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# FSBS15CH60F

## Motion SPM® 3 Series

### Features

- UL Certified No. E209204 (UL1557)
- 600 V - 15 A 3-Phase IGBT Inverter with Integral Gate Drivers and Protection
- Built-In Thermal Shutdown Function
- Low-Loss, Short-Circuit Rated IGBTs
- Low Thermal Resistance Using Ceramic Substrate
- Dedicated Vs Pins Simplify PCB Layout
- Separate Open-Emitter Pins from Low-Side IGBTs for Three-Phase Current Sensing
- Single-Grounded Power Supply
- Isolation Rating: 2500 V<sub>rms</sub> / min.

### Applications

- Motion Control - Home Appliance / Industrial Motor

### Related Resources

- [AN-9035 - Motion SPM 3 Series Ver.2 User's Guide](#)

### General Description

FSBS15CH60F is a Motion SPM® 3 module providing a fully-featured, high-performance inverter output stage for AC Induction, BLDC, and PMSM motors. These modules integrate optimized gate drive of the built-in IGBTs to minimize EMI and losses, while also providing multiple on-module protection features including under-voltage lockouts, over-current shutdown, and fault reporting. The built-in, high-speed HVIC requires only a single supply voltage and translates the incoming logic-level gate inputs to the high-voltage, high-current drive signals required to properly drive the module's internal IGBTs. Separate negative IGBT terminals are available for each phase to support the widest variety of control algorithms.

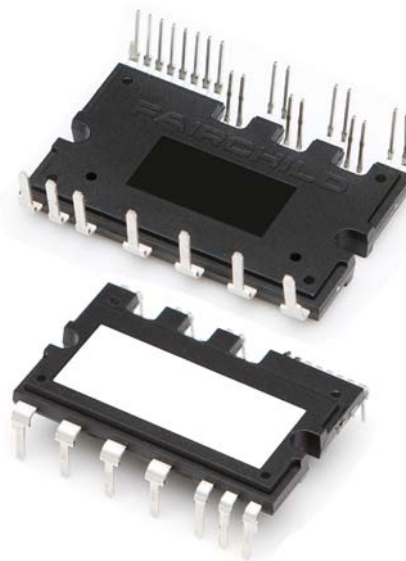


Figure 1. Package Overview

### Package Marking and Ordering Information

| Device      | Device Marking | Package   | Packing Type | Quantity |
|-------------|----------------|-----------|--------------|----------|
| FSBS15CH60F | FSBS15CH60F    | SPMBA-027 | Rail         | 10       |

### Integrated Power Functions

- 600 V - 15 A IGBT inverter for three-phase DC / AC power conversion (please refer to Figure 3)

### Integrated Drive, Protection and System Control Functions

- For inverter high-side IGBTs: gate drive circuit, high-voltage isolated high-speed level shifting control circuit Under-Voltage Lock-Out Protection (UVLO)  
 Note: Available bootstrap circuit example is given in Figures 10 and 11.
- For inverter low-side IGBTs: gate drive circuit, Short-Circuit Protection (SCP) control supply circuit Under-Voltage Lock-Out Protection (UVLO)
- Fault signaling: corresponding to UVLO (low-side supply) and SC faults
- Input interface: active-HIGH interface, works with 3.3 / 5 V logic, Schmitt-trigger input

### Pin Configuration

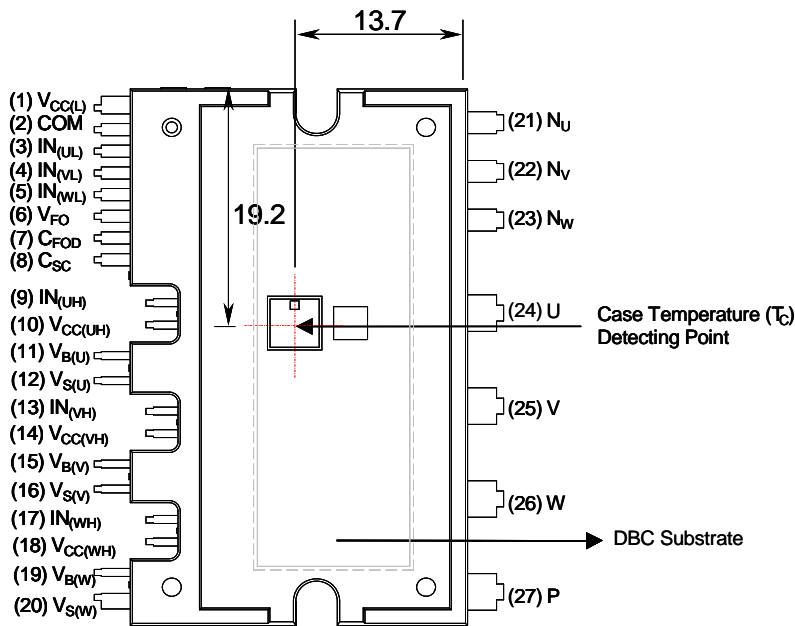


Figure 2. Top View

## Pin Descriptions

| Pin Number | Pin Name     | Pin Description   |
|------------|--------------|---|
| 1          | $V_{CC(L)}$  | Low-Side Common Bias Voltage for IC and IGBTs Driving                 |
| 2          | COM          | Common Supply Ground  |
| 3          | $IN_{(UL)}$  | Signal Input for Low-Side U-Phase                                     |
| 4          | $IN_{(VL)}$  | Signal Input for Low-Side V-Phase                                     |
| 5          | $IN_{(WL)}$  | Signal Input for Low-Side W-Phase                                     |
| 6          | $V_{FO}$     | Fault Output  |
| 7          | $C_{FOD}$    | Capacitor for Fault Output Duration Selection                         |
| 8          | $C_{SC}$     | Capacitor (Low-pass Filter) for Short-Circuit Current Detection Input |
| 9          | $IN_{(UH)}$  | Signal Input for High-Side U-Phase                                    |
| 10         | $V_{CC(UH)}$ | High-Side Bias Voltage for U-Phase IC                                 |
| 11         | $V_{B(U)}$   | High-Side Bias Voltage for U-Phase IGBT Driving                       |
| 12         | $V_{S(U)}$   | High-Side Bias Voltage Ground for U-Phase IGBT Driving                |
| 13         | $IN_{(VH)}$  | Signal Input for High-Side V-Phase                                    |
| 14         | $V_{CC(VH)}$ | High-Side Bias Voltage for V-Phase IC                                 |
| 15         | $V_{B(V)}$   | High-Side Bias Voltage for V-Phase IGBT Driving                       |
| 16         | $V_{S(V)}$   | High-Side Bias Voltage Ground for V-Phase IGBT Driving                |
| 17         | $IN_{(WH)}$  | Signal Input for High-Side W Phase                                    |
| 18         | $V_{CC(WH)}$ | High-Side Bias Voltage for W-Phase IC                                 |
| 19         | $V_{B(W)}$   | High-Side Bias Voltage for W-Phase IGBT Driving                       |
| 20         | $V_{S(W)}$   | High-Side Bias Voltage Ground for W-Phase IGBT Driving                |
| 21         | $N_U$        | Negative DC-Link Input for U-Phase                                    |
| 22         | $N_V$        | Negative DC-Link Input for V-Phase                                    |
| 23         | $N_W$        | Negative DC-Link Input for W-Phase                                    |
| 24         | U            | Output for U-Phase  |
| 25         | V            | Output for V-Phase  |
| 26         | W            | Output for W-Phase  |
| 27         | P            | Positive DC-Link Input  |

### Internal Equivalent Circuit and Input/Output Pins



**Figure 3. Internal Block Diagram**

**1st Notes:**

1. Inverter low-side is composed of three IGBTs, freewheeling diodes for each IGBT, and one control IC. It has gate drive and protection functions.
2. Inverter power side is composed of four inverter DC-link input terminals and three inverter output terminals.
3. Inverter high-side is composed of three IGBTs, freewheeling diodes, and three drive ICs for each IGBT.

## Absolute Maximum Ratings ( $T_J = 25^\circ\text{C}$ , unless otherwise specified.)

### Inverter Part

| Symbol                 | Parameter                          | Conditions                                       | Rating    | Unit             |
|------------------------|------------------------------------|--|-----------|------------------|
| $V_{PN}$               | Supply Voltage                     | Applied between P- $N_U$ , $N_V$ , $N_W$         | 450       | V                |
| $V_{PN(\text{Surge})}$ | Supply Voltage (Surge)             | Applied between P- $N_U$ , $N_V$ , $N_W$         | 500       | V                |
| $V_{CES}$              | Collector - Emitter Voltage        |  | 600       | V                |
| $\pm I_C$              | Each IGBT Collector Current        | $T_C = 25^\circ\text{C}$                         | 15        | A                |
| $\pm I_{CP}$           | Each IGBT Collector Current (Peak) | $T_C = 25^\circ\text{C}$ , Under 1ms Pulse Width | 30        | A                |
| $P_C$                  | Collector Dissipation              | $T_C = 25^\circ\text{C}$ per Chip                | 32        | W                |
| $T_J$                  | Operating Junction Temperature     | (2nd Note 1)                                     | -20 ~ 125 | $^\circ\text{C}$ |

#### 2nd Notes:

- The maximum junction temperature rating of the power chips integrated within the Motion SPM® 3 product is  $150^\circ\text{C}$  (at  $T_C \leq 100^\circ\text{C}$ ). However, to insure safe operation of the Motion SPM 3 product, the average junction temperature should be limited to  $T_{J(\text{ave})} \leq 125^\circ\text{C}$  (at  $T_C \leq 100^\circ\text{C}$ )

### Control Part

| Symbol   | Parameter                      | Conditions  | Rating              | Unit |
|----------|--------------------------------|---|---------------------|------|
| $V_{CC}$ | Control Supply Voltage         | Applied between $V_{CC(UH)}$ , $V_{CC(VH)}$ , $V_{CC(WH)}$ , $V_{CC(L)}$ - COM                          | 20                  | V    |
| $V_{BS}$ | High-Side Control Bias Voltage | Applied between $V_{B(U)} - V_{S(U)}$ , $V_{B(V)} - V_{S(V)}$ , $V_{B(W)} - V_{S(W)}$                   | 20                  | V    |
| $V_{IN}$ | Input Signal Voltage           | Applied between $IN_{(UH)}$ , $IN_{(VH)}$ , $IN_{(WH)}$ , $IN_{(UL)}$ , $IN_{(VL)}$ , $IN_{(WL)}$ - COM | -0.3 ~ 17           | V    |
| $V_{FO}$ | Fault Output Supply Voltage    | Applied between $V_{FO}$ - COM  | -0.3 ~ $V_{CC}+0.3$ | V    |
| $I_{FO}$ | Fault Output Current           | Sink Current at $V_{FO}$ Pin  | 5                   | mA   |
| $V_{SC}$ | Current-Sensing Input Voltage  | Applied between $C_{SC}$ - COM  | -0.3 ~ $V_{CC}+0.3$ | V    |

### Total System

| Symbol                | Parameter  | Conditions  | Rating    | Unit             |
|-----------------------|--|---|-----------|------------------|
| $V_{PN(\text{PROT})}$ | Self-Protection Supply Voltage Limit (Short-Circuit Protection Capability) | $V_{CC} = V_{BS} = 13.5 \sim 16.5 \text{ V}$<br>$T_J = 125^\circ\text{C}$ , Non-Repetitive, $< 2 \mu\text{s}$ | 400       | V                |
| $T_C$                 | Module Case Operation Temperature  | $-20^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$ , See Figure 2  | -20 ~ 100 | $^\circ\text{C}$ |
| $T_{STG}$             | Storage Temperature  |   | -40 ~ 125 | $^\circ\text{C}$ |
| $V_{ISO}$             | Isolation Voltage  | 60 Hz, Sinusoidal, AC 1 Minute, Connect Pins to Heat Sink Plate   | 2500      | $V_{\text{rms}}$ |

### Thermal Resistance

| Symbol         | Parameter                           | Condition                             | Min. | Typ. | Max. | Unit               |
|----------------|-------------------------------------|---------------------------------------|------|------|------|--------------------|
| $R_{th(j-c)Q}$ | Junction to Case Thermal Resistance | Inverter IGBT Part (per 1 / 6 module) | -    | -    | 3.1  | $^\circ\text{C/W}$ |
| $R_{th(j-c)F}$ |                                     | Inverter FWD Part (per 1 / 6 module)  | -    | -    | 3.6  | $^\circ\text{C/W}$ |

#### 2nd Notes:

- For the measurement point of case temperature( $T_C$ ), please refer to Figure 2.

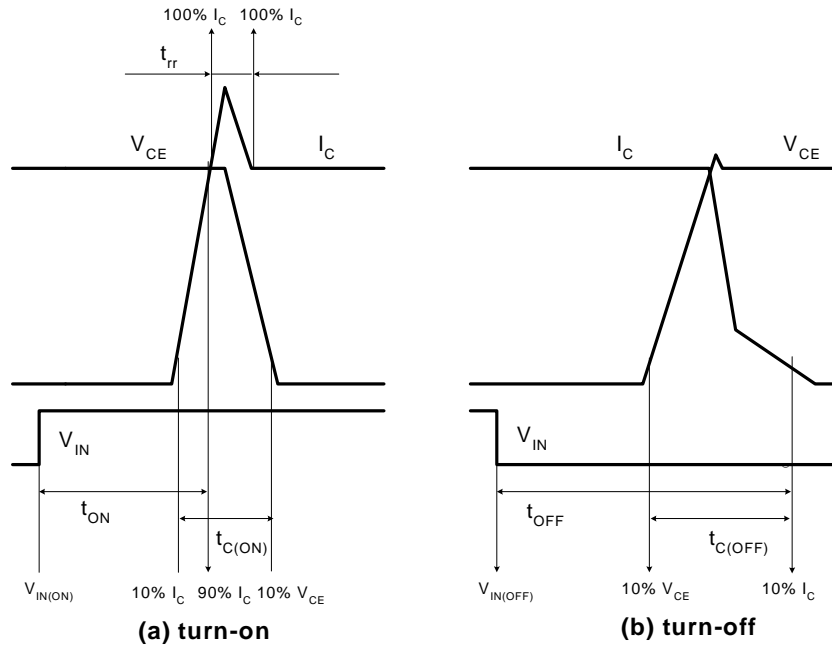
**Electrical Characteristics** ( $T_J = 25^\circ\text{C}$ , unless otherwise specified.)

**Inverter Part**

| Symbol        | Parameter                              | Conditions   | Min.         | Typ. | Max. | Unit          |               |
|---------------|--|--|--------------|------|------|---------------|---------------|
| $V_{CE(SAT)}$ | Collector - Emitter Saturation Voltage | $V_{CC} = V_{BS} = 15\text{ V}$<br>$V_{IN} = 5\text{ V}$   | -            | -    | 2.3  | V             |               |
| $V_F$         | FWDI Forward Voltage                   | $V_{IN} = 0\text{ V}$  | -            | -    | 2.1  | V             |               |
| HS            | Switching Times                        | $V_{PN} = 300\text{ V}, V_{CC} = V_{BS} = 15\text{ V}$<br>$I_C = 15\text{ A}$<br>$V_{IN} = 0\text{ V} \leftrightarrow 5\text{ V}$ , Inductive Load<br>(2nd Note 3) | $t_{ON}$     | -    | 0.4  | -             | $\mu\text{s}$ |
|               |  |  | $t_{C(ON)}$  | -    | 0.28 | -             | $\mu\text{s}$ |
|               |  |  | $t_{OFF}$    | -    | 0.67 | -             | $\mu\text{s}$ |
|               |  |  | $t_{C(OFF)}$ | -    | 0.35 | -             | $\mu\text{s}$ |
|               |  |  | $t_{rr}$     | -    | 0.10 | -             | $\mu\text{s}$ |
| LS            | Switching Times                        | $V_{PN} = 300\text{ V}, V_{CC} = V_{BS} = 15\text{ V}$<br>$I_C = 15\text{ A}$<br>$V_{IN} = 0\text{ V} \leftrightarrow 5\text{ V}$ , Inductive Load<br>(2nd Note 3) | $t_{ON}$     | -    | 0.55 | -             | $\mu\text{s}$ |
|               |  |  | $t_{C(ON)}$  | -    | 0.24 | -             | $\mu\text{s}$ |
|               |  |  | $t_{OFF}$    | -    | 0.73 | -             | $\mu\text{s}$ |
|               |  |  | $t_{C(OFF)}$ | -    | 0.34 | -             | $\mu\text{s}$ |
|               |  |  | $t_{rr}$     | -    | 0.10 | -             | $\mu\text{s}$ |
| $I_{CES}$     | Collector - Emitter Leakage Current    | $V_{CE} = V_{CES}$   | -            | -    | 250  | $\mu\text{A}$ |               |

**2nd Notes:**

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 time of IGBT itself under the given gate driving condition internally. For the detailed information, please see Figure 4.



**Figure 4. Switching Time Definition**

## Electrical Characteristics (T<sub>J</sub> = 25°C, unless otherwise specified.)

### Control Part

| Symbol               | Parameter                                | Conditions  | Min. | Typ. | Max. | Unit |
|----------------------|--|---|------|------|------|------|
| I <sub>QCCL</sub>    | Quiescent V <sub>CC</sub> Supply Current | V <sub>CC</sub> = 15 V<br>I <sub>N(UL, VL, WL)</sub> = 0 V  | -    | -    | 23   | mA   |
| I <sub>QCCH</sub>    |  | V <sub>CC</sub> = 15 V<br>I <sub>N(UH, VH, WH)</sub> = 0 V  | -    | -    | 100  | μA   |
| I <sub>QBS</sub>     | Quiescent V <sub>BS</sub> Supply Current | V <sub>BS</sub> = 15 V<br>I <sub>N(UH, VH, WH)</sub> = 0 V  | -    | -    | 500  | μA   |
| V <sub>FOH</sub>     | Fault Output Voltage                     | V <sub>SC</sub> = 0 V, V <sub>FO</sub> Circuit: 4.7 kΩ to 5 V Pull-up                               | 4.5  | -    | -    | V    |
| V <sub>FOL</sub>     |  | V <sub>SC</sub> = 1 V, V <sub>FO</sub> Circuit: 4.7 kΩ to 5 V Pull-up                               | -    | -    | 0.8  | V    |
| V <sub>SC(ref)</sub> | Short Circuit Current Trip Level         | V <sub>CC</sub> = 15 V (2nd Note 4)   | 0.45 | 0.50 | 0.55 | V    |
| TSD                  | Over-Temperature Protection              | Temperature at LVIC   | 125  | 145  | 175  | V    |
| ΔTSD                 | Over-Temperature Protection Hysteresis   | Temperature at LVIC   | -    | 18   | -    | V    |
| UV <sub>CCD</sub>    | Supply Circuit Under-Voltage Protection  | Detection Level   | 10.7 | 11.9 | 13.0 | V    |
| UV <sub>CCR</sub>    |  | Reset Level   | 11.2 | 12.4 | 13.2 | V    |
| UV <sub>BSD</sub>    |  | Detection Level   | 10.1 | 11.3 | 12.5 | V    |
| UV <sub>BSR</sub>    |  | Reset Level   | 10.5 | 11.7 | 12.9 | V    |
| t <sub>FOD</sub>     | Fault-out Pulse Width                    | C <sub>FOD</sub> = 33 nF (2nd Note 5)   | 1.0  | 1.8  | -    | ms   |
| V <sub>IN(ON)</sub>  | ON Threshold Voltage                     | Applied between I <sub>N(UH)</sub> , I <sub>N(VH)</sub> , I <sub>N(WH)</sub> , I <sub>N(UL)</sub> , | 3.0  | -    | -    | V    |
| V <sub>IN(OFF)</sub> | OFF Threshold Voltage                    | I <sub>N(VL)</sub> , I <sub>N(WL)</sub> - COM   | -    | -    | 0.8  | V    |

#### 2nd Notes:

4. Short-circuit protection is functioning only at the low-sides.

5. The fault-out pulse width t<sub>FOD</sub> depends on the capacitance value of C<sub>FOD</sub> according to the following approximate equation: C<sub>FOD</sub> = 18.3 x 10<sup>-6</sup> x t<sub>FOD</sub> [F]

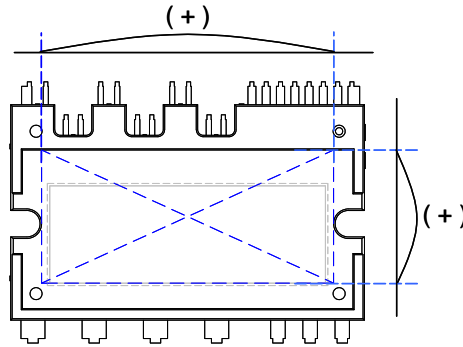
### Recommended Operating Conditions

| Symbol  | Parameter                              | Conditions  | Min. | Typ. | Max. | Unit   |
|---|--|---|------|------|------|--------|
| V <sub>PN</sub>                                 | Supply Voltage                         | Applied between P - N <sub>U</sub> , N <sub>V</sub> , N <sub>W</sub>  | -    | 300  | 400  | V      |
| V <sub>CC</sub>                                 | Control Supply Voltage                 | Applied between V <sub>CC(UH)</sub> , V <sub>CC(VH)</sub> , V <sub>CC(WH)</sub> , V <sub>CC(L)</sub> - COM                            | 13.5 | 15   | 16.5 | V      |
| V <sub>BS</sub>                                 | High-Side Bias Voltage                 | Applied between V <sub>B(U)</sub> - V <sub>S(U)</sub> , V <sub>B(V)</sub> - V <sub>S(V)</sub> , V <sub>B(W)</sub> - V <sub>S(W)</sub> | 13.0 | 15   | 18.5 | V      |
| dV <sub>CC</sub> / dt,<br>dV <sub>BS</sub> / dt | Control Supply Variation               |   | -1   | -    | 1    | V / μs |
| t <sub>dead</sub>                               | Blanking Time for Preventing Arm-Short | For Each Input Signal   | 2.0  | -    | -    | μs     |
| f <sub>PWM</sub>                                | PWM Input Signal                       | -20°C ≤ T <sub>C</sub> ≤ 100°C, -20°C ≤ T <sub>J</sub> ≤ 125°C  | -    | -    | 20   | kHz    |
| V <sub>SEN</sub>                                | Voltage for Current Sensing            | Applied between N <sub>U</sub> , N <sub>V</sub> , N <sub>W</sub> - COM (Including Surge Voltage)                                      | -4   |      | 4    | V      |



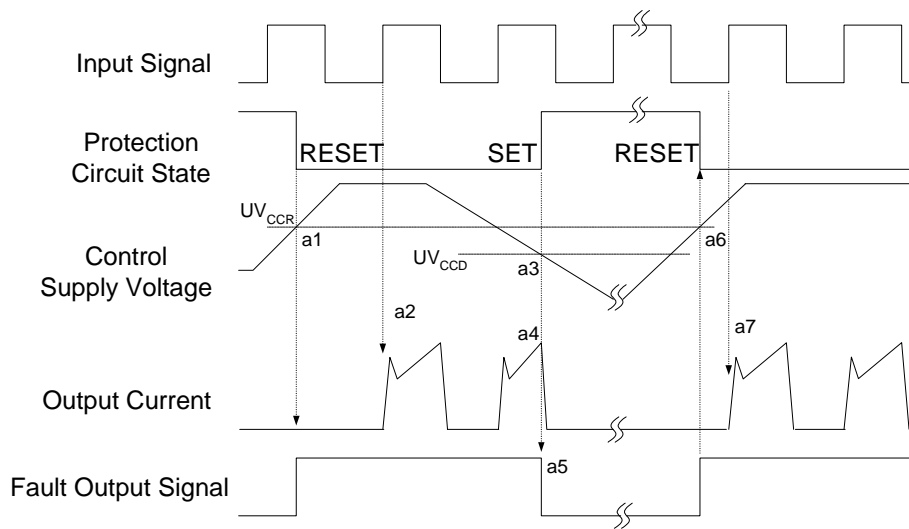
**Mechanical Characteristics and Ratings**

| Parameter       | Conditions         |                      | Min. | Typ.  | Max. | Unit |
|-----------------|--------------------|----------------------|------|-------|------|------|
| Mounting Torque | Mounting Screw: M3 | Recommended 0.62 N•m | 0.51 | 0.62  | 0.72 | N•m  |
| Device Flatness |                    | See Figure 5         | 0    | -     | +120 | μm   |
| Weight          |                    |                      | -    | 15.40 | -    | g    |



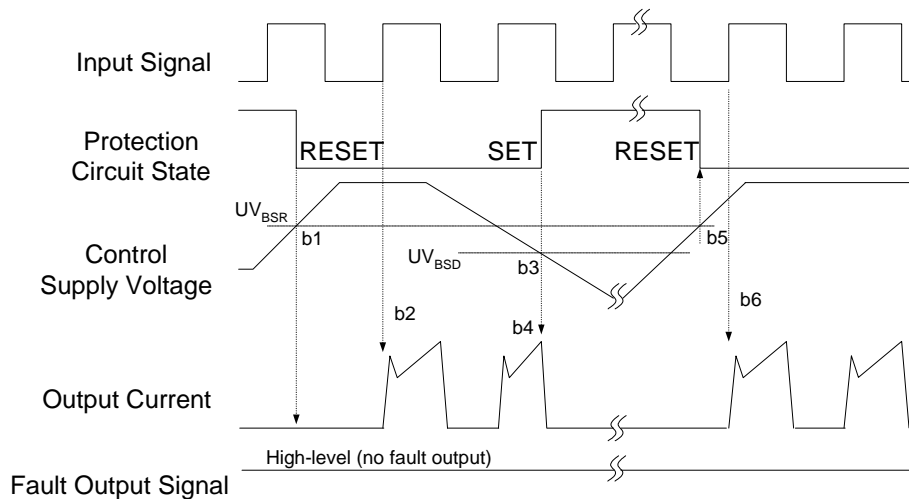
**Figure 5. Flatness Measurement Position**

### Time Charts of Protective Function



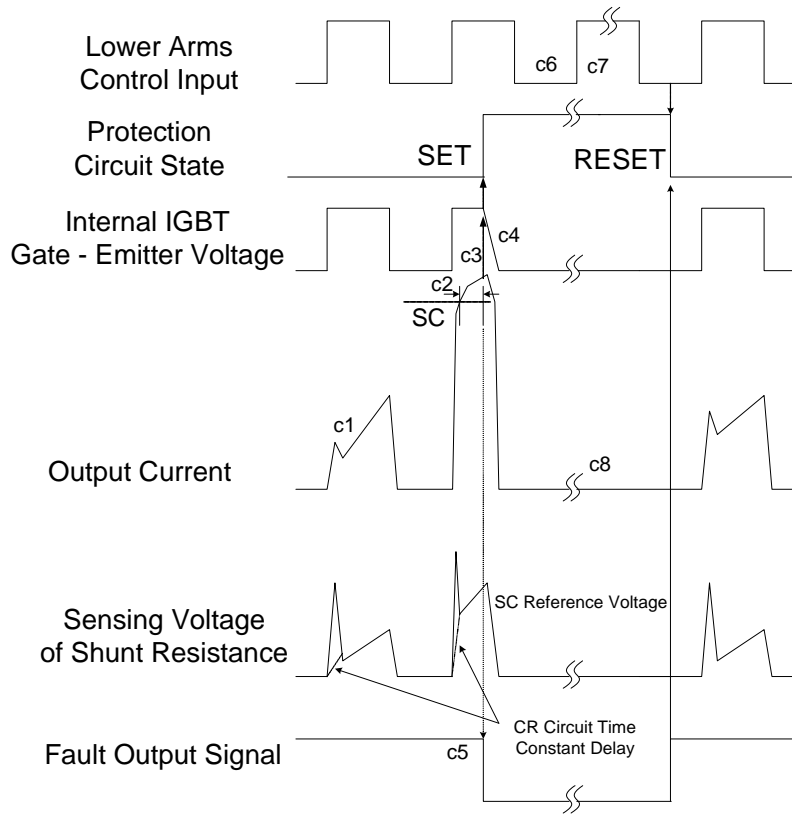
- a1 : Control supply voltage rises: after the voltage rises  $UV_{CCR}$ , the circuits start to operate when next input is applied.
- a2 : Normal operation: IGBT ON and carrying current.
- a3 : Under-Voltage detection ( $UV_{CCD}$ ).
- a4 : IGBT OFF in spite of control input condition.
- a5 : Fault output operation starts.
- a6 : Under-Voltage reset ( $UV_{CCR}$ ).
- a7 : Normal operation: IGBT ON and carrying current.

**Figure 6. Under-Voltage Protection (Low-Side)**



- b1 : Control supply voltage rises: after the voltage reaches  $UV_{BSR}$ , the circuits start to operate when next input is applied.
- b2 : Normal operation: IGBT ON and carrying current.
- b3 : Under-Voltage detection ( $UV_{BSD}$ ).
- b4 : IGBT OFF in spite of control input condition, but there is no fault output signal.
- b5 : Under-Voltage reset ( $UV_{BSR}$ ).
- b6 : Normal operation: IGBT ON and carrying current.

**Figure 7. Under-Voltage Protection (High-Side)**



(with the external shunt resistance and CR connection)

- c1 : Normal operation: IGBT ON and carrying current.
- c2 : Short-Circuit current detection (SC trigger).
- c3 : Hard IGBT gate interrupt.
- c4 : IGBT turns OFF.
- c5 : Fault output timer operation starts: the pulse width of the fault output signal is set by the external capacitor  $C_{FO}$ .
- c6 : Input "LOW": IGBT OFF state.
- c7 : Input "HIGH": IGBT ON state, but during the active period of fault output, the IGBT doesn't turn ON.
- c8 : IGBT OFF state.

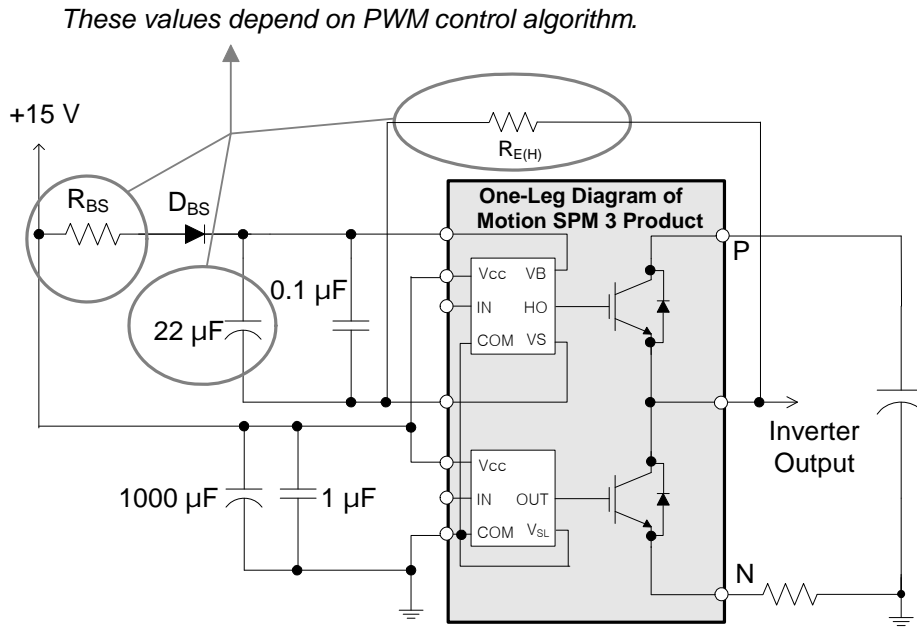
**Figure 8. Short-Circuit Protection (Low-Side Operation Only)**



**Figure 9. Recommended MCU I/O Interface Circuit**

**3rd Notes:**

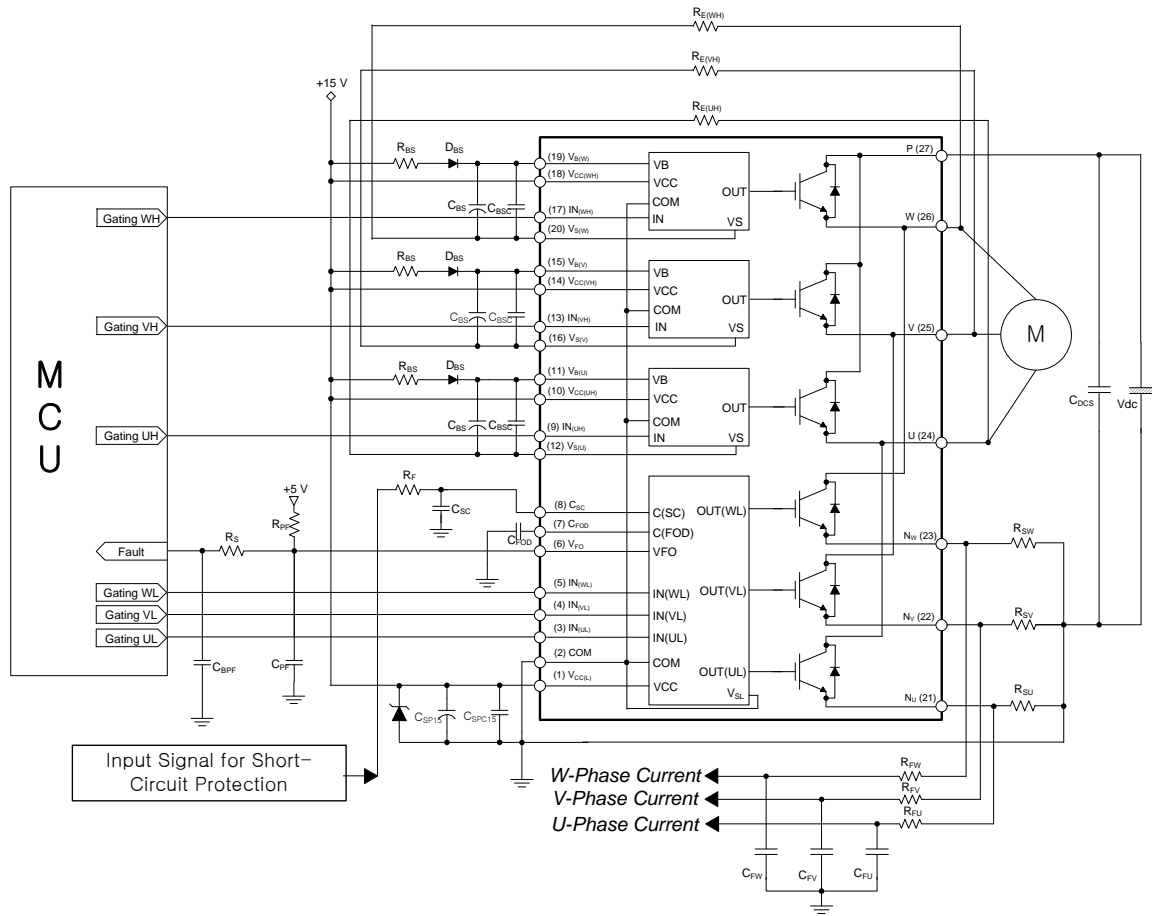
1. RC coupling at each input (parts shown dotted) might change depending on the PWM control scheme in the application and the wiring impedance of the application's printed circuit board. The Motion SPM® 3 Product input signal section integrates a 3.3 kΩ(typ.) pull-down resistor. Therefore, when using an external filtering resistor, pay attention to the signal voltage drop at input terminal.
2. The logic input works with standard CMOS or LSTTL outputs.



**Figure 10. Recommended Bootstrap Operation Circuit and Parameters**

**3rd Notes:**

3. It would be recommended that the bootstrap diode,  $D_{BS}$ , has soft and fast recovery characteristics.
4. The bootstrap resistor ( $R_{BS}$ ) should be three times greater than  $R_{E(H)}$ . The recommended value of  $R_{E(H)}$  is 5.6 Ω, but it can be increased up to 20 Ω (maximum) for a slower  $dv/dt$  of high-side.
5. The ceramic capacitor placed between  $V_{CC}$  - COM should be over 1 μF and mounted as close to the pins of the Motion SPM 3 product as possible.

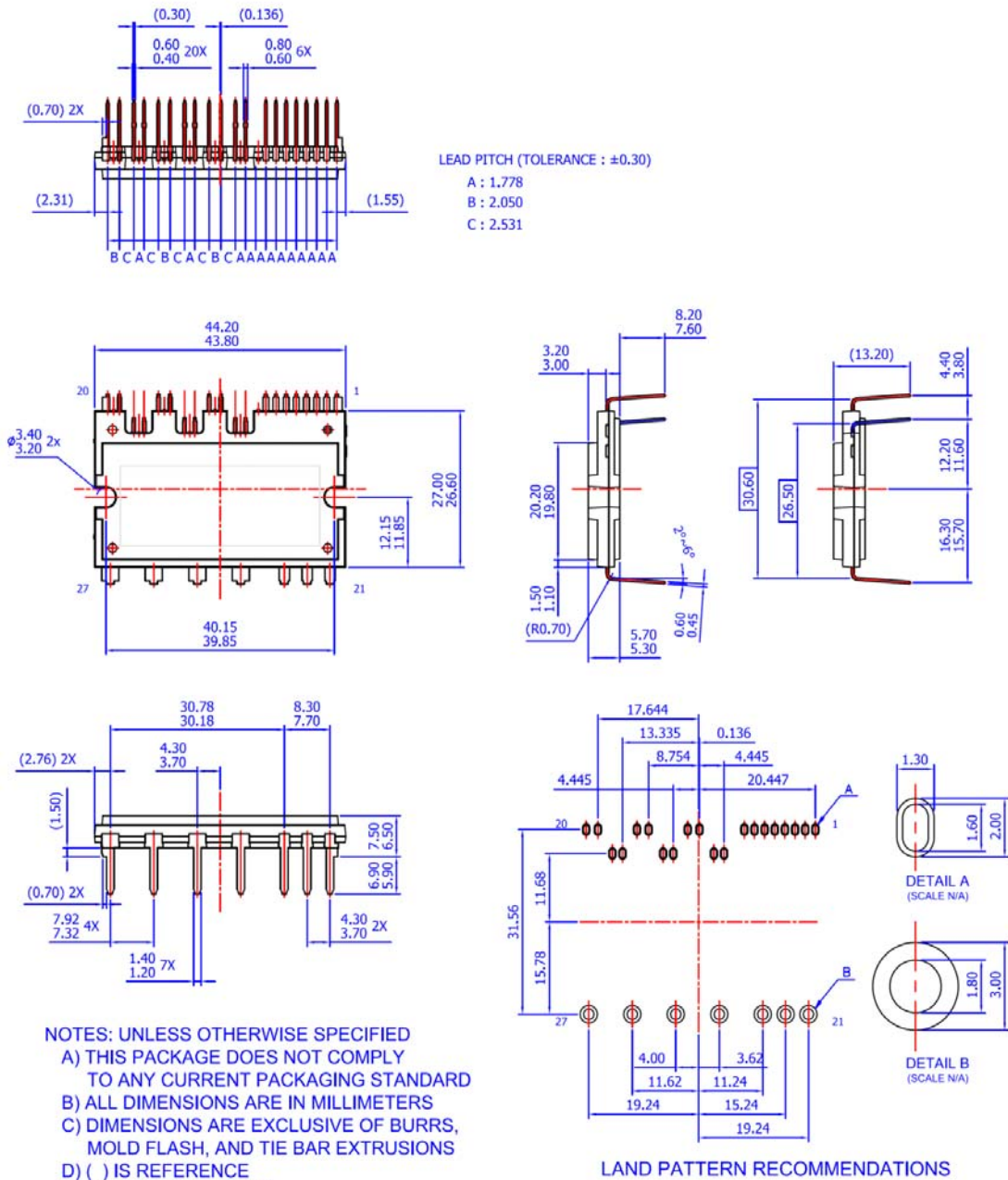


**Figure 11. Typical Application Circuit**

**4th Notes:**

1. To avoid malfunction, the wiring of each input should be as short as possible (less than 2 - 3 cm).
2. By virtue of integrating an application-specific type of HVIC inside the Motion SPM® 3 product, direct coupling to MCU terminals without any optocoupler or transformer isolation is possible.
3. V<sub>FOD</sub> output is open-collector type. This signal line should be pulled up to the positive side of the 5 V power supply with approximately 4.7 kΩ resistance (please refer to Figure 9).
4. C<sub>SP15</sub> of around seven times larger than bootstrap capacitor C<sub>BS</sub> is recommended.
5. V<sub>FOD</sub> output pulse width should be determined by connecting an external capacitor (C<sub>FOD</sub>) between C<sub>FOD</sub> (pin 7) and COM (pin 2). (Example : if C<sub>FOD</sub> = 33 nF, then t<sub>FOD</sub> = 1.8 ms (typ.)) Please refer to the 2nd note 5 for calculation method.
6. Input signal is active-HIGH type. There is a 3.3 kΩ resistor inside the IC to pull down each input signal line to GND. When employing RC coupling circuits, set up such RC couple that input signal agree with turn-off / turn-on threshold voltage.
7. To prevent errors of the protection function, the wiring around R<sub>F</sub> and C<sub>SC</sub> should be as short as possible.
8. In the short-circuit protection circuit, please select the R<sub>F</sub>C<sub>SC</sub> time constant in the range 1.5 ~ 2 μs.
9. Each capacitor should be mounted as close to the pins of the Motion SPM 3 product as possible.
10. To prevent surge destruction, the wiring between the smoothing capacitor 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 μF between the P & GND pins is recommended.
11. Relays are used in almost every systems of electrical equipment in home appliances. In these cases, there should be sufficient distance between the MCU and the relays.
12. C<sub>SP15</sub> should be over 1 μF and mounted as close to the pins of the Motion SPM 3 product as possible.

## Detailed Package Outline Drawings



- NOTES: UNLESS OTHERWISE SPECIFIED  
 A) THIS PACKAGE DOES NOT COMPLY TO ANY CURRENT PACKAGING STANDARD  
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