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FNA51560T1/T3

Motion SPM® 55 系列

特性

- 通过 UL 第 E209204 号认证 (UL1557)
- 600 V - 15 A 三相 IGBT 逆变器 (包含提供栅极驱动和保护的控制 IC)
- 低损耗、短路额定的 IGBT
- 低端 IGBT 的独立发射极开路引脚用于三相电流感测
- 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
- 互锁功能
- 用于栅极驱动和欠压保护的 HVIC
- 内置于 HVIC 的温度感测
- 针对 5 kHz 开关频率进行优化
- 绝缘等级: 1500 V_{rms} / 分钟

应用

- 运动控制 — 家用设备 / 工业电机

相关资料

概述

FNA51560T1/T3 是一款先进的 Motion SPM 55 模块, 为交流感应、无刷直流电机和 PMSM 电机提供非常全面的高性能逆变器输出平台。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、互锁功能、过流保护、驱动 IC 的热量监测和故障报告。内置的高速 HVIC 只需要一个单电源电压, 将逻辑电平栅极输入转化为适合驱动模块强健的短路额定的 IGBT 的高电压, 高电流驱动信号。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。

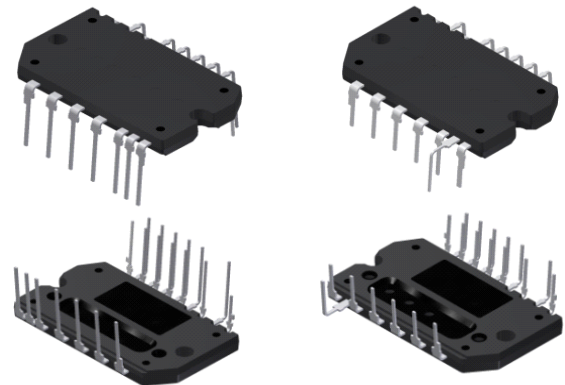


图 1. 封装概览

封装标识与订购信息

器件	器件标识	封装	包装类型	数量
FNA51560T1	FNA51560T1	SPMFA-B20	Rail	13
FNA51560T3	FNA51560T3	SPMFA-A20	Rail	13

集成的功率功能

- 600 V - 15 A IGBT 逆变器，适用于三相 DC / AC 功率转换（请参阅图 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

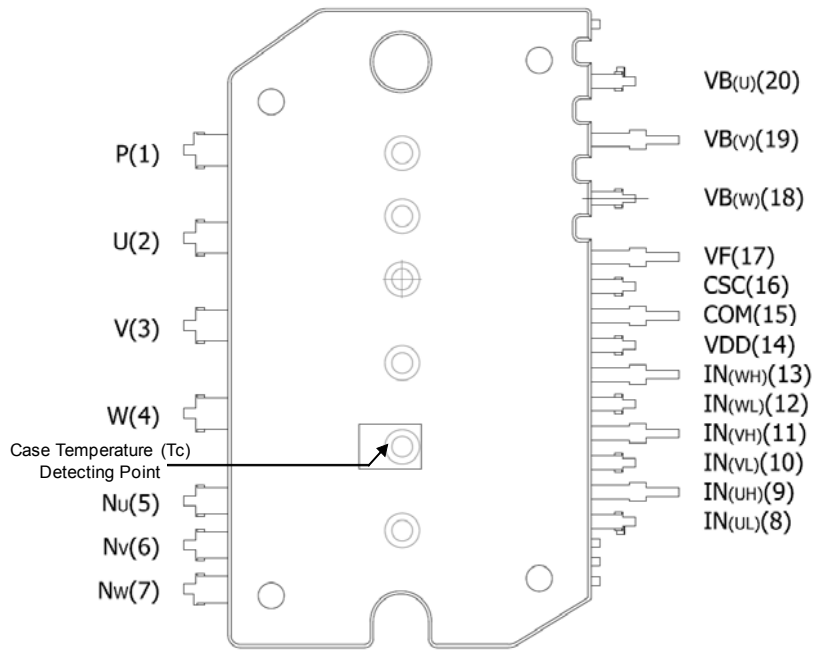


图 2. 俯视图

引脚描述

引脚号	引脚名	引脚描述
1	P	直流输入正端
2	U, V _{S(U)}	U 相输出
3	V, V _{S(V)}	V 相输出
4	W, V _{S(W)}	W 相输出
5	N _U	U 相的直流输入负端
6	N _V	V 相的直流输入负端
7	N _W	W 相的直流输入负端
8	IN _(UL)	低端 U 相的信号输入
9	IN _(UH)	高端 U 相的信号输入
10	IN _(VL)	低端 V 相的信号输入
11	IN _(VH)	高端 V 相的信号输入
12	IN _(WL)	低端 W 相的信号输入
13	IN _(WH)	高端 W 相的信号输入
14	V _{DD}	IC 和 IGBT 驱动的公共偏压
15	COM	公共电源接地
16	C _{SC}	短路电流感测输入电容（低通滤波器）
17	V _F	故障输出，关闭输入，驱动 IC 的温度输出
18	V _{B(W)}	W 相 IGBT 驱动的高端偏压
19	V _{B(V)}	V 相 IGBT 驱动的高端偏压
20	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

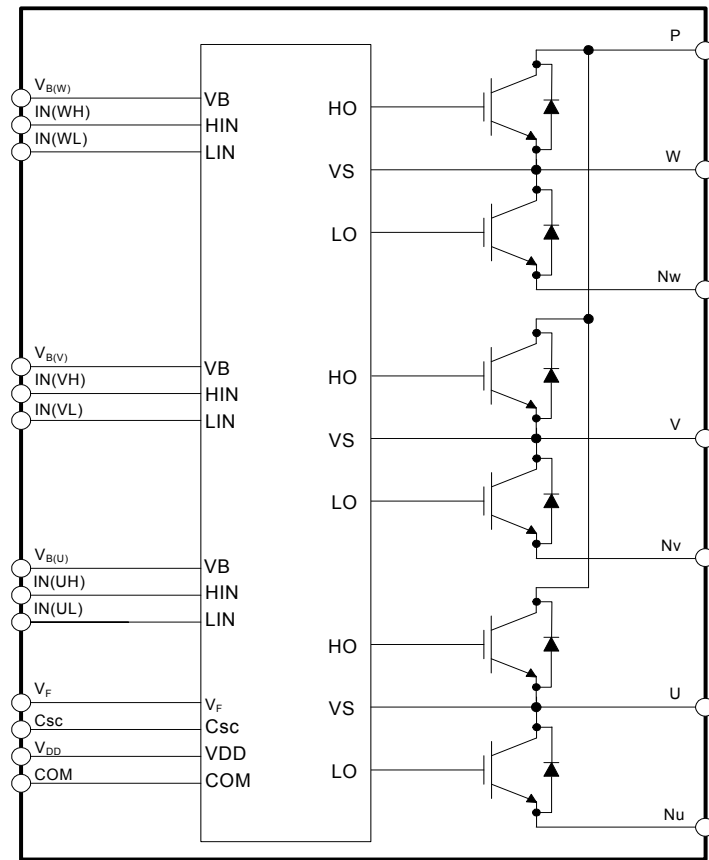


图 3. 内部框图

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. 包含 6 个 IGBT 的栅极驱动和保护功能的单驱动 IC
4. 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	$T_C = 25^\circ\text{C}$, $T_J < 150^\circ\text{C}$	15	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	30	A
P_C	集电极功耗	$T_C = 25^\circ\text{C}$, 单个芯片	27	W
T_J	工作结温	(注 5)	-40 ~ 150	$^\circ\text{C}$

注:

5. Motion SPM® 55 产品中集成的功率芯片的最大结温额定值为 150°C 。**控制部分**

符号	参数	工作条件	额定值	单位
V_{DD}	控制电源电压	施加在 V_{DD} - 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	$-0.3 \sim V_{DD} + 0.3$	V
V_F	故障电源电压	施加在 V_F - COM 之间	$-0.3 \sim V_{DD} + 0.3$	V
I_F	故障电流	V_F 引脚处的灌电流	5	mA
V_{SC}	电流感测输入电压	施加在 C_{SC} - COM 之间	$-0.3 \sim V_{DD} + 0.3$	V

整个系统

符号	参数	工作条件	额定值	单位
$V_{PN(Prot)}$	自我保护限制电源电压 (短路保护能力)	$V_{DD} = V_{BS} = 13.5 \sim 16.5 \text{ V}$ $T_J = 150^\circ\text{C}$, 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	1500	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)	-	-	4.55	$^\circ\text{C} / \text{W}$
$R_{th(j-c)F}$		逆变器 FWD 部分 (每 1 / 6 模块)	-	-	5.4	$^\circ\text{C} / \text{W}$

注:

6. 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	$V_{DD} = V_{BS} = 15\text{ V}$ $V_{IN} = 5\text{ V}$ $I_C = 15\text{ A}$	$T_J = 25^\circ\text{C}$	-	1.45	1.85	V
			$T_J = 150^\circ\text{C}$		1.65		V
V_F	FWD 正向电压	$V_{IN} = 0\text{ V}$ $I_F = 15\text{ A}$	$T_J = 25^\circ\text{C}$	-	1.7	2.1	V
			$T_J = 150^\circ\text{C}$		1.7		V
HS	开关时间	$V_{PN} = 400\text{ V}, V_{DD} = V_{BS} = 15\text{ V}, I_C = 15\text{ A}$ $T_J = 25^\circ\text{C}$ $V_{IN} = 0\text{ V} \leftrightarrow 5\text{ V}$, 电感负载 (注 7)	t_{ON}	-	700	-	ns
			$t_{C(ON)}$	-	140	-	ns
			t_{OFF}	-	850	-	ns
			$t_{C(OFF)}$	-	140	-	ns
			t_{rr}	-	85	-	ns
LS	开关时间	$V_{PN} = 400\text{ V}, V_{DD} = V_{BS} = 15\text{ V}, I_C = 15\text{ A}$ $T_J = 25^\circ\text{C}$ $V_{IN} = 0\text{ V} \leftrightarrow 5\text{ V}$, 电感负载 (注 7)	t_{ON}	-	800	-	ns
			$t_{C(ON)}$	-	250	-	ns
			t_{OFF}	-	850	-	ns
			$t_{C(OFF)}$	-	150	-	ns
			t_{rr}	-	90	-	ns
I_{CES}	集电极 — 发射极间漏电流	$V_{CE} = V_{CES}$	-	-	1	mA	

注:

7. 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。

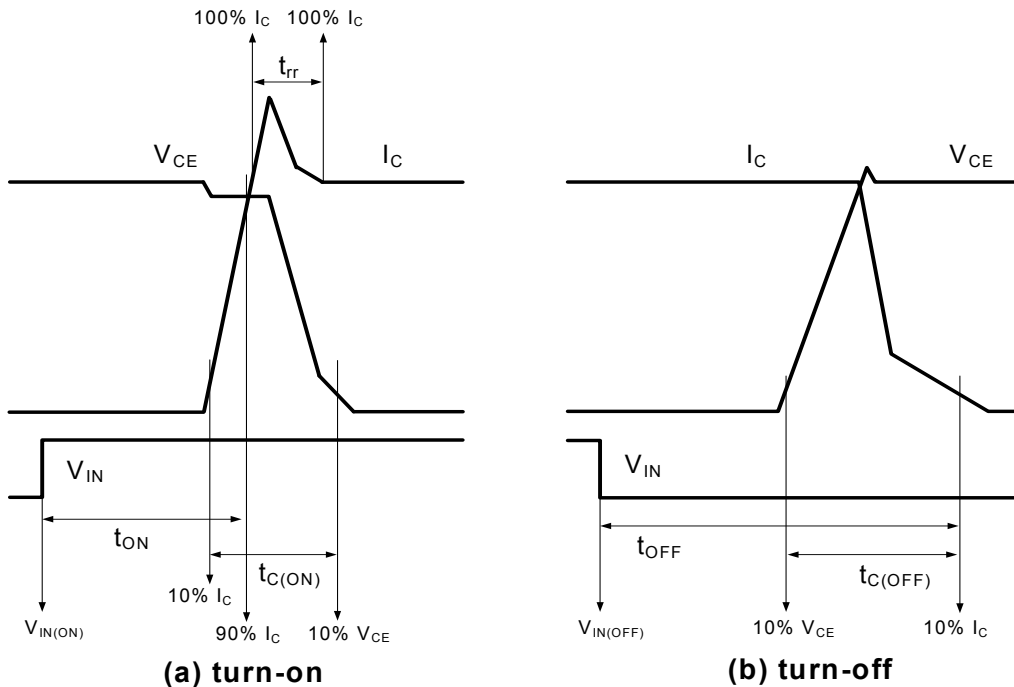


图 4. 开关时间的定义

控制部分

符号	参数	工作条件	最小值	典型值	最大值	单位	
I_{QDD}	V_{DD} 静态电源电流	$V_{DD} = 15\text{ V}$, $I_{N(UH, VH, WH, UL, VL, WL)} = 0\text{ V}$	$V_{DD} - \text{COM}$	-	2.0	2.6	mA
I_{PDD}	V_{DD} 工作电源电流	$V_{DD} = 15\text{ V}$, $f_{PWM} = 20\text{ kHz}$, duty = 50%, 施加一个 PWM 信号输入	$V_{DD} - \text{COM}$	-	2.5	3.5	mA
I_{QBS}	V_{BS} 静态电源电流	$V_{BS} = 15\text{ V}$, $I_{N(UH, VH, WH)} = 0\text{ V}$	$V_{B(U)} - V_{S(U)}$, $V_{B(V)} - V_{S(V)}$, $V_{B(W)} - V_{S(W)}$	-	70	100	μA
I_{PBS}	V_{BS} 工作电源电流	$V_{DD} = V_{BS} = 15\text{ V}$, $f_{PWM} = 20\text{ kHz}$, duty = 50%, 施加于高端的一个 PWM 信号输入	$V_{B(U)} - V_{S(U)}$, $V_{B(V)} - V_{S(V)}$, $V_{B(W)} - V_{S(W)}$	-	600	800	μA
V_{FH}	故障输出电压	$V_{SC} = 0\text{ V}$, V_F 电路: 4.7 k Ω 至 5 V 上拉	4.5	-	-	V	
V_{FL}		$V_{SC} = 1\text{ V}$, V_F 电路: 4.7 k Ω 至 5 V 上拉	-	-	0.5	V	
$V_{SC(ref)}$	短路触发电平	$V_{DD} = 15\text{ V}$ (注 4)	0.45	0.5	0.55	V	
UV_{DDD}	电源电路欠压保护	检测电平	10.0	11.5	13.0	V	
UV_{DDR}		复位电平	10.5	12.0	13.5	V	
UV_{BSD}		检测电平	9.5	11.0	12.5	V	
UV_{BSR}		复位电平	10.0	11.5	13.0	V	
V_{FT}	HVIC 温度感应电压	$V_{DD} = V_{BS} = 15\text{ V}$, $T_{HVIC} = 25^\circ\text{C}$, 4.7 k Ω 至 5 V 上拉 (图 5)	4.43	4.58	4.71	V	
t_{FOD}	故障输出脉宽		40	100	-	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	-	-	2.4	V	
$V_{IN(OFF)}$	关断阈值电压		0.8	-	-	V	

注:

8. 短路保护作用于全部 6 个 IGBT。

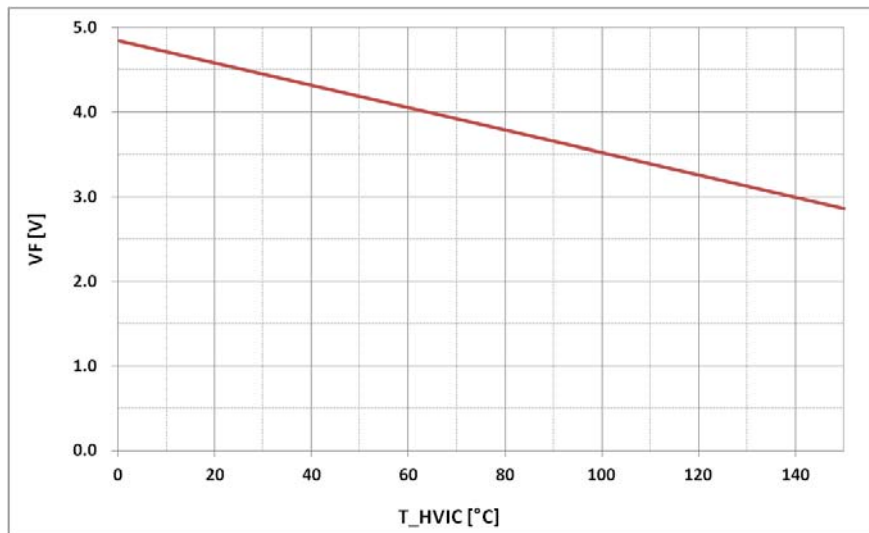


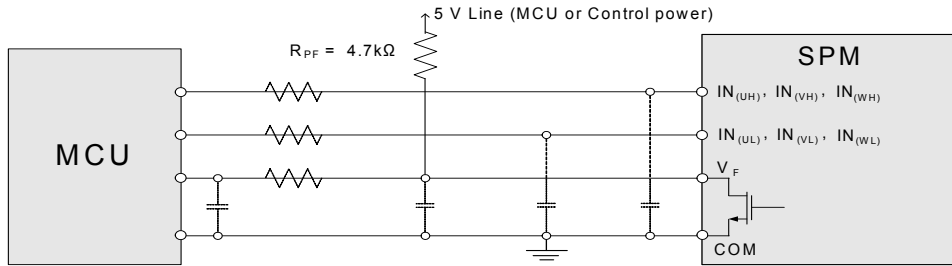
图 .5. IC 温度输出曲线 V-T (采用 4.7 kohm 电阻上拉至 5 V)

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_{DD}	控制电源电压	施加于 V_{DD} - COM 之间	13.5	15	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	18.5	V
dV_{DD}/dt , dV_{BS}/dt	控制电源波动		-1	-	1	V / μ s
t_{dead}	防止桥臂直通的死区时间	适用于每个输入信号	1.0	-	-	μ 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 9)	1.0	-	-	μ s
$P_{WIN(OFF)}$			1.0	-	-	

注:

9. 此产品可能不会响应，若输入脉宽值低于最低推荐值。



注:

10. 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 55 产品的输入信号部分集成了 5 k Ω （典型值）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 6. 推荐的 MCU I/O 接口电路

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 7		-50	-	100	μm
安装扭矩	安装螺钉: - M3 注释图 8	建议 $0.7 \text{ N} \cdot \text{m}$	0.6	0.7	0.8	$\text{N} \cdot \text{m}$
		建议 $7.1 \text{ kg} \cdot \text{cm}$	5.9	6.9	7.9	$\text{kg} \cdot \text{cm}$
重量			-	6.0	-	g

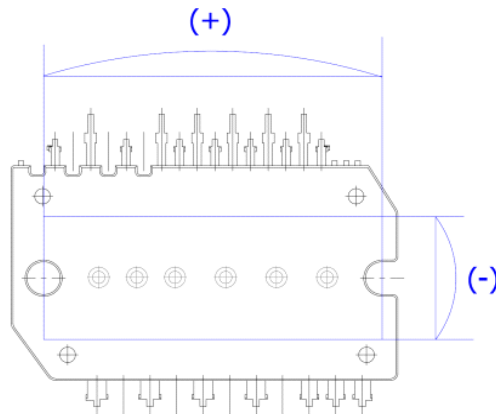


图 7. 平面度测量位置

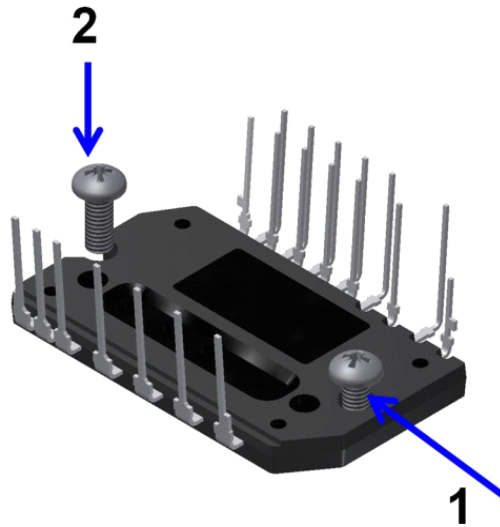
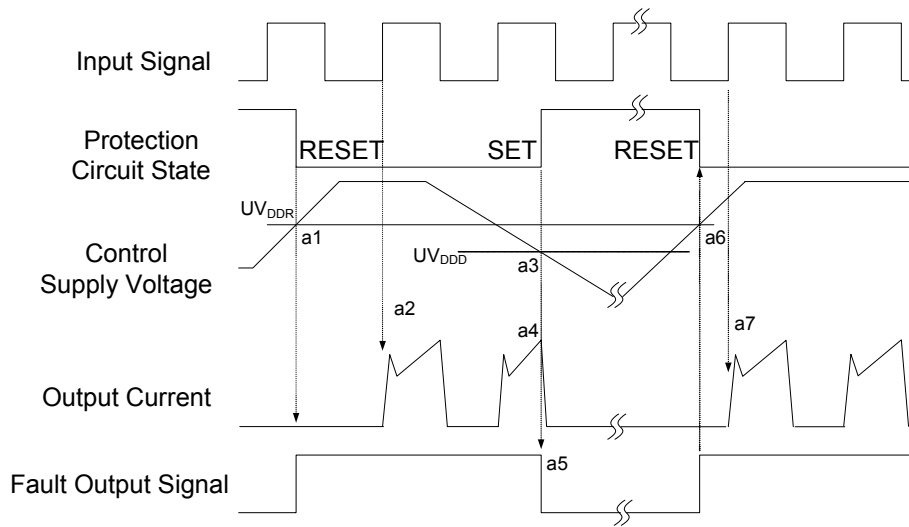


图 8. 安装螺钉时的扭紧顺序

注:

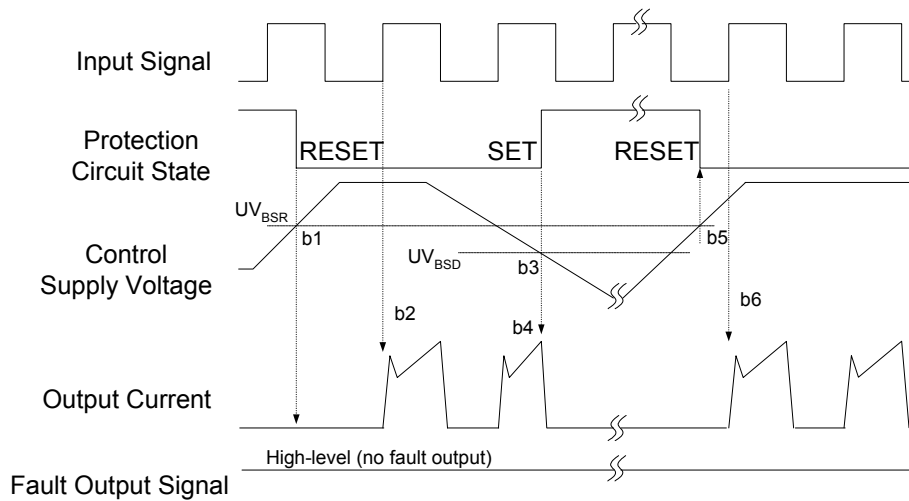
11. 安装或扭动螺丝时切勿过分用力。扭力过大会造成封装破裂，产生毛刺并破坏铝质散热片。
12. 避免用力不均衡。图 10 显示了安装螺钉时，推荐的扭紧顺序。不平坦的安装会导致 SPM 55 产品的陶瓷基板损坏。预旋紧扭矩约为最大额定扭矩的 20 ~ 30%。

保护功能时序图



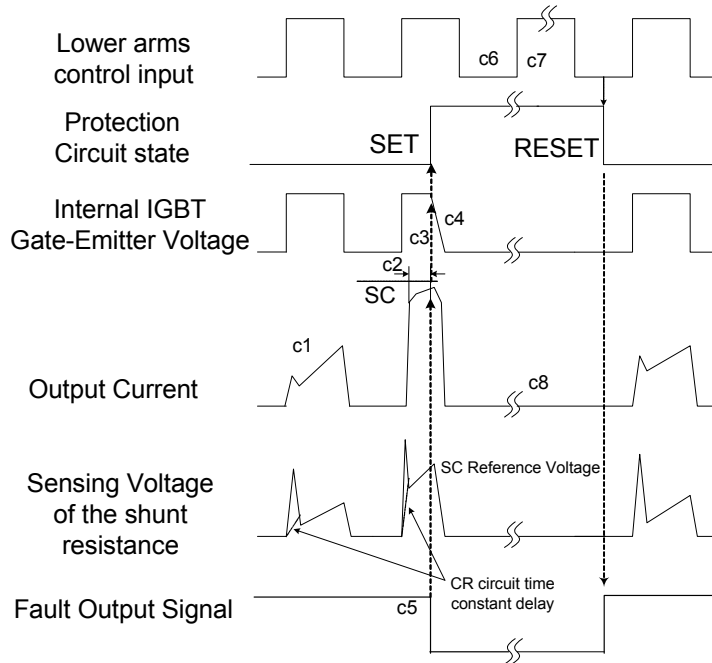
- a1: 控制电源电压上升: 当电压上升到 UV_{DDR} 后, 等到下一个开通信号时, 对应的电路才开始动作。
- a2: 正常工作: IGBT 导通并加载负载电流。
- a3: 欠压检测 (UV_{DDD})。
- a4: 不论控制输入的条件, IGBT 都关断。
- a5: 故障输出工作启动。
- a6: 欠压复位 (UV_{DDR})。
- a7: 正常工作: IGBT 导通并加载负载电流。

图 9. 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。

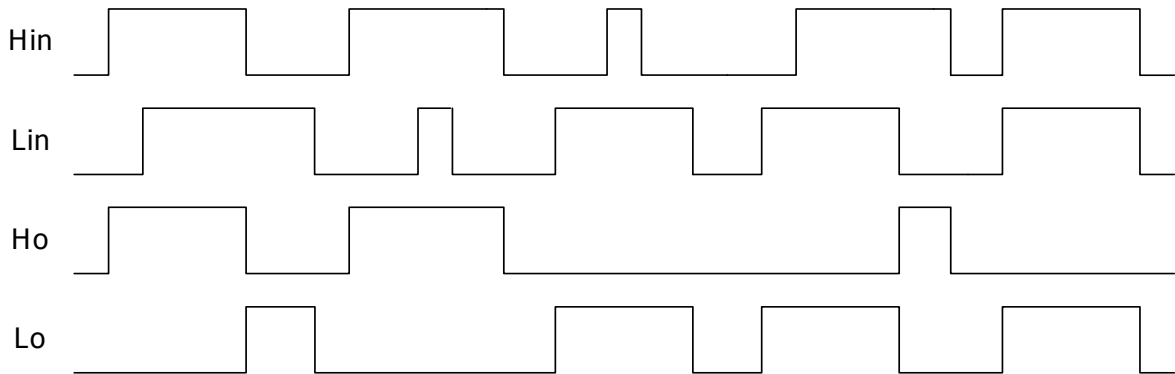
图 10. 欠压保护 (高端)



(包含外部分流电阻和 CR 连接)

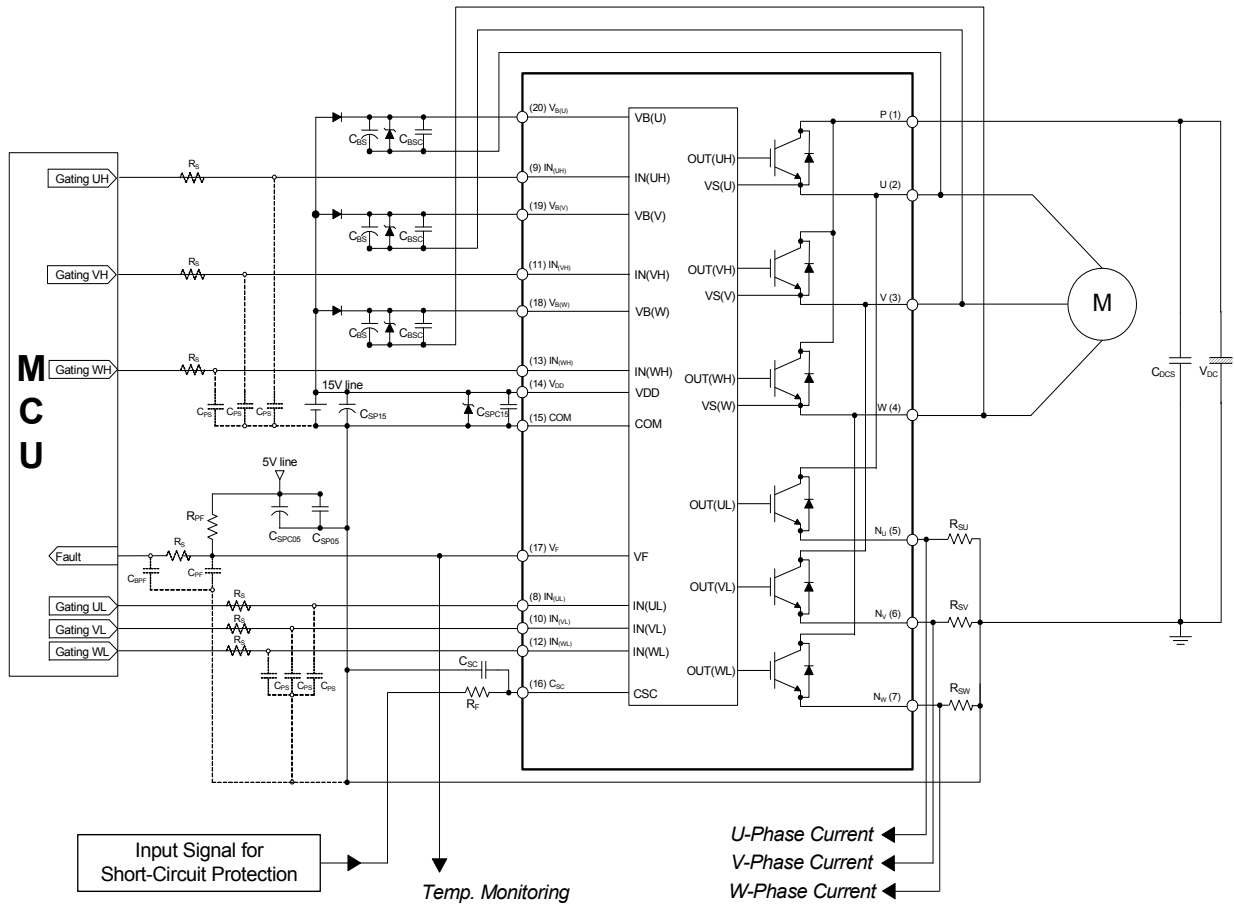
- c1: 正常工作: IGBT 导通并加载负载电流。
- c2: 短路电流检测 (SC 触发)。
- c3: IGBT 栅极硬中断。
- c4: IGBT 关断。
- c5: 输入“L”: IGBT 关断状态。
- c6: 输入“H”: IGBT 导通状态, 但是在故障输出有效的时间内, IGBT 不导通。
- c7: IGBT 关断状态。

图 11. 短路保护



- Hin: 高端输入信号
- Lin: 低端输入信号
- Ho: 高端内部的 IGBT 栅极 — 发射极电压
- Lo: 低端内部的 IGBT 栅极 — 发射极电压

图 12. 互锁功能

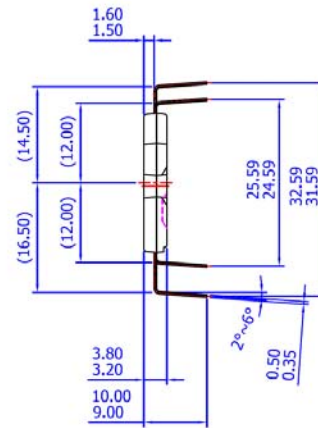
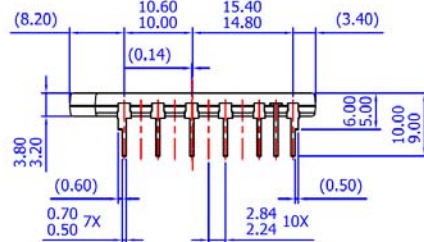
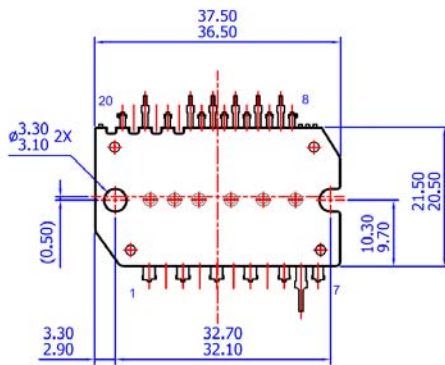
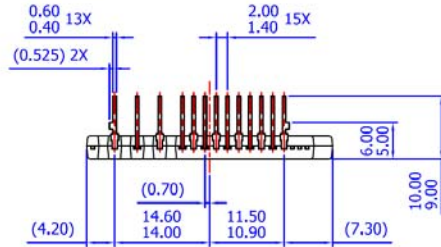


注:

- 1) 为了避免故障，应尽可能缩短每个输入端的连线。（小于 2 ~ 3 cm）
- 2) 因为 Motion SPM® 55 产品内部集成了一个具有特殊功能的 HVIC，接口电路与 MCU 端口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_F 型。该信号线应当采用一个能把 I_{FO} 上升到 5 mA 的电阻上拉至 MCU 或控制电源的正极。请参阅图 14。
- 4) 推荐 C_{SP15} 的取值应大于自举电容 C_{BS} 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。推荐采用 RC 耦合电路，以避免输入信号波动。R_SC_{PS} 时间常数应该选择在 50 ~ 150 ns 范围内。（推荐 R_S = 100 Ω，C_{PS} = 1 nF）
- 6) 为了防止保护功能出错，R_F 和 C_{SC} 周围的连线应该尽可能的短。
- 7) 在短路保护电路中，R_FC_{SC} 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_U，N_V，N_W 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 55 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 和 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，CPU 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_{BS} 选择温度特性好的电解电容。同时，为 C_{BS} 选择 0.1 ~ 0.2 μF 温度和频率特性好的 R- 类陶瓷电容。
- 14) 详细信息，请参考应用说明。

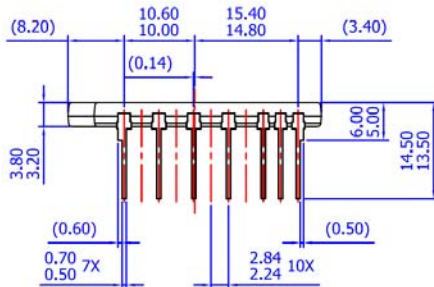
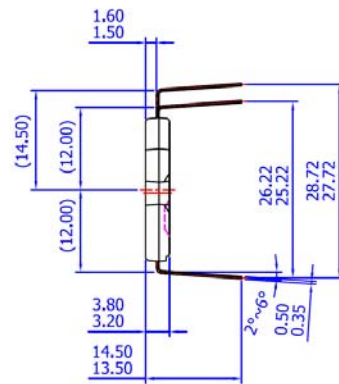
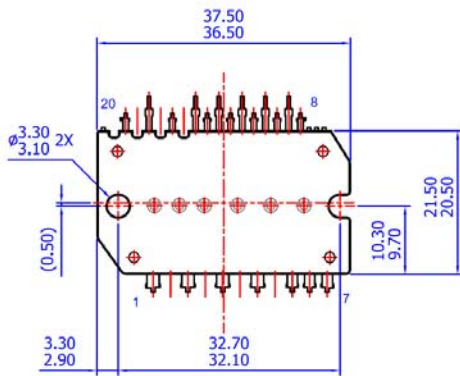
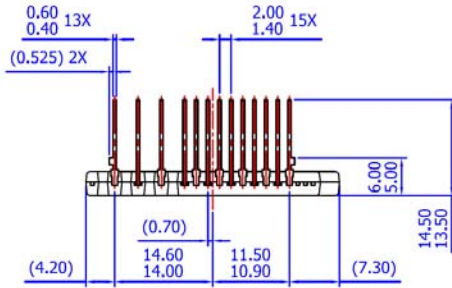
图 13. 典型应用电路

封装轮廓详图 (FNA51560T1, Short Lead)



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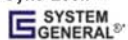





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