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# FNC42060F / FNC42060F2

## Motion SPM® 45 系列

### 特性

- 通过 UL 第 E209204 号认证 (UL1557)
- 600 V - 20 A 三相 IGBT 逆变器，包含栅极驱动和保护的控制 IC
- 使用陶瓷基板实现非常低的热阻
- 低损耗、短路额定的 IGBT
- 内置自举二极管和专用的 Vs 引脚以简化印刷电路板布局
- 内置负温度系数热敏电阻可实现温度监测
- 低端 IGBT 的独立发射极开路引脚用于三相电流感测
- 单接地电源供电
- 针对 5 kHz 开关频率进行优化
- 绝缘等级：2000 V<sub>rms</sub> / 分钟

### 应用

- 运动控制 - 家用设备 / 工业电机

### 相关资料

- [AN-9070 - Motion SPM® 45 Series Users Guide](#)
- [AN-9071 - Motion SPM® 45 Series Thermal Performance Information](#)
- [AN-9072 - Motion SPM® 45 Series Mounting Guidance](#)
- [RD-344 - Reference Design \(Three Shunt Solution\)](#)
- [RD-345 - Reference Design \(One Shunt Solution\)](#)

### 概述

FNC42060F / FNC42060F2 是一款先进的 Motion SPM® 45 模块，为交流感应、BLDC 和 PMSM 电机提供功能齐全的高性能逆变器输出级。这些模块综合优化了内置 IGBT 的栅极驱动以最小化电磁干扰和能量损耗。同时也提供多重模组保护特性，集成欠压闭锁，过流保护，热量监测和故障报告。内置高速 HVIC 芯片仅需要单电源电压并将逻辑电平栅极输入信号转换为高电压、高电流驱动信号，从而有效驱动模块的内部 IGBT。独立的 IGBT 负端在每个相位均有效，可支持大量不同种类的控制算法。

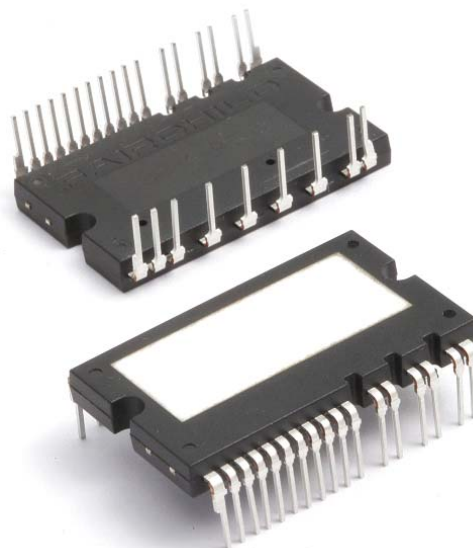


图 1. 封装概览

### 封装标识与订购信息

器件	器件标识	封装	包装类型	数量
FNC42060F	FNC42060F	SPMAA-A26	Rail	12
FNC42060F2	FNC42060F2	SPMAA-C26	Rail	12

## 集成的功率功能

- 600 V - 20 A IGBT 逆变器，适用于三相 DC / AC 功率变换（请参见图 3）

## 集成的驱动、保护和系统控制功能

- 对于逆变器高端 IGBT：栅极驱动电路、高压隔离的高速电平转换控制电路欠压锁定保护（UVLO）
- 对于逆变器低端 IGBT：栅极驱动电路、短路保护 (SCP)、控制电源电路欠压锁定保护（UVLO）
- 故障信号：对应 UVLO（低端电源）和短路故障
- 输入接口：高电平有效接口，可用于 3.3 / 5 V 逻辑电平，施密特触发脉冲输入

## 引脚布局

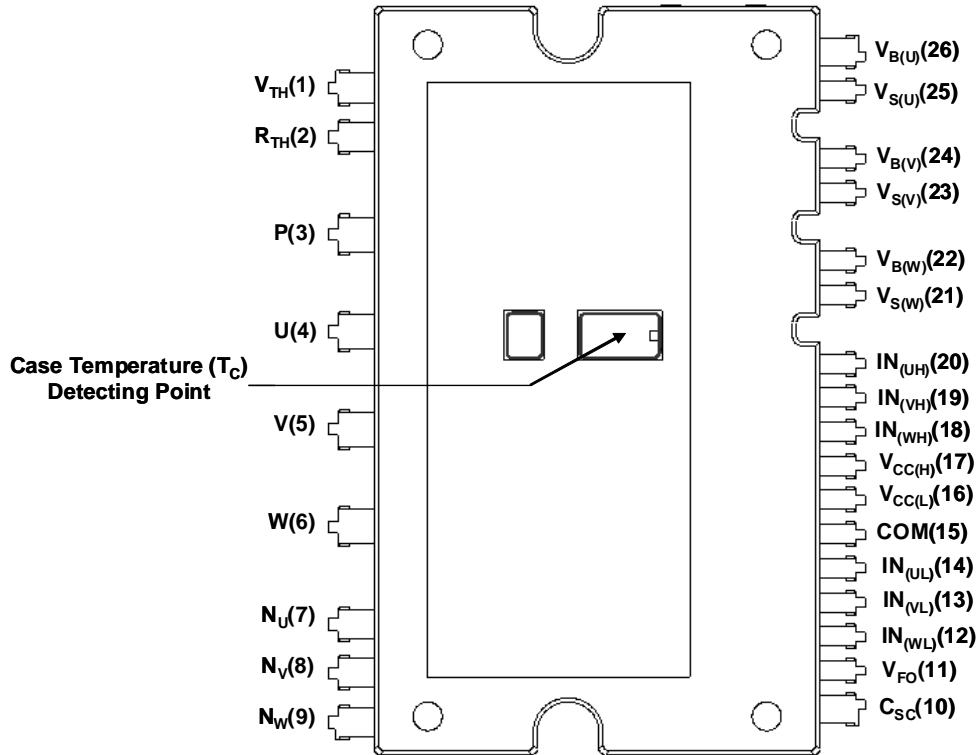


图 2. 俯视图

## 引脚描述

引脚号	引脚名	引脚描述
1	$V_{TH}$	热敏电阻偏压
2	$R_{TH}$	用于热敏电阻（温度检测）的串联电阻
3	P	直流输入正端
4	U	U 相输出
5	V	V 相输出
6	W	W 相输出
7	$N_U$	U 相的直流输入负端
8	$N_V$	V 相的直流输入负端
9	$N_W$	W 相的直流输入负端
10	$C_{SC}$	短路电流感测输入电容（低通滤波器）
11	$V_{FO}$	故障输出
12	$IN_{(WL)}$	低端 W 相的信号输入
13	$IN_{(VL)}$	低端 V 相的信号输入
14	$IN_{(UL)}$	低端 U 相的信号输入
15	COM	公共电源接地
16	$V_{CC(L)}$	IC 和 IGBT 驱动的低端公共偏压
17	$V_{CC(H)}$	IC 和 IGBT 驱动的高端公共偏压
18	$IN_{(WH)}$	高端 W 相的信号输入
19	$IN_{(VH)}$	高端 V 相的信号输入
20	$IN_{(UH)}$	高端 U 相的信号输入
21	$V_{S(W)}$	W 相 IGBT 驱动的高端偏压接地
22	$V_{B(W)}$	W 相 IGBT 驱动的高端偏压
23	$V_{S(V)}$	V 相 IGBT 驱动的高端偏压接地
24	$V_{B(V)}$	V 相 IGBT 驱动的高端偏压
25	$V_{S(U)}$	U 相 IGBT 驱动的高端偏压接地
26	$V_{B(U)}$	U 相 IGBT 驱动的高端偏压

### 内部等效电路与输入 / 输出引脚



图 3. 内部框图

**注:**

1. 逆变器的高端由三个 IGBT 及相应的续流二极管和一个控制 IC 组成。
2. 逆变器的低端由三个 IGBT 及相应的续流二极管和一个控制 IC 组成。具有栅极驱动和保护功能。
3. 逆变器的功率端由逆变器的四个直流母线输入端和三个输出端组成。

**绝对最大额定值** ( $T_J = 25^\circ\text{C}$ , 除非另有说明。)**逆变器部分**

符号	参数	工作条件	额定值	单位
$V_{PN}$	电源电压	施加在 P - $N_U$ , $N_V$ , $N_W$ 之间	450	V
$V_{PN}$ (浪涌)	电源电压 (浪涌)	施加在 P - $N_U$ , $N_V$ , $N_W$ 之间	500	V
$V_{CES}$	集电极 - 发射极之间电压		600	V
$\pm I_C$	单个 IGBT 的集电极电流	$T_C = 25^\circ\text{C}$ , $T_J < 150^\circ\text{C}$	20	A
$\pm I_{CP}$	单个 IGBT 的集电极电流 (峰值)	$T_C = 25^\circ\text{C}$ , $T_J < 150^\circ\text{C}$ , 脉冲宽度小于 1 ms	40	A
$P_C$	集电极功耗	$T_C = 25^\circ\text{C}$ , 单个芯片	50	W
$T_J$	工作结温	(注 1)	-40 ~ 150	$^\circ\text{C}$

注:

1. Motion SPM® 45 内部集成的功率芯片的最大额定结温是  $150^\circ\text{C}$ 。**控制部分**

符号	参数	工作条件	额定值	单位
$V_{CC}$	控制电源电压	施加在 $V_{CC(H)}$ , $V_{CC(L)}$ - COM 之间	20	V
$V_{BS}$	高端控制偏压	施加在 $V_{B(U)}$ - $V_{S(U)}$ , $V_{B(V)}$ - $V_{S(V)}$ , $V_{B(W)}$ - $V_{S(W)}$	20	V
$V_{IN}$	输入信号电压	施加在 $IN_{(UH)}$ , $IN_{(VH)}$ , $IN_{(WH)}$ , $IN_{(UL)}$ , $IN_{(VL)}$ , $IN_{(WL)}$ - COM 之间	-0.3 ~ $V_{CC} + 0.3$	V
$V_{FO}$	故障输出电源电压	施加在 $V_{FO}$ - COM 之间	-0.3 ~ $V_{CC} + 0.3$	V
$I_{FO}$	故障输出电流	$V_{FO}$ 引脚处的灌电流	1	mA
$V_{SC}$	电流感测输入电压	施加在 $C_{SC}$ - COM 之间	-0.3 ~ $V_{CC} + 0.3$	V

**自举二极管部分**

符号	参数	工作条件	额定值	单位
$V_{RRM}$	最大重复反向电压		600	V
$I_F$	正向电流	$T_C = 25^\circ\text{C}$ , $T_J < 150^\circ\text{C}$	0.50	A
$I_{FP}$	正向电流 (峰值)	$T_C = 25^\circ\text{C}$ , $T_J < 150^\circ\text{C}$ , 脉冲宽度小于 1 ms	1.50	A
$T_J$	工作结温		-40 ~ 150	$^\circ\text{C}$

**整个系统**

符号	参数	工作条件	额定值	单位
$V_{PN(Prot)}$	自我保护电源电压限制 (短路保护能力)	$V_{CC} = V_{BS} = 13.5 \sim 16.5 \text{ V}$ $T_J = 150^\circ\text{C}$ , 非重复性, $< 2 \mu\text{s}$	400	V
$T_{STG}$	存储温度		-40 ~ 125	$^\circ\text{C}$
$V_{ISO}$	绝缘电压	60 Hz, 正弦波形, 交流 1 分钟, 连接陶瓷基板到引脚	2000	$V_{rms}$

**热阻**

符号	参数	工作条件	最小值	典型值	最大值	单位
$R_{th(j-c)Q}$	结点 - 壳体的热阻	逆变器 IGBT 部分 (每 1/6 模块)	-	-	2.5	$^\circ\text{C}/\text{W}$
$R_{th(j-c)F}$		逆变器 FWD 部分 (每 1/6 模块)	-	-	3.6	$^\circ\text{C}/\text{W}$

注:

2. 关于壳体温度 ( $T_C$ ) 的测量点, 参见图 2。

**电气特性** ( $T_J = 25^\circ\text{C}$ , 除非另有说明。)

**逆变器部分**

符号	参数	工作条件	最小值	典型值	最大值	单位	
$V_{CE(SAT)}$	集电极 - 发射极间饱和电压	$V_{CC} = V_{BS} = 15\text{ V}$ $V_{IN} = 5\text{ V}$ $I_C = 20\text{ A}, T_J = 25^\circ\text{C}$	-	1.85	2.35	V	
$V_F$	FWD 正向电压	$V_{IN} = 0\text{ V}$ $I_F = 20\text{ A}, T_J = 25^\circ\text{C}$	-	1.95	2.45	V	
HS	开关时间	$V_{PN} = 300\text{ V}, V_{CC} = V_{BS} = 15\text{ V}, I_C = 20\text{ A}$ $T_J = 25^\circ\text{C}$ $V_{IN} = 0\text{ V} \leftrightarrow 5\text{ V}$ , 电感负载 (注 3)	$t_{ON}$	0.45	0.75	1.25	$\mu\text{s}$
			$t_{C(ON)}$	-	0.20	0.45	$\mu\text{s}$
			$t_{OFF}$	-	0.70	1.20	$\mu\text{s}$
			$t_{C(OFF)}$	-	0.15	0.40	$\mu\text{s}$
			$t_{rr}$	-	0.15	-	$\mu\text{s}$
LS		$V_{PN} = 300\text{ V}, V_{CC} = V_{BS} = 15\text{ V}, I_C = 20\text{ A}$ $T_J = 25^\circ\text{C}$ $V_{IN} = 0\text{ V} \leftrightarrow 5\text{ V}$ , 电感负载 (注 3)	$t_{ON}$	0.45	0.75	1.25	$\mu\text{s}$
			$t_{C(ON)}$	-	0.20	0.45	$\mu\text{s}$
			$t_{OFF}$	-	0.75	1.25	$\mu\text{s}$
			$t_{C(OFF)}$	-	0.15	0.40	$\mu\text{s}$
			$t_{rr}$	-	0.15	-	$\mu\text{s}$
$I_{CES}$	集电极 - 发射极间漏电流	$V_{CE} = V_{CES}$	-	-	5	mA	

注:

3.  $t_{ON}$  和  $t_{OFF}$  包括模块内部驱动 IC 的传输延迟时间。 $t_{C(ON)}$  和  $t_{C(OFF)}$  指在内部给定的栅极驱动条件下, IGBT 本身的开关时间。详细信息, 请参见图 4。

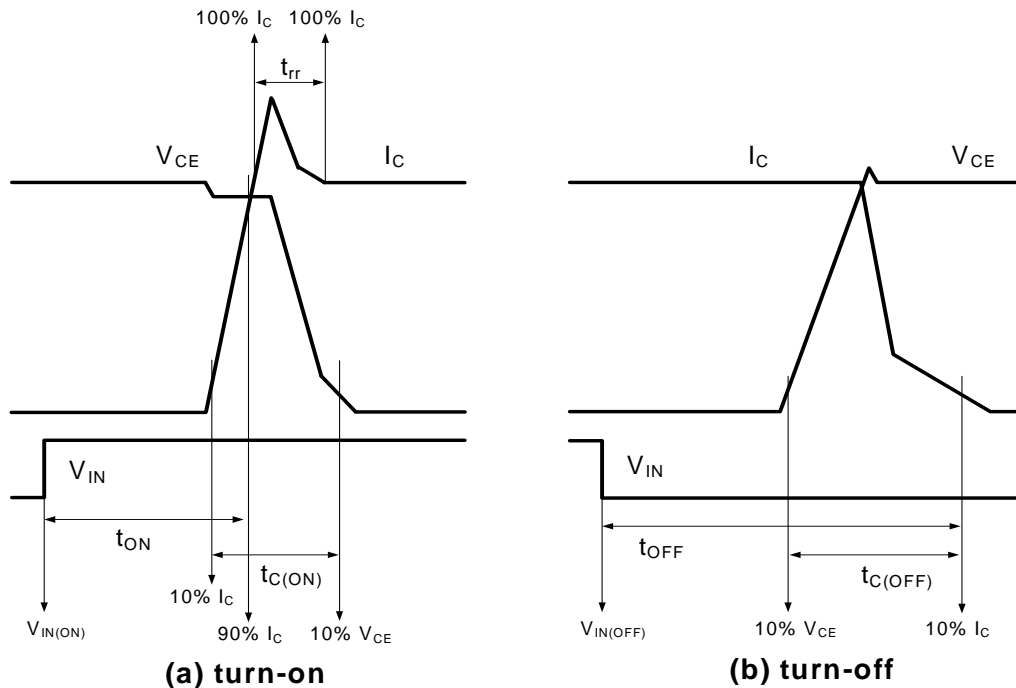


图 4. 开关时间的定义

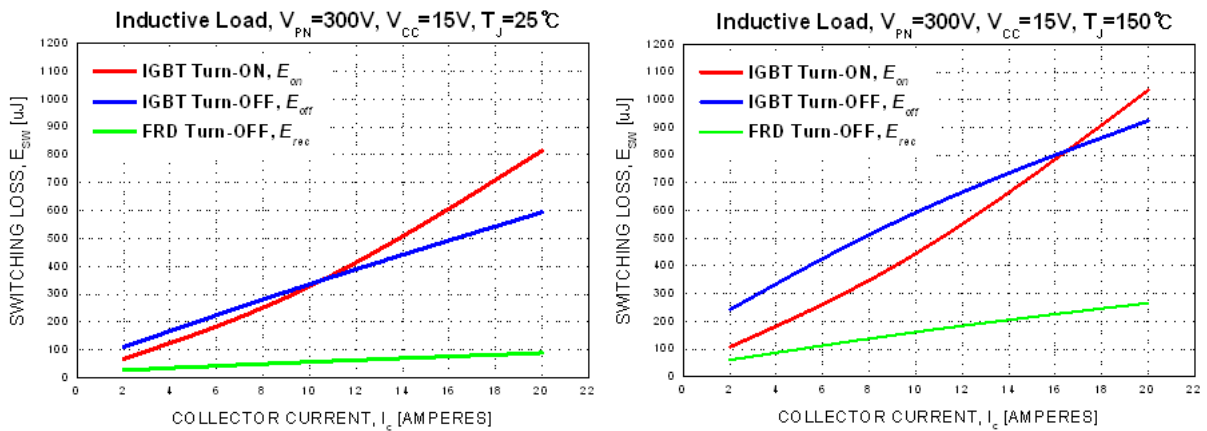


图 5. 开关损耗特性（典型值）

控制部分

符号	参数	工作条件	最小值	典型值	最大值	单位
$I_{QCCH}$	$V_{CC}$ 静态电源电流	$V_{CC(H)} = 15 V, I_{N(UH, VH, WH)} = 0 V$	$V_{CC(H)} - COM$	-	-	0.10 mA
$I_{QCCL}$		$V_{CC(L)} = 15 V, I_{N(UL, VL, WL)} = 0 V$	$V_{CC(L)} - COM$	-	-	2.65 mA
$I_{PCCH}$	$V_{CC}$ 电源电流	$V_{CC(L)} = 15 V, f_{PWM} = 20 kHz$ , 占空比 = 50%, 施加于高端的一个 PWM 信号输入	$V_{CC(H)} - COM$	-	-	0.15 mA
$I_{PCCL}$		$V_{CC(L)} = 15 V, f_{PWM} = 20 kHz$ , 占空比 = 50%, 施加于低端的一个 PWM 信号输入	$V_{CC(L)} - COM$	-	-	4.00 mA
$I_{QBS}$	$V_{BS}$ 静态电源电流	$V_{BS} = 15 V, I_{N(UH, VH, WH)} = 0 V$	$V_{B(U)} - V_{S(U)}, V_{B(V)} - V_{S(V)}, V_{B(W)} - V_{S(W)}$	-	-	0.30 mA
$I_{PBS}$	$V_{BS}$ 工作电源电流	$V_{CC} = V_{BS} = 15 V, f_{PWM} = 20 kHz$ , 占空比 = 50%, 施加于高端的一个 PWM 信号输入	$V_{B(U)} - V_{S(U)}, V_{B(V)} - V_{S(V)}, V_{B(W)} - V_{S(W)}$	-	-	2.00 mA
$V_{FOH}$	故障输出电压	$V_{SC} = 0 V, V_{FO}$ 电路: 10 kΩ 至 5 V 上拉	4.5	-	-	V
$V_{FOL}$		$V_{SC} = 1 V, V_{FO}$ 电路: 10 kΩ 至 5 V 上拉	-	-	0.5	V
$V_{SC(ref)}$	短路触发电平	$V_{CC} = 15 V$ (注 4)	0.45	0.50	0.55	V
$UV_{CCD}$	电源电路欠压保护	检测电平	10.5	-	13.0	V
$UV_{CCR}$		复位电平	11.0	-	13.5	V
$UV_{BSD}$		检测电平	10.0	-	12.5	V
$UV_{BSR}$		复位电平	10.5	-	13.0	V
$t_{FOD}$	故障输出脉宽		30	-	-	μs
$V_{IN(ON)}$	导通阈值电压	施加在 $I_{N(UH)}, I_{N(VH)}, I_{N(WH)}, I_{N(UL)}, I_{N(VL)}, I_{N(WL)}$ - COM 之间	-	-	2.6	V
$V_{IN(OFF)}$	关断阈值电压		0.8	-	-	V
$R_{TH}$	阻值 (热敏电阻)	@ $T_{TH} = 25^\circ C$ , (注 5)	-	47	-	kΩ
		@ $T_{TH} = 100^\circ C$	-	2.9	-	kΩ

注:

4. 短路电流保护仅作用于低端。
5.  $T_{TH}$  为热敏电阻自身的温度。若需获得结壳温度 ( $T_C$ ), 请根据具体应用进行试验。



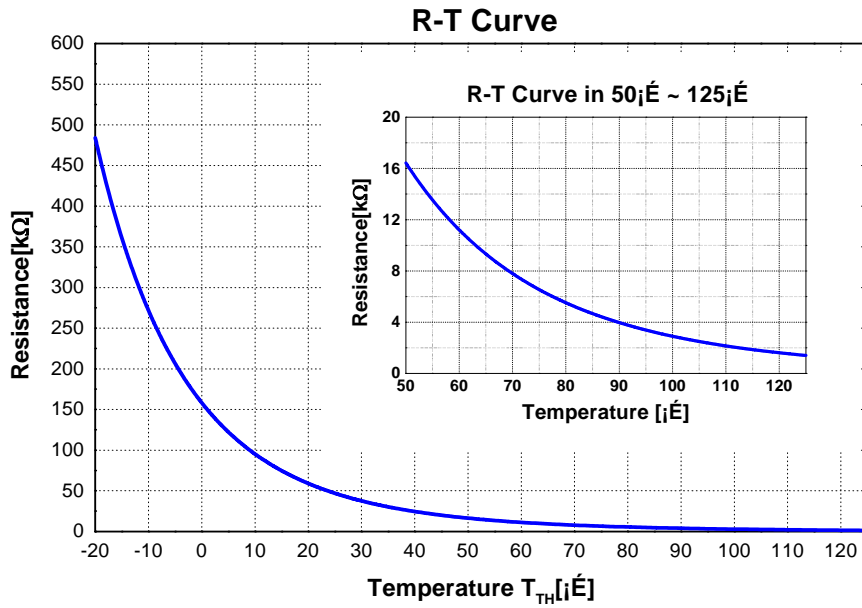


图 .6. 内置热敏电阻的 R-T 曲线

**自举二极管部分**

符号	参数	工作条件	最小值	典型值	最大值	单位
$V_F$	正向电压	$I_F = 0.1 \text{ A}, T_C = 25^\circ\text{C}$	-	2.5	-	V
$t_{rr}$	反向恢复时间	$I_F = 0.1 \text{ A}, T_C = 25^\circ\text{C}$	-	80	-	ns

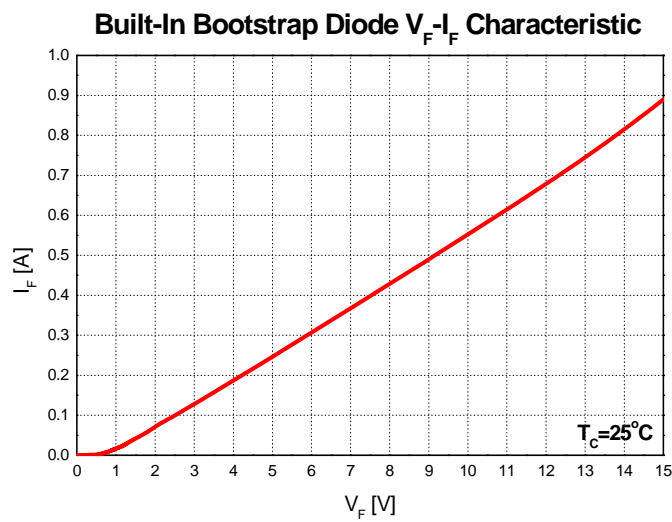


图 7. 内置自举二极管特性

注:

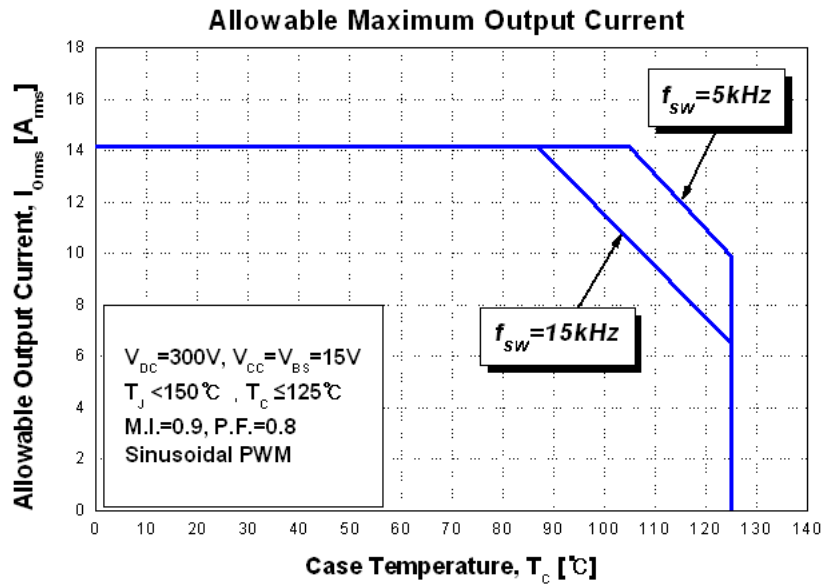
6. 内置自举二极管其阻抗特性约为 15 Ω。

### 推荐工作条件

符号	参数	工作条件	最小值	典型值	最大值	单位
$V_{PN}$	电源电压	施加在 P - $N_U, N_V, N_W$ 之间	-	300	400	V
$V_{CC}$	控制电源电压	施加在 $V_{CC(H)}, V_{CC(L)}$ 之间	13.5	15.0	16.5	V
$V_{BS}$	高端偏压	施加在 $V_{B(U)} - V_{S(U)}, V_{B(V)} - V_{S(V)}, V_{B(W)} - V_{S(W)}$	13.0	15.0	18.5	V
$dV_{CC}/dt, dV_{BS}/dt$	控制电源波动		-1	-	1	V/ $\mu$ s
$t_{dead}$	防止桥臂直通的死区时间	适用于每个输入信号	1.5	-	-	$\mu$ s
$f_{PWM}$	PWM 输入信号	$-40^\circ\text{C} < T_J < 150^\circ\text{C}$	-	-	20	kHz
$V_{SEN}$	电流感测的电压	施加在 $N_U, N_V, N_W - COM$ 之间 (包括浪涌电压)	-4		4	V
$P_{WIN(ON)}$	最小输入脉宽	(注 7)	0.7	-	-	$\mu$ s
$P_{WIN(OFF)}$			0.7	-	-	

注:

7. 此产品可能不会响应, 若输入脉宽值低于最低推荐值。



注:

8. 这个允许输出电流值为此产品安全工作时的参考值。考虑到实际应用和工作条件, 它可能会改变。

### 机械特性和额定值

参数	工作条件		最小值	典型值	最大值	单位
器件平面度	见图 9		0	-	+ 120	μm
安装扭矩	安装螺钉: M3	建议 0.7 N·m	0.6	0.7	0.8	N·m
	见图 10	建议 7.1 kg·cm	6.2	7.1	8.1	kg·cm
重量			-	11.00	-	g

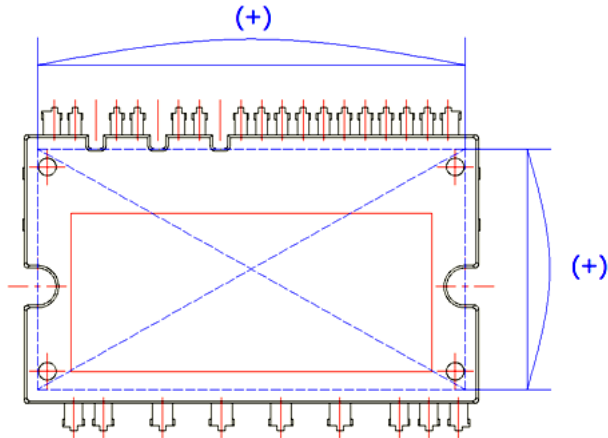


图 9. 平面度测量位置

Pre - Screwing : 1→2

Final Screwing : 2→1

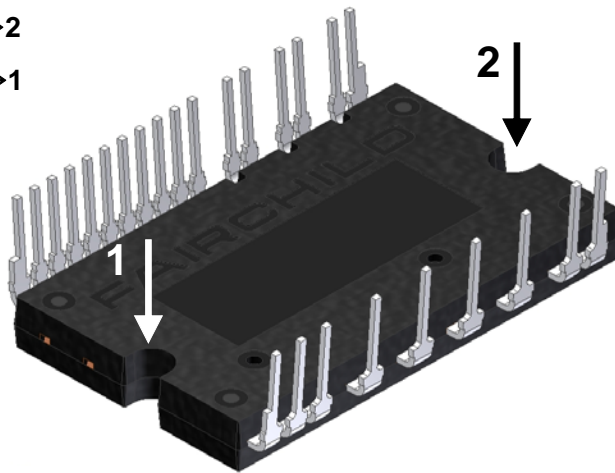


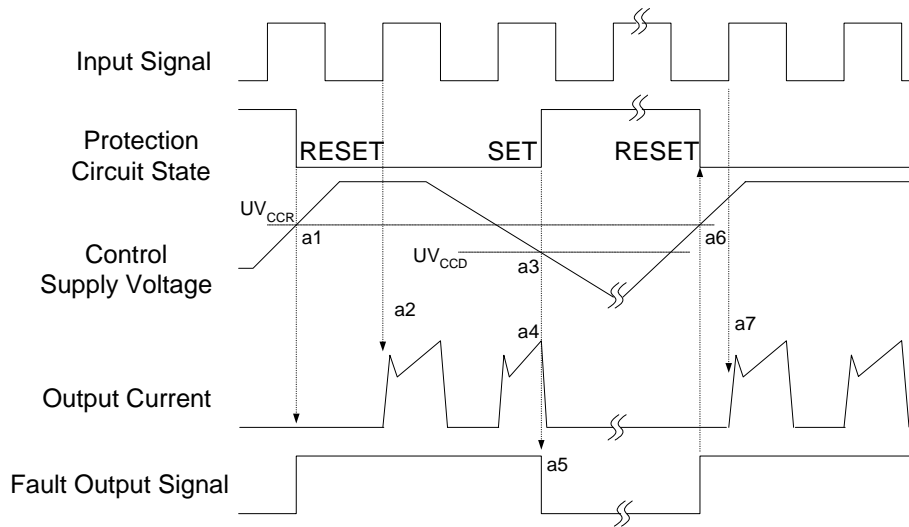
图 10. 安装螺钉时的扭紧顺序

注:

9. 安装或扭动螺丝时切勿过分用力。扭力过大会造成陶瓷破裂，产生毛刺并破坏铝质散热片。

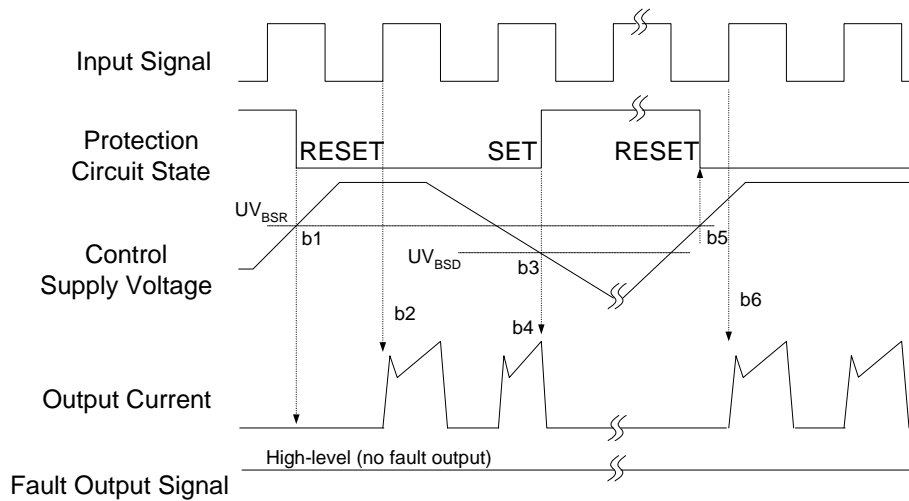
10. 避免用力不均衡。图 10 显示了安装螺钉时，推荐的扭紧顺序。不平坦的安装会导致 SPM® 45 封装的陶瓷基板损坏。预旋紧扭矩约为最大额定扭矩的 20~30%。

### 保护功能时序图



- a1: 控制电源电压上升: 当电压上升到  $UV_{CCR}$  后, 等到下一个开通信号时, 对应的电路才开始动作。
- a2: 正常工作: IGBT 导通并加载负载电流。
- a3: 欠压检测 ( $UV_{CCD}$ )。
- a4: 不论控制输入的条件, IGBT 都关断。
- a5: 故障输出工作启动。
- a6: 欠压复位 ( $UV_{CCR}$ )。
- a7: 正常工作: IGBT 导通并加载负载电流。

图 11. 欠压保护 (低端)



- b1: 控制电源电压上升: 当电压上升到  $UV_{BSR}$  后, 等到下一个输入信号时, 对应的电路才开始动作。
- b2: 正常工作: IGBT 导通并加载负载电流。
- b3: 欠压检测 ( $UV_{BSD}$ )。
- b4: 不论控制输入的条件, IGBT 都关闭, 且无故障输出信号。
- b5: 欠压复位 ( $UV_{BSR}$ )。
- b6: 正常工作: IGBT 导通并加载负载电流。

图 12. 欠压保护 (高端)

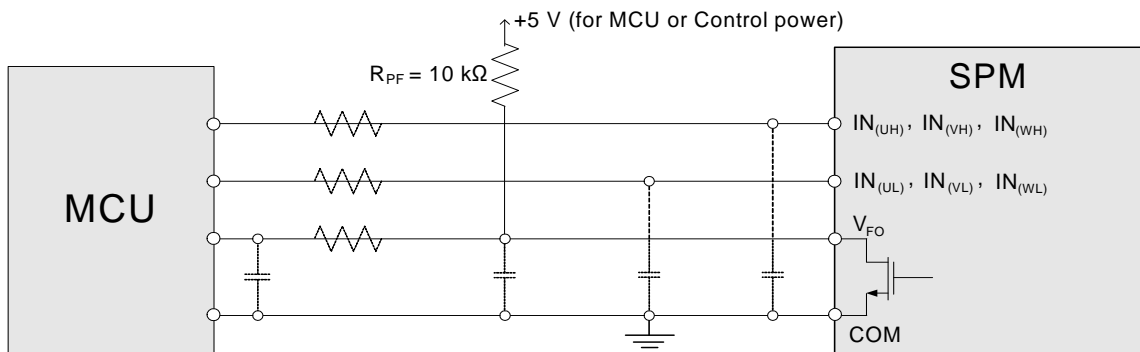


(包含外部分流电阻和 CR 连接)

- c1: 正常工作: IGBT 导通并加载负载电流。
- c2: 短路电流感测 (SC 触发)。
- c3: IGBT 栅极硬中断。
- c4: IGBT 关断。
- c5: 输入 "LOW": IGBT 关断状态。
- c6: 输入 "HIGH": IGBT 导通, 但是在故障输出有效的时间内, IGBT 不导通。
- c7: IGBT 关断状态。

**图 13. 短路保护 (仅适用于低端工作)**

### 输入 / 输出接口电路



**图 14. 推荐的 MCU I/O 接口电路**

注:

11. 每个输入端的 RC 耦合 (虚线显示部分) 可能随着应用程序中使用的 PWM 控制方案和应用程序印刷电路板接线阻抗而改变。Motion SPM® 45 产品的输入信号部分集成了典型值为 5 kΩ (的下拉电阻。因此, 当使用外部的滤波电阻时, 请注意该信号在输入端的压降。

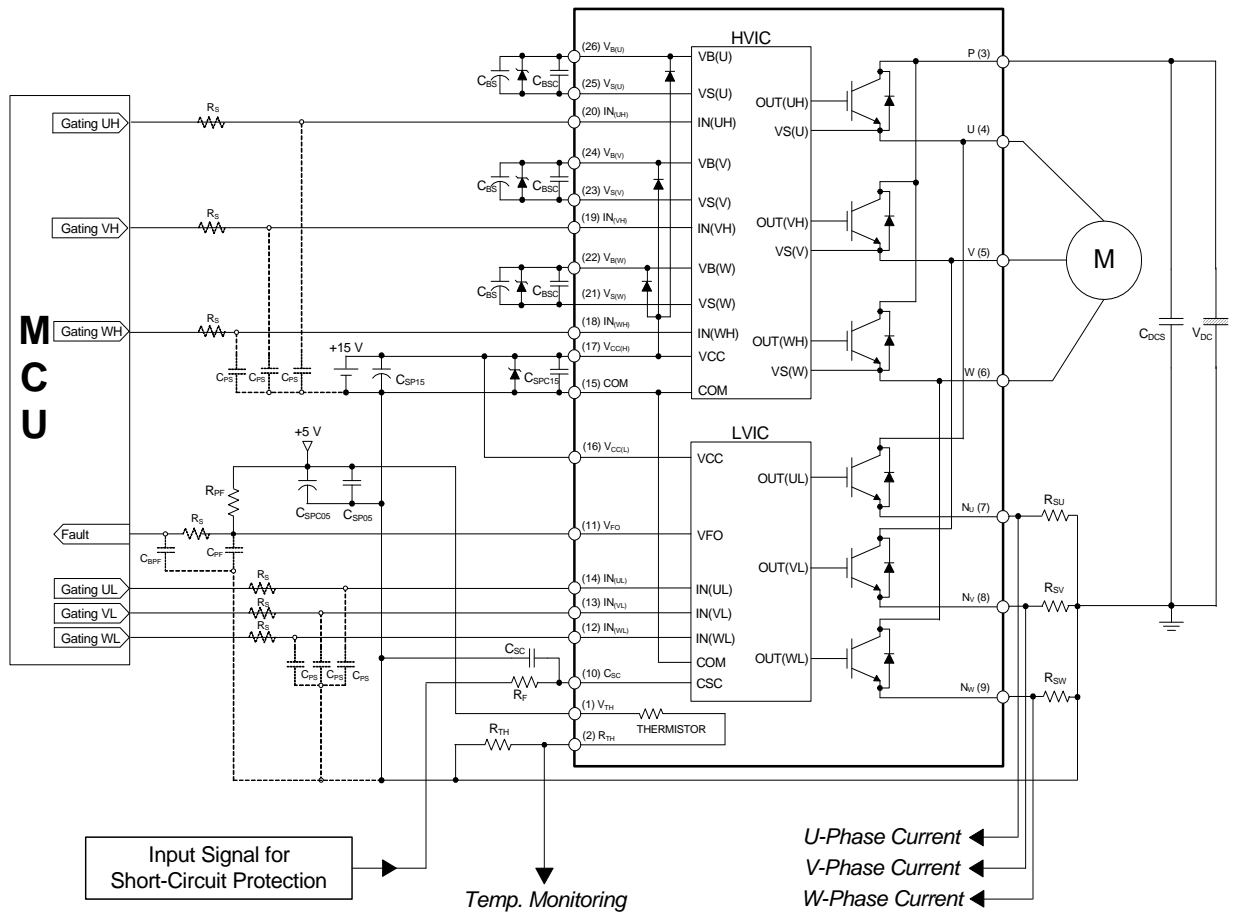


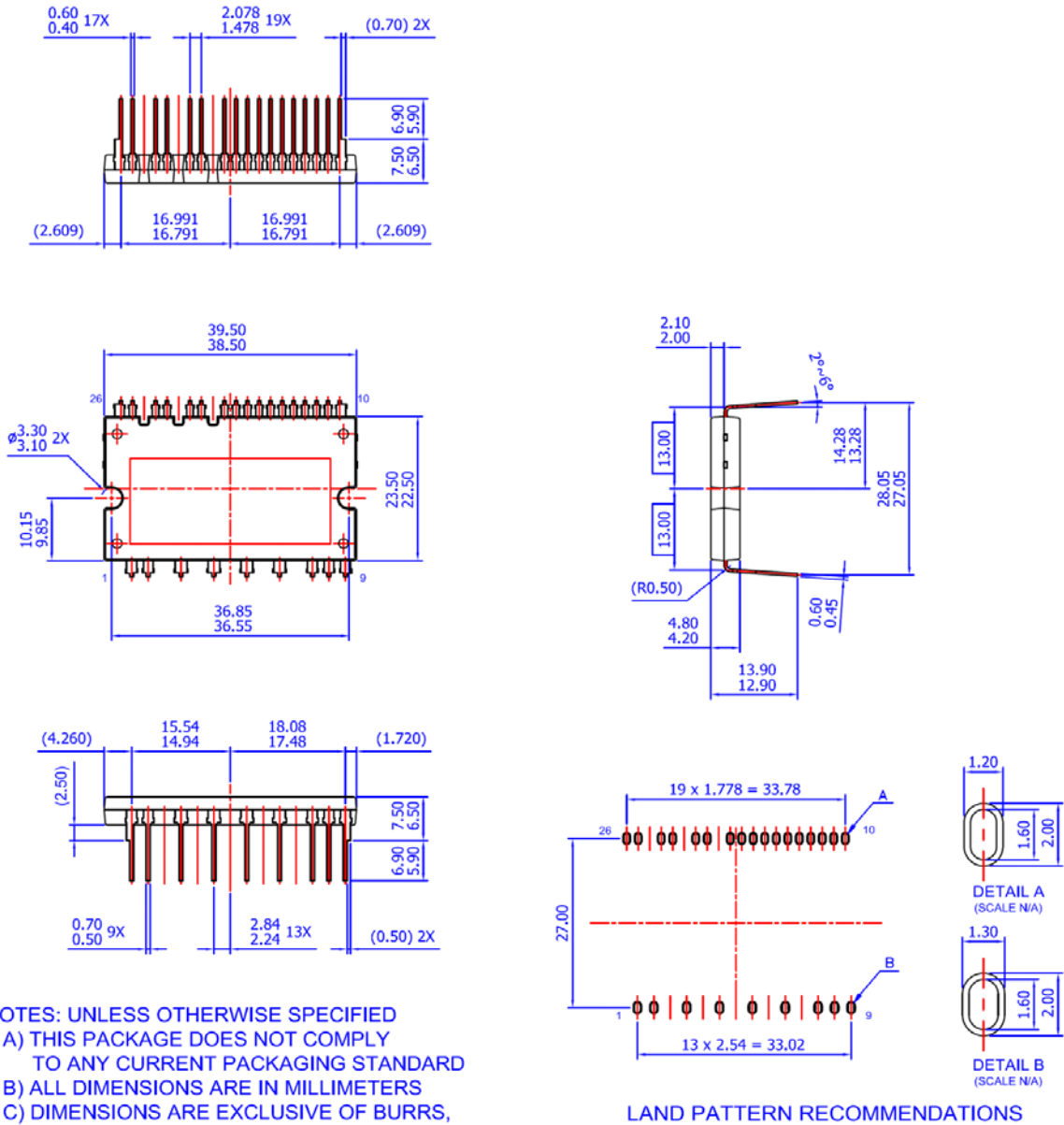
图 15. 典型应用电路

注:

- 1) 为了避免故障，每个输入端的连线必须尽可能短（小于 2-3cm）。
- 2) 因为 Motion SPM® 45 产品 内部集成了一个具有特殊功能的 HVIC 芯片，接口电路与 CPU 终端的直接耦合是可行的，不需要任何光耦合器或变压器隔离。
- 3) V<sub>F0</sub> 输出是漏极开路型。此信号线应该用电阻上拉至 MCU 或控制电源正极，以使 I<sub>F0</sub> 达到 1mA（请参考图 14）。
- 4) 推荐 C<sub>SP15</sub> 的取值应大于自举电容 C<sub>BS</sub> 的 7 倍左右。
- 5) 输入信号为高电平有效。在 IC 中，有一个 5 kΩ 的电阻将每一个输入信号线下拉接地。应采用 RC 耦合电路，以避免输入信号波动。R<sub>S</sub>C<sub>PS</sub> 时间常数应在 50 ~ 150 ns 的范围内进行选择（建议 R<sub>S</sub> = 100 Ω, C<sub>PS</sub> = 1 nF）。
- 6) 为了防止保护功能出错，R<sub>F</sub> 和 C<sub>SC</sub> 周围的连线应该尽可能的短。
- 7) 在短路保护电路中，R<sub>F</sub>C<sub>SC</sub> 的时间常数应在 1.5 ~ 2 μs 的范围内选取。
- 8) 控制 GND 线和功率 GND 线包括 N<sub>U</sub>, N<sub>V</sub>, N<sub>W</sub> 必须连接在同一点上。请不要用宽的模块连接控制 GND 线和功率 GND 线。同时，控制 GND 线和功率 GND 线之间的接线距离应该尽可能的短。
- 9) 每个电容都应尽可能地靠近 Motion SPM 45 产品的引脚安装。
- 10) 为防止浪涌的破坏，应尽可能缩短滤波电容和 P & GND 引脚间的连线。推荐在 P 和 GND 引脚间使用 0.1 ~ 0.22 μF 的高频无感电容。
- 11) 在各种家用电器设备系统中，几乎都用到了继电器。在这些情况下，MCU 和继电器之间应留有足够的距离。
- 12) 在每一对控制电源端应该采用齐纳二极管或者瞬态电压抑制器来保护 IC 不受浪涌破坏（推荐 22 V / 1 W，齐纳阻抗特性低于 15 Ω 的齐纳二极管）。
- 13) 请为 C<sub>BS</sub> 选择温度特性好的电解电容。同时，为 CBSC 选择 0.1 ~ 0.2 μF 温度和频率特性好的 R- 类陶瓷电容。
- 14) 详细类容，请参考 AN-9070, AN-9071, AN-9072, RD-344 和 RD-345。



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