lower arm)	0.65	1.15	1.65	μs	
t <sub>C(on)</sub>			-	0.35	0.55	μs	
t <sub>off</sub>			-	1.00	1.50	μs	
t <sub>C(off)</sub>			-	0.10	0.20	μs	
t <sub>rr</sub>			-	0.25	-	μs	
I <sub>DSS</sub>	Drain-source cut-off current	V <sub>DS</sub> =V <sub>DSS</sub>	T <sub>ch</sub> = 25°C	-	-	1	mA
			T <sub>ch</sub> = 125°C	-	-	10	

### CONTROL (PROTECTION) PART

Symbol	Parameter	Condition	Limits			Unit	
			Min.	Typ.	Max.		
I <sub>D</sub>	Circuit current	Total of V <sub>P1</sub> -V <sub>NC</sub> , V <sub>N1</sub> -V <sub>NC</sub>	V <sub>D</sub> =15V, V <sub>IN</sub> =0V	-	-	2.80	mA
			V <sub>D</sub> =15V, V <sub>IN</sub> =5V	-	-	2.80	
I <sub>DB</sub>		Each part of V <sub>UFB</sub> -U, V <sub>VFB</sub> -V, V <sub>WFB</sub> -W	V <sub>D</sub> =V <sub>DB</sub> =15V, V <sub>IN</sub> =0V	-	-	0.10	mA
			V <sub>D</sub> =V <sub>DB</sub> =15V, V <sub>IN</sub> =5V	-	-	0.10	
V <sub>SC(ref)</sub>	Short circuit trip level	V <sub>D</sub> = 15V (Note 4)	0.43	0.48	0.53	V	
UV <sub>DBt</sub>	P-side Control supply under-voltage protection(UV)	T <sub>ch</sub> ≤125°C	Trip level	7.0	10.0	12.0	V
UV <sub>DBr</sub>			Reset level	7.0	10.0	12.0	V
UV <sub>Dt</sub>	N-side Control supply under-voltage protection(UV)	T <sub>ch</sub> ≤125°C	Trip level	10.3	-	12.5	V
UV <sub>Dr</sub>			Reset level	10.8	-	13.0	V
OT <sub>t</sub>	Over temperature protection (OT) (Note5)	V <sub>D</sub> = 15V Detect LVIC temperature	Trip level	100	120	140	°C
OT <sub>rh</sub>			Hysteresis of trip-reset	-	10	-	°C
V <sub>FOH</sub>	Fault output voltage	V <sub>SC</sub> = 0V, F <sub>O</sub> terminal pulled up to 5V by 10kΩ	4.9	-	-	V	
V <sub>FOL</sub>		V <sub>SC</sub> = 1V, I <sub>FO</sub> = 1mA	-	-	0.95	V	
t <sub>FO</sub>	Fault output pulse width	(Note 6)	20	-	-	μs	
I <sub>IN</sub>	Input current	V <sub>IN</sub> = 5V	0.70	1.00	1.50	mA	
V <sub>th(on)</sub>	ON threshold 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>	-	2.10	2.60	V	
V <sub>th(off)</sub>	OFF threshold voltage		0.80	1.30	-		
V <sub>th(hys)</sub>	ON/OFF threshold hysteresis voltage		0.35	0.65	-		
V <sub>F</sub>	Bootstrap Di forward voltage	I <sub>F</sub> =10mA including voltage drop by limiting resistor (Note 7)	1.1	1.7	2.3	V	
R	Built-in limiting resistance	Included in bootstrap Di	80	100	120	Ω	

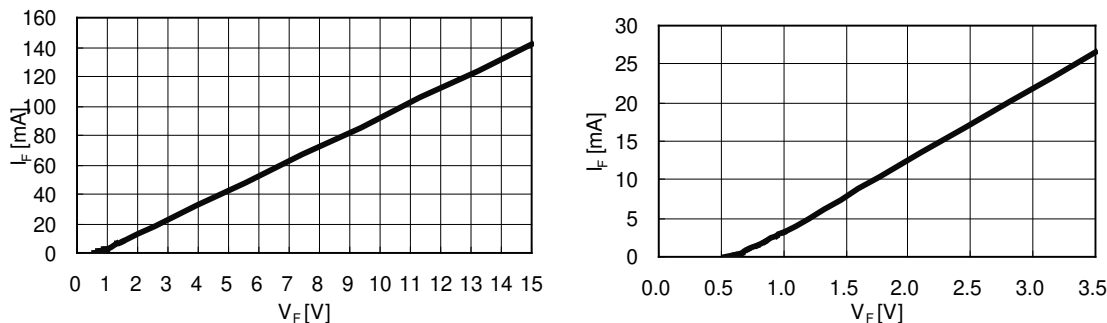
Note 4 : SC protection works for N-side only. Please select the external shunt resistance such that the SC trip-level is less than 1.7 times of the current rating.

5 : When the LVIC temperature exceeds OT trip temperature level(OT<sub>t</sub>), OT protection works and Fo outputs. In that case if the heat sink dropped off or fixed loosely, don't reuse that DIPIM. (There is a possibility that channel temperature of power chips exceeded maximum T<sub>ch</sub>(150°C).)

6 : 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.)

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

Fig. 2 Characteristics of bootstrap Di V<sub>F</sub>-I<sub>F</sub> curve (@Ta=25°C) including voltage drop by limiting resistor (Right chart is enlarged chart.)



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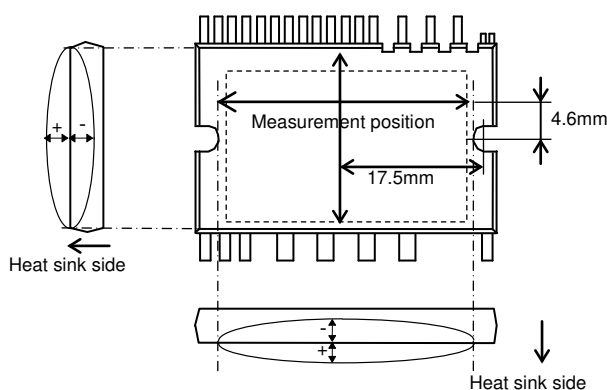
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**MECHANICAL CHARACTERISTICS AND RATINGS**

Parameter	Condition		Limits			Unit
			Min.	Typ.	Max.	
Mounting torque	Mounting screw : M3 (Note 8)	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	EIAJ-ED-4701	10	-	-	s
Terminal bending strength	Control terminal: Load 2.45N Power terminal: Load 4.9N 90deg. bend	EIAJ-ED-4701	2	-	-	times
Weight			-	8.5	-	g
Heat-sink flatness	(Note 9)		-50	-	100	μm

Note 8: Plain washers (ISO 7089~7094) are recommended.

Note 9: Measurement point of heat sink flatness



**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	1.0	-	-	μs	
$f_{PWM}$	PWM input frequency	$T_C \leq 100^\circ\text{C}$ , $T_{ch} \leq 125^\circ\text{C}$	-	-	20	kHz	
$I_o$	Allowable r.m.s. current	$V_{DD} = 300\text{V}$ , $V_D = 15\text{V}$ , P.F = 0.8, Sinusoidal PWM $T_C \leq 100^\circ\text{C}$ , $T_{ch} \leq 125^\circ\text{C}$ (Note10)	$f_{PWM} = 5\text{kHz}$	-	-	2.5	Arms
			$f_{PWM} = 15\text{kHz}$	-	-	2.0	
$P_{WIN(on)}$	Minimum input pulse width	(Note 11)	0.7	-	-	μs	
$P_{WIN(off)}$			0.7	-	-		
$V_{NC}$	$V_{NC}$ variation	Between $V_{NC}$ -NU, NV, NW (including surge)	-5.0	-	+5.0	V	
$T_{ch}$	Channel temperature		-20	-	+125	°C	

Note 10: Allowable r.m.s. current depends on the actual application conditions.

11: DIPIPM might not make response if the input signal pulse width is less than  $P_{WIN(on)}$ ,  $P_{WIN(off)}$ .

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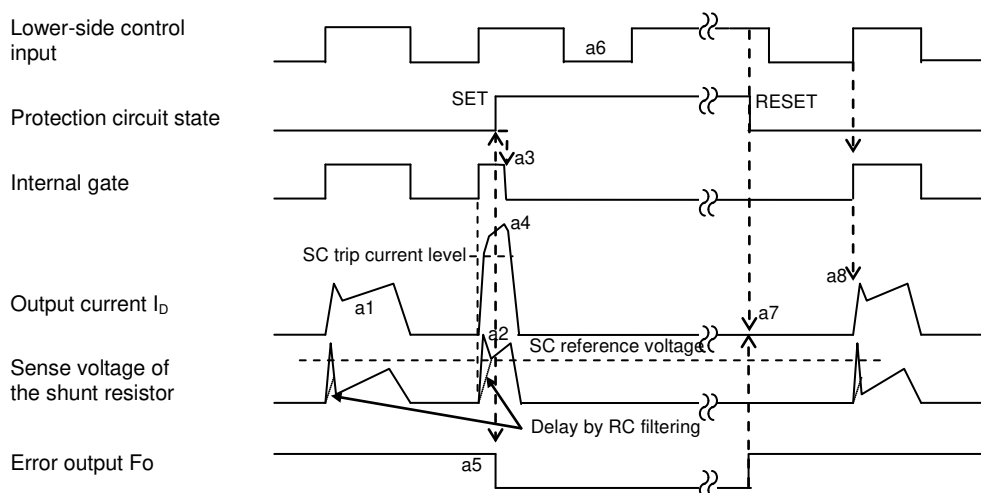
TRANSFER MOLDING TYPE

INSULATED TYPE

Fig. 3 Timing Charts of The DIIPM Protective Functions

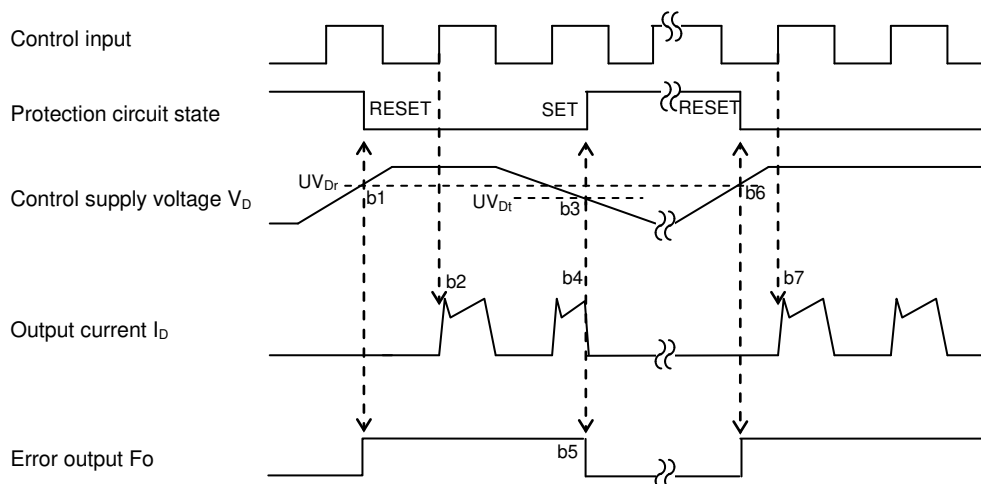
[A] Short-Circuit Protection (N-side only with the external shunt resistor and RC filter)

- a1. Normal operation: MOSFET 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 MOSFET shut down within 2.0 $\mu$ s when SC.)
- a3. All N-side MOSFET's gates are hard interrupted.
- a4. All N-side MOSFETs turn OFF.
- a5.  $F_o$  outputs for  $t_{Fo}$ =minimum 20 $\mu$ s.
- a6. Input = "L": MOSFET OFF
- a7.  $F_o$  finishes output, but MOSFETs don't turn on until inputting next ON signal (L $\rightarrow$ H).  
(MOSFET of each phase can return to normal state by inputting ON signal to each phase.)
- a8. Normal operation: MOSFET ON and outputs current.



[B] Under-Voltage Protection (N-side,  $UV_D$ )

- b1. Control supply voltage  $V_D$  exceeds under voltage reset level ( $UV_{Dr}$ ), but MOSFET turns ON by next ON signal (L $\rightarrow$ H).  
(MOSFET of each phase can return to normal state by inputting ON signal to each phase.)
- b2. Normal operation: MOSFET ON and outputs current.
- b3.  $V_D$  level drops to under voltage trip level. ( $UV_{Dt}$ ).
- b4. All N-side MOSFETs 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: MOSFET ON and outputs current.



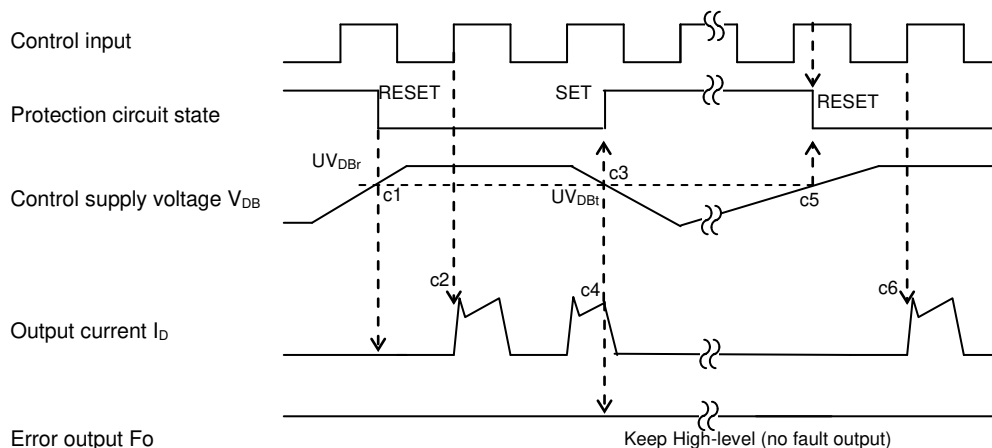
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### [C] Under-Voltage Protection (P-side, $UV_{DB}$ )

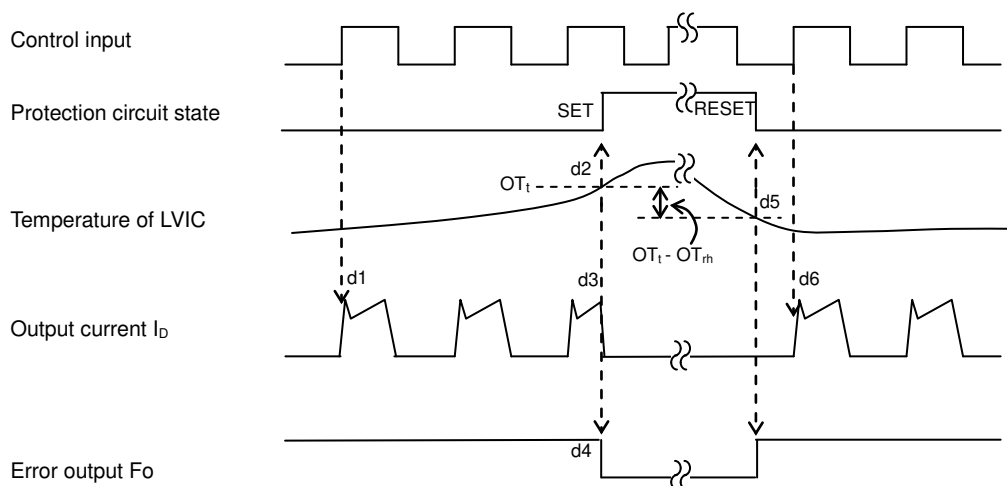
- c1. Control supply voltage  $V_{DB}$  rises. After the voltage reaches under voltage reset level  $UV_{DBr}$ , MOSFET turns on by next ON signal (L→H).
- c2. Normal operation: MOSFET ON and outputs current.
- c3.  $V_{DB}$  level drops to under voltage trip level ( $UV_{DBt}$ ).
- c4. MOSFET of the 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: MOSFET ON and outputs current.



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

- d1. Normal operation: MOSFET ON and outputs current.
- d2. LVIC temperature exceeds over temperature trip level ( $OT_t$ ).
- d3. All N-side MOSFETs 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: MOSFET turns on by next ON signal (L→H).

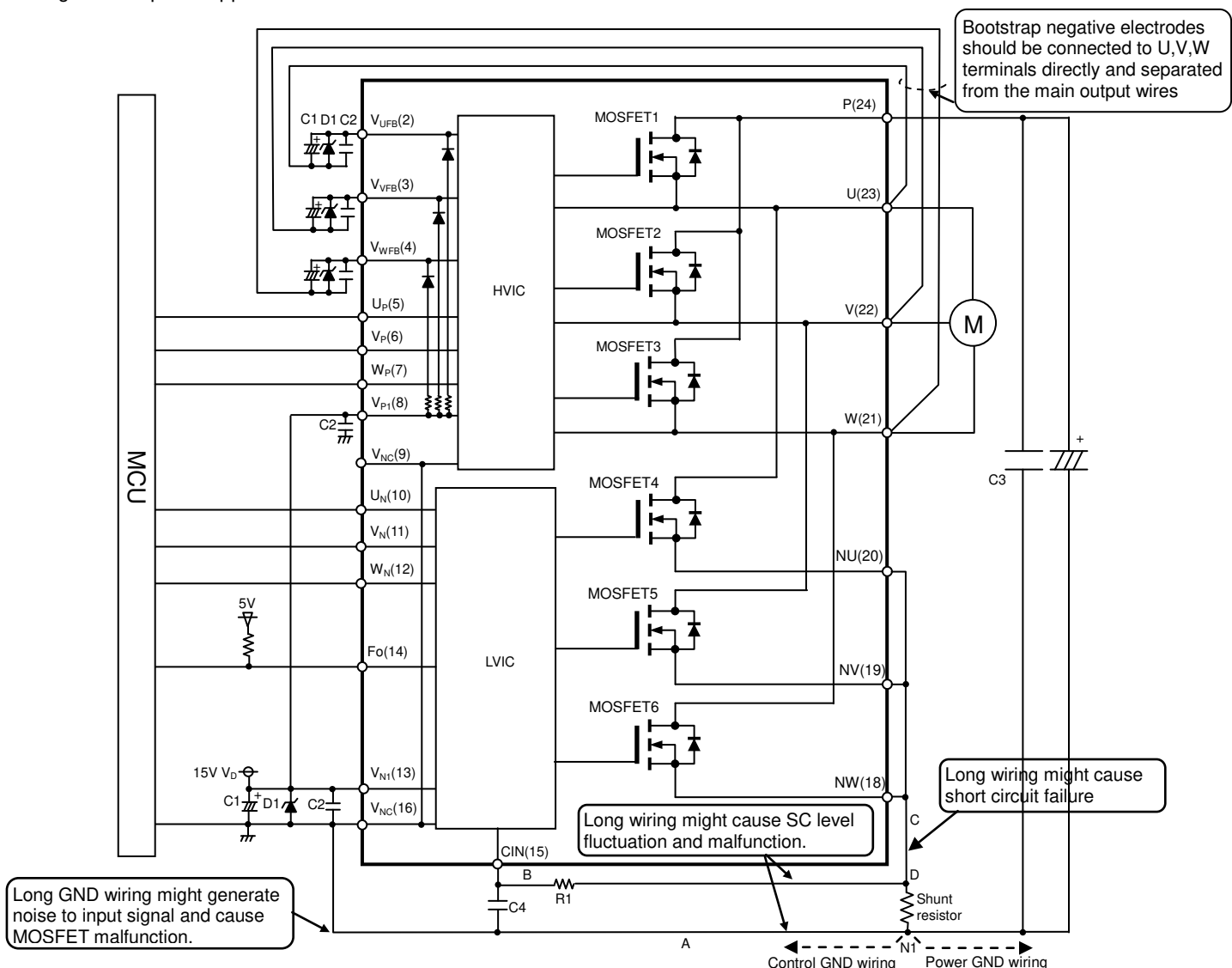
(MOSFET of each phase can return to normal state by inputting ON signal to each phase.)



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Fig. 4 Example of Application Circuit

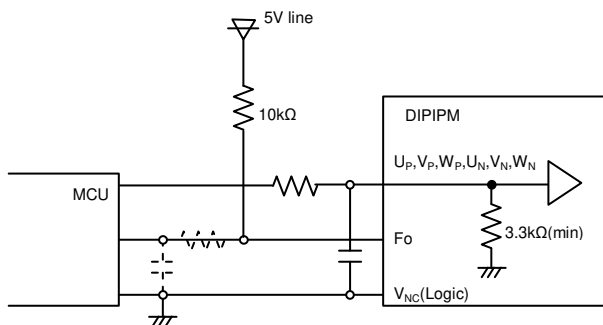


- (1) If control GND is connected with power GND by common broad pattern, it may cause malfunction by power GND fluctuation. It is recommended to connect control GND and power GND at only a point N1 (near the terminal of shunt resistor).
- (2) It is recommended to insert a Zener diode D1(24V/1W) between 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 $\mu$ s~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. 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. (I<sub>Fo</sub> is estimated roughly by the formula of control power supply voltage divided by pull-up resistance. In the case of pulled up to 5V, 10k $\Omega$  (5k $\Omega$  or more) is recommended.)
- (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 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  $\leq$  +/-1V/ $\mu$ s, Vrippl $\leq$ 2Vp-p.
- (13) For DIPIPM, it isn't recommended to drive same load by parallel connection with other phase MOSFET or other DIPIPM.



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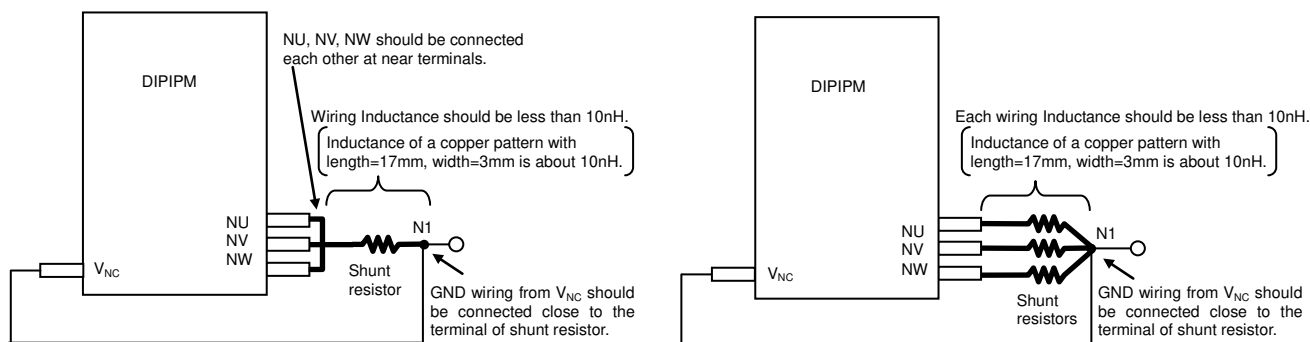
Fig. 5 MCU I/O Interface Circuit



Note)

Design for input RC filter depends on PWM control scheme used in the application and wiring impedance of the printed circuit board. DIPIPM 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. F<sub>O</sub> output is open drain type. It should be pulled up to control power supply (e.g. 5V, 15V) with a resistor that makes F<sub>O</sub> sink current I<sub>F<sub>O</sub></sub> 1mA or less. In the case of pulled up to 5V supply, 10kΩ (5kΩ or more) is recommended.

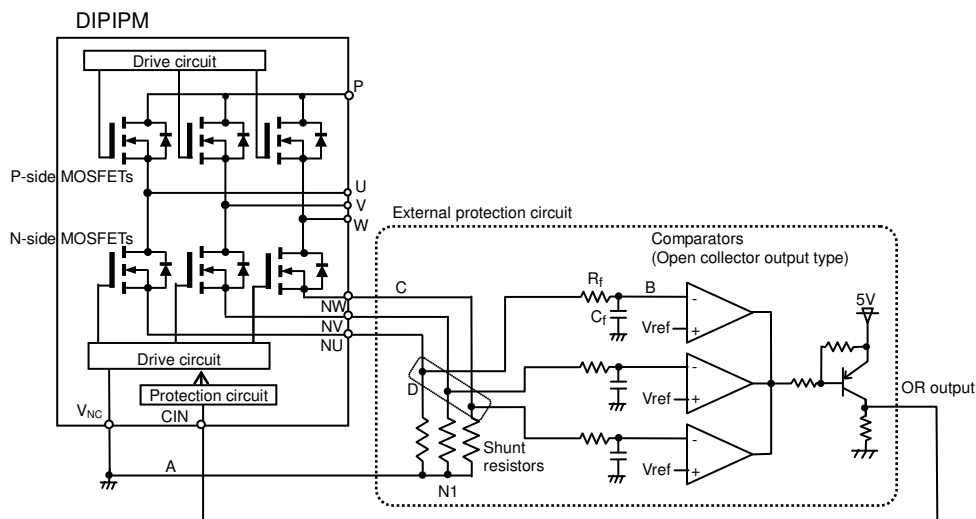
Fig. 6 Pattern Wiring Around the Shunt Resistor



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

Fig. 7 Pattern Wiring Around the Shunt Resistor (for the case of open source)

When DIPIPM 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 MOSFET 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 0.53V (=maximum  $V_{sc(ref)}$  rating).

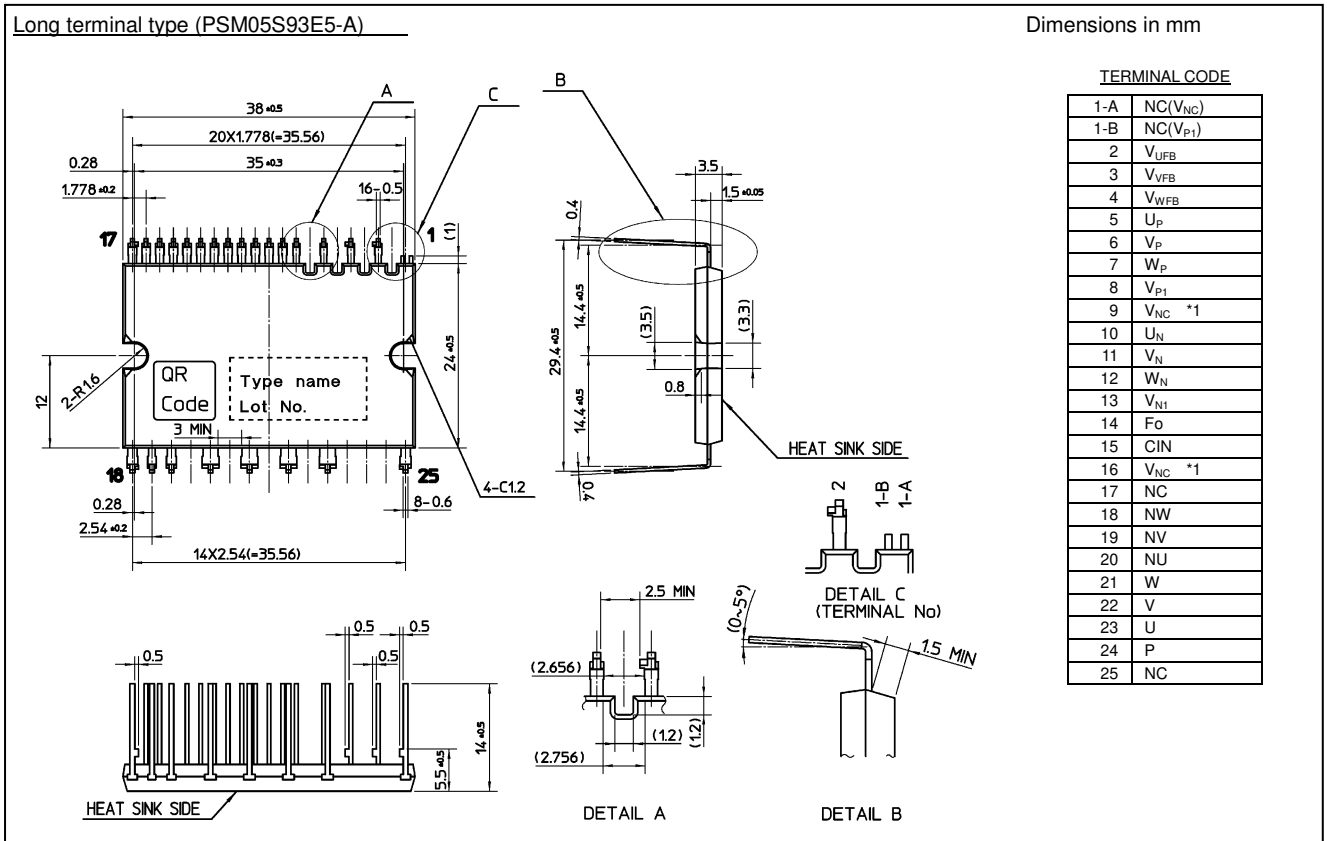
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Fig. 8 Package Outlines



1) 9 & 16 pins (V<sub>NC</sub>) are connected inside DIPIPM, please connect either one to the control power supply GND outside and leave another one open.

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## Revision Record

Rev.	Date	Page	Revised contents
1	15/10/2013	-	New
2	20/ 3/2014	2	Add Note1.

**Keep safety first in your circuit designs!**

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