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February 2016

# FSBB20CH60C

## Motion SPM<sup>®</sup> 3 Series

### Features

- UL Certified No. E209204 (UL1557)
- 600 V - 20 A 3-Phase IGBT Inverter with Integral Gate Drivers and Protection
- Low-Loss, Short-Circuit Rated IGBTs
- Very Low Thermal Resistance Using Al<sub>2</sub>O<sub>3</sub> DBC Substrate
- Built-in Bootstrap Diodes and 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-9044 - Motion SPM<sup>®</sup> 3 Series Users Guide](#)

### General Description

FSBB20CH60C is an advanced Motion SPM<sup>®</sup> 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.

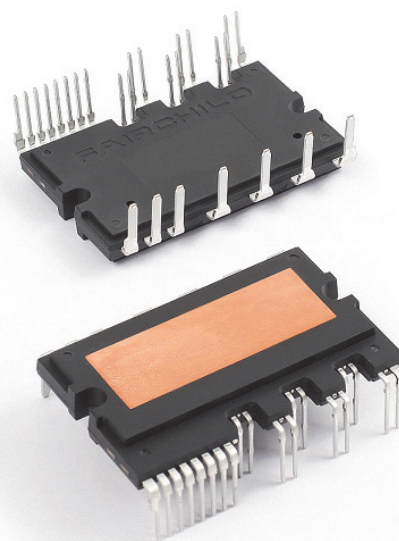


Figure 1. Package Overview

### Package Marking and Ordering Information

Device	Device Marking	Package	Packing Type	Quantity
FSBB20CH60C	FSBB20CH60C	SPMCC-027	Rail	10

## Integrated Power Functions

- 600 V - 20 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 12 and 13.
- 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

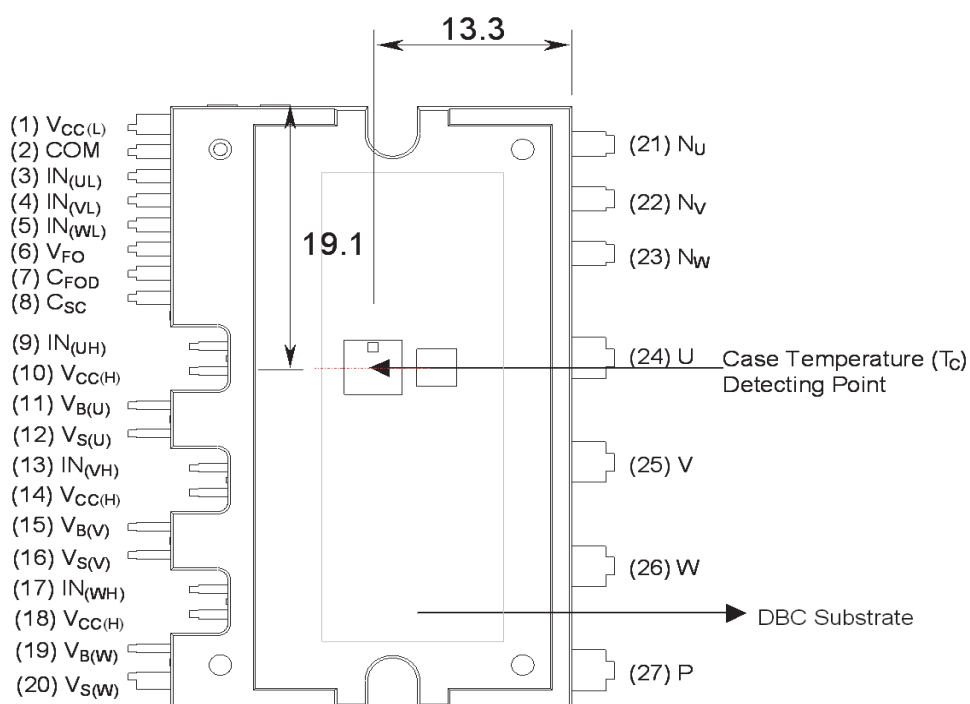
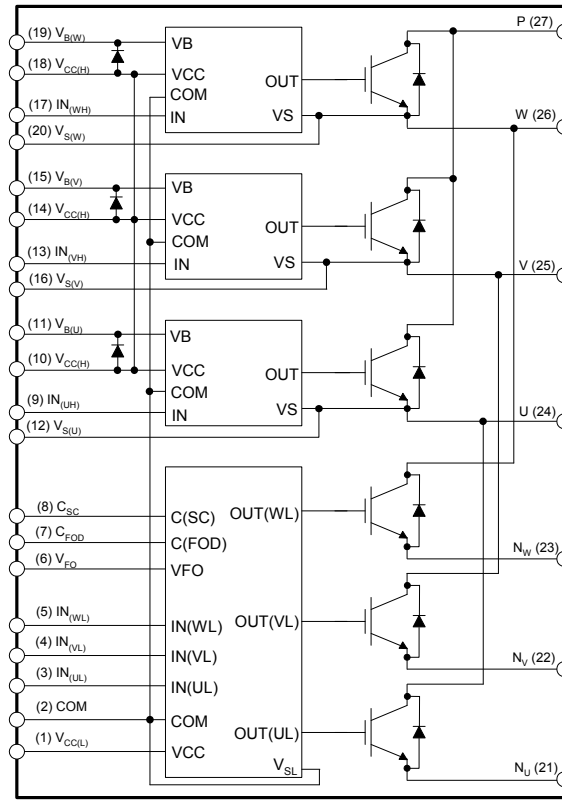


Figure 2. Top View

## 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	$V_{CC(H)}$	High-Side Common Bias Voltage for IC and IGBTs Driving
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	$V_{CC(H)}$	High-Side Common Bias Voltage for IC and IGBTs Driving
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	$V_{CC(H)}$	High-Side Common Bias Voltage for IC and IGBTs Driving
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	$T_C = 25^\circ\text{C}$ , $T_J \leq 150^\circ\text{C}$	20	A
$\pm I_{CP}$	Each IGBT Collector Current (Peak)	$T_C = 25^\circ\text{C}$ , $T_J \leq 150^\circ\text{C}$ , Under 1 ms Pulse Width	40	A
$P_C$	Collector Dissipation	$T_C = 25^\circ\text{C}$ per Chip	62	W
$T_J$	Operating Junction Temperature	(2nd Note 1)	- 40 ~ 150	$^\circ\text{C}$

**2nd Notes:**

1. The maximum junction temperature rating of the power chips integrated within the Motion SPM® 3 product is  $150^\circ\text{C}$  (at  $T_C \leq 125^\circ\text{C}$ ).

**Control Part**

Symbol	Parameter	Conditions	Rating	Unit
$V_{CC}$	Control Supply Voltage	Applied between $V_{CC(H)}$ , $V_{CC(L)}$ - 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 ~ $V_{CC} + 0.3$	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

**Bootstrap Diode Part**

Symbol	Parameter	Conditions	Rating	Unit
$V_{RRM}$	Maximum Repetitive Reverse Voltage		600	V
$I_F$	Forward Current	$T_C = 25^\circ\text{C}$ , $T_J \leq 150^\circ\text{C}$	0.5	A
$I_{FP}$	Forward Current (Peak)	$T_C = 25^\circ\text{C}$ , $T_J \leq 150^\circ\text{C}$ Under 1 ms Pulse Width	2.0	A
$T_J$	Operating Junction Temperature		-40 ~ 150	$^\circ\text{C}$

**Total System**

Symbol	Parameter	Conditions	Rating	Unit
$V_{PN(\text{PROT})}$	Self-Protection Supply Voltage Limit (Short-Circuit Protection Capability)	$V_{CC} = V_{BS} = 13.5 \sim 16.5 \text{ V}$ $T_J = 150^\circ\text{C}$ , Non-Repetitive, < 2 $\mu\text{s}$	400	V
$T_C$	Module Case Operation Temperature	$-40^\circ\text{C} \leq T_J \leq 150^\circ\text{C}$ , 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, Connect Pins to Heat Sink Plate	2500	$V_{rms}$

**Thermal Resistance**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$R_{th(j-c)Q}$	Junction to Case Thermal Resistance	Inverter IGBT part (per 1 / 6 module)	-	-	2.0	$^\circ\text{C} / \text{W}$
$R_{th(j-c)F}$		Inverter FWDi part (per 1 / 6 module)	-	-	3.0	$^\circ\text{C} / \text{W}$

**2nd Notes:**

2. 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	$V_{CC} = V_{BS} = 15\text{ V}$ $V_{IN} = 5\text{ V}$ $I_C = 20\text{ A}$ , $T_J = 25^\circ\text{C}$	-	-	2.0	V
$V_F$	FWDi Forward Voltage	$V_{IN} = 0\text{ V}$ $I_F = 20\text{ A}$ , $T_J = 25^\circ\text{C}$	-	-	2.2	V
HS	$t_{ON}$	$V_{PN} = 300\text{ V}$ , $V_{CC} = V_{BS} = 15\text{ V}$ $I_C = 20\text{ A}$ $V_{IN} = 0\text{ V} \leftrightarrow 5\text{ V}$ , Inductive Load (2nd Note 3)	-	0.75	-	$\mu\text{s}$
	$t_{C(ON)}$		-	0.2	-	$\mu\text{s}$
	$t_{OFF}$		-	0.45	-	$\mu\text{s}$
	$t_{C(OFF)}$		-	0.15	-	$\mu\text{s}$
	$t_{rr}$		-	0.1	-	$\mu\text{s}$
LS	$t_{ON}$	$V_{PN} = 300\text{ V}$ , $V_{CC} = V_{BS} = 15\text{ V}$ $I_C = 20\text{ A}$ $V_{IN} = 0\text{ V} \leftrightarrow 5\text{ V}$ , Inductive Load (2nd Note 3)	-	0.5	-	$\mu\text{s}$
	$t_{C(ON)}$		-	0.3	-	$\mu\text{s}$
	$t_{OFF}$		-	0.45	-	$\mu\text{s}$
	$t_{C(OFF)}$		-	0.15	-	$\mu\text{s}$
	$t_{rr}$		-	0.1	-	$\mu\text{s}$
$I_{CES}$	Collector - Emitter Leakage Current	$V_{CE} = V_{CES}$	-	-	1	mA

**2nd Notes:**

3.  $t_{ON}$  and  $t_{OFF}$  include the propagation delay time 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.

**Control Part**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$I_{QCCL}$	Quiescent $V_{CC}$ Supply Current	$V_{CC} = 15\text{ V}$ $I_{N(UL, VL, WL)} = 0\text{ V}$ $V_{CC(L)} - \text{COM}$	-	-	23	mA
$I_{QCCH}$		$V_{CC} = 15\text{ V}$ $I_{N(UH, VH, WH)} = 0\text{ V}$ $V_{CC(H)} - \text{COM}$	-	-	600	$\mu\text{A}$
$I_{QBS}$	Quiescent $V_{BS}$ Supply Current	$V_{BS} = 15\text{ V}$ $I_{N(UH, VH, WH)} = 0\text{ V}$ $V_{B(U)} - V_{S(U)}$ , $V_{B(V)} - V_{S(V)}$ , $V_{B(W)} - V_{S(W)}$	-	-	500	$\mu\text{A}$
$V_{FOH}$	Fault Output Voltage	$V_{SC} = 0\text{ V}$ , $V_{FO}$ Circuit: 4.7 k $\Omega$ to 5 V Pull-up	4.5	-	-	V
$V_{FOL}$		$V_{SC} = 1\text{ V}$ , $V_{FO}$ Circuit: 4.7 k $\Omega$ to 5 V Pull-up	-	-	0.8	V
$V_{SC(ref)}$	Short-Circuit Current Trip Level	$V_{CC} = 15\text{ V}$ (2nd Note 4)	0.45	0.50	0.55	V
TSD	Over-Temperature Protection	Temperature at LVIC	-	160	-	$^\circ\text{C}$
$\Delta\text{TSD}$	Over-Temperature Protection Hysteresis	Temperature at LVIC	-	5	-	$^\circ\text{C}$
$UV_{CCD}$	Supply Circuit Under-Voltage Protection	Detection Level	10.7	11.9	13.0	V
$UV_{CCR}$		Reset Level	11.2	12.4	13.4	V
$UV_{BSD}$		Detection Level	10	11	12	V
$UV_{BSR}$		Reset Level	10.5	11.5	12.5	V
$t_{FOD}$	Fault-Out Pulse Width	$C_{FOD} = 33\text{ nF}$ (2nd Note 5)	1.0	1.8	-	ms
$V_{IN(ON)}$	ON Threshold Voltage	Applied between $I_{N(UH)}$ , $I_{N(VH)}$ , $I_{N(WH)}$ , $I_{N(UL)}$ , $I_{N(VL)}$ , $I_{N(WL)} - \text{COM}$	2.8	-	-	V
$V_{IN(OFF)}$	OFF Threshold Voltage		-	-	0.8	V

**2nd Notes:**

4. Short-circuit protection is functioning only at the low-sides.  
 5. The fault-out pulse width  $t_{FOD}$  depends on the capacitance value of  $C_{FOD}$  according to the following approximate equation:  $C_{FOD} = 18.3 \times 10^{-6} \times t_{FOD} [\text{F}]$

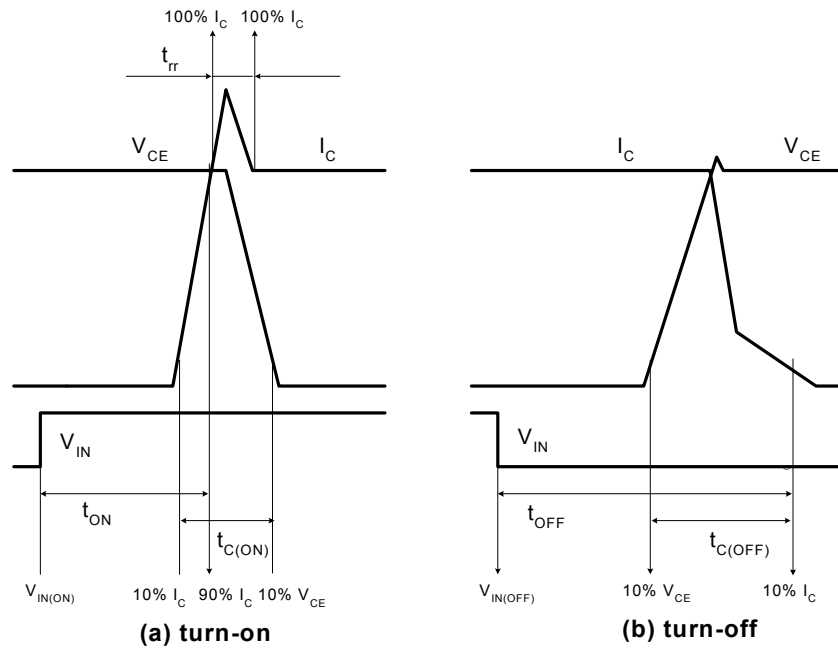


Figure 4. Switching Time Definition

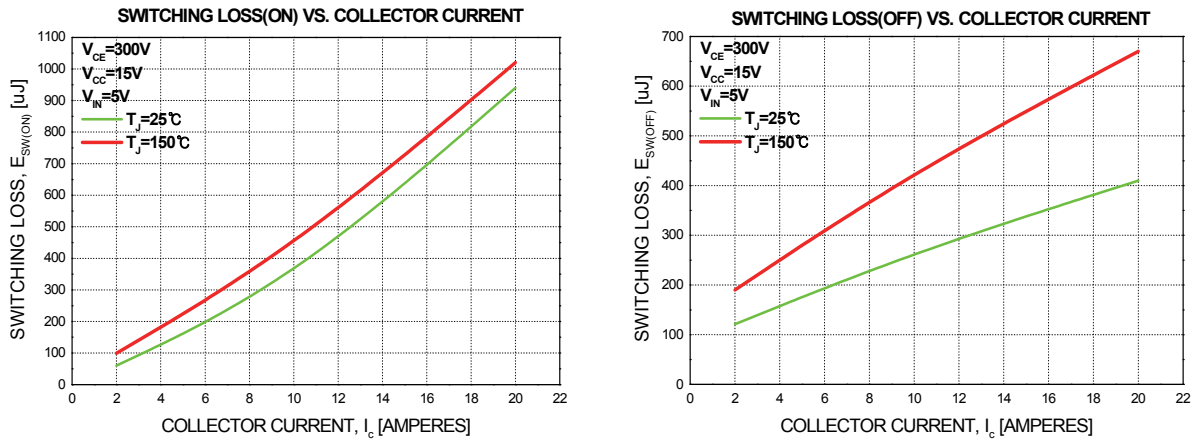
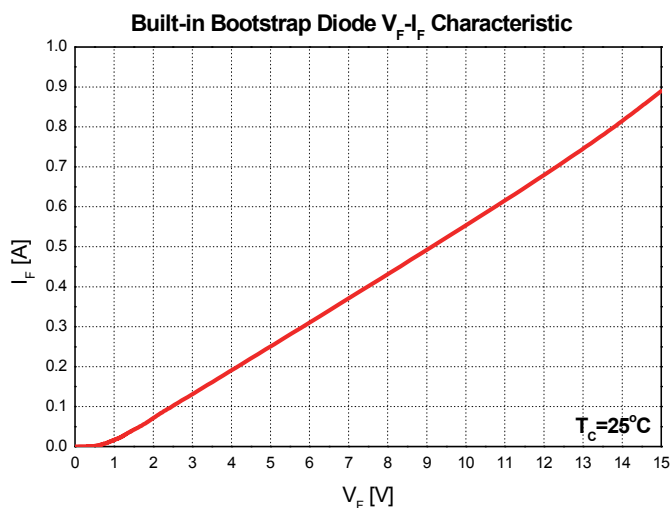


Figure 5. Switching Loss Characteristics (Typical)



**Bootstrap Diode Part**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_F$	Forward Voltage	$I_F = 0.1 \text{ A}$ , $T_C = 25^\circ\text{C}$	-	2.5	-	V
$t_{rr}$	Reverse Recovery Time	$I_F = 0.1 \text{ A}$ , $T_C = 25^\circ\text{C}$	-	80	-	ns

**Figure 6. Built-in Bootstrap Diode Characteristics****2nd Notes:**

6. Built-in bootstrap diode includes around 15  $\Omega$  resistance characteristic.

**Recommended Operating Conditions**

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$V_{PN}$	Supply Voltage	Applied between P - $N_U$ , $N_V$ , $N_W$	-	300	400	V
$V_{CC}$	Control Supply Voltage	Applied between $V_{CC(H)}$ , $V_{CC(L)}$ - COM	13.5	15.0	16.5	V
$V_{BS}$	High-Side Bias Voltage	Applied between $V_{B(U)} - V_{S(U)}$ , $V_{B(V)} - V_{S(V)}$ , $V_{B(W)} - V_{S(W)}$	13.0	15.0	18.5	V
$dV_{CC}/dt$ , $dV_{BS}/dt$	Control Supply Variation		-1	-	1	V / $\mu\text{s}$
$t_{dead}$	Blanking Time for Preventing Arm-Short	Each Input Signal	2	-	-	$\mu\text{s}$
$f_{PWM}$	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
$V_{SEN}$	Voltage for Current Sensing	Applied between $N_U$ , $N_V$ , $N_W$ - 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	0.80	N•m
Device Flatness		See Figure 7	0	-	+120	μm
Weight			-	15.00	-	g

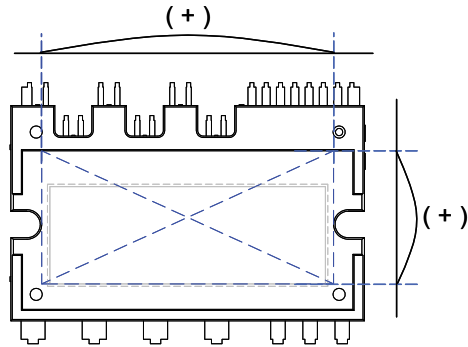
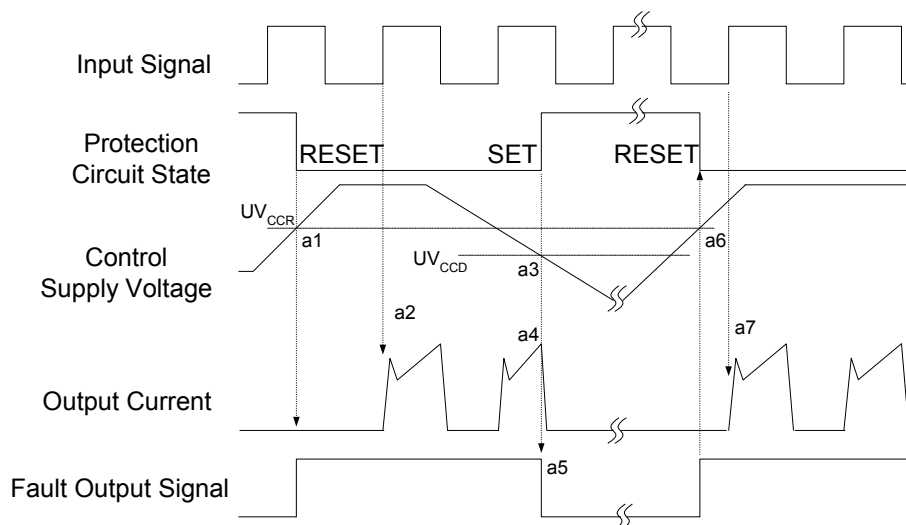


Figure 7. Flatness Measurement Position

## 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 ( $UV_{CCD}$ ).

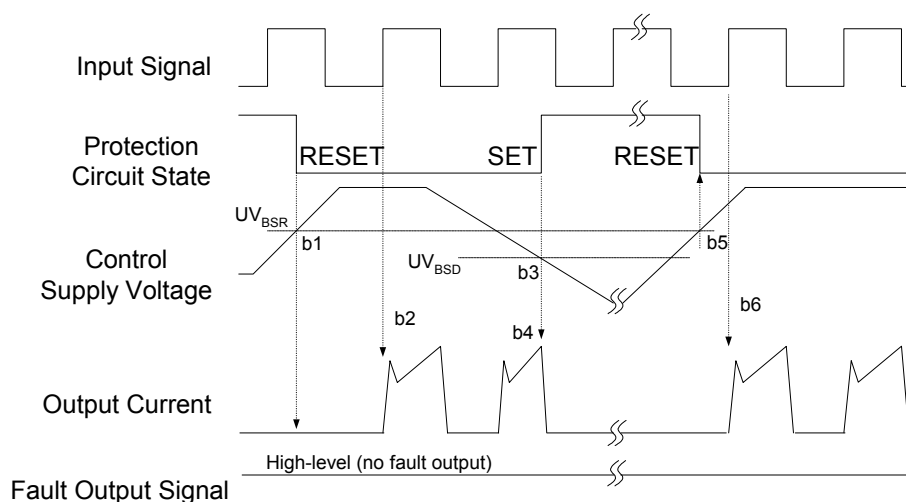
a4 : IGBT OFF in spite of control input condition.

a5 : Fault output operation starts.

a6 : Under-voltage reset ( $UV_{CCR}$ ).

a7 : Normal operation: IGBT ON and carrying current.

**Figure 8. 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.

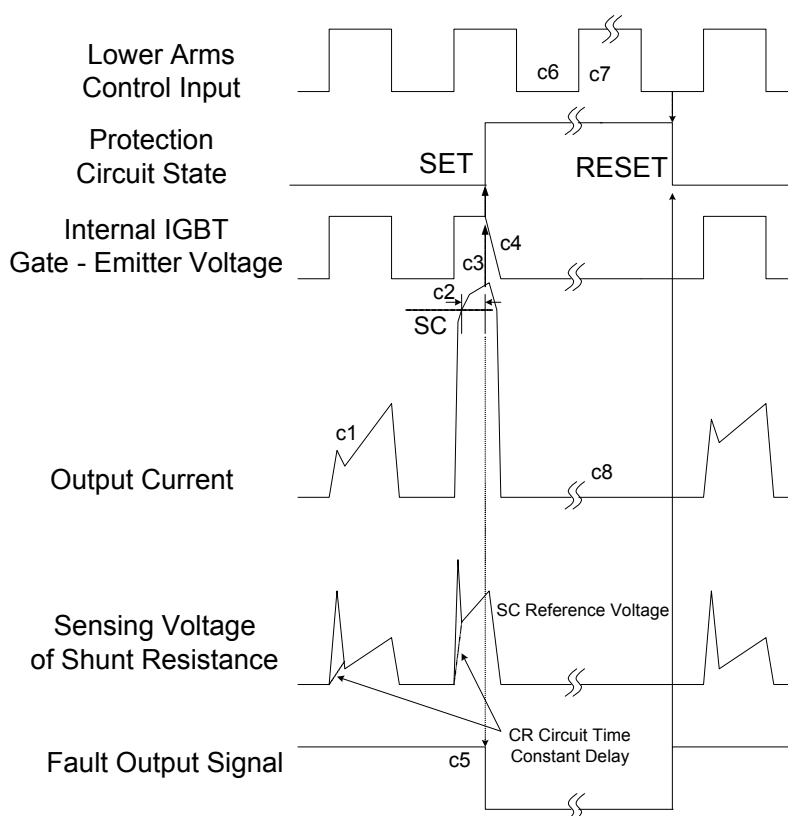
b3 : Under-voltage detection ( $UV_{BSD}$ ).

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 9. 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.

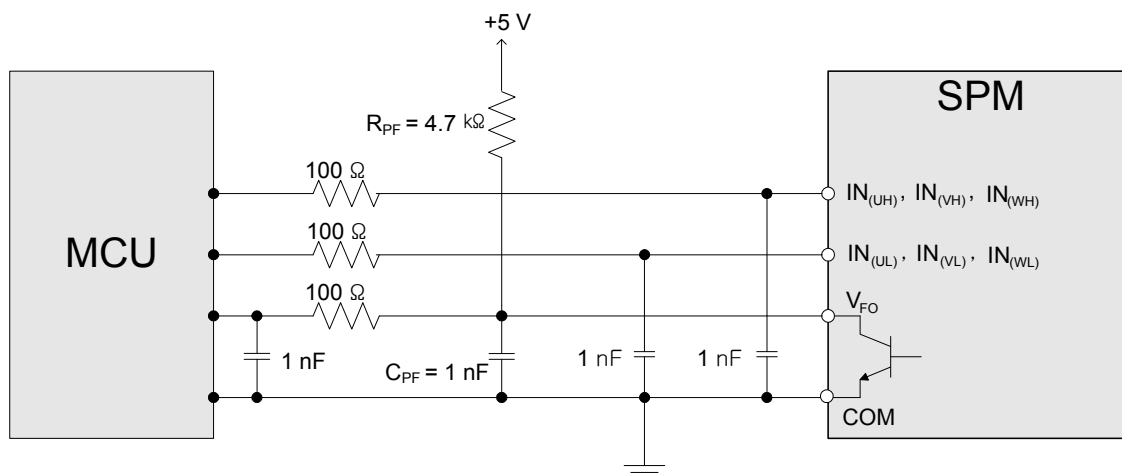
c5 : Fault output timer operation starts: the pulse width of the fault output signal is set by the external capacitor  $C_{FO}$ .

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.

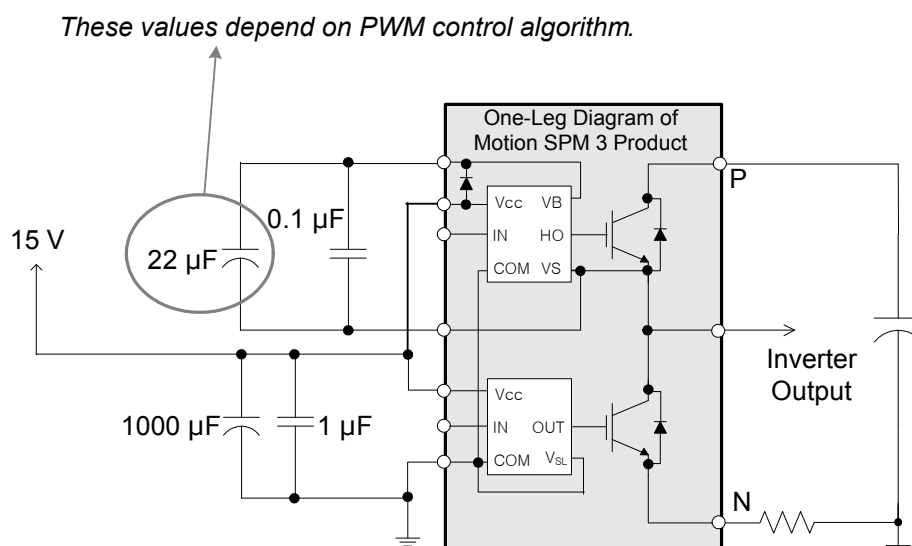
**Figure 10. Short-Circuit Protection (Low-Side Operation Only)**



**Figure 11. Recommended MCU I/O Interface Circuit**

**3rd Notes:**

1. RC coupling at each input might change depending on the PWM control scheme in the application and the wiring impedance of the application's printed circuit board. The input signal section of the Motion SPM® 3 product integrates a 5 kΩ (typ.) pull-down resistor. Therefore, when using an external filtering resistor, please pay attention to the signal voltage drop at input terminal.
2. The logic input works with standard CMOS or LSTTL outputs.



**Figure 12. Recommended Bootstrap Operation Circuit and Parameters**

**3rd Notes:**

3. The ceramic capacitor placed between  $V_{CC}$  - COM should be over 1  $\mu$ F and mounted as close to the pins of the Motion SPM 3 product as possible.

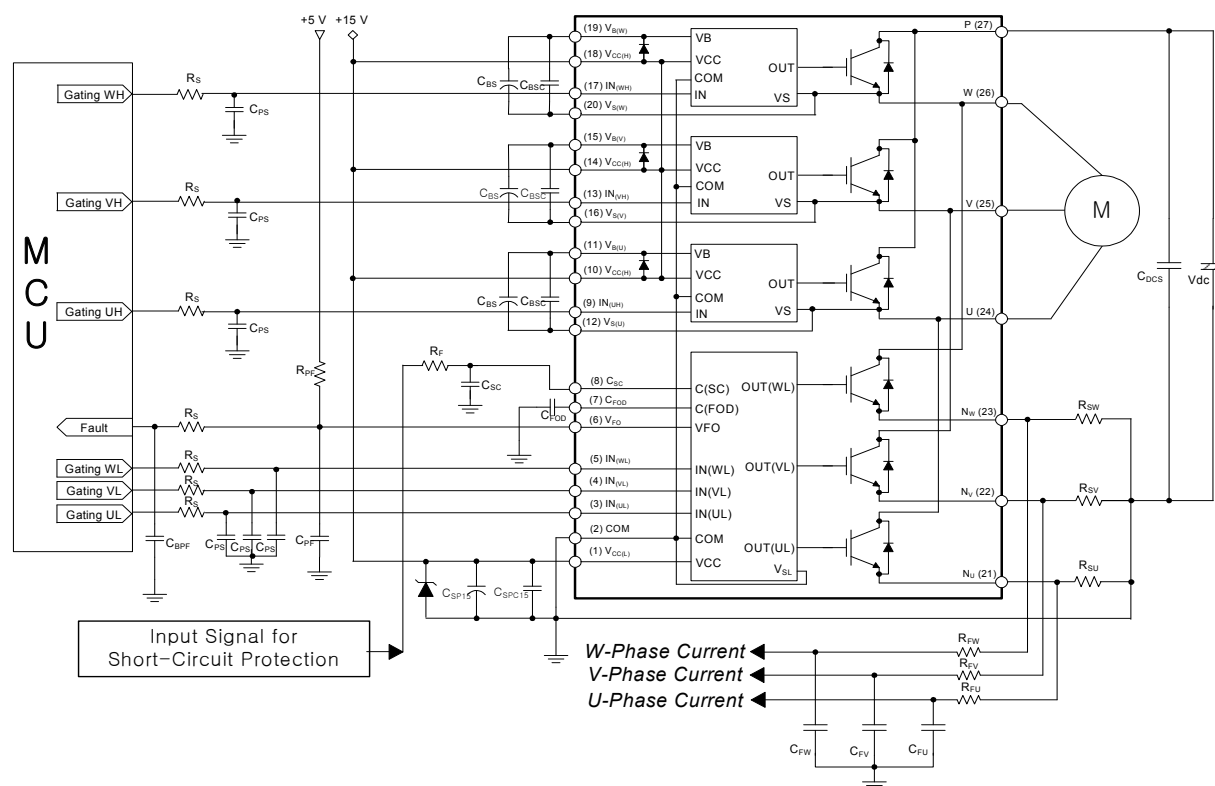
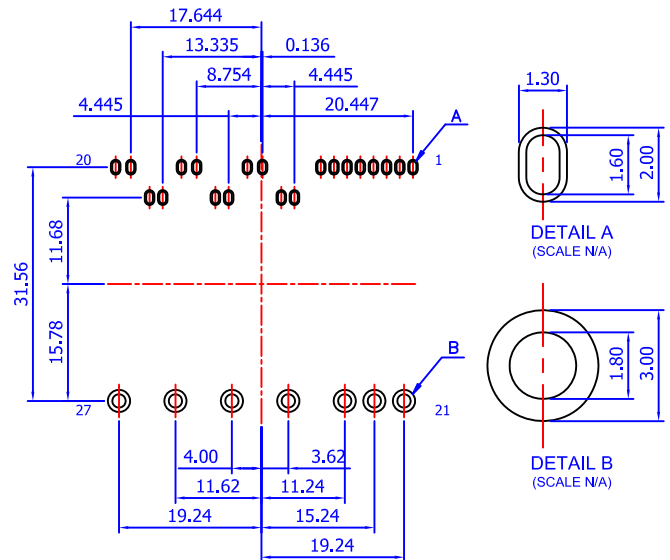
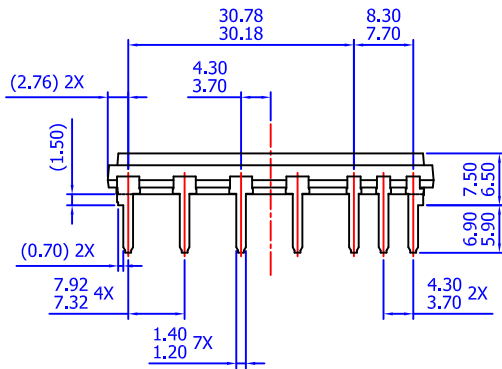
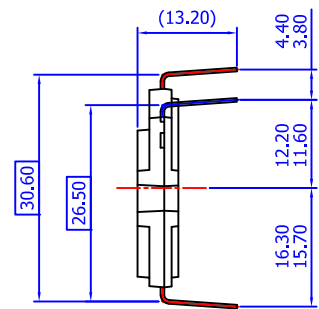
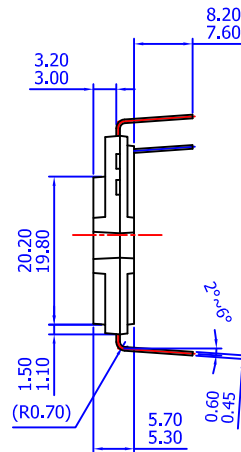
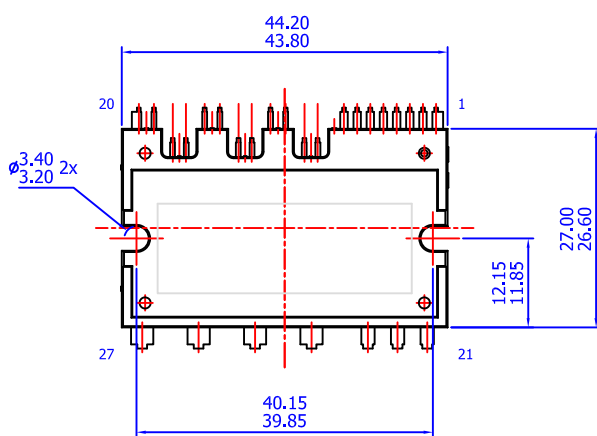
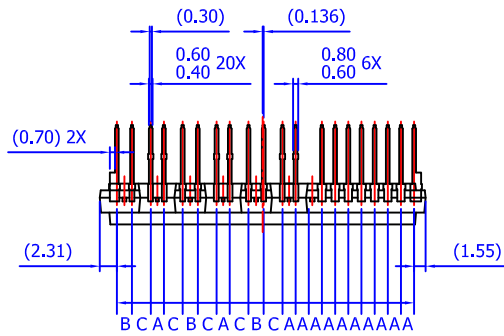


Figure 13. Typical Application Circuit

## 4th Notes:

1. To avoid malfunction, the wiring of each input should be as short as possible (less than 2 - 3cm).
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.  $V_{FO}$  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 k $\Omega$  resistance (please refer to Figure 11).
4.  $C_{SP15}$  of around seven times larger than bootstrap capacitor  $C_{BS}$  is recommended.
5.  $V_{FO}$  output pulse width should be determined by connecting an external capacitor ( $C_{FOD}$ ) between  $C_{FOD}$  (pin 7) and COM (pin 2). (Example: if  $C_{FOD} = 33$  nF, then  $t_{FO} = 1.8$  ms (typ.)) Please refer to the 2nd note 5 for calculation method.
6. 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 used to prevent input signal oscillation.  $R_S C_{PS}$  time constant should be selected in the range 50 ~ 150 ns.  $C_{PS}$  should not be less than 1 nF (recommended  $R_S = 100 \Omega$ ,  $C_{PS} = 1$  nF).
7. To prevent errors of the protection function, the wiring around  $R_F$  and  $C_{SC}$  should be as short as possible.
8. In the short-circuit protection circuit, please select the  $R_F C_{SC}$  time constant in the range 1.5 ~ 2.0  $\mu$ s.
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  $\mu$ F 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.  $C_{SP15}$  should be over 1  $\mu$ F and mounted as close to the pins of the Motion SPM 3 product as possible.



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