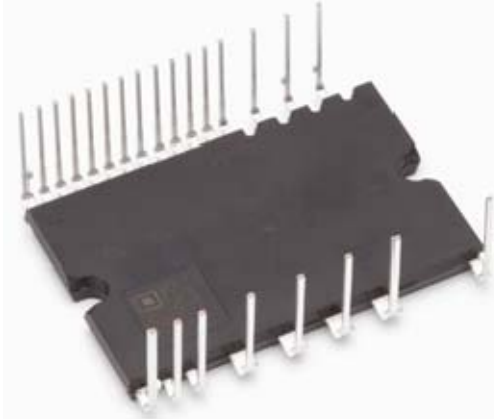


< DIIPM >

# PSM03S93E5-A

TRANSFER MOLDING TYPE  
INSULATED TYPE

## OUTLINE



## MAIN FUNCTION AND RATINGS

- 3 phase DC/AC inverter
- 500V / 3A (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

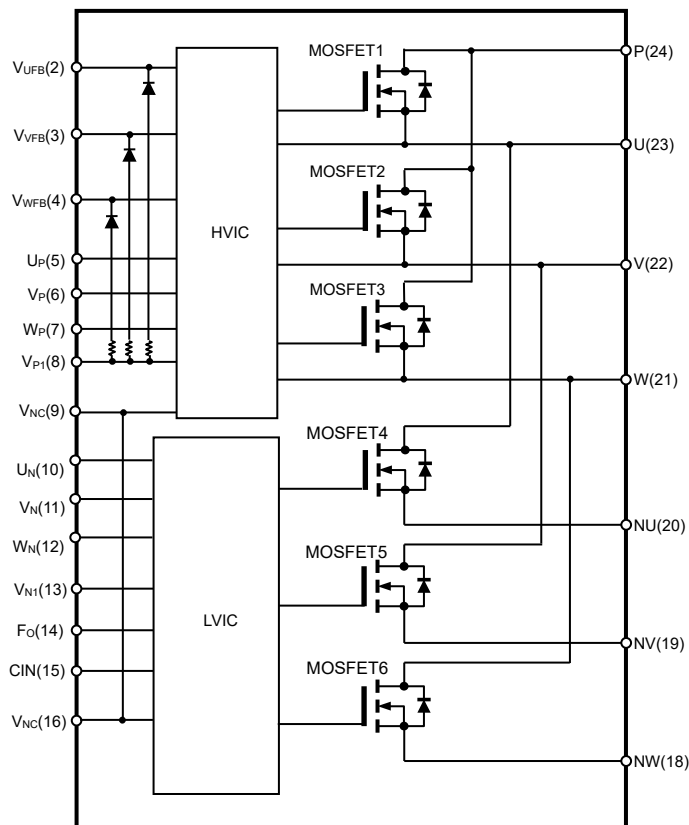
PSM03S93E5-A

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



# PSM03S93E5-A

TRANSFER MOLDING TYPE  
INSULATED TYPE

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

### INVERTER PART

| Symbol                 | Parameter                        | Condition                            | Ratings  | Unit |
|------------------------|----------------------------------|--------------------------------------|----------|------|
| V <sub>DD</sub>        | Supply voltage                   | Applied between P-NU,NV,NW           | 400      | V    |
| V <sub>DD(surge)</sub> | Supply voltage (surge)           | Applied between P-NU,NV,NW           | 450      | V    |
| V <sub>DSS</sub>       | Drain-source voltage             |                                      | 500      | V    |
| ±I <sub>D</sub>        | Each MOSFET drain current        | T <sub>C</sub> = 25°C (Note 1)       | 3        | A    |
| ±I <sub>DP</sub>       | Each MOSFET drain current (peak) | T <sub>C</sub> = 25°C, less than 1ms | 6        | A    |
| P <sub>D</sub>         | Drain dissipation                | T <sub>C</sub> = 25°C, per 1 chip    | 29.4     | W    |
| T <sub>ch</sub>        | Channel temperature              | (Note 2)                             | -20~+150 | °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°C(@Tc≤100°C).However, to ensure safe operation of DIIPM, the average channel temperature should be limited to Tch(Ave)≤125°C (@Tc≤100°C).

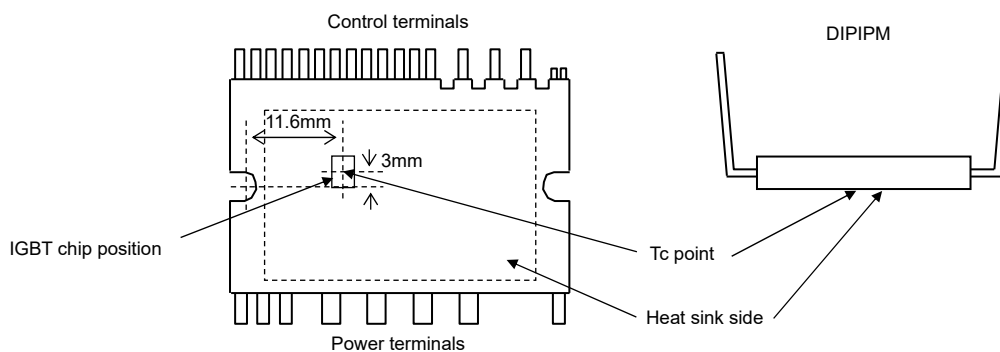
### CONTROL (PROTECTION) PART

| 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  | 1                        | 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>DD(PROT)</sub> | Self protection supply voltage limit (Short circuit protection capability) | V <sub>D</sub> = 13.5~16.5V, Inverter Part<br>T <sub>ch</sub> = 125°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   | -20~+100 | °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 heat sink 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(ch-c)Q</sub> | Channel to case thermal resistance (Note3) | 1/6 module | -      | -    | 3.4  | 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 heat sink. 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).

# PSM03S93E5-A

TRANSFER MOLDING TYPE  
INSULATED TYPE

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

### INVERTER PART

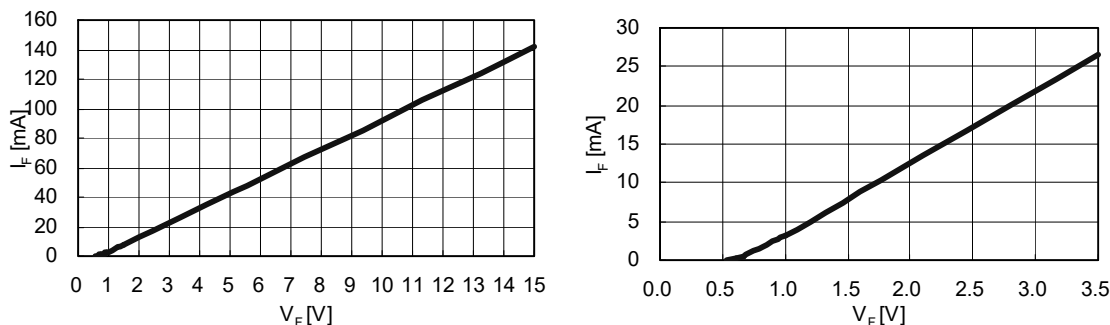
| Symbol              | Parameter                        | Condition  | Limits                  |      |      | Unit |    |
|---------------------|----------------------------------|--|-------------------------|------|------|------|----|
|                     |                                  |  | Min.                    | 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> = 3A   | T <sub>ch</sub> = 25°C  | -    | 1.50 | 2.00 | Ω  |
|                     |                                  |  | T <sub>ch</sub> = 125°C | -    | 3.40 | 4.50 |    |
| V <sub>SD</sub>     | Source-drain voltage drop        | V <sub>IN</sub> = 0V, -I <sub>D</sub> = 3A   | -                       | 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<br>I <sub>D</sub> = 3A, T <sub>ch</sub> = 125°C, V <sub>IN</sub> = 0→5V<br>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>tr</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,<br>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 |    |
|                      |  |  | 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   | Trip level  | 100  | 120  | 140  | °C |
| OT <sub>th</sub>     |  | Detect LVIC temperature  | 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>F0</sub> = 1mA  | -   | -    | 0.95 | V    |    |
| t <sub>F0</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 DIIPM. (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.)



# PSM03S93E5-A

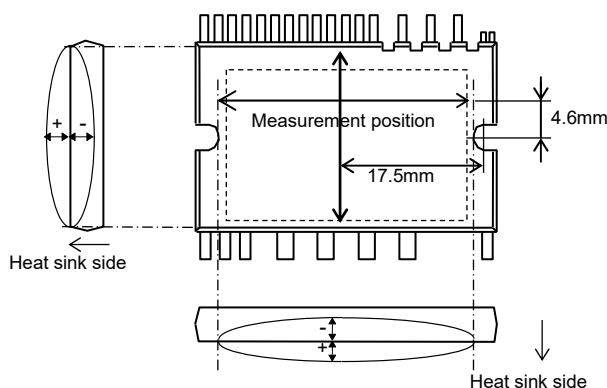
TRANSFER MOLDING TYPE  
INSULATED TYPE

## 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<br>Power terminal: Load 9.8N                 | JEITA-ED-4701       | 10     | -    | -    | s     |
| Terminal bending strength | Control terminal: Load 2.45N<br>Power terminal: Load 4.9N<br>90deg. bend | JEITA-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,<br>Sinusoidal PWM<br>$T_C \leq 100^\circ\text{C}$ , $T_{ch} \leq 125^\circ\text{C}$ (Note10) | $f_{PWM} = 5\text{kHz}$  | -    | -    | 1.5  | Arms |
|                             |                                 |   | $f_{PWM} = 15\text{kHz}$ | -    | -    | 1.2  |      |
| PWIN(on)                    | Minimum input pulse width       | (Note 11)   | 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    |      |
| $T_{ch}$                    | Channel temperature             |   | -20                      | -    | +125 | °C   |      |

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

11: DIIPM might not make response if the input signal pulse width is less than PWIN(on), PWIN(off).

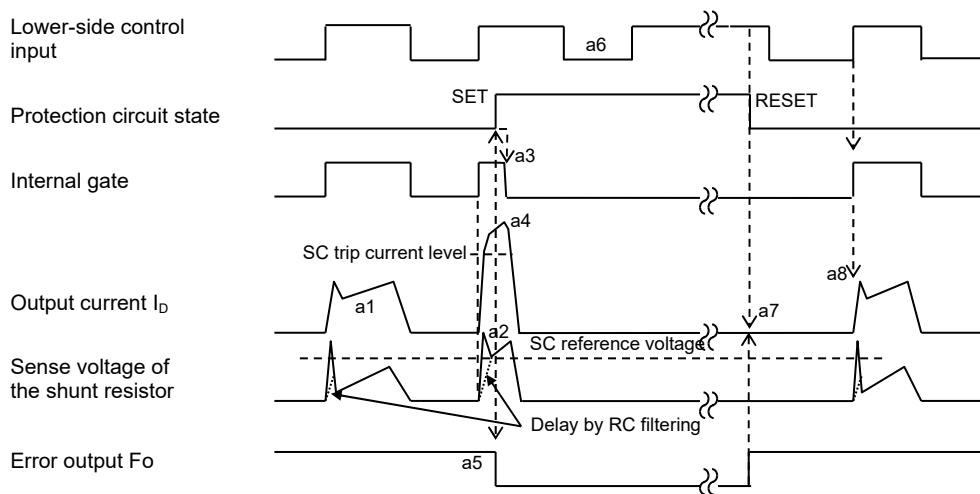
# PSM03S93E5-A

TRANSFER MOLDING TYPE  
INSULATED TYPE

Fig. 3 Timing Charts of The DIIPM Protective Functions

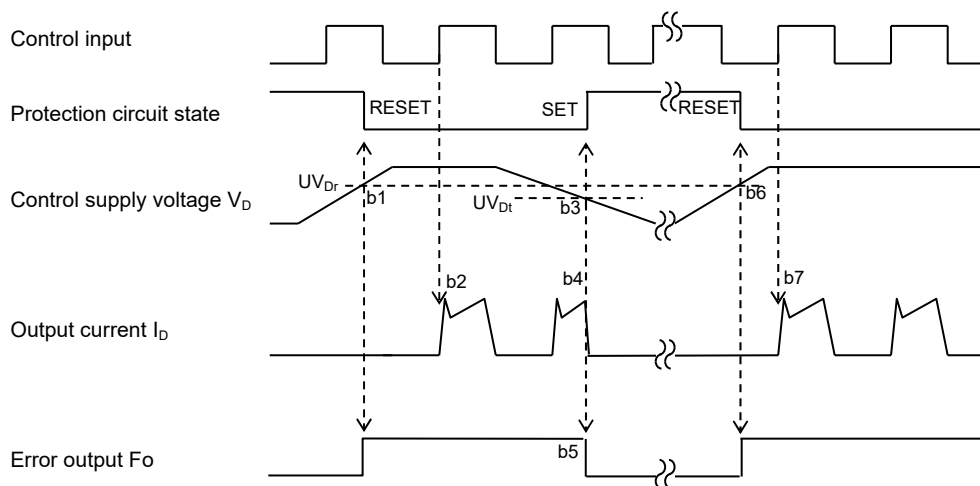
[A] Short-Circuit Protection (N-side only with the external shunt resistor and RC filter)

- 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<sub>D</sub>)

- 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.

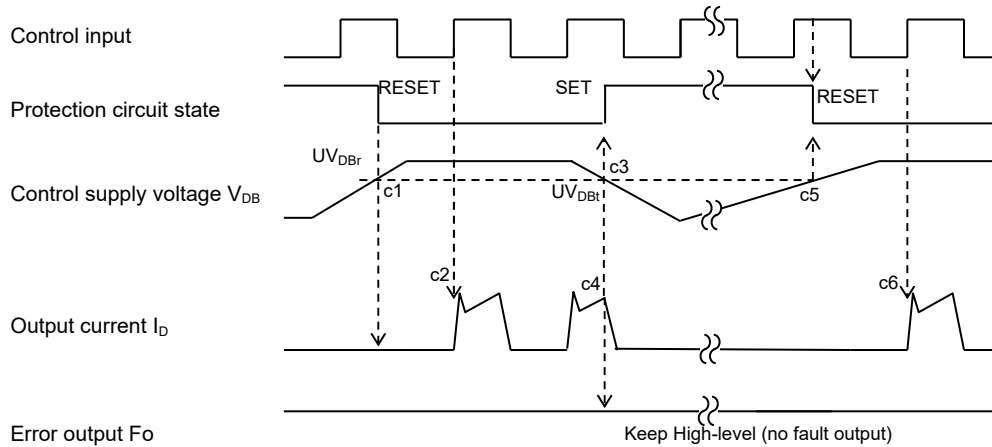


# PSM03S93E5-A

TRANSFER MOLDING TYPE  
INSULATED TYPE

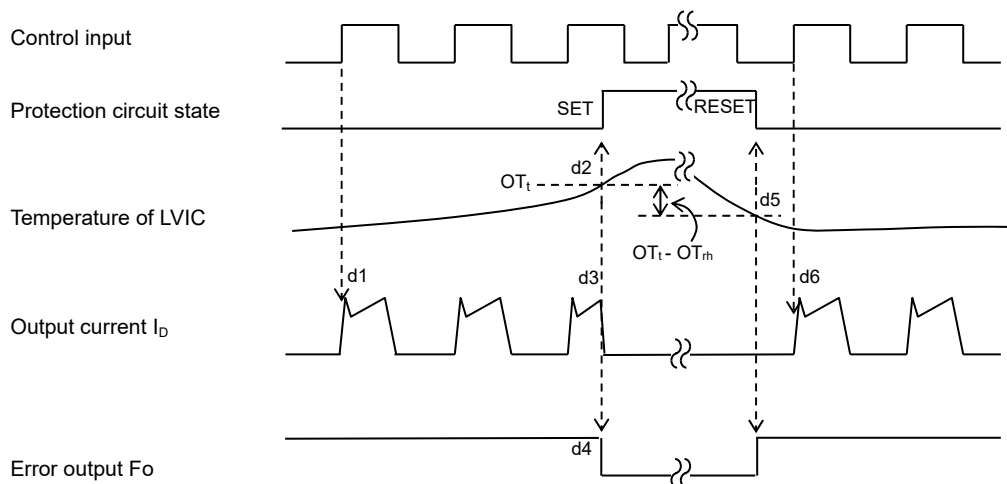
## [C] Under-Voltage Protection (P-side, $UV_{DB}$ )

- c1. Control supply voltage  $V_{DB}$  rises. After the voltage reaches under voltage reset level  $UV_{DBr}$ , 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)

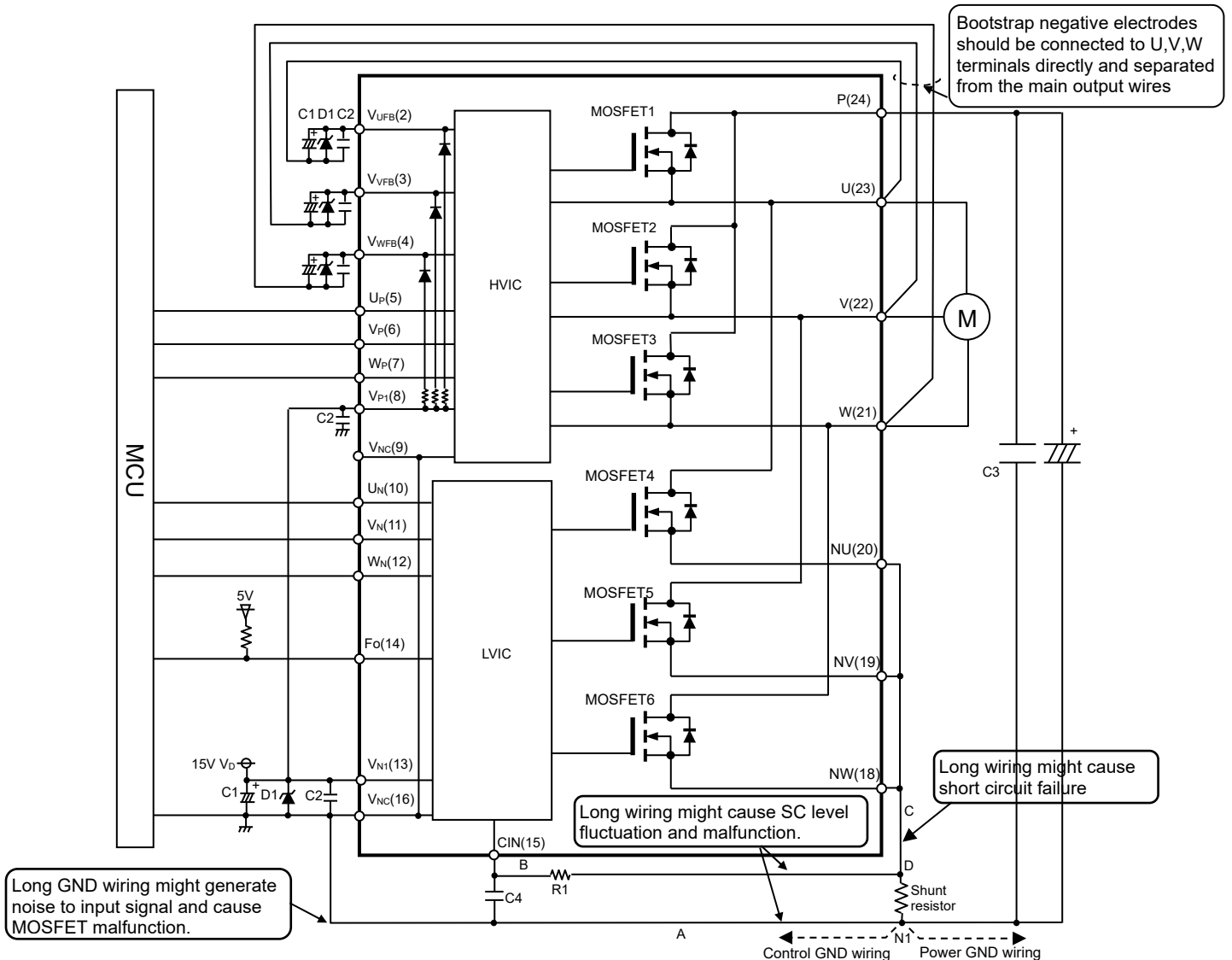
- d1. Normal operation: MOSFET ON and outputs current.
  - d2. LVIC temperature exceeds over temperature trip level ( $OT_t$ ).
  - d3. All N-side MOSFETs turn OFF in spite of control input condition.
  - d4.  $F_o$  outputs for  $t_{Fo}$ =minimum 20 $\mu$ s, but output is extended during LVIC temperature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



# PSM03S93E5-A

TRANSFER MOLDING TYPE  
INSULATED TYPE

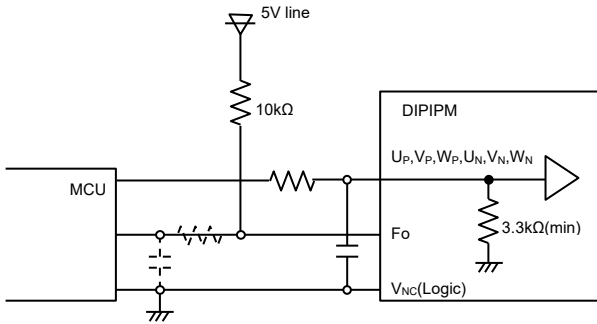
Fig. 4 Example of Application Circuit



- (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 0.1-0.22μF 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<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, 10kΩ (5kΩ 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 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 ≤ ±1V/μs, V<sub>ripple</sub> ≤ 2Vp-p.
- (13) For DIIPM, it isn't recommended to drive same load by parallel connection with other phase MOSFET or other DIIPM.

< DIIPIM >  
**PSM03S93E5-A**  
 TRANSFER MOLDING TYPE  
 INSULATED TYPE

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. 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 control power supply (e.g. 5V, 15V) with a resistor that makes Fo sink current  $I_{Fo}$  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

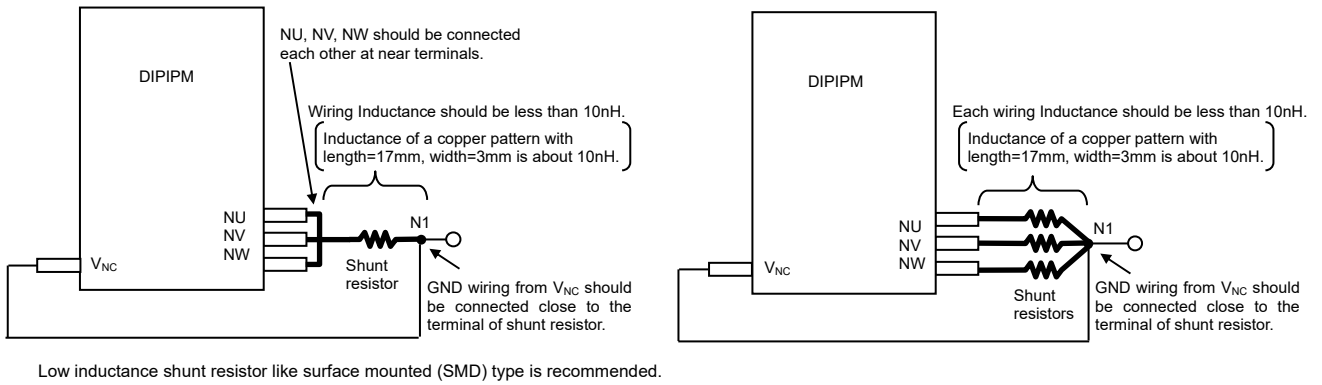
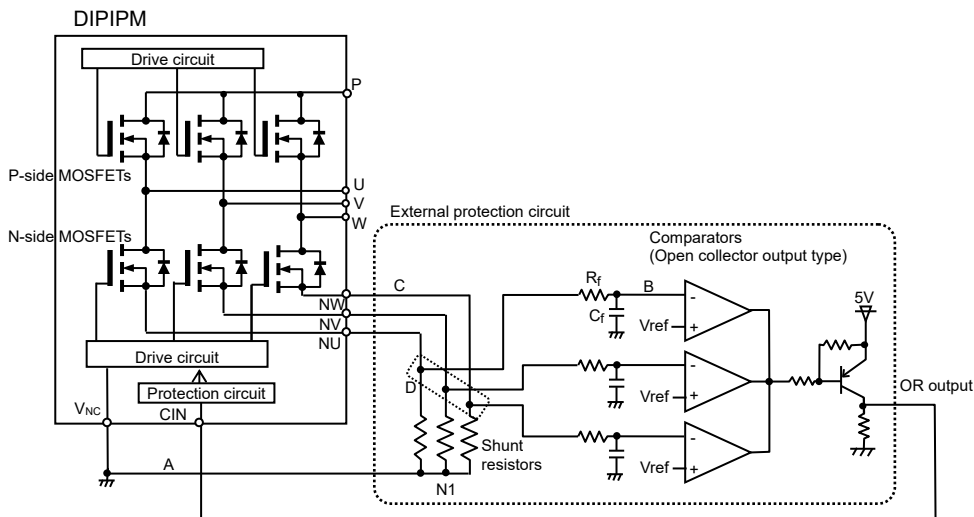


Fig. 7 Pattern Wiring Around the Shunt Resistor (for the case of open source)

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 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).

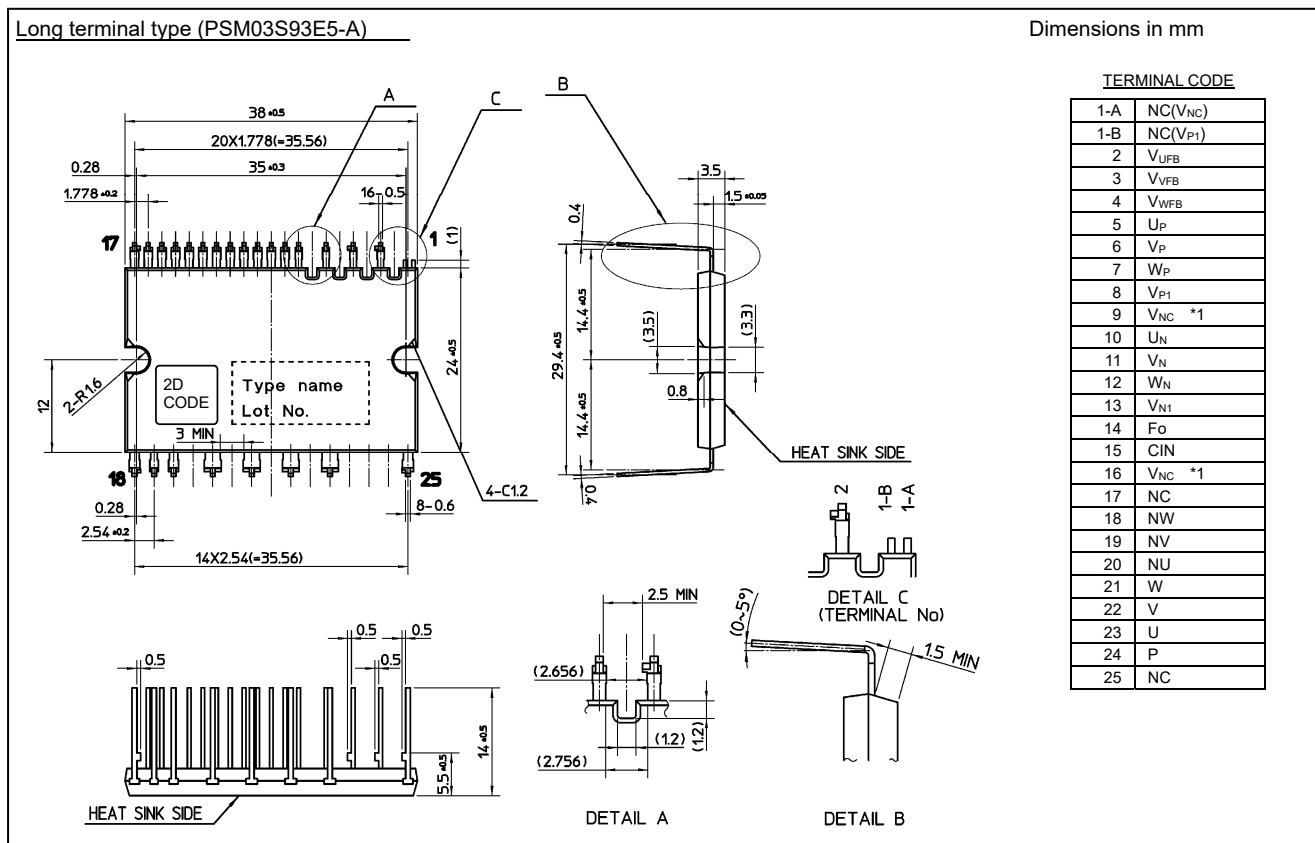


< DIIPM >

# PSM03S93E5-A

TRANSFER MOLDING TYPE  
INSULATED TYPE

Fig. 8 Package Outlines



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.

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