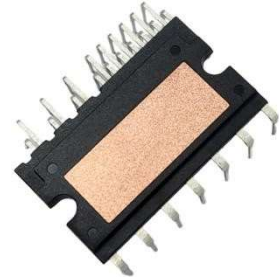


## Features

- 650V 10A 3-Phase IGBT Inverter
- Low-Losses & Short-Circuit-Rated IGBTs
- Soft Reverse Recovery Diodes
- Built-In BootStrap Diodes
- Very Low Thermal Resistance with DBC Substrate
- Separate Open-Emitters from Low-Side IGBTs
- Under-Voltage Lock-Out for high side and low side
- Short-Circuit Protection
- Over Temperature Protection
- LVIC Temperature Output
- 3.3V and 5V Input Logic Compatible : Active High
- Fault Signaling : LVIC UVLO and Short-circuit Protection
- Isolation Rating of 2000 Vrms/1 min
- UL 1557 Certified(File E540859)



## Typical Applications

- Air-conditioner, Washing machine etc.
- Motor Control - Industrial Motor (AC 200V Class)

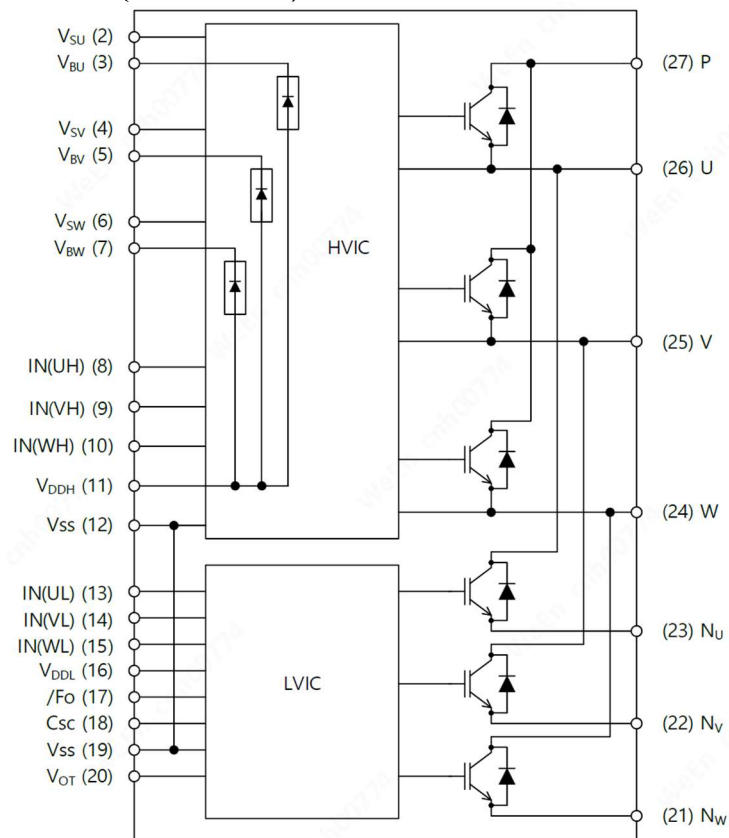


Figure 1. Internal Circuit

## PIN DESCRIPTION

| Pin Number | Pin Name         | Pin Description                                        |
|------------|------------------|--------------------------------------------------------|
| 2          | V <sub>SU</sub>  | High-Side Bias Voltage Ground for U Phase IGBT Driving |
| 3          | V <sub>BU</sub>  | High-Side Bias Voltage for U Phase IGBT Driving        |
| 4          | V <sub>SV</sub>  | High-Side Bias Voltage Ground for V Phase IGBT Driving |
| 5          | V <sub>BV</sub>  | High-Side Bias Voltage for V Phase IGBT Driving        |
| 6          | V <sub>SW</sub>  | High-Side Bias Voltage Ground for W Phase IGBT Driving |
| 7          | V <sub>BW</sub>  | High-Side Bias Voltage for W Phase IGBT Driving        |
| 8          | IN(UH)           | Signal Input for High-Side U Phase                     |
| 9          | IN(VH)           | Signal Input for High-Side V Phase                     |
| 10         | IN(WH)           | Signal Input for High-Side W Phase                     |
| 11         | V <sub>DDH</sub> | High-Side Bias Voltage for IC                          |
| 12         | V <sub>SS</sub>  | High-Side Common Supply Ground, connected to LVIC      |
| 13         | IN(UL)           | Signal Input for Low-Side U Phase                      |
| 14         | IN(VL)           | Signal Input for Low-Side V Phase                      |
| 15         | IN(WL)           | Signal Input for Low-Side W Phase                      |
| 16         | V <sub>DDL</sub> | Low-Side Bias Voltage for IC and IGBTs Driving         |
| 17         | /FO              | Fault Output                                           |
| 18         | Csc              | Input for Current Protection                           |
| 19         | V <sub>SS</sub>  | Low-Side Common Supply Ground                          |
| 20         | V <sub>OT</sub>  | Voltage Output for LVIC Temperature                    |
| 21         | N <sub>W</sub>   | Negative DC-Link Input for W Phase                     |
| 22         | N <sub>V</sub>   | Negative DC-Link Input for V Phase                     |
| 23         | N <sub>U</sub>   | Negative DC-Link Input for U Phase                     |
| 24         | W                | Output for W Phase                                     |
| 25         | V                | Output for V Phase                                     |
| 26         | U                | Output for U Phase                                     |
| 27         | P                | Positive DC-Link Input                                 |

**ABSOLUTE MAXIMUM RATINGS** ( $T_j = 25^\circ\text{C}$  unless otherwise noted)

| Symbol               | Rating                             | Conditions                                                                             | Rating  | Unit             |
|----------------------|------------------------------------|----------------------------------------------------------------------------------------|---------|------------------|
| <b>INVERTER PART</b> |                                    |                                                                                        |         |                  |
| $V_{PN}$             | Supply Voltage                     | Applied between P-N <sub>U</sub> , N <sub>V</sub> , N <sub>W</sub>                     | 450     | V                |
| $V_{PN(surge)}$      | Supply Voltage (Surge)             | Applied between P-N <sub>U</sub> , N <sub>V</sub> , N <sub>W</sub>                     | 550     | V                |
| $V_{CES}$            | Collector-Emitter Voltage          |                                                                                        | 650     | V                |
| $I_C$                | Each IGBT Collector Current        | $T_C=25^\circ\text{C}$ , $T_j \leq 150^\circ\text{C}$                                  | 10      | A                |
| $I_{CP}$             | Each IGBT Collector Current (Peak) | $T_C=25^\circ\text{C}$ , $T_j \leq 150^\circ\text{C}$ , Under 1ms Pulse Width (Note 1) | 20      | A                |
| $P_C$                | Collector Dissipation              | $T_C=25^\circ\text{C}$ per One Chip (Note 1)                                           | 60      | W                |
| $T_j$                | Operating Junction Temperature     |                                                                                        | -40~150 | $^\circ\text{C}$ |

**CONTROL PART**

|          |                                |                                                                           |                    |                  |
|----------|--------------------------------|---------------------------------------------------------------------------|--------------------|------------------|
| $V_{DD}$ | Control Supply Voltage         | Applied between $V_{DDH}$ , $V_{DDL}-V_{SS}$                              | 20                 | V                |
| $V_{BS}$ | High-Side Control Bias Voltage | Applied between $V_{BU}-V_{SU}$ , $V_{BV}-V_{SV}$ , $V_{BW}-V_{SW}$       | 20                 | V                |
| $V_{IN}$ | Input Signal Voltage           | Applied between IN(UH), IN(VH), IN(WH), IN(UL), IN(VL), IN(WL) - $V_{SS}$ | -0.5~ $V_{DD}+0.5$ | V                |
| $V_{FO}$ | Fault Output Supply Voltage    | Applied between $F_O-V_{SS}$                                              | -0.5~ $V_{DD}+0.5$ | V                |
| $I_{FO}$ | Fault Output Current           | Sink Current at $F_O$ pin                                                 | 5                  | mA               |
| $V_{SC}$ | Current Sensing Input Voltage  | Applied between $C_{SC}-V_{SS}$                                           | -0.5~ $V_{DD}+0.5$ | V                |
| $T_j$    | Operating Junction Temperature |                                                                           | -40~150            | $^\circ\text{C}$ |

**BOOSTSTRAP DIODE PART**

|           |                                    |  |         |                  |
|-----------|------------------------------------|--|---------|------------------|
| $V_{RRM}$ | Maximum Repetitive Reverse Voltage |  | 650     | V                |
| $T_j$     | Operating Junction Temperature     |  | -40~150 | $^\circ\text{C}$ |

**TOTAL SYSTEM**

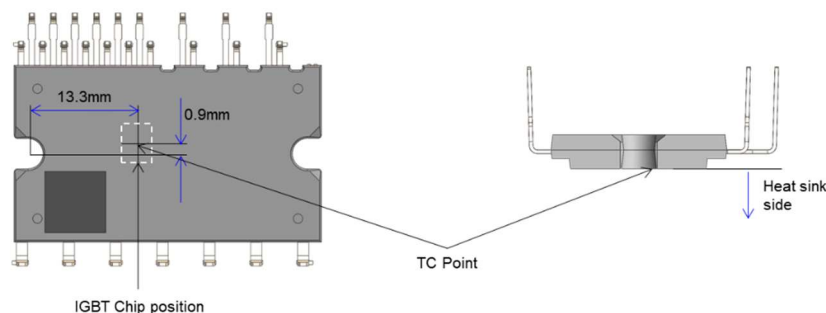
|                |                                                                            |                                                                                                      |         |                  |
|----------------|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|---------|------------------|
| $V_{PN(Prot)}$ | Self-Protection Supply Voltage Limit (Short-Circuit Protection Capability) | $V_{DD}=V_{BS}=13.5\sim 16.5\text{V}$ , $T_j=150^\circ\text{C}$ , Non-Repetitive, $< 2\ \mu\text{s}$ | 400     | V                |
| $T_C$          | Module Case Operation Temperature                                          | See Figure 2                                                                                         | -40~125 | $^\circ\text{C}$ |
| $T_{stg}$      | Storage Temperature                                                        |                                                                                                      | -40~125 | $^\circ\text{C}$ |
| $V_{iso}$      | Isolation Voltage                                                          | 60 Hz, Sinusoidal, AC 1 Minute, Connection Pins to Heat Sink Plate                                   | 2000    | Vrms             |

Note 1: These values had been made an acquisition by the calculation considered to design factor.

**THERMAL RESISTANCE**

| Symbol         | Parameter                                    | Conditions                          | Min | Typ | Max | Unit               |
|----------------|----------------------------------------------|-------------------------------------|-----|-----|-----|--------------------|
| $R_{th(j-c)Q}$ | Junction-to-Case Thermal Resistance (Note 2) | Inverter IGBT Part (per 1/6 module) | —   | —   | 2.1 | $^\circ\text{C/W}$ |
| $R_{th(j-c)F}$ |                                              | Inverter FWDi Part (per 1/6 module) | —   | —   | 3.6 | $^\circ\text{C/W}$ |

Note 2: For the measurement point of case temperature ( $T_c$ ), please refer to Figure 2.



**Figure 2.  $T_c$  Measurement Point**

**ELECTRICAL CHARACTERISTICS** ( $T_j = 25^\circ\text{C}$  unless otherwise specified.)

| Symbol               | Parameter           | Conditions                           | Min                                                                                                                                                     | Typ                                        | Max | Unit |     |    |
|----------------------|---------------------|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|-----|------|-----|----|
| INVERTER PART        |                     |                                      |                                                                                                                                                         |                                            |     |      |     |    |
| V <sub>CE(sat)</sub> |                     | Collector-Emitter Saturation Voltage | V <sub>DD</sub> =V <sub>BS</sub> =15V V <sub>IN</sub> =5V                                                                                               | I <sub>C</sub> =10A, T <sub>J</sub> =25°C  | —   | 1.6  | 1.9 | V  |
| V <sub>F</sub>       |                     | FWDi Forward Voltage                 | V <sub>IN</sub> =0V                                                                                                                                     | I <sub>C</sub> =−10A, T <sub>J</sub> =25°C | —   | 1.7  | 2.0 | V  |
| HS                   | t <sub>on</sub>     | Switching Times                      | V <sub>PN</sub> =300V, V <sub>DD</sub> =15 V, I <sub>C</sub> =10A T <sub>J</sub> =25°C<br>V <sub>IN</sub> =0V↔5V, Inductive Load, See Figure 3 (Note 3) |                                            | —   | 1.3  | —   | μs |
|                      | t <sub>c(on)</sub>  |                                      |                                                                                                                                                         |                                            | —   | 0.1  | —   | μs |
|                      | t <sub>off</sub>    |                                      |                                                                                                                                                         |                                            | —   | 1.3  | —   | μs |
|                      | t <sub>c(off)</sub> |                                      |                                                                                                                                                         |                                            | —   | 0.1  | —   | μs |
|                      | t <sub>rr</sub>     |                                      |                                                                                                                                                         |                                            | —   | 0.1  | —   | μs |
| LS                   | t <sub>on</sub>     |                                      | V <sub>PN</sub> =300V, V <sub>DD</sub> =15 V, I <sub>C</sub> =10A T <sub>J</sub> =25°C<br>V <sub>IN</sub> =0V↔5V, Inductive Load, See Figure 3 (Note 3) |                                            | —   | 1.3  | —   | μs |
|                      | t <sub>c(on)</sub>  |                                      |                                                                                                                                                         |                                            | —   | 0.1  | —   | μs |
|                      | t <sub>off</sub>    |                                      |                                                                                                                                                         |                                            | —   | 1.4  | —   | μs |
|                      | t <sub>c(off)</sub> |                                      |                                                                                                                                                         |                                            | —   | 0.1  | —   | μs |
|                      | t <sub>rr</sub>     |                                      |                                                                                                                                                         |                                            | —   | 0.1  | —   | μs |
| I <sub>CES</sub>     |                     | Collector-Emitter Leakage Current    | V <sub>CE</sub> = V <sub>CES</sub>                                                                                                                      |                                            | —   | —    | 1   | mA |

Note 3:  $t_{on}$  and  $t_{off}$  include the propagation delay of the internal drive IC.  $t_{c(on)}$  and  $t_{c(off)}$  are the switching times of IGBT under the given gate-driving condition internally. For the detailed information, please see Figure 3.

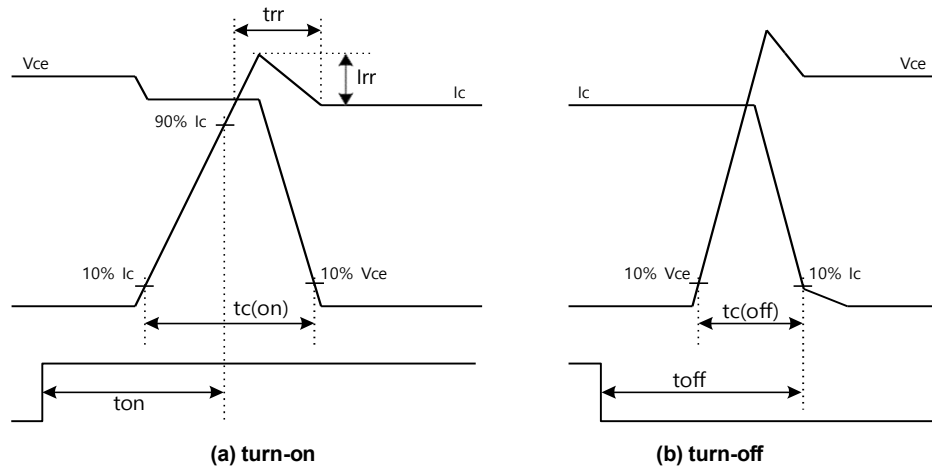


Figure 3. Switching Time Definition

| Symbol               | Parameter                                | Conditions                                                                                 | Min                                                                                                       | Typ   | Max  | Unit  |    |
|----------------------|------------------------------------------|--------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|-------|------|-------|----|
| CONTROL PART         |                                          |                                                                                            |                                                                                                           |       |      |       |    |
| I <sub>QDDH</sub>    | Quiescent V <sub>DD</sub> Supply Current | V <sub>DDH</sub> =15V,<br>V <sub>IN(UH,VH,WH)</sub> =0V                                    | V <sub>DDH</sub> -V <sub>SS</sub>                                                                         | —     | —    | 0.1   | mA |
| I <sub>QDDL</sub>    |                                          | V <sub>DDL</sub> =15V,<br>V <sub>IN(UL,VL,WL)</sub> =0V                                    | V <sub>DDL</sub> -V <sub>SS</sub>                                                                         | —     | —    | 2.0   | mA |
| I <sub>QBS</sub>     | Quiescent V <sub>BS</sub> Supply Current | V <sub>DDH</sub> =V <sub>DDL</sub> =V <sub>BS</sub> =15V,<br>V <sub>IN(UH,VH,WH)</sub> =0V | V <sub>BU</sub> -V <sub>SU</sub> , V <sub>BV</sub> -V <sub>SV</sub> ,<br>V <sub>BW</sub> -V <sub>SW</sub> | —     | —    | 0.1   | mA |
| V <sub>FOH</sub>     | Fault Output Voltage                     | V <sub>DDL</sub> =15V, V <sub>sc</sub> =0V,<br>V <sub>FO</sub> Circuit: 10kΩ to 5V Pull-up | 4.90                                                                                                      | —     | —    | V     |    |
| V <sub>FOL</sub>     |                                          | V <sub>DDL</sub> =15V, V <sub>sc</sub> =1V, I <sub>FO</sub> =1mA                           | —                                                                                                         | —     | 0.95 | V     |    |
| V <sub>SC(ref)</sub> | Short Circuit Trip Level (Note 4)        | V <sub>DDL</sub> =15V                                                                      | C <sub>SC</sub> -V <sub>SS</sub>                                                                          | 0.455 | 0.48 | 0.505 | V  |

ELECTRICAL CHARACTERISTICS (Tj = 25°C unless otherwise specified.) (continued)

| Symbol               | Parameter                                        | Conditions                                                                                              | Min  | Typ  | Max  | Unit |
|----------------------|--------------------------------------------------|---------------------------------------------------------------------------------------------------------|------|------|------|------|
| <b>CONTROL PART</b>  |                                                  |                                                                                                         |      |      |      |      |
| U <sub>VDD</sub>     | Supply Circuit Under-Voltage Protection          | Detection Level                                                                                         | 10.3 | —    | 12.5 | V    |
| U <sub>VDDR</sub>    |                                                  | Reset Level                                                                                             | 10.8 | —    | 13.0 | V    |
| U <sub>VBSD</sub>    |                                                  | Detection Level                                                                                         | 10.0 | —    | 12.0 | V    |
| U <sub>VBSR</sub>    |                                                  | Reset Level                                                                                             | 10.5 | —    | 12.5 | V    |
| I <sub>IN</sub>      | Input Current (Note 6)                           | V <sub>IN</sub> = 5V                                                                                    | 0.7  | 1.0  | 1.5  | mA   |
| V <sub>IN(ON)</sub>  | ON Threshold Voltage                             | Applied between V <sub>IN(UH,VH,WH)</sub> -V <sub>SS</sub> , V <sub>IN(UL,VL,WL)</sub> -V <sub>SS</sub> | —    | —    | 2.6  | V    |
| V <sub>IN(OFF)</sub> | OFF Threshold Voltage                            |                                                                                                         | 0.8  | —    | —    | V    |
| OT <sub>trip</sub>   | Over temperature protection                      | V <sub>DDL</sub> =15V<br>Detect LVIC temperature                                                        | 130  | 140  | 150  | °C   |
| OT <sub>hys</sub>    |                                                  | Hysteresis of trip-reset                                                                                | —    | 10   | —    | °C   |
| V <sub>OT</sub>      | Voltage Output for LVIC Temperature Sensing Unit | V <sub>DDL</sub> =15V, T <sub>LVIC</sub> =25°C<br>See Figure 4 and 5 (Note 5)                           | 0.88 | 1.13 | 1.39 | V    |
| t <sub>FOD</sub>     | Fault-Out Pulse Width                            |                                                                                                         | 20   | —    | —    | us   |

Note 4: Short-circuit current protection functions only at the low-sides because the sense current is divided from main current at low-side IGBTs. Inserting the shunt resistor for monitoring the phase current at NU, NV, NW terminal, the trip level of the short-circuit current is changed.

Note 5: T<sub>LVIC</sub> is LVIC temperature and V<sub>OT</sub> is only for sensing the temperature of LVIC and cannot shut down IGBTs automatically. The relationship between V<sub>OT</sub> voltage output and LVIC temperature is described in Figure 5. It is recommended to add a ceramic capacitor of 10 nF or more between V<sub>OT</sub> and V<sub>SS</sub> to make the V<sub>OT</sub> more stable. Refer to the application note for this product about usage of V<sub>OT</sub>.

Note 6: RC coupling at each input might change depending on the PWM control scheme used in the application and the wiring impedance of the application's printed circuit board. The input signal section integrates 5 kΩ (typ.) pull-down resistor. Therefore, when using an external filtering resistor, please pay attention to the signal voltage drop at the input terminal.

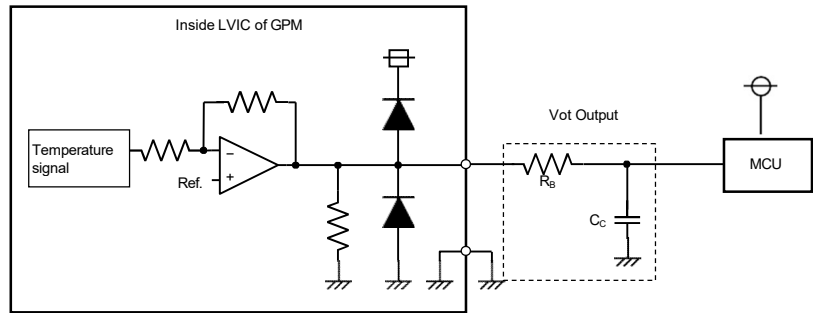


Figure 4. Internal Block Diagram and Interface Circuit of V<sub>OT</sub>

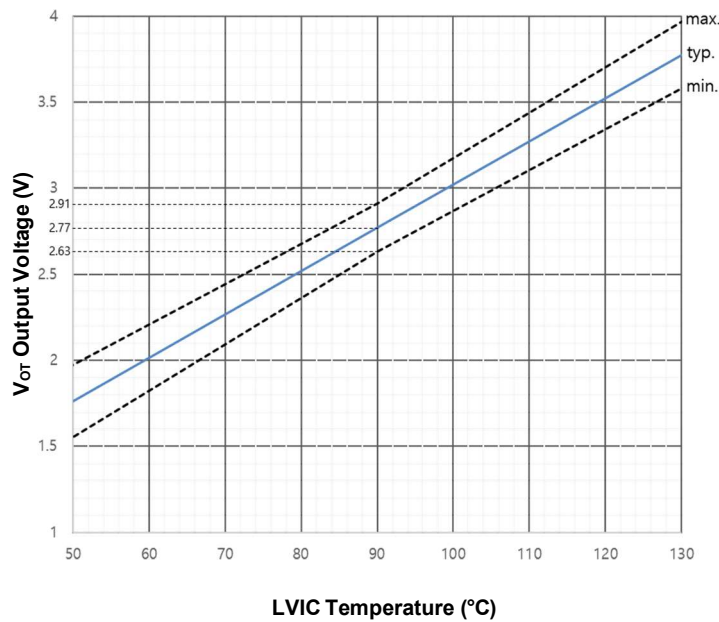


Figure 5. Temperature Profile of V<sub>OT</sub>

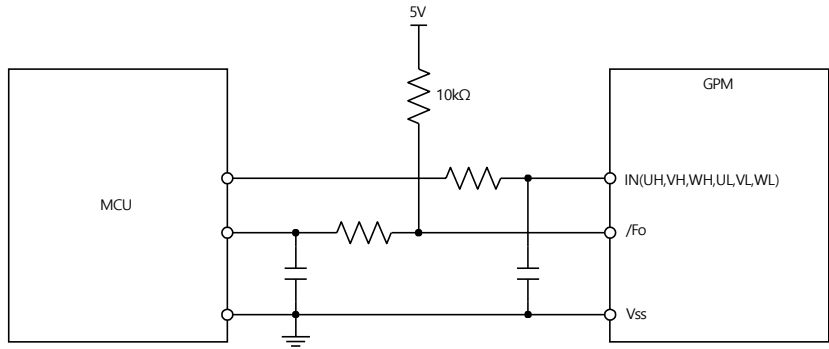


Figure 6. Recommended MCU I/O Interface Circuit

**ELECTRICAL CHARACTERISTICS** ( $T_j = 25^\circ\text{C}$  unless otherwise specified.) (continued)  
**BOOTSTRAP DIODE/RESISTOR PART**

| Symbol | Parameter       | Conditions                                  |              | Min | Typ | Max | Unit |
|--------|-----------------|---------------------------------------------|--------------|-----|-----|-----|------|
| $V_F$  | Forward Voltage | $I_F=0.01\text{A}$ , $T_j=25^\circ\text{C}$ | See Figure 7 | –   | 2.5 | –   | V    |

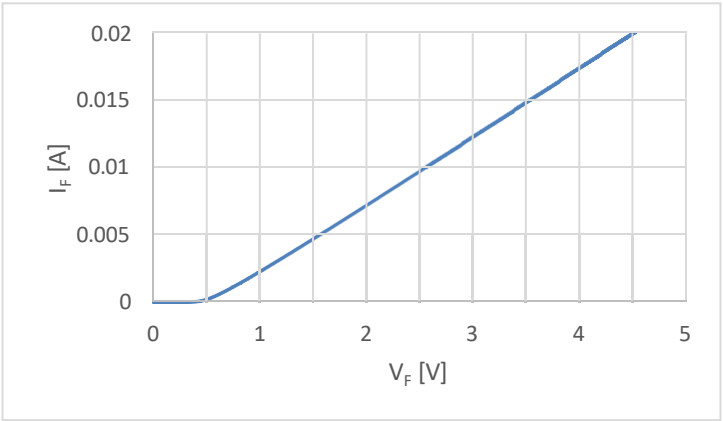


Figure 7. Characteristics of Bootstrap Diode

**RECOMMENDED OPERATING RANGES**

| Symbol                                      | Parameter                                | Conditions                                                                                                             | Min  | Typ  | Max  | Unit             |
|---------------------------------------------|------------------------------------------|------------------------------------------------------------------------------------------------------------------------|------|------|------|------------------|
| $V_{PN}$                                    | Supply Voltage                           | Applied between P–N <sub>U</sub> , N <sub>V</sub> , N <sub>W</sub>                                                     | –    | 300  | 400  | V                |
| $V_{DD}$                                    | Control Supply Voltage                   | Applied between V <sub>DDH</sub> –V <sub>SS</sub> , V <sub>DDL</sub> –V <sub>SS</sub>                                  | 13.5 | 15.0 | 16.5 | V                |
| $V_{BS}$                                    | High-Side Control Bias Voltage           | Applied between V <sub>BU</sub> –V <sub>SU</sub> , V <sub>BV</sub> –V <sub>SV</sub> , V <sub>BW</sub> –V <sub>SW</sub> | 13.0 | 15.0 | 18.5 | V                |
| $\frac{dV_{DD}}{dt}$ , $\frac{dV_{BS}}{dt}$ | Control Supply Variation                 |                                                                                                                        | –1   | –    | +1   | V/ $\mu\text{s}$ |
| $t_{\text{dead}}$                           | Blanking Time for Preventing Arm – Short | For Each Input Signal                                                                                                  | 1.0  | –    | –    | $\mu\text{s}$    |
| $f_{\text{PWM}}$                            | PWM Input Signal                         | $-40^\circ\text{C} \leq T_c \leq 125^\circ\text{C}$ , $-40^\circ\text{C} \leq T_j \leq 150^\circ\text{C}$              | –    | –    | 20   | kHz              |
| PWIN(ON)                                    | Minimum Input Pulse Width                | (Note 7)                                                                                                               | 0.7  | –    | –    | $\mu\text{s}$    |
| PWIN(OFF)                                   |                                          |                                                                                                                        | 0.7  | –    | –    |                  |
| $T_j$                                       | Junction Temperature                     |                                                                                                                        | –40  | –    | +150 | $^\circ\text{C}$ |

Note 7: This product might not make output response if input pulse width is less than the recommended value.

PACKAGE MARKING AND ORDERING INFORMATION

| Device       | Device Marking | Package | Shipping   |
|--------------|----------------|---------|------------|
| WSMG10T07MK1 | WSMG10T07MK1   | DIP26   | 704 ea/box |

MECHANICAL CHARACTERISTICS AND RATINGS

| Parameter                 | Conditions                                                                | Min  | Typ  | Max  | Unit  |
|---------------------------|---------------------------------------------------------------------------|------|------|------|-------|
| Device Flatness           | See Figure 8                                                              | -50  | -    | 100  | μm    |
| Mounting Torque           | Mounting Screw: M3                                                        | 0.59 | 0.69 | 0.78 | N·m   |
| Terminal Pulling Strength | Control terminal : Load 5N<br>Power terminal : Load 10N                   | 10   | -    | -    | s     |
| Terminal Bending Strength | Control terminal : Load 5N<br>Power terminal : Load 10N<br>90 degree Bend | 2    | -    | -    | times |
| Weight                    |                                                                           | -    | 5.5  | -    | g     |

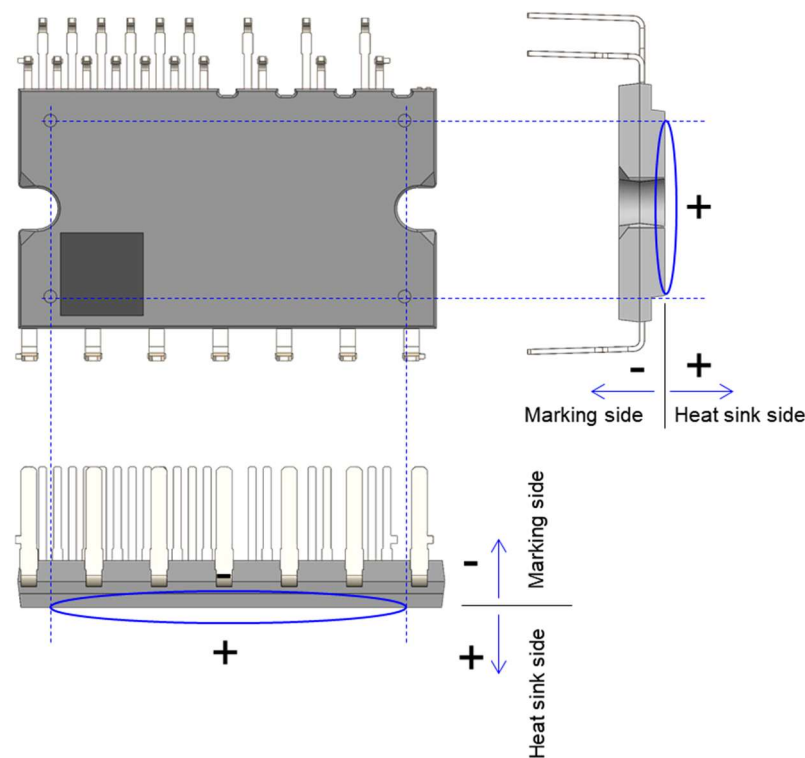
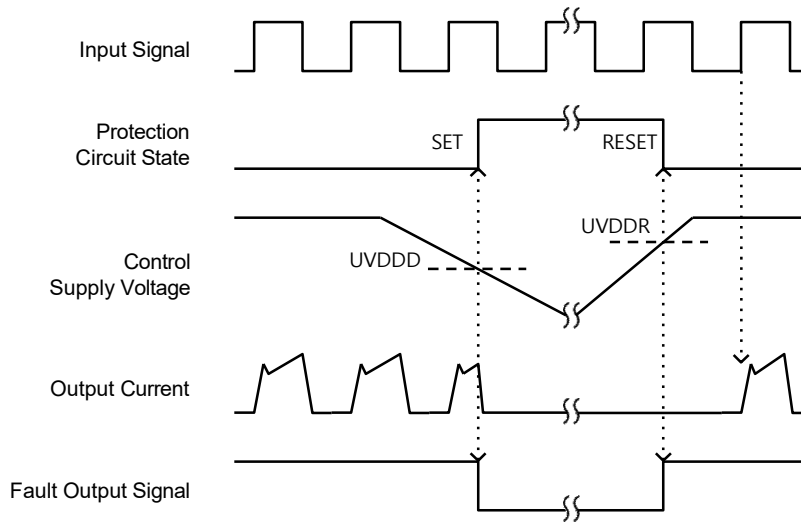


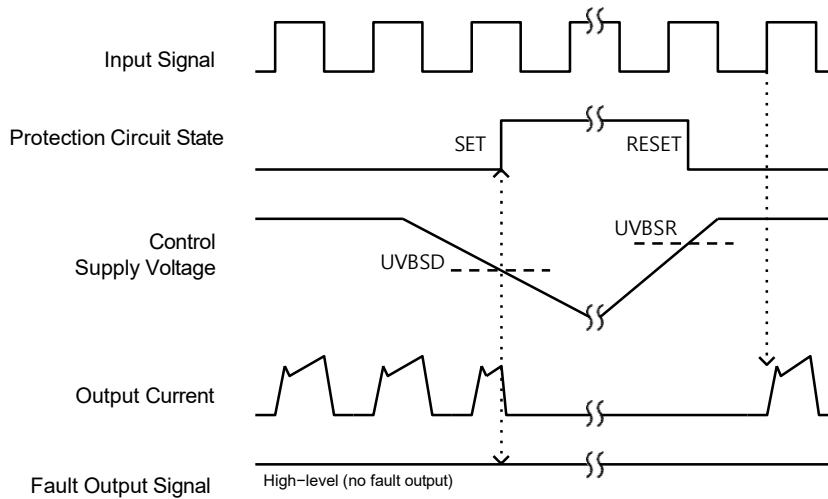
Figure 8. Flatness Measurement Position

## TIME CHARTS OF GPMs PROTECTIVE FUNCTION



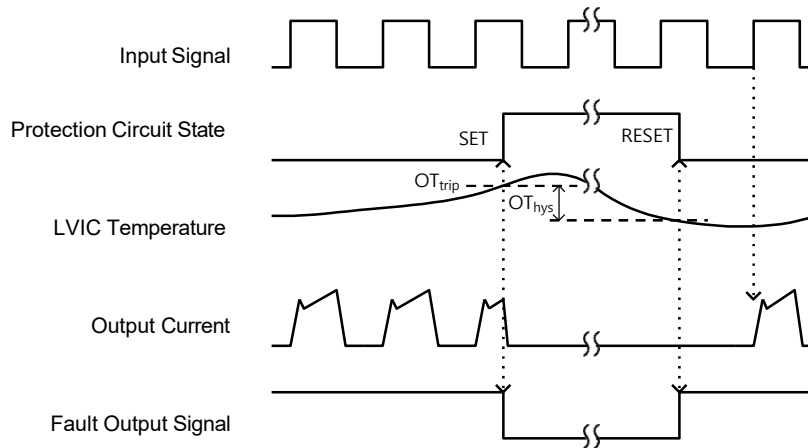
- 1: Normal operation: IGBT ON and carrying current.
- 2: Under-voltage detection (UVDDD).
- 3: IGBT OFF in spite of control input condition.
- 4: Fault output operation starts with a fixed pulse width (min. 20us).
- 5: Under-voltage reset (UVDDR).
- 6: Normal operation: IGBT ON and carrying current by triggering next signal from LOW to HIGH.

Figure 9. Under-voltage Protection (Low-side)



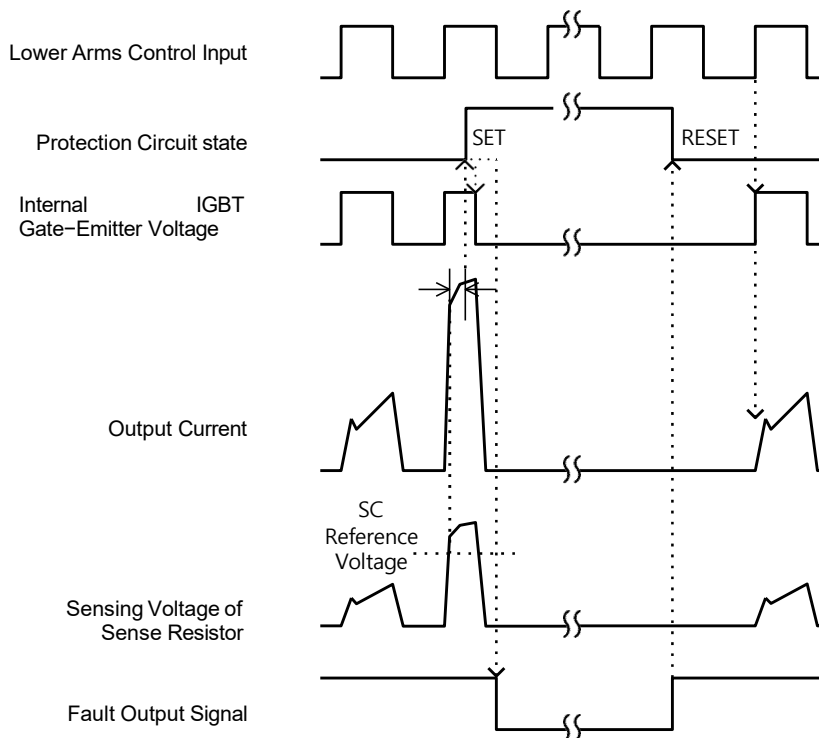
- 1: Normal operation: IGBT ON and carrying current.
- 2: Under-voltage detection (UVBSD).
- 3: IGBT OFF in spite of control input condition, but there is no fault output signal.
- 4: Under-voltage reset (UVBSR).
- 5: Normal operation: IGBT ON and carrying current by triggering next signal from LOW to HIGH.

Figure 10. Under-voltage Protection (High-side)



- 1: Normal operation: IGBT ON and carrying current.
- 2: LVIC temperature exceeds OT trip level ( $OT_{trip}$ ).
- 3: All low-side IGBTs OFF in spite of control input condition.
- 4: Fault output operation starts with a fixed pulse width (min. 20us).
- 5: LVIC temperature drop to OT reset level.
- 6: Normal operation: IGBT ON and carrying current by triggering next signal from LOW to HIGH.

**Figure 11. Over-temperature Protection**



- 1: Normal operation: IGBT ON and carrying current.
- 2: Short-circuit current detection (SC trigger).
- 3: All low-side IGBTs gates are hard interrupted.
- 4: All low-side IGBTs turn OFF.
- 5: Fault output operation starts with a fixed pulse width (min. 20us).
- 6: Input HIGH – IGBT ON state, but during the active period of fault output, the IGBT doesn't turn ON.
- 7: Fault output operation finishes, but IGBT doesn't turn on until triggering the next signal from LOW to HIGH.
- 8: Normal operation: IGBT ON and carrying current.

**Figure 12. Short-circuit Current Protection (Low-side Operation Only)**

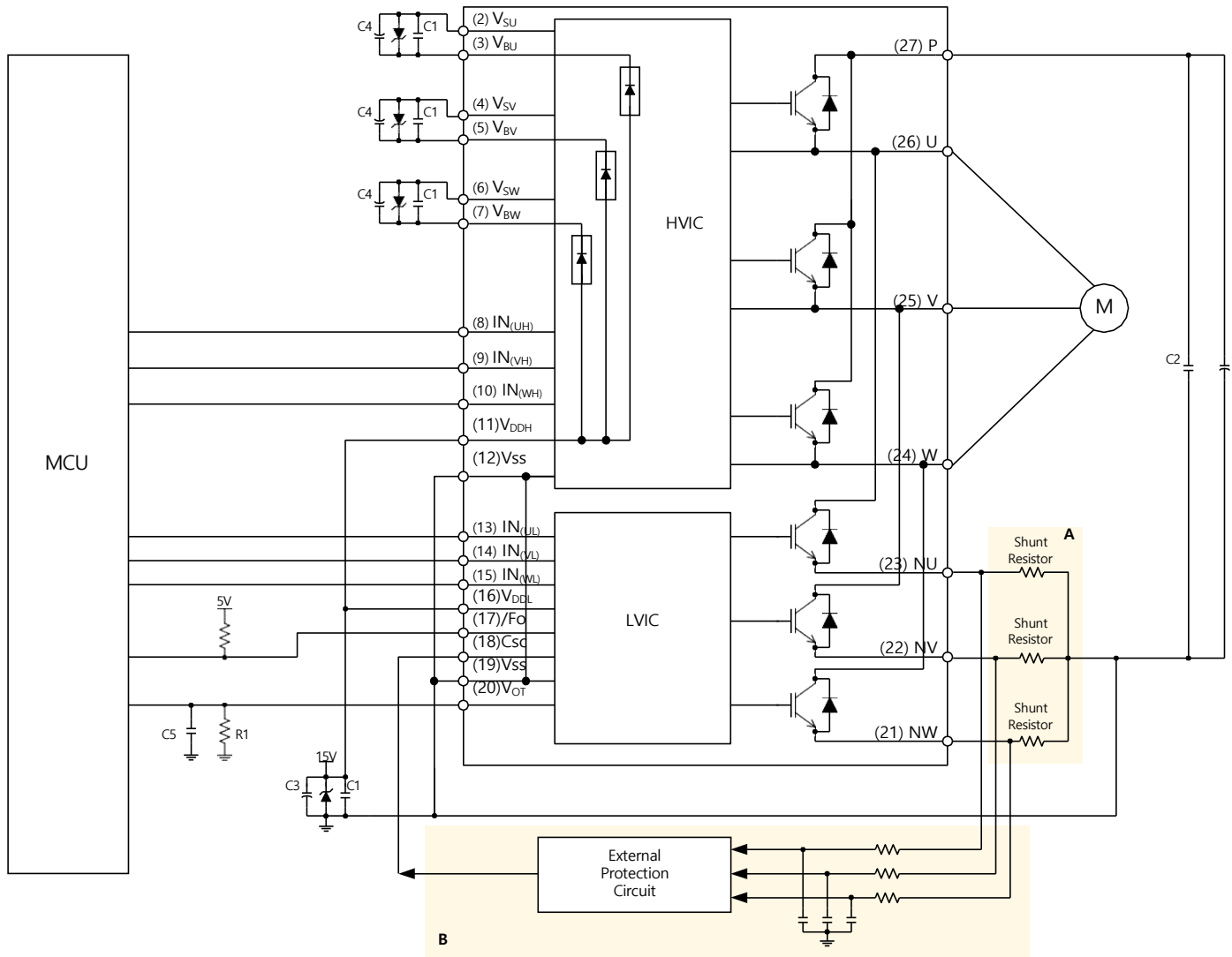
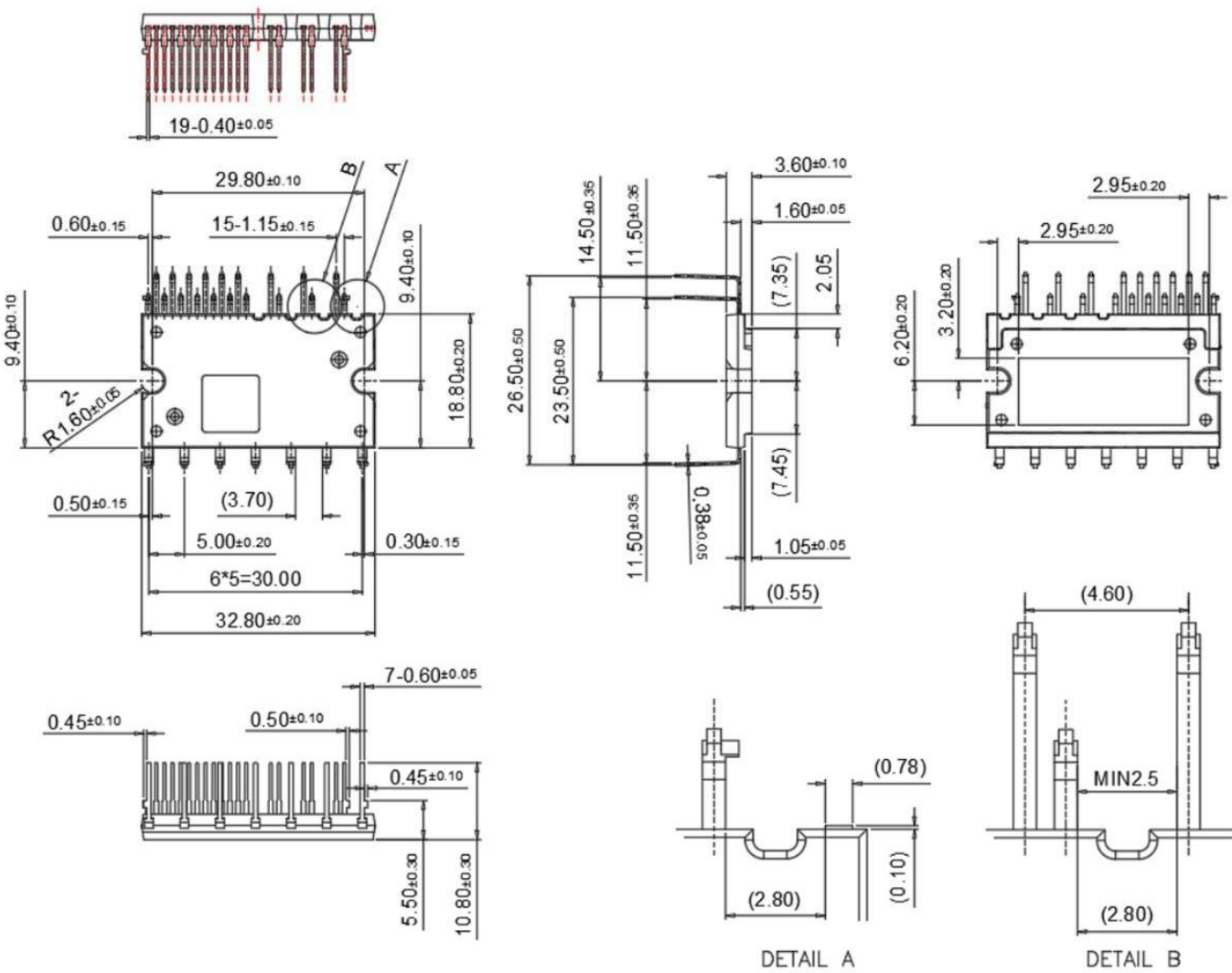


Figure 13. Typical Application Circuit

1. To avoid malfunction, the wiring of each input should be as short as possible (less than 2–3 cm).
2. Fault output is an open-drain type. This signal line should be pulled up to the positive side of the MCU or control power supply with a resistor that makes  $I_{FO}$  up to 1 mA. Please refer to Figure 6.
3. Input signal is active-HIGH type. There is a 5 k $\Omega$  resistor inside the IC to pull-down each input signal line to GND. RC coupling circuits should be adopted for the prevention of input signal oscillation. RC time constant should be selected in the range 50~150 ns (recommended R = 100 $\Omega$ , C = 1 nF). Please refer to Figure 6.
4. Each wiring pattern inductance of point A should be minimized (recommend less than 10 nH). Use the shunt resistor Rsh of surface mounted (SMD) type to reduce wiring inductance.
5. To insert the shunt resistor to measure each phase current at  $N_U$ ,  $N_V$ ,  $N_W$  terminal, it makes to change the trip level  $I_{SC}$  about the short-circuit current.
6. To prevent errors in the protection function, the wiring of point B should be as short as possible.
7. For stable protection function, use the sense resistor Rsh with resistance variation within 1% and low inductance value.
8. In the short-circuit protection circuit, select the RC time constant of protection circuit in the range 2.0~2.5  $\mu$ s.
9. Each capacitor C1 should be mounted as close to the pins of the GPM product as possible.
10. To prevent surge destruction, the wiring between the smoothing capacitor C2 and the P & GND pins should be as short as possible. The use of a high-frequency non-inductive capacitor of around 0.1~0.22  $\mu$ F between the P & GND pins is recommended.
11. Relays are used in most systems of electrical equipment in industrial application. In these cases, there should be sufficient distance between the MCU and the relays.
12. The Zener diode or transient voltage suppressor should be adopted for the protection of ICs from the surge destruction between each pair of control supply terminals (recommended Zener diode is 22V/1W, which has the lower Zener impedance characteristic than about 15  $\Omega$ ).
13. C3 of around seven times larger than bootstrap capacitor C4 is recommended.
14. Please choose the electrolytic capacitor with good temperature characteristics in C4. Choose 0.1~0.2 $\mu$ F R-category ceramic capacitors with good temperature and frequency characteristics in C1.
15. For stable analog voltage output for LVIC temperature, please use ceramic capacitor for C5.

PACKAGE DIMENSIONS



# 13. Legal information

## Data sheet status

| Document status [1][2]         | Product status [3] | Definition                                                                            |
|--------------------------------|--------------------|---------------------------------------------------------------------------------------|
| Objective [short] data sheet   | Development        | This document contains data from the objective specification for product development. |
| Preliminary [short] data sheet | Qualification      | This document contains data from the preliminary specification.                       |
| Product [short] data sheet     | Production         | This document contains the product specification.                                     |

- [1] Please consult the most recently issued document before initiating or completing a design.
- [2] The term 'short data sheet' is explained in section "Definitions".
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