

# **Motion SPM® 5 Series**

## NFA50460R4B, NFA50460R47

#### **General Description**

The NFA50460R4B/7 is an advanced Motion SPM5 module providing a fully featured, high performance inverter output stage for AC induction, BLDC and PMSM motors such as refrigerators, fans and pumps. These modules integrate optimized gate drive of the built-in IGBTs (FS4 RC IGBT technology) to minimize EMI and losses, while also providing multiple on-module protection features including under-voltage lockouts and thermal monitoring. The built-in high speed Driver IC 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 open emitter IGBT terminals are available for each phase to support the widest variety of control algorithms.

#### **Features**

- UL Certified No. E209204 (UL1557)
- 600 V FS4 RC IGBT 3-Phase Inverter with Gate Drivers and Protection
- Built-In Bootstrap Diodes Simplify PCB Layout
- Separate Open–Emitter Pins from Low–Side IGBTs for Three–Phase Current–Sensing
- Active-High Interface, Works with 3.3 / 5 V Logic, Schmitt-Trigger Input
- Optimized for Low Electromagnetic Interference
- Driver IC Temperature Sensing Built-In for Temperature Monitoring
- Driver IC for Gate Driving and Under-Voltage Protection
- Isolation Rating: 1500 V<sub>rms</sub>/min.
- Moisture Sensitive Level (MSL) 3 for SMD PKG
- RoHS Compliant

#### **Applications**

• 3-Phase Inverter Driver for Small Power AC Motor Drives

#### **Related Source**

- AN–9080 Motion SPM<sup>®</sup> 5 Series Version 2 User's Guide
- AN-9082 Motion SPM<sup>®</sup> 5 Series Thermal Performance by Contact <u>Pressure</u>



SPM5P-023 / 23LD, PDD STD, FULL PACK, DIP TYPE CASE MODEJ



SPM5Q-023 / 23LD, PDD STD, SPM23-BD (Ver1.5) SMD TYPE CASE MODEM

#### **MARKING DIAGRAM**

O \$Y NFA50460R4x &Z&K&E&E&E&3

#### ORDERING INFORMATION

See detailed ordering and shipping information on page 2 of this data sheet.

#### **ORDERING INFORMATION**

| Device      | Device Marking | Package   | ackage Packing Type† Reel Size |        | Quantity |
|-------------|----------------|-----------|--------------------------------|--------|----------|
| NFA50460R4B | NFA50460R4B    | SPM5P-023 | Rail                           | NA     | 15       |
| NFA50460R47 | NFA50460R47    | SPM5Q-023 | Tape & Reel                    | 330 mm | 450      |

<sup>†</sup>For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

#### ABSOLUTE MAXIMUM RATINGS (V<sub>DD</sub> = V<sub>BS</sub> = 15 V, T<sub>C</sub> = 25°C, unless otherwise noted)

| Symbol                 | Parameter                                 | Conditions  | Rating                     | Unit             |
|------------------------|---|---|----------------------------|------------------|
| INVERTER PA            | ART (Each IGBT Unless Otherwise Specified | )   |                            |                  |
| $V_{PN}$               | Supply Voltage                            | Applied between P - N <sub>U</sub> , N <sub>V</sub> , N <sub>W</sub>  | 450                        | V                |
| V <sub>PN(Surge)</sub> | Supply Voltage (Surge)                    | Applied between P - N <sub>U</sub> , N <sub>V</sub> , N <sub>W</sub>  | 500                        | V                |
| V <sub>CES</sub>       | Collector – Emitter Voltage               |   | 600                        | V                |
| ±l <sub>C</sub>        | Each IGBT Collector Current               | T <sub>C</sub> = 25°C, V <sub>DD</sub> = 15 V, T <sub>J</sub> < 150°C   | 4                          | Α                |
| ±I <sub>CP</sub>       | Each IGBT Collector Current, Peak         | $T_C$ = 25°C, $V_{DD}$ = 15 V, $T_J$ < 150°C,<br>Under 1 ms Pulse Width (Note 2)                                      | 8                          | Α                |
| P <sub>C</sub>         | Collector Dissipation                     | T <sub>C</sub> = 25°C per One Chip (Note 2)   | 10.3                       | W                |
| TJ                     | Operating Junction Temperature            |   | -40~150                    | °C               |
| CONTROL PA             | ART (Each IC Unless Otherwise Specified)  |   |                            |                  |
| $V_{DD}$               | Control Supply Voltage                    | Applied between V <sub>DD</sub> and V <sub>SS</sub>   | 20                         | V                |
| $V_{BS}$               | High-Side Control Bias Voltage            | Applied between $V_B$ and $V_S$   | 20                         | V                |
| V <sub>IN</sub>        | Input Signal Voltage                      | Applied between HIN, LIN and V <sub>SS</sub>  | -0.3~V <sub>DD</sub> + 0.3 | V                |
| BOOTSTRAP              | DIODE PART (Each Bootstrap Diode Unless   | s Otherwise Specified)  |                            |                  |
| V <sub>RRM</sub>       | Maximum Repetitive Reverse Voltage        |   | 600                        | V                |
| I <sub>F</sub>         | Forward Current                           | T <sub>C</sub> = 25°C, T <sub>J</sub> < 150°C (Note 2)  | 0.5                        | Α                |
| I <sub>FP</sub>        | Forward Current (Peak)                    | $T_C$ = 25°C, $T_J$ < 150°C, Under 1 ms<br>Pulse Width (Note 2)   | 1.5                        | Α                |
| THERMAL RE             | SISTANCE                                  | •   |                            |                  |
| R <sub>th(j-c)Q</sub>  | Junction to Case Thermal Resistance       | Inverter IGBT Part (per 1/6 Module)<br>(Note 1)   | 12.2                       | °C/W             |
| TOTAL SYSTI            | EM  | •   |                            |                  |
| tsc                    | Short Circuit Withstand Time              | $V_{DD} = V_{BS} \le 16.5 \text{ V}, V_{PN} \le 400 \text{ V},$<br>$T_J = 150^{\circ}\text{C}, \text{Non-repetitive}$ | 3                          | μs               |
| TJ                     | Operating Junction Temperature            |   | -40~150                    | °C               |
| T <sub>STG</sub>       | Storage Temperature                       |   | -40~125                    | °C               |
| V <sub>ISO</sub>       | Isolation Voltage                         | 60 Hz, Sinusoidal, AC 1 minute,<br>Connect Pins to Heat Sink Plate  | 1500                       | V <sub>rms</sub> |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

- For the measurement point of case temperature T<sub>C</sub>, Please refer to Figure 4.
   These values had been made an acquisition by the calculation considered to design factor.
- 3. Using continuously under heavy loads or excessive assembly conditions (e.g. the application of high temperature/ current/ voltage and the significant change in temperature, etc.) may cause this product to decrease in the reliability significantly even if the operating conditions (i.e. operating temperature/ current/ voltage, etc.) are within the absolute maximum ratings and the operating ranges.

#### **PIN DESCRIPTION**

| Pin No.                                      | Pin Name             | Description  |  |  |
|--|----------------------|--|--|--|
| 1  | V <sub>SS</sub>      | IC Common Supply Ground  |  |  |
| 2  | V <sub>B(U)</sub>    | High-Side Bias Voltage for U phase IGBT Driving                          |  |  |
| 3  | V <sub>DD(U)</sub>   | Low-Side Bias Voltage for U phase IC and IGBT Driving                    |  |  |
| 4  | HIN <sub>(U)</sub>   | Signal Input for High-Side U Phase                                       |  |  |
| 5  | LIN <sub>(U)</sub>   | Signal Input for Low-Side U Phase  |  |  |
| 6  | N.C                  | N.C  |  |  |
| 7  | V <sub>B(V)</sub>    | High-Side Bias Voltage for V phase IGBT Driving                          |  |  |
| 8  | V <sub>DD(V)</sub>   | Low-Side Bias Voltage for V phase IC and IGBT Driving                    |  |  |
| 9  | HIN <sub>(V)</sub>   | Signal Input for High-Side V Phase                                       |  |  |
| 10   | LIN <sub>(V)</sub>   | Signal Input for Low-Side V Phase  |  |  |
| 11   | VTS                  | Voltage Output for IC Temperature Sensing Unit                           |  |  |
| 12   | V <sub>B(W)</sub>    | High-Side Bias Voltage for W phase IGBT Driving                          |  |  |
| 13   | V <sub>DD(W)</sub>   | Low-Side Bias Voltage for W phase IC and IGBT Driving                    |  |  |
| 14   | HIN <sub>(W)</sub>   | Signal Input for High-Side W Phase                                       |  |  |
| 15   | LIN <sub>(W)</sub>   | Signal Input for Low-Side W Phase  |  |  |
| 16   | N.C                  | N.C  |  |  |
| 17   | Р                    | Positive DC-Link Input   |  |  |
| 18   | U, V <sub>S(U)</sub> | Output for U Phase & High-Side Bias Voltage GND for U phase IGBT Driving |  |  |
| 19   | N <sub>U</sub>       | Negative DC-Link Input for U Phase                                       |  |  |
| 20   | N <sub>V</sub>       | Negative DC-Link Input for V Phase                                       |  |  |
| 21   | V, V <sub>S(V)</sub> | Output for V Phase & High-Side Bias Voltage GND for V phase IGBT Driving |  |  |
| 22 N <sub>W</sub><br>23 W, V <sub>S(W)</sub> |                      | Negative DC-Link Input for W Phase                                       |  |  |
|  |                      | Output for W Phase & High-Side Bias Voltage GND for W phase IGBT Driving |  |  |

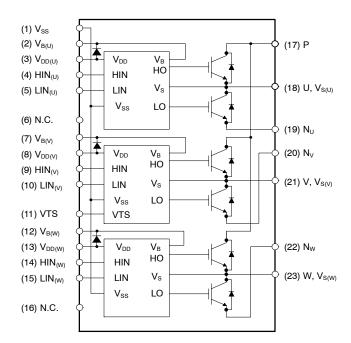


Figure 1. Pin Configuration and Internal Block Diagram (Bottom View)

#### NOTE:

4. Emitter terminal of each low-side IGBT is not connected to supply ground or bias voltage ground inside Motion SPM 5 product. External connections should be made as indicated in Figure 3.

#### **ELECTRICAL CHARACTERISTICS** (T<sub>.1</sub> = 25°C, V<sub>DD</sub> = V<sub>BS</sub> = 15 V unless otherwise noted)

| Symbol               | Parameter                                | Test   | Conditions   | Min. | Тур.   | Max.  | Unit |
|----------------------|--|--|--|------|--------|-------|------|
| INVERTE              | R PART (Each IGBT unless otherwise spec  | ified)   |  |      | •      | •     |      |
| BV <sub>CES</sub>    | Collector-Emitter Breakdown Voltage      | V <sub>IN</sub> = 0 V, I <sub>D</sub> = 1 mA (Note 5)  |  | 600  | -      | -     | V    |
| I <sub>CES</sub>     | Collector-Emitter Leakage Current        | V <sub>IN</sub> = 0 V, V <sub>CE</sub> = 600 \   | /  | -    | -      | 1     | mA   |
| V <sub>CE(SAT)</sub> | Collector-Emitter Saturation Voltage     | V <sub>DD</sub> = V <sub>BS</sub> = 15 V, V <sub>IN</sub>  | <sub>I</sub> = 5 V, I <sub>C</sub> = 4 A, T <sub>J</sub> = 25°C  | -    | 1.75   | 2.2   | V    |
|                      |  | $V_{DD} = V_{BS} = 15 \text{ V}, V_{IN}$   | <sub>I</sub> = 5 V, I <sub>C</sub> = 4 A, T <sub>J</sub> = 150°C   | -    | 2.0    | -     |      |
| V <sub>F</sub>       | Emitter-Collector Forward Voltage        | V <sub>IN</sub> = 0 V, I <sub>F</sub> = 4 A, T <sub>J</sub>  | $V_{IN} = 0 \text{ V, } I_F = 4 \text{ A, } T_J = 25^{\circ}\text{C}$ $V_{IN} = 0 \text{ V, } I_F = 4 \text{ A, } T_J = 150^{\circ}\text{C}$ |      | 1.87   | 2.3   | ٧    |
|                      |  | $V_{IN} = 0 \text{ V}, I_F = 4 \text{ A}, T_J$   |  |      | 2.0    | _     |      |
| t <sub>ON</sub>      | Switching Times                          | $V_{PN} = 300 \text{ V}, V_{DD} = V_{I}$   |  | -    | 370    | -     | ns   |
| t <sub>OFF</sub>     |  | $V_{IN} = 0 V \leftrightarrow 5 V$ , Induce High- and Low-Side I   | ctive Load,<br>IGBT Switching (Note 6)   | -    | 358    | _     | ns   |
| t <sub>rr</sub>      |  |  |  | _    | 151    | _     | ns   |
| E <sub>ON</sub>      |  |  |  | _    | 150    | _     | μJ   |
| E <sub>OFF</sub>     |  |  |  |      | 35     | _     | μJ   |
| RBSOA                | Reverse-Bias Safe Operating Area         | $V_{PN}$ = 400 V, $V_{DD}$ = $V_{I}$<br>$V_{CE}$ = $BV_{CES}$ , $T_{J}$ = 15<br>High- and Low-Side I     |  |      | Full S | quare |      |
| CONTRO               | PART (Each HVIC Unless Otherwise Spe     | cified)  |  |      |        |       |      |
| $I_{QDD}$            | Quiescent V <sub>DD</sub> Current        | V <sub>DD</sub> = 15 V, V <sub>IN</sub> = 0 V  | Applied between $V_{DD}$ and $V_{SS}$  | -    | -      | 200   | μΑ   |
| I <sub>QBS</sub>     | Quiescent V <sub>BS</sub> Current        | $V_{BS} = 15 \text{ V}, V_{IN} = 0 \text{ V}$  | $ \begin{array}{c} \text{Applied between $V_{B(U)}-U$,} \\ V_{B(V)}-V, \ V_{B(W)}-W \end{array} $  | -    | -      | 100   | μΑ   |
| I <sub>PDD</sub>     | Operating V <sub>DD</sub> Supply Current | V <sub>DD</sub> - V <sub>SS</sub>  | V <sub>DD</sub> = 15 V, f <sub>PWM</sub> = 20 kHz,<br>duty = 50%, Applied to One<br>PWM Signal Input for<br>Low-Side                         | -    | -      | 900   | μА   |
| I <sub>PBS</sub>     | Operating V <sub>BS</sub> Supply Current | $ \begin{aligned} &V_{B(U)} - V_{S(U)}, \\ &V_{B(V)} - V_{S(V)}, \\ &V_{B(W)} - V_{S(W)} \end{aligned} $ | V <sub>DD</sub> = V <sub>BS</sub> = 15 V,<br>f <sub>PWM</sub> = 20 kHz,<br>Duty = 50%, Applied to<br>One PWM Signal Input<br>for High–Side   | -    | -      | 800   | μА   |
| UV <sub>DDD</sub>    | Low-Side Under-voltage Protection        | V <sub>DD</sub> Under-voltage Pr   | rotection Detection Level  | 7.4  | 8.0    | 9.4   | V    |
| UV <sub>DDR</sub>    | (Figure 8)                               | V <sub>DD</sub> Under-voltage Pr   | rotection Reset Level  | 8.0  | 8.9    | 9.8   | V    |
| UV <sub>BSD</sub>    | High-Side Under-voltage Protection       | V <sub>BS</sub> Under-voltage Pr   | otection Detection Level   | 7.4  | 8.0    | 9.4   | V    |
| UV <sub>BSR</sub>    | (Figure 8)                               | V <sub>BS</sub> Under-voltage Protection Reset Level   |  | 8.0  | 8.9    | 9.8   | V    |
| V <sub>TS</sub>      | IC Temperature Sensing Voltage Output    | V <sub>DD</sub> = 15 V, T <sub>driver</sub> = 25°C (Note 8)  |  | 600  | 790    | 980   | mV   |
| V <sub>IH</sub>      | ON Threshold Voltage                     | Logic HIGH Level   | Applied between HIN, LIN   | -    | _      | 2.9   | V    |
| V <sub>IL</sub>      | OFF Threshold Voltage                    | OFF Threshold Voltage Logic LOW Level and V <sub>SS</sub>  |  | 0.8  | -      | -     | V    |
| воотѕт               | RAP DIODE PART (Each bootstrap diode u   | nless otherwise specified  | d)   | -    | ā.     | -     | -    |
| V <sub>FB</sub>      | Forward Voltage                          | I <sub>F</sub> = 0.1 A, T <sub>C</sub> = 25°C  | (Note 9)   | -    | 2.5    | -     | V    |
| t <sub>rrB</sub>     | Reverse Recovery Time                    | I <sub>F</sub> = 0.1 A, T <sub>C</sub> = 25°C  |  | -    | 80     | -     | ns   |
|                      | -  | •  |  |      |        | -     |      |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

#### RECOMMENDED OPERATING CONDITION

| Symbol               | Parameter                              | Conditions  | Min.              | Тур. | Max.     | Unit |
|----------------------|--|---|-------------------|------|----------|------|
| V <sub>PN</sub>      | Supply Voltage                         | Applied between P and N   | > V <sub>DD</sub> | 300  | 450      | V    |
| V <sub>DD</sub>      | Control Supply Voltage                 | Applied between V <sub>DD</sub> and V <sub>SS</sub>                     | 14.0              | 15.0 | 16.5     | V    |
| V <sub>BS</sub>      | High-Side Bias Voltage                 | Applied between V <sub>B</sub> and V <sub>S</sub>                       | 13.0              | 15.0 | 18.5     | V    |
| V <sub>IN(ON)</sub>  | Input ON Threshold Voltage             | Applied between HIN, LIN and V <sub>SS</sub>                            | 3.0               | -    | $V_{DD}$ | V    |
| V <sub>IN(OFF)</sub> | Input OFF Threshold Voltage            |   | 0                 | -    | 0.6      | V    |
| t <sub>dead</sub>    | Blanking Time for Preventing Arm-Short | V <sub>DD</sub> = V <sub>BS</sub> = 13.5~16.5 V, T <sub>J</sub> ≤ 150°C | 1.0               | -    | _        | μS   |
| f <sub>PWM</sub>     | PWM Switching Frequency                | $T_J \le 150^{\circ}C$  | -                 | _    | 20       | kHz  |

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

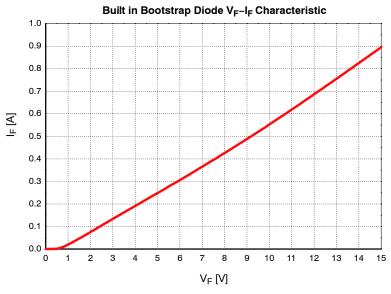
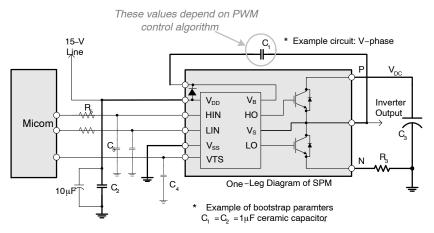


Figure 2. Built-in Bootstrap Diode Characteristics (Typical)

#### NOTES:

- BV<sub>CES</sub> is the absolute maximum voltage rating between collector and emitter terminal of each IGBT inside Motion SPM 5 product. V<sub>PN</sub> should be sufficiently less than this value considering the effect of the stray inductance so that V<sub>CE</sub> should not exceed BV<sub>CES</sub> in any case.
- 6. t<sub>ON</sub> and t<sub>OFF</sub> include the propagation delay time of the internal driver IC. Listed values are measured at the laboratory test condition, and they can be different according to the field applications due to the effect of different printed circuit boards and wirings. Please see Figure 6 for the switching time definition with the switching test circuit of Figure 7.
- 7. The peak current and voltage of each IGBT during the switching operation should be included in the Safe Operating Area (SOA). Please see Figure 7 for the RBSOA test circuit that is same as the switching test circuit.
- 8. VTS is only for sensing temperature of module and cannot shutdown IGBTs automatically.
- 9. Built in bootstrap diode includes around 15  $\Omega$  resistance characteristic. Please refer to Figure 2.

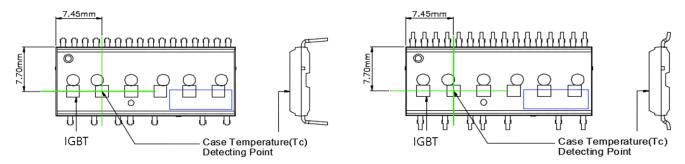


| HIN  | LIN  | Output    | Note              |
|------|------|-----------|-------------------|
| 0    | 0    | Z         | Both IGBT Off     |
| 0    | 1    | 0         | Low-side IGBT On  |
| 1    | 0    | $V_{DC}$  | High-side IGBT On |
| 1    | 1    | Forbidden | Shoot-through     |
| Open | Open | Z         | Same as (0,0)     |

Figure 3. Recommended CPU Interface and Bootstrap Circuit with Parameters

#### NOTES:

- 10. Parameters for bootstrap circuit elements are dependent on PWM algorithm. Typical example of parameters is shown above.
- 11. RC coupling (R<sub>5</sub> and C<sub>5</sub>) and C<sub>4</sub> at each input of SPM and Micom (Indicated as dotted lines) may be used to prevent improper signal due to surge noise.
- 12. Bold lines should be short and thick in PCB pattern to have small stray inductance of circuit, which results in the reduction of surge voltage. Bypass capacitors such as C<sub>1</sub>, C<sub>2</sub> and C<sub>3</sub> should have good high-frequency characteristics to absorb high-frequency ripple current.



**Figure 4. Case Temperature Measurement** 

#### NOTE:

13. Attach the thermocouple on top of the heatsink-side of SPM (between SPM and heatsink if applied) to get the correct temperature measurement.

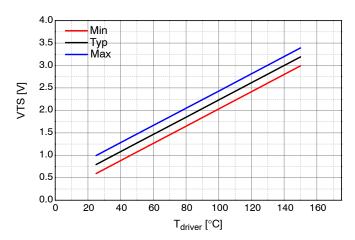


Figure 5. Temperature Profile of VTS

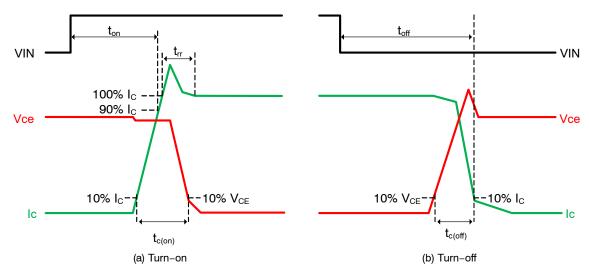


Figure 6. Switching Time Definitions

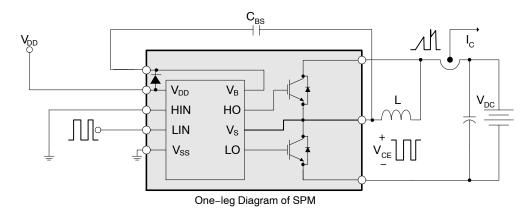


Figure 7. Switching and RBSOA (Single-pulse) Test Circuit (Low-side)

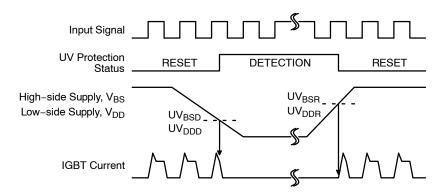


Figure 8. Under-Voltage Protection (High-side and Low-side)

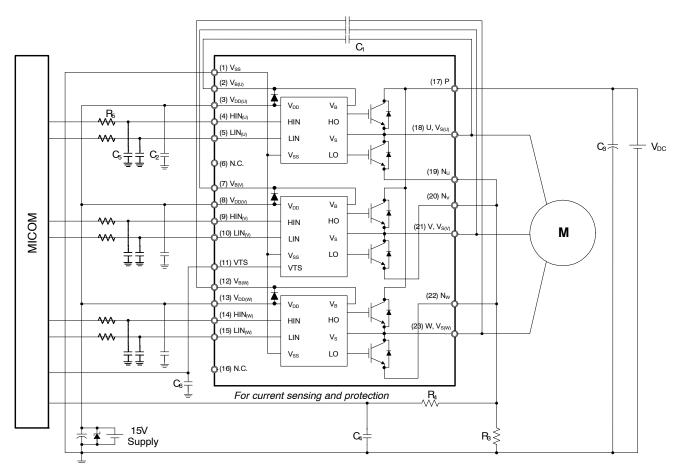


Figure 9. Example of Application Circuit

#### NOTES:

- 14. About pin position, refer to Figure 1.
- 15. RC coupling (R<sub>5</sub> and C<sub>5</sub>, R<sub>4</sub> and C<sub>4</sub>) and C<sub>6</sub> at each input of Motion SPM 5 product and Micom are useful to prevent improper input signal caused by surge noise.
- 16. The voltage drop across R<sub>3</sub> affects the low side switching performance and the bootstrap characteristics since it is placed between V<sub>SS</sub> and the emitter terminal of the low side IGBT. For this reason, the voltage drop across R<sub>3</sub> should be less than 1 V in the steady–state.
- 17. Ground wires and output terminals, should be thick and short in order to avoid surge voltage and malfunction of IC.
- 18.All the filter capacitors should be connected close to Motion SPM 5 product, and they should have good characteristics for rejecting high-frequency ripple current.

#### **TYPICAL PERFORMANCE CHARACTERISTICS**

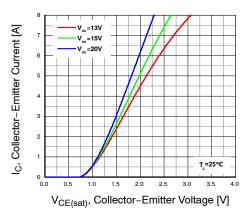


Figure 10. Typ. Collector–Emitter Saturation Voltage

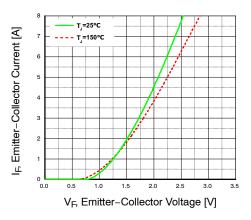


Figure 12. Typ. Emitter-Collector Forward Voltage

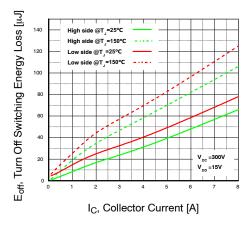


Figure 14. Typ. Turn Off Switching Energy Loss

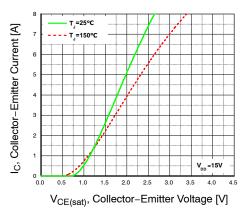


Figure 11. Typ. Collector–Emitter Saturation Voltage

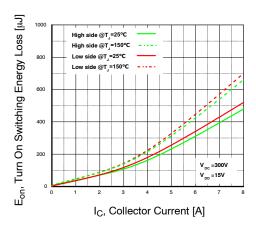


Figure 13. Typ. Turn On Switching Energy Loss

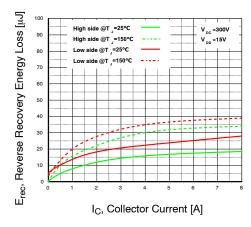


Figure 15. Typ. Reverse Recovery Energy Loss

#### TYPICAL PERFORMANCE CHARACTERISTICS

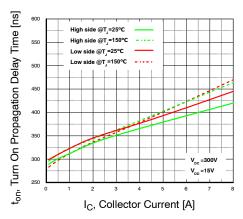
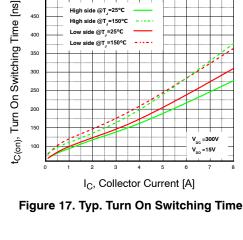


Figure 16. Typ. Turn On Propagation Delay Time



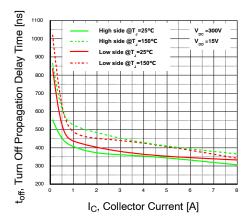


Figure 18. Typ. Turn Off Propagation Delay Time

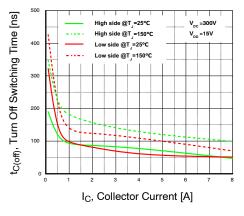


Figure 19. Typ. Turn Off Switching Time

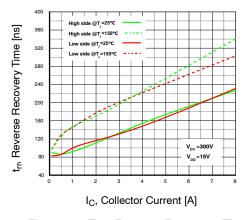


Figure 20. Typ. Reverse Recovery Time

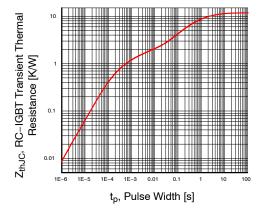


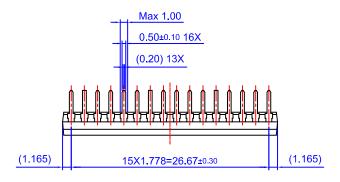
Figure 21. RC-IGBT Transient Thermal Resistance

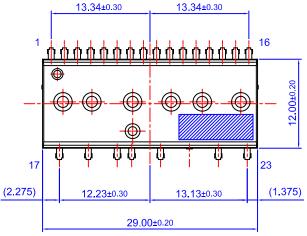
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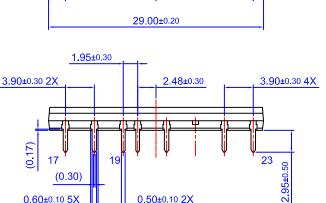


#### SPM5E-023 / 23LD, PDD STD, FULL PACK, DIP TYPE **CASE MODEJ ISSUE O**

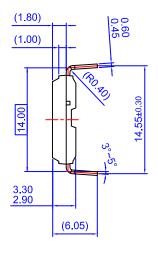
**DATE 31 JAN 2017** 







0.50±0.10 2X PIN19,20



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0,60±0.10 5X

Max 1.00

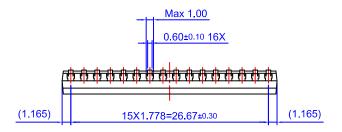


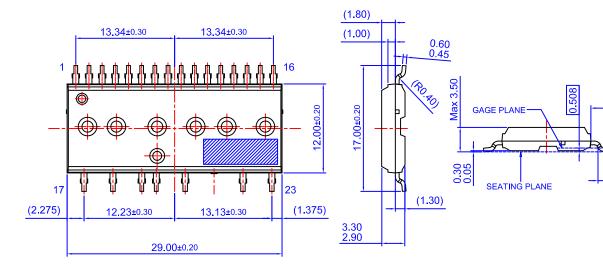
#### SPM5H-023 / 23LD, PDD STD, SPM23-BD (Ver1.5) SMD TYPE CASE MODEM ISSUE O

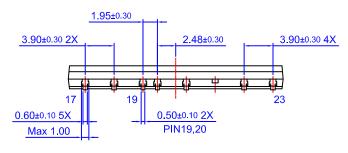
**DATE 31 JAN 2017** 

(2.50)

1.50±0.20

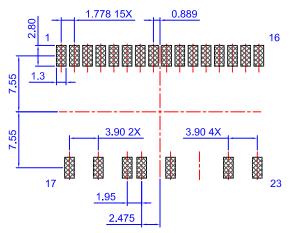






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