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用户指南：

FEBFAN9673_B01H2500A
评测板

2.5 kW 三通道 CCM PFC
含 12 V_{SB} 模块
评测板

飞兆特色产品：
FAN9673

关于本测试板的直接问题或意见：
“全球支持中心”

Fairchild Semiconductor.com

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本用户指南支持 2500 W 评估板用于三通道 CCM PFC（使用 FAN9673）。应与 FAN9673、数据手册以及 Fairchild 应用笔记配合使用，有问题请咨询技术支持团队。请访问 Fairchild 网站：www.fairchildsemi.com/。

1. 引言

FAN9673 是一款用于控制 PFC 预调节器的 32 引脚，连续导通模式 (CCM) 功率因数校正 (PFC) 控制器 IC。FAN9673 包括平均电流和升压型功率因数校正，使电源完全符合 IEC1000-3-2 规范。TriFault Detect™ 功能帮助减少外部元件，并为反馈环路提供全面保护，如过压。当发生负载突然下降时，过压比较器关断 PFC 级。RDY 信号可用于通电序列控制。通道管理 (CM) 功能可以分别启用/禁用每个通道。FAN9673 也包括 PFC 软启动、峰值电流限制和输入电压导通/欠压保护。

1.1. 特性

- 连续导通模式控制
- 最多三通道 PFC 控制
- 平均电流模式控制
- PFC 从机通道外部信号/通道管理功能控制
- 可编程工作频率范围：18 kHz~40 kHz 或 55 kHz~75 kHz
- 可编程 PFC 输出电压
- 限流的两个类型
- TriFault Detect™ 防止反馈环路故障
- SAG 保护
- 可编程软启动
- 欠压锁定 (UVLO)
- 差分电流感测
- 在 32 引脚 LQFP 封装内可用

2. 评估板规格

本表格中的所有数据均在 25°C 环境温度下测得。

表 1. 特性和性能总结

说明	符号	数值	评论
输出功率	P_O	2.5 kW	
效率	Eff, η	>95%	
输入电压	V_{AC}	180~264 V	
输入频率		47~63 Hz	
输出电压	V_{OUT}, V_{PFC}	393 V	$V_{PVO}=0 V$
接入 / 掉电电压	V_{BIBO}	170 V / 155 V	
PFC 频率	f_{SW}	40 kHz	
PFC RDY	V_{RDY}	2.4 V / 1.55 V (VPFC 的 96%/62%)	

3. 照片

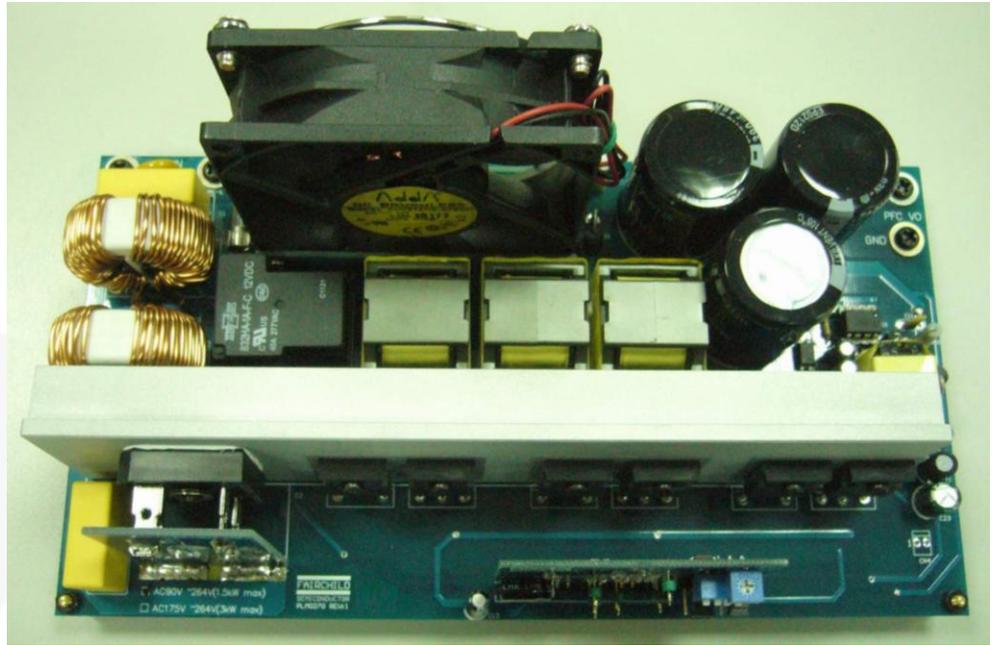


图 1. 俯视图

4. 印刷电路板

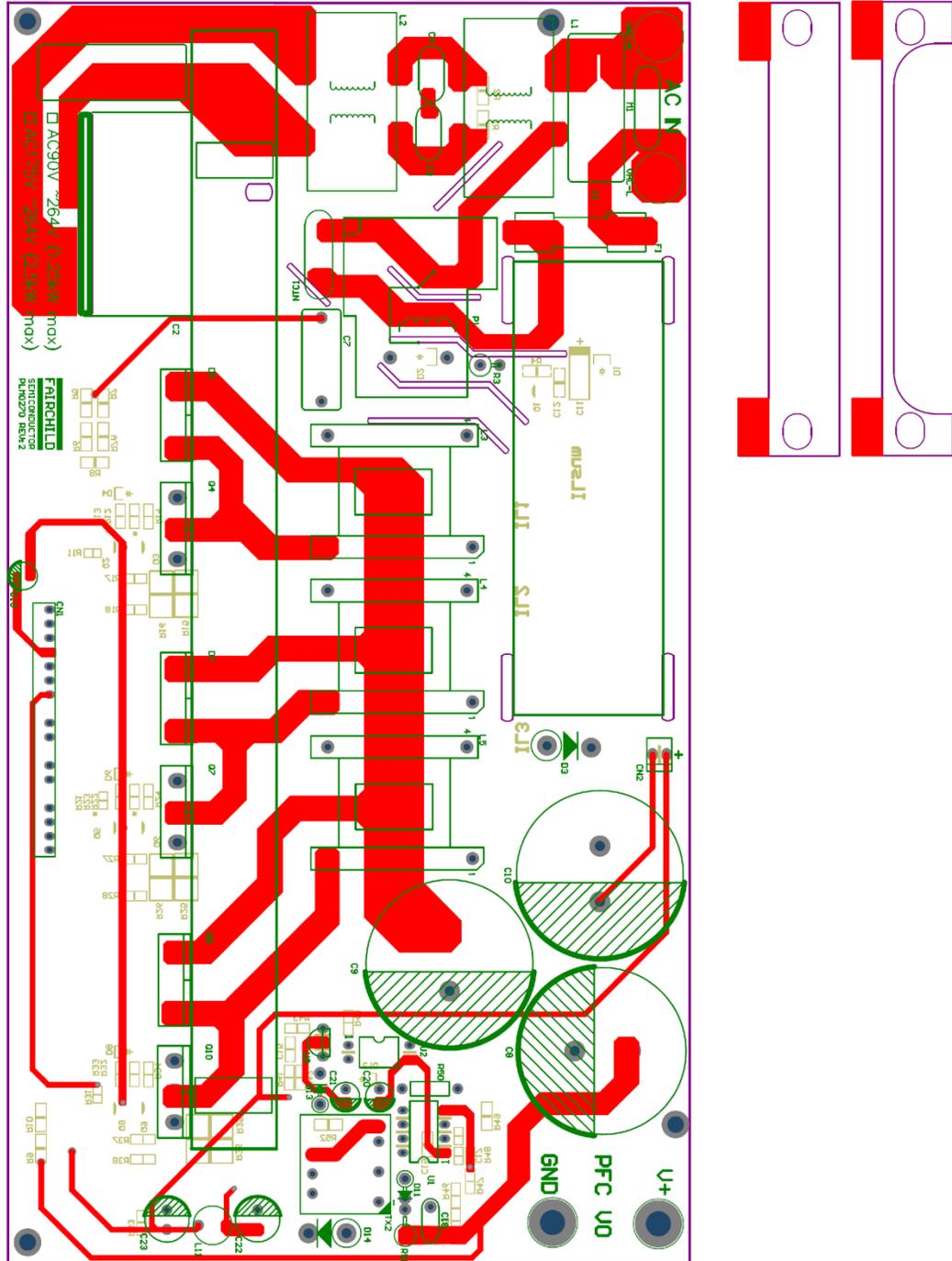


图 2. 评估板的顶层

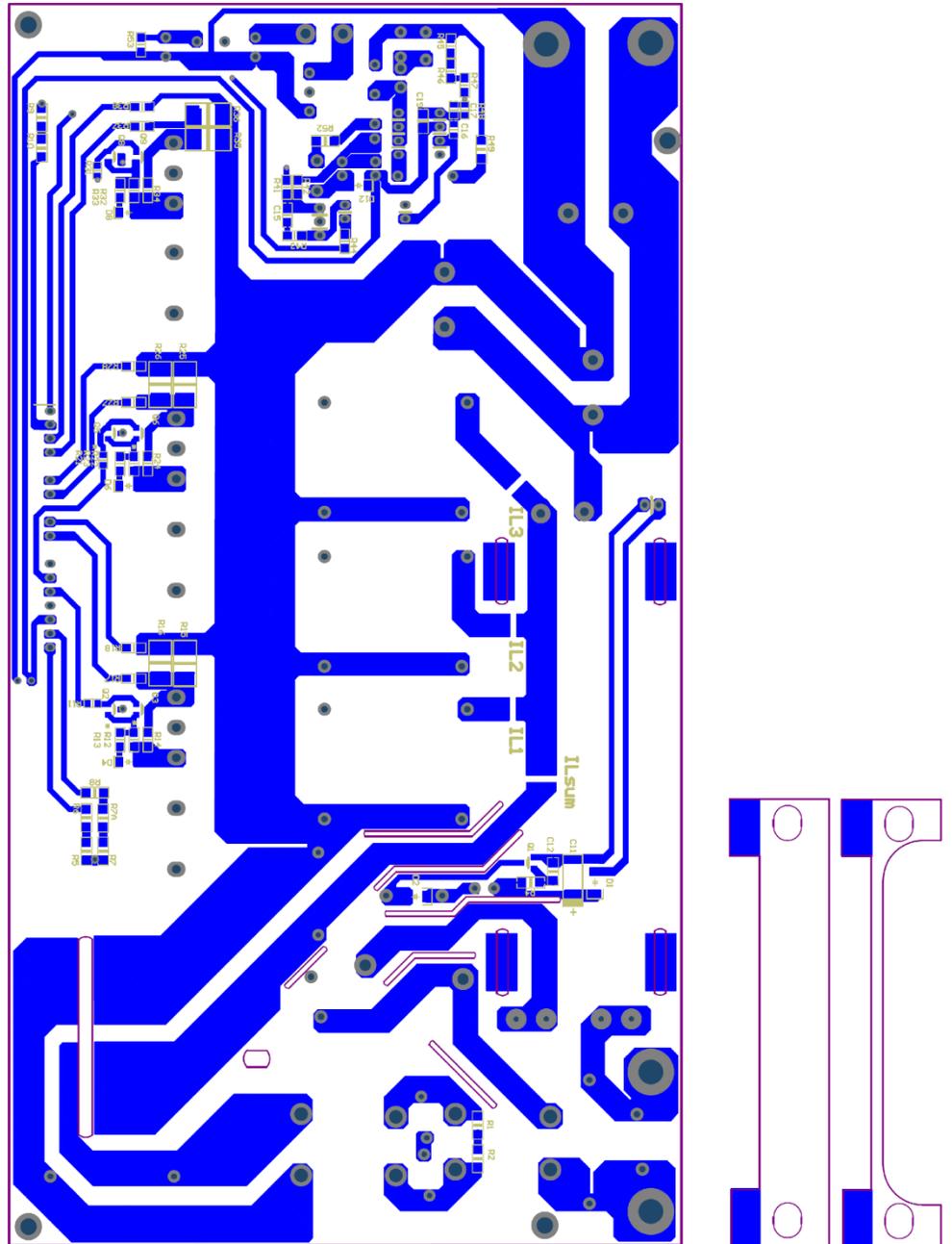


图 3. 评估板的底层

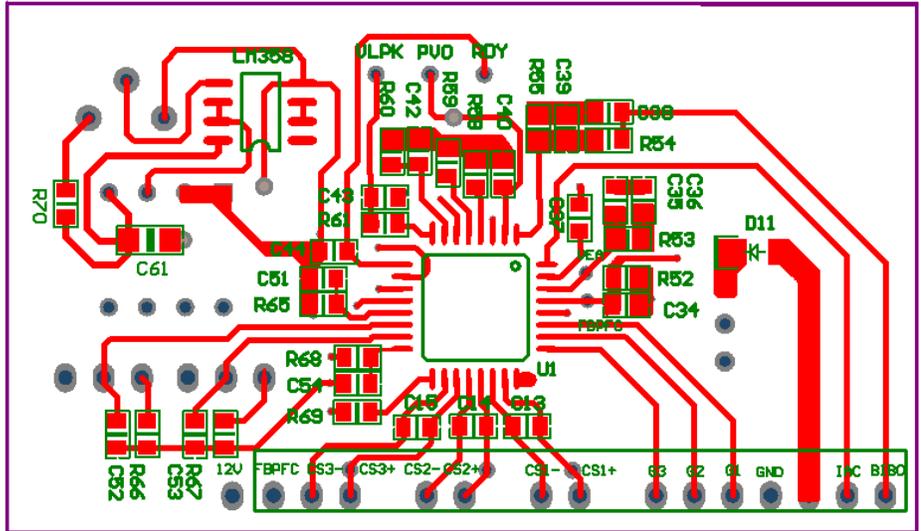


图 4. 子卡顶层

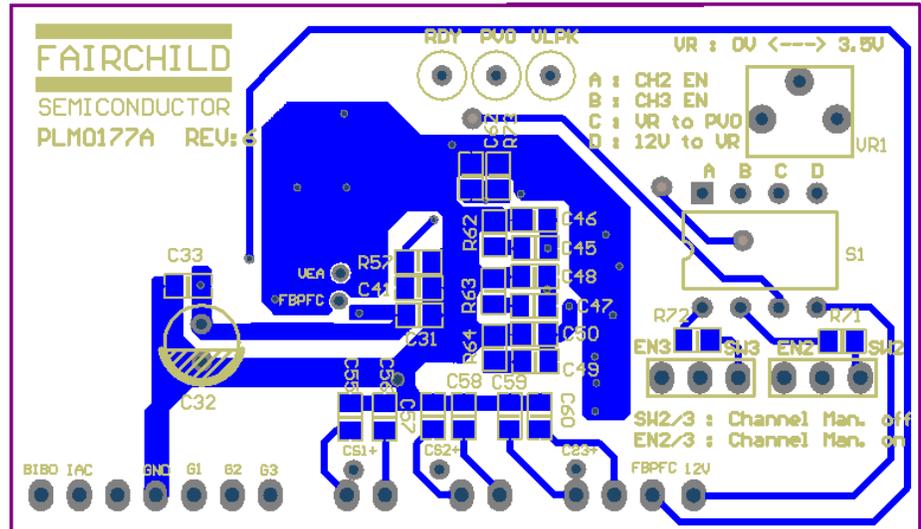


图 5. 子卡底层

6. 材料清单

主板 (PLM270 修订版 1)					
标号	数量	器件编号	数值	说明	生产厂商
BD1	1	GBPC5006			
PLM0276BV0	1			Transfer Card for Bridge	
C1, C2	2		1 μ F / 275 V	X Capacitor	
C11	1		10 μ F / 25 V		
C12	1		1 nF / 1 kV		
C13, C21	2		22 μ F / 50 V		
C15	1		10 nF / 50 V		
C16	1		47 nF / 50 V		
C18	1		1 nF / 1 kV		
C19	1		0.1 μ F		
C20	1		4.7 μ F / 50 V		
C22, C23	2		330 μ F / 25 V		
C3, C4	2		2.2 pF / 250 V	Y Capacitor	
C7	1		1 μ F / 450 V	MPE	
C8, C9, C10	3		390 μ F / 450 V		
CN1	1		CON18		
CN2	1		CON2		
D1, D2	2		S1J		
D11	1	UF1007			
D13	1	1N4935			Fairchild
D14	1	SF34			
D3	1	1N5406			Fairchild
D4, D6, D8, D12	4	1N4148			
D5, D7, D9	3	FFH15S60STU			Fairchild
F1	1	Slow Blow Fuse	30 A / 250 V		
L1, L2	2	FS3010H-1LB		EMI	FORMOSA SHING GA ENTERPRISE CO., LTE.
L11	1		10 μ H		
L3, L4, L5	3	Core Type: QP2925H	220 μ H		
M1	1		MOV		
Q1	1	2N7002A			
Q2, Q5, Q8	3	2222A			
Q3, Q6, Q9	3	2907			
Q4, Q7, Q10	3	FGH20N60UFD			Fairchild
R1, R2, R4, R5, R6	5	SMD 1206	1 M Ω		
R10	1	SMD 1206	1.5 M Ω		
R11, R21, R31	3		220 Ω		
R12, R22, R32	3		20 Ω		
R13, R23, R33	3		10 Ω		
R14, R24, R34, R42	4		10 k Ω		
R15, R25, R35	3	SMD 2512	30 m Ω / 2 W		



主板 (PLM270 修订版 1)					
标号	数量	器件编号	数值	说明	生产厂商
R17, R18, R27, R28, R37, R38	6		470 Ω		
R3	1		20 Ω / 350 V / 0.5 W		
R41	1		38.3 k Ω		
R43	1		20 k Ω		
R44	1		560 Ω		
R48	1		3.9 k Ω		
R49, R50, R52	3		0 Ω		
R51	1		100 k Ω		
R7	1	SMD 1206	5.1 M Ω		
R7A	1	SMD 1206	4.7 M Ω		
R9, R8	1	SMD 1206	2.2 M Ω		
Relay1	1	Power Relay	40 A		
TX2	1	750342371		12 V _{SB} Transformer	Würth Elektronik
U1	1	FSL126HR		Controller	Fairchild
U2	1	PC-817			
U8	1	TL431			

子卡 (PLM0177A 修订版 6)					
标号	数量	器件编号	数值	说明	生产厂商
C35, C40, C41, C42, C51, C54	6	SMD 0805	0.01 μ F		
C38	1	SMD 0805	0.047 μ F		
C31, C33, C43, C44	4	SMD 0805	0.1 μ F		
C36, C37, C39, C52, C53	5	SMD 0805	0.47 μ F		
C45, C47, C49	3	SMD 0805	1.2 nF		
C46, C48, C50, C62	4	SMD 0805	100 pF		
C63, C64	2	SMD 0805	330 pF		
C32	1		10 μ /50 V		
C13, C14, C15	2	SMD 0805	1 nF		
C55, C56, C57, C58, C59, C60	6	SMD 0805	2.2 nF		
C34	1	SMD 0805	470 pF		
CN1	1			CON14	
D11	1		1N4148		
U1	1	FAN9673		Controller	Fairchild
U2	1	LM358D			Fairchild
R56, R65, R72, R71	4	SMD 0805	0 Ω		
R60	1	SMD 0805	10 k Ω		
R73	1	SMD 0805	12.1 k Ω		
R57	1	SMD 0805	27 k Ω		
R55	1	SMD 0603	16.2 k Ω		
R62, R63, R64	3	SMD 0805	17.4 k Ω		

子卡 (PLM0177A 修订版 6)					
标号	数量	器件编号	数值	说明	生产厂商
R54	1	SMD 0805	200 kΩ		
R59	1	SMD 0805	20 kΩ		
VR1	1	SMD 0805	20 kΩ		
R52	1	SMD 0805	23.7 kΩ		
R58	1	SMD 0805	38.3 kΩ		
R61	1	SMD 0805	4.7 kΩ		
R68	1	SMD 0805	470 kΩ		
R66, R67, R70	3	SMD 0805	47 kΩ		
R53	1	SMD 0805	75 kΩ		
S1	1	DIP-4		Switch	

7. 变压器和绕组规格

7.1. TX2 规格

- 磁芯: EE-16 (3C94)
- 骨架: 10 个引脚

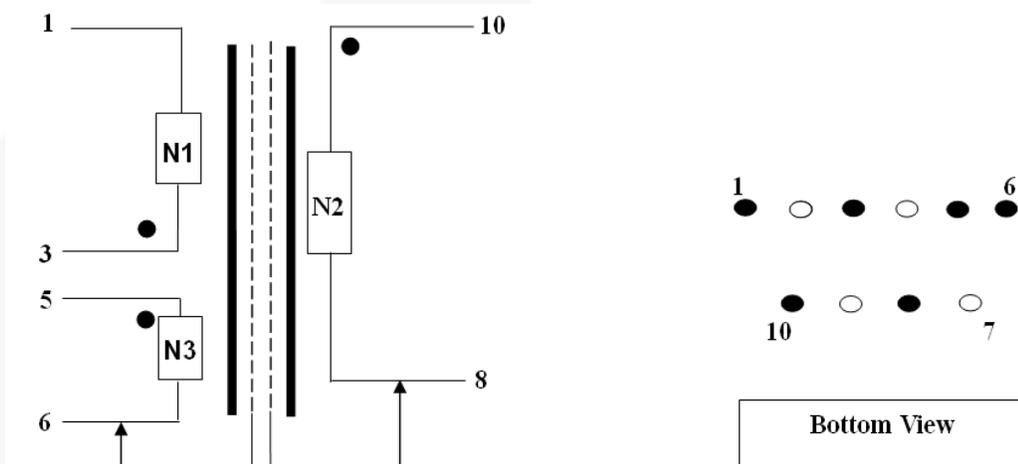


图 8. 变压器规格与结构

表 2. 绕组规格

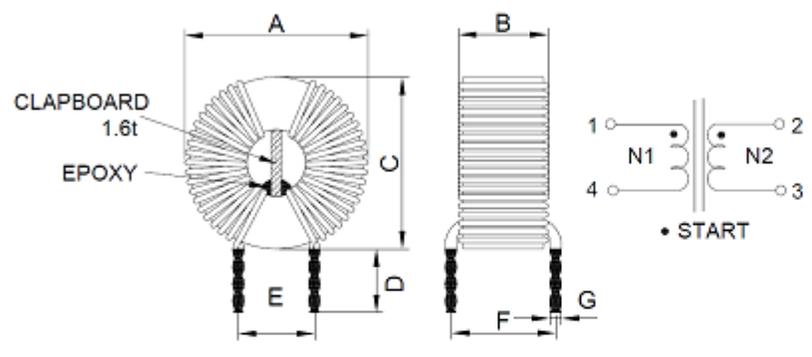
编号	绕组	引脚 (S → F)	绕线	匝数	绕线方式
1	N1	3 → 2	0.29φ×1	36	螺线管绕制
2	绝缘: 聚酯带 t = 0.025 mm, 3 层				
3	N2	N2	N2	N2	N2
4	绝缘: 聚酯带 t = 0.025 mm, 3 层				
5	N1	N1	N1	N1	N1
6	绝缘: 聚酯带 t = 0.025 mm, 6 层				
7	N3	N3	N3	N3	N3
8	绝缘: 聚酯带 t = 0.025 mm, 3 层				
9	铜箔 1.2T 至引脚 6				

表 3. 电气特性

	引脚	规格
电感量	3 - 1	800 μH ±5%

7.2. L1 和 L2 规格

SPECIFICATION FOR PRODUCTS

CUST	Fairchild	OUT DWG NO.	FS-XJ077AR																
ITEM	FS3010H-1LB	DATE	07/22/2011																
PART NO.		REV:A/0																	
1.OUT LINE DIMENSION:																			
 <table border="1" data-bbox="1088 672 1364 1029"> <thead> <tr> <th colspan="2">SPEC.(mm)</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>40.0 MAX</td> </tr> <tr> <td>B</td> <td>20.0 MAX</td> </tr> <tr> <td>C</td> <td>38.0 MAX</td> </tr> <tr> <td>D</td> <td>10.0±1.0</td> </tr> <tr> <td>E</td> <td>10.0REF</td> </tr> <tr> <td>F</td> <td>18.0REF</td> </tr> <tr> <td>G</td> <td>2.8MAX</td> </tr> </tbody> </table>				SPEC.(mm)		A	40.0 MAX	B	20.0 MAX	C	38.0 MAX	D	10.0±1.0	E	10.0REF	F	18.0REF	G	2.8MAX
SPEC.(mm)																			
A	40.0 MAX																		
B	20.0 MAX																		
C	38.0 MAX																		
D	10.0±1.0																		
E	10.0REF																		
F	18.0REF																		
G	2.8MAX																		
2.WINDING & ELECTRONICS: (10kHz /0.1V) 25°C																			
ITEM	START	FINISH	MATERIAL	URNS	COLOR	INDUCTANCE	DCR(mΩ)												
N1	1	4	2UEW φ1.2*2P	15.5TS	N	8.0mH MIN	/												
N2	2	3	2UEW φ1.2*2P	15.5TS	N	8.0mH MIN	/												
3.TEST INSTRUMENTS: L.C.R.CH-1062;																			
4.MATERIAL LIST:																			
NO	ITEM	MATERIAL	SUPPLIER	UL NO.	CLASS														
1	CORE	FS3010H-1LB	FRIENDSHIP ELECTRONICS CO.,LTD																
2	WIRE	2UEW	PACIFIC ELECTRIC WIRE & CABLE CO.,LTD.	E201757	130°C														
3	EPOXY	3300HL	DONGGUAN EATTO ELECTRONIC MATERIAL CO.,LTD	E218090	90°C														
4	CLAPBOARD	FR-4	HUIZHOU JIANYONG INSULATED PRODUCT CO.,LTD	E123995	130°C														

7.3. L3、L4 和 L5 规格

- Core: QP2925H (3C94)
- 骨架: 4 个引脚

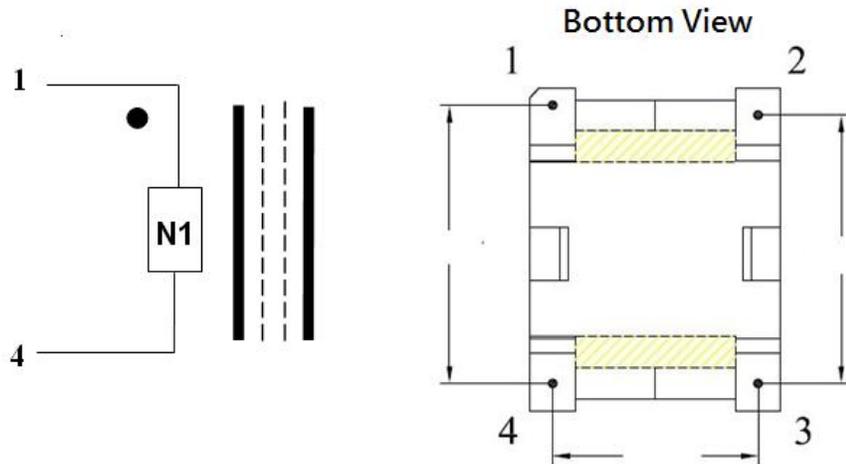


图 9. 变压器规格与结构

表 4. 绕组规格

编号	绕组	引脚 (S → F)	绕线	匝数	绕线方式
1	N1	1 → 4	0.1φ×40 *2	46	螺线管绕制
2	绝缘: 聚酯带, t = 0.025 mm, 2 层				
3	铜箔 1.2T 至 PIN3				

表 5. 电气特性

	引脚	规格
电感量	1 - 4	220 μH ± 5%

7.4. L11 规格

- 磁芯：铁氧体磁芯 DRWW 6x10(6ψ*10 mm)
- 骨架：2 个引脚

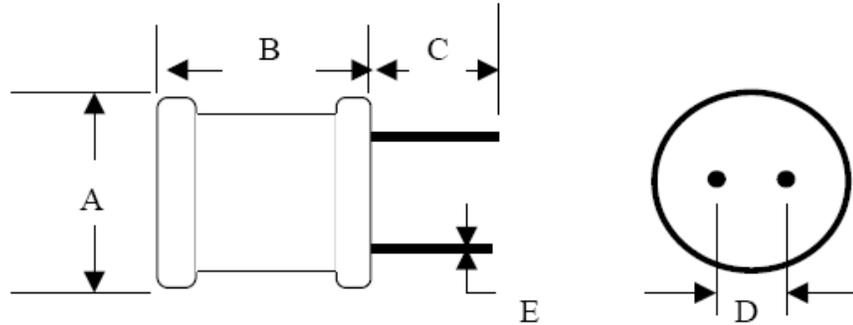


图 10. 变压器规格与结构

表 6. 绕组规格

编号	绕组	引脚 (S → F)	绕线	匝数	绕线方式
1	N1	1 → 2	0.55 mm	18	螺线管绕制
2	铁氧体磁芯 DRWW 6x10 (6ψ*10 mm)				

表 7. 电气特性

	引脚	规格
电感量	1 - 2	10 μH ± 5%

8. 测试条件与测试设备

8.1. 特性

表 8. 测试条件和测试设备

测试模式	FEBFAN9673_B01H2500A
测试日期	2013 年 11 月 4 日
测试温度	环境温度 25°C
测试设备	交流电源: EXTECH 6220 交流/直流电子负载: Chroma 63020 电表: HIOKI 3390 示波器: Lecroy Wavesurfer 424
测试项目	1. 交流上调和下调 2. PFC 开/关和准备 3. 纹波和噪声 4. 效率 5. 谐波电流

8.2. 测试步骤

为评估板供电之前, 需验证交流电压源极是否与评估板的线路输入端相连, 以及, 交流-直流电子负载是否与 PFC 输出相连。

1. 设置电子负载为空载或轻载条件, 并将交流电压应用到评估板输入的两端。
2. 当交流电压 (180~264 V_{AC}) 为评估板供电时, FAN9673 开始正常操作, 板上反激转换器提供 12 V_{SB} 输出。反激变压器的辅助绕组为 V_{DD} 电压供电, 以便 FAN9673 为 PFC 级供电。
3. PFC 启动由 V_{EA} 电平控制。在软启动电压达到 6 V 之前, V_{EA} 电平由软启动限制。
4. 当批量电容或 PFC 输出电压达到稳态值, 392 V 时, 电子负载的负载条件可改为测试系统性能。

提示:

1. 需添加外部风扇以帮助评估板上的 NTC、IGBT、二极管和桥接散热。

9. 评估板性能

9.1. 交流上调和下调

测试条件:

将输入电压从 180 V 调至 264 V 或从 264 V 调至 180 V, 输出电压应正常, PFC 总线的输出应小于 450 V。

测试结果:

CH1: V_{VEA} CH3: V_{PFC} CH4: $V_{Bridge+}$

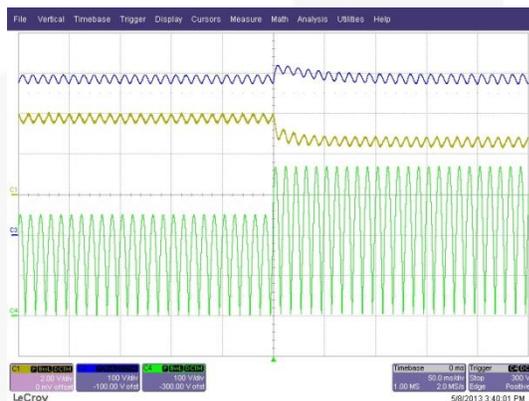


图 11. 180 V→264 V 2500 W 负载

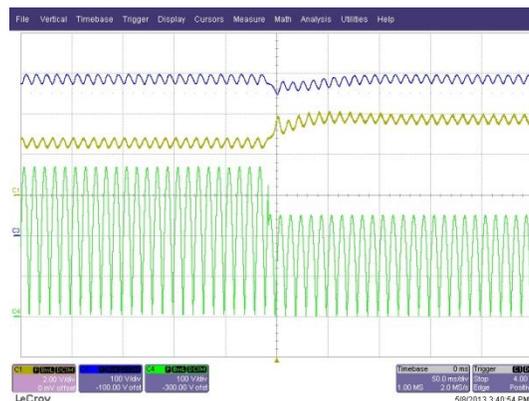


图 12. 264 V→180 V 2500 W 负载

9.2. 5.4 PFC ON / OFF & RDY

测试结果:

CH1: V_{RDY} CH3: V_{PFC} CH4: $V_{Bridge+}$



图 13. PFC 导通



图 14. PFC 关断

9.3. 纹波和噪声

测试结果:

CH3: V_{PFC}

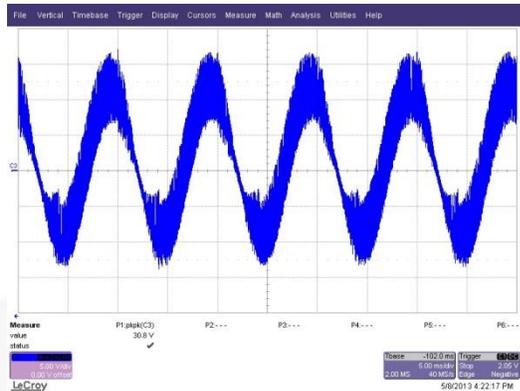


图 15. 180 V / 50 Hz

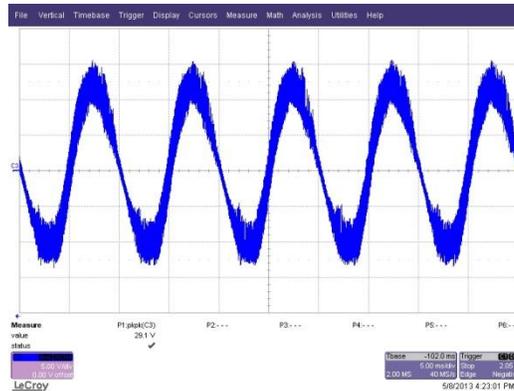


图 16. 264 V / 50 Hz

9.4. 效率

测试条件:

在最小、中等和最大负载时测量效率。

测试结果:

FAN9673	输入瓦数 (W)	输出瓦数 (W)	效率
A. $V_{IN}=180\text{ V}$ (在 25% 负载时)	653	627	96.02%
B. $V_{IN}=180\text{ V}$ (在 50% 负载时)	1298	1256	96.76%
C. $V_{IN}=180\text{ V}$ (在 75% 负载时)	1943	1877	96.60%
D. $V_{IN}=180\text{ V}$ (在 100% 负载时)	2594	2503	96.49%
E. $V_{IN}=220\text{ V}$ (在 25% 负载时)	650	628	96.62%
F. $V_{IN}=220\text{ V}$ (在 50% 负载时)	1292	1256	97.21%
G. $V_{IN}=220\text{ V}$ (在 75% 负载时)	1923	1872	97.35%
H. $V_{IN}=220\text{ V}$ (在 100% 负载时)	2573	2503	97.28%
I. $V_{IN}=264\text{ V}$ (在 25% 负载时)	646	628	97.21%
J. $V_{IN}=264\text{ V}$ (在 50% 负载时)	1286	1256	97.67%
K. $V_{IN}=264\text{ V}$ (在 75% 负载时)	1915	1873	97.81%
L. $V_{IN}=264\text{ V}$ (在 100% 负载时)	2561	2505	97.81%

9.5. 谐波电流

测试结果:

FAN9673			
输入电压	条件	PF	THD (%)
180 V / 50 Hz	25% 负载	0.989	13.58
	50% 负载	0.993	10.81
	75% 负载	0.995	9.10
	100% 负载	0.997	7.39
220 V / 50 Hz	25% 负载	0.986	12.21
	50% 负载	0.992	11.65
	75% 负载	0.994	10.04
	100% 负载	0.995	9.46
264 V / 50 Hz	25% 负载	0.958	22.33
	50% 负载	0.972	21.87
	75% 负载	0.973	22.46
	100% 负载	0.974	22.37

180 V / 50 Hz 输入电流波形和谐波

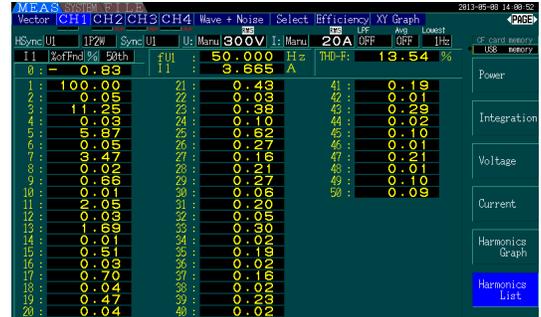
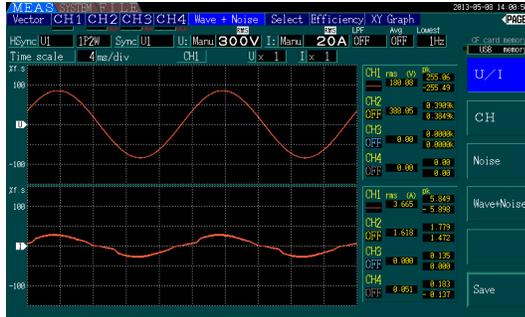


图 17. 25% 负载

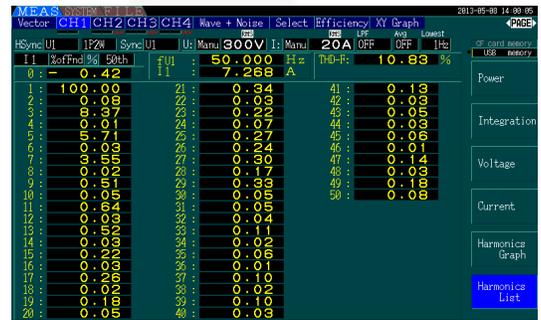
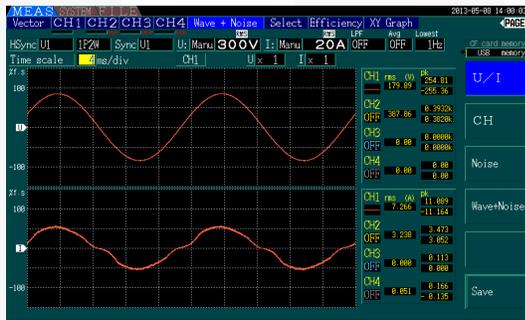


图 18. 50% 负载

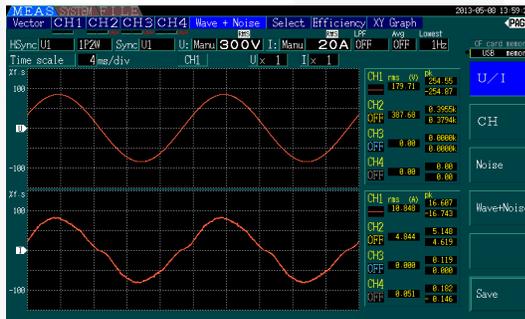


图 19. 75% 负载

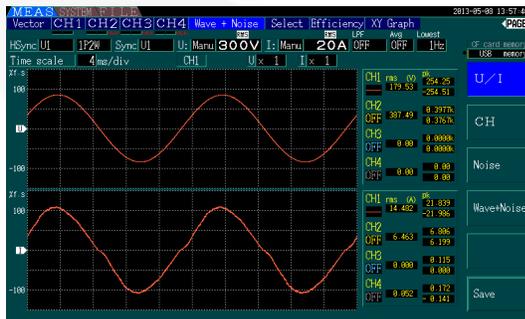


图 20. 100% 负载

220 V / 50 Hz 输入电流波形和谐波

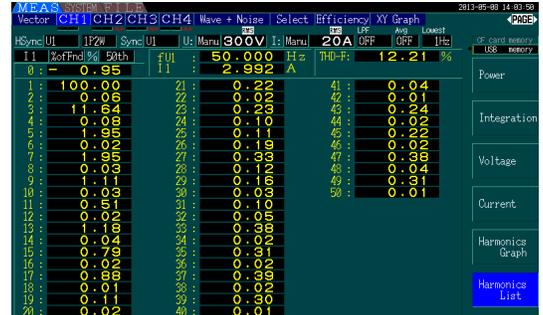
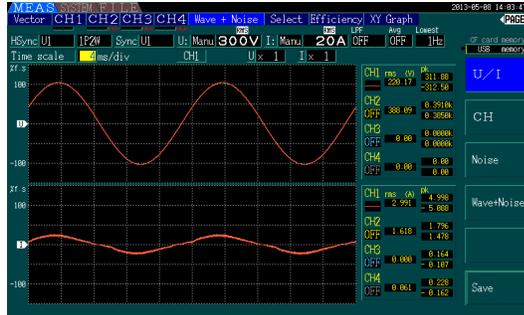


图 21. 25% 负载

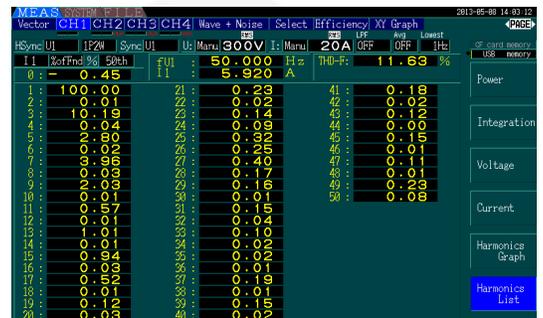


图 22. 50% 负载

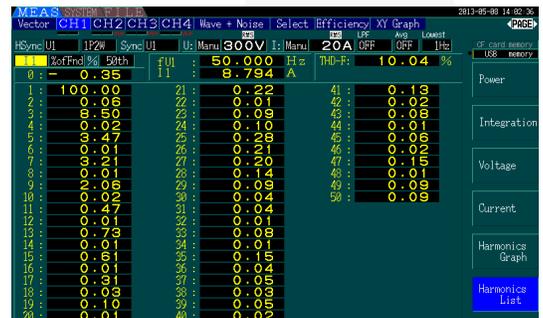
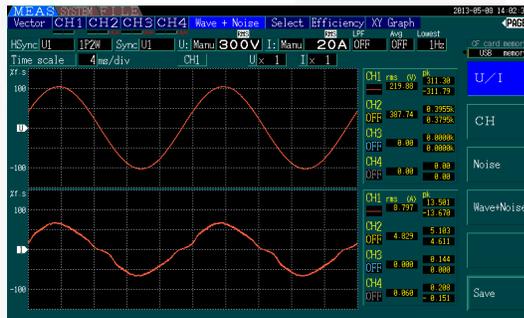


图 23. 75% 负载

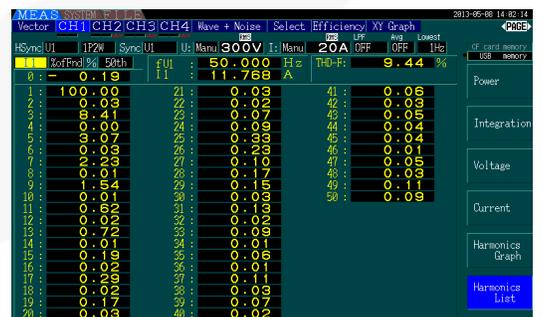
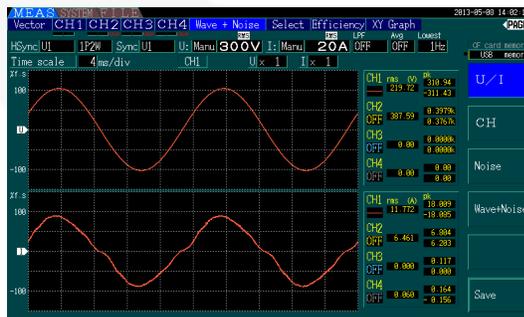


图 24. 100% 负载

264 V / 50 Hz 输入电流波形和谐波

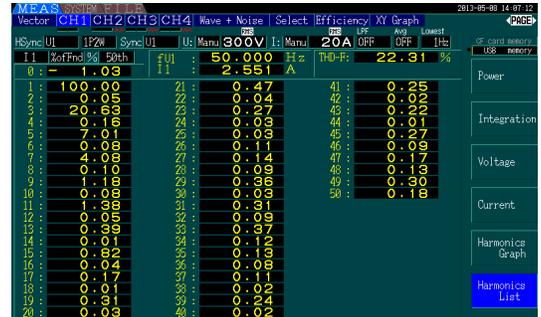


图 25. 25% 负载

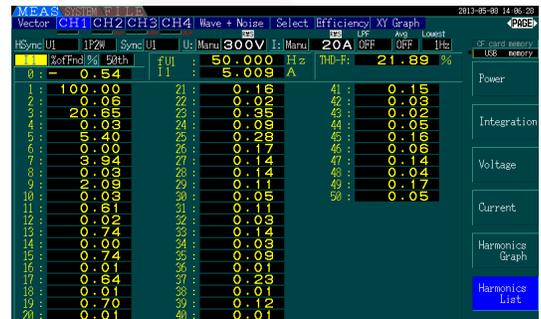
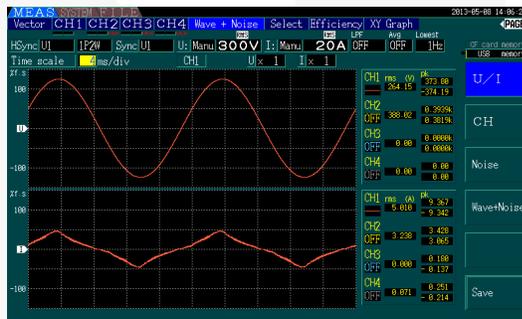


图 26. 50% 负载

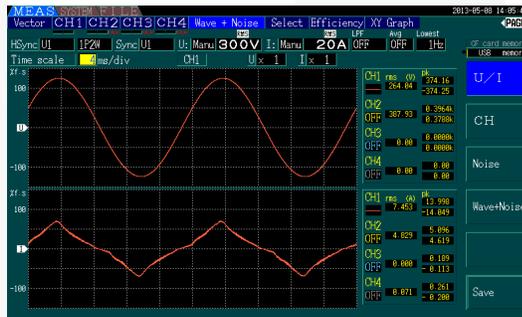


图 27. 75% 负载

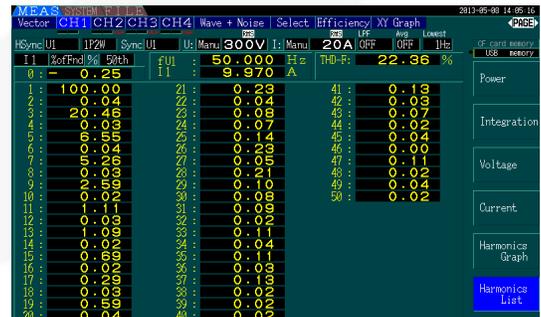
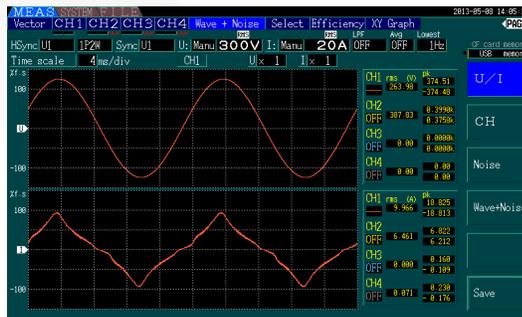


图 28. 100% 负载

10. 安全预防措施



在接通 FEBFAN9673_B01H2500A 评估板的电源之前，所有人员必须阅读并了解安全预防措施和电源开关程序。

FEBFAN9673_B01H2500A 评估板在致命电压下运行，并具有存储大量电荷的大电容。意外接触可能导致实验室设备受损、人员受伤，甚至可能致命。请在接触和操作此板时格外小心。请始终遵守实验室安全预防措施，包括：

- A. 在将工作电压施加到电路板上之前，连接的所有电脑和测量设备都必须与交流市电绝缘。或者，电路板的交流/直流电源应相互绝缘。
- B. 在此电路板上使用示波器时，应与交流电线绝缘。或者，可使用高压 (700 V+) 绝缘探针。
- C. 工作台表面应保持整洁，无任何导电材料。
- D. 开启开关接通交流电源时，需谨慎。
- E. 存在交流线路电压时，千万不可探测或移动板上的探针。
- F. 在断开高功率负载之前确保批量电容进行放电。

注意：

请注意，即使通过外部供电将交流市电与电脑绝缘，也需要通过 LAN、VGA 接地，或者使用其它方式连接至外设。

11. Revision History

Rev.	Date	Description
1.0.0	Jan 2014	Initial release
1.0.1	July	BOM updated
1.2	Jan. 2015	BOM updated

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