Design Example Report

Chipown

标题	基于 PN8371 的 4.5W 灯丝灯 LED 应用方案 150V30mA
规格	输入电压：85~265V 全电压 输出功率：4.5W 输出电压：150V 输出电流：30mA±5%
应用范围	LED 灯丝灯内置电源
文件编号	DER-8371-14-P039
编写时间	2014-09-29
编写部门	应用二部
版本号	V1.1

特性概述：

·双面板工艺，单面贴片元器件，面积：Φ20mm；
·输入电压：85~265Vac 电压范围；
·输出功率：4.5W；
·拥有 LED 灯开路、短路、过温调节等功能；
·拥有电流采样电阻短路保护；
·LED 开路或短路时输入功率小于 0.3W；
·启动时间小于 100mS；

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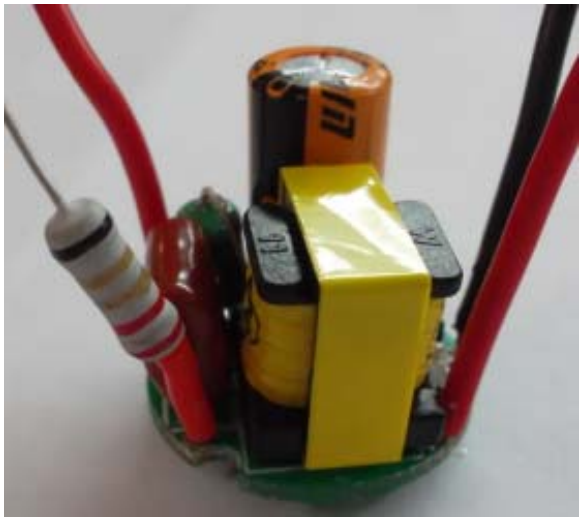
1. 电源介绍

该报告提供了一种基于 PN8371 的 150V/30mA 输出的 LED 驱动电源。芯片集成度高，BOM 器件个数少，具有 LED 灯开路、短路、过温调节以及电流采用电阻短路保护等功能

该报告包含原理图，电源输入输出规格，BOM 表，变压器参数，EMI 测试，PCB LAYOUT 等数据。

以下为该电源的实物图片：



2. 电源规格明细

最大输入输出电气特性：

项目描述	标号	Min	Typ	Max	Unit	备注
输入电压	Vin	85	115/230	265	V	50/60Hz
输出电压	Vout		150		V	
输出电流	Iout		30		mA	
输出功率	Pout		4.5		W	
效　　率	η	85			%	
工作环境	Tamb	-30	25	75	℃	外部环境

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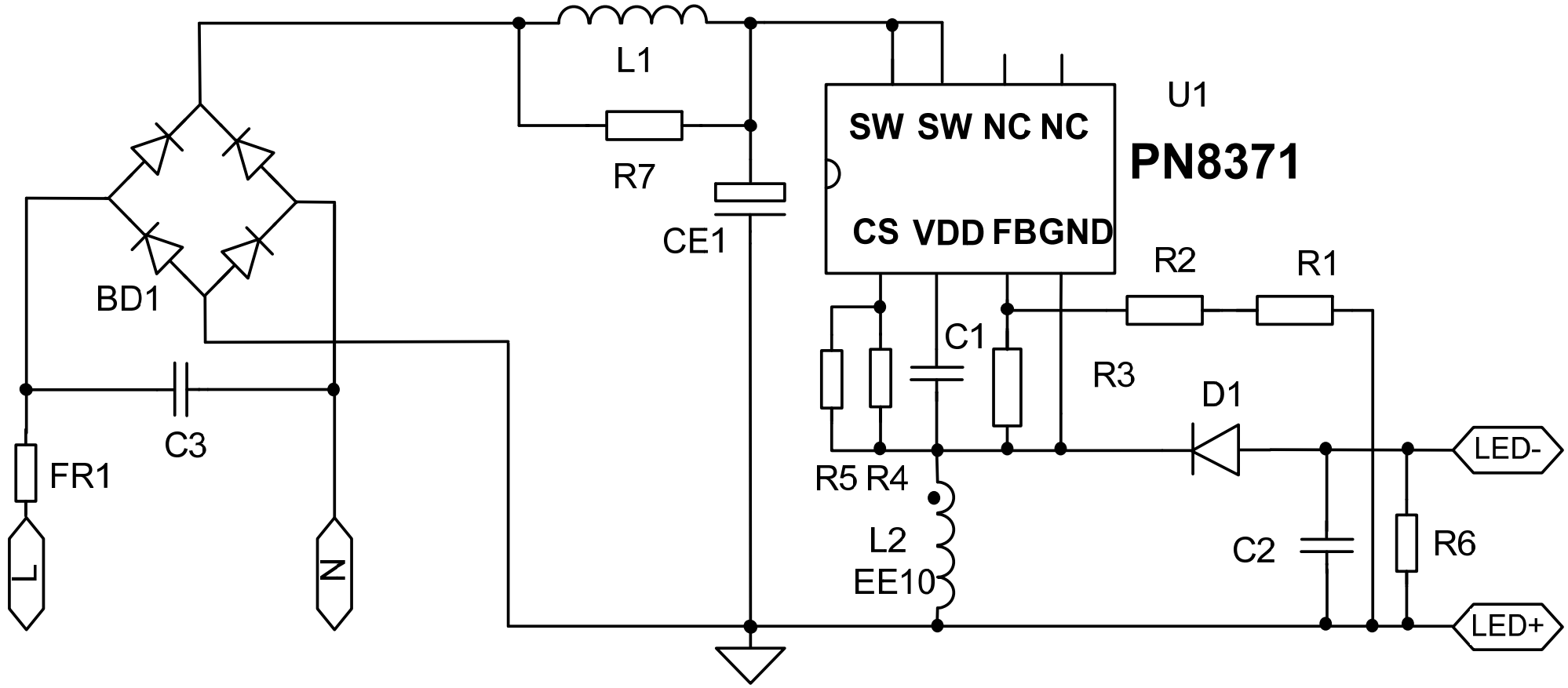
3. 电源原理图



Note: 具体参数以 BOM 为准

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4. 电路描述

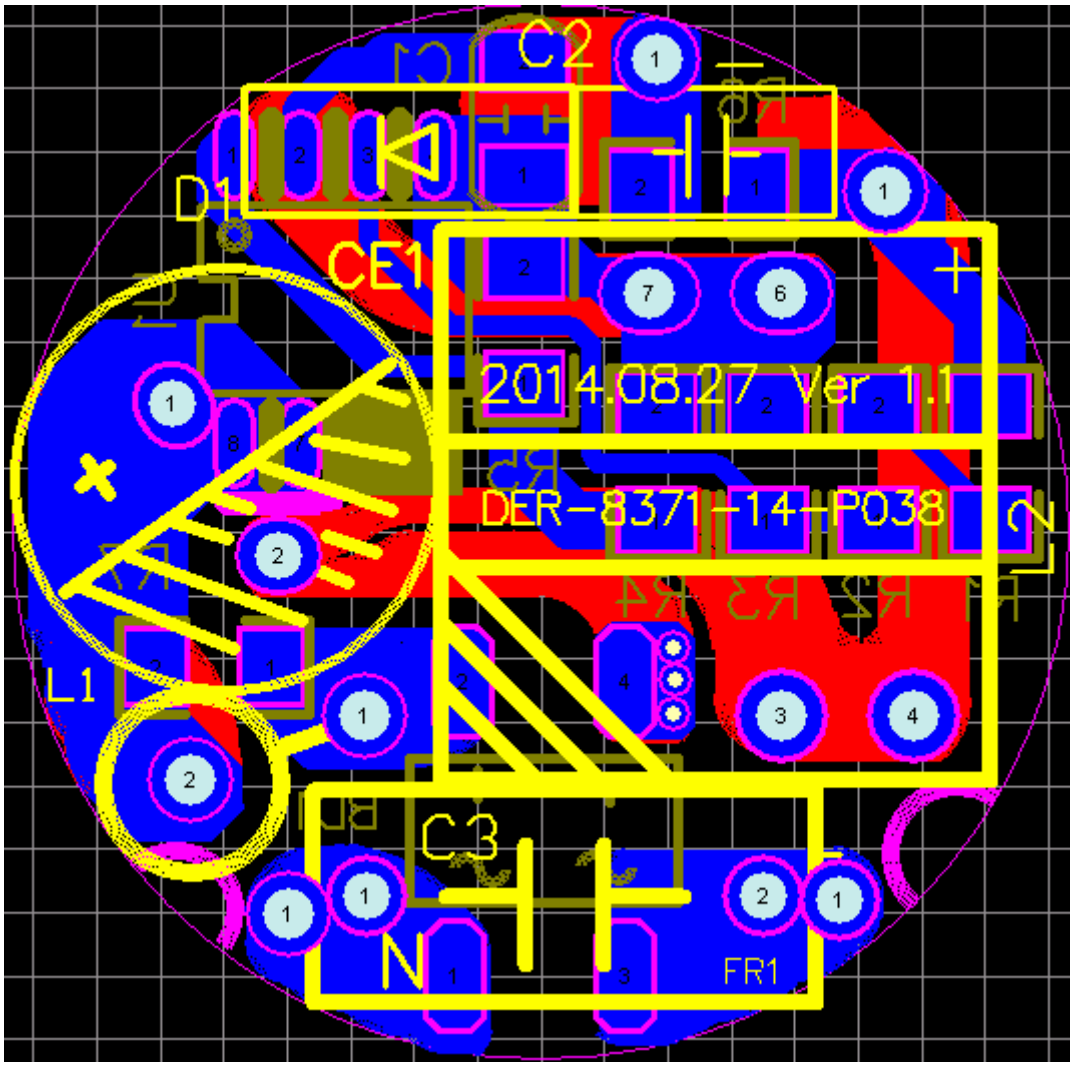
电路图中R1、R2、R3为反馈分压电阻，可间接采样出的电压，LED开路时，输出电压会很高，调整R1、R2和R3的比例，可调节LED开路时的输出电压；并且等比例调节R1、R2和R3可改善Io的输入线电压调整率；

当 PN8371 本体温度太高时，其内置的 OTC 保护功能会及时动作，以保护整个系统；

当 LED 发生短路或开路时，系统将进入打嗝模式直到异常状态消除。

5. PCB LAYOUT

PCB 为普通双面板工艺，双面元器件，铜厚 1OZ，基材为 FR-4。PCB 直径为 20mm，厚 1.2mm。污染等级符合 CLASS2。



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6. Bill of Materials

序号	元件标号	元件名称	元件型号	封装尺寸	数量	备注
1	BD1	整流桥	MB6S	SMD SOIC-4	1	
2	CE1	电解电容	400V/8.2uF	Φ 8*12	1	Low ESR
3	C1	瓷片电容	50V/2.2uF	SMD 0805	1	
4	C2		500V/470nF	SMD 1206	1	
5	C3	CBB	400V/100nF	DIP 脚距 7.5mm	1	
6	D1	二极管	US1J	SMD SMA	1	
7	FR1	保险电阻	2.2Ω/0.5W	DIP 1/2W	1	线绕电阻
8	L1	电感	1.0mH	色环 0510	1	
9	L2	电感	7.0mH	EE10	1	
10	R1	电阻	270KΩ	SMD 0805	1	1%
11	R2		270KΩ	SMD 0805	1	1%
12	R3		9.1KΩ	SMD 0805	1	1%
13	R4		4.7Ω	SMD 0805	1	1%
14	R5		8.2Ω	SMD 0805	1	1%
15	R6		470KΩ	SMD 0805	1	
16	R7		3.3KΩ	SMD 0805	1	
17	U1	IC	PN8371	SOP8	1	

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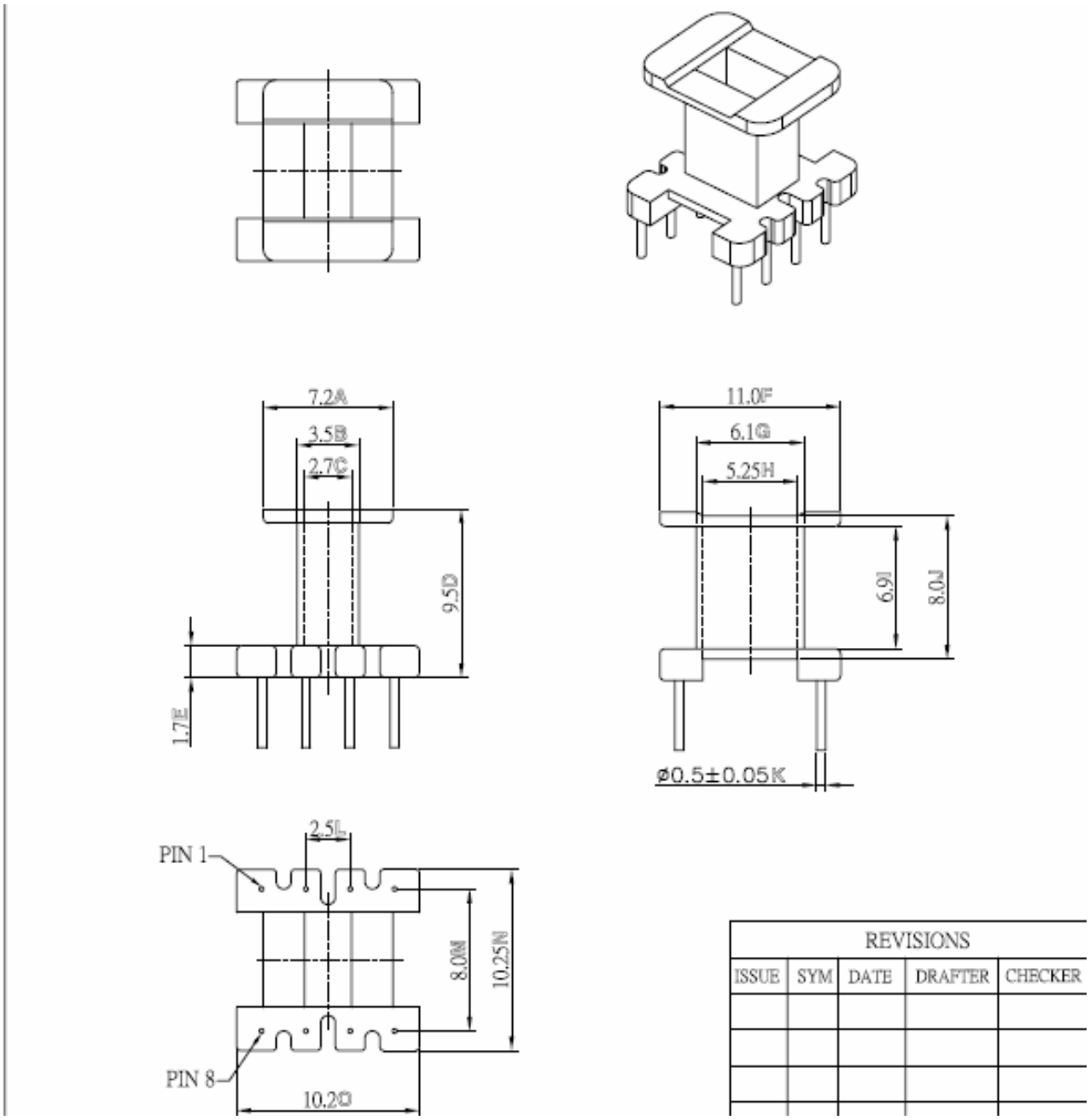
7. 变压器规格（EE10 立式）

7.1 骨架尺寸：



REVISIONS				
ISSUE	SYM	DATE	DRAFTER	CHECKER

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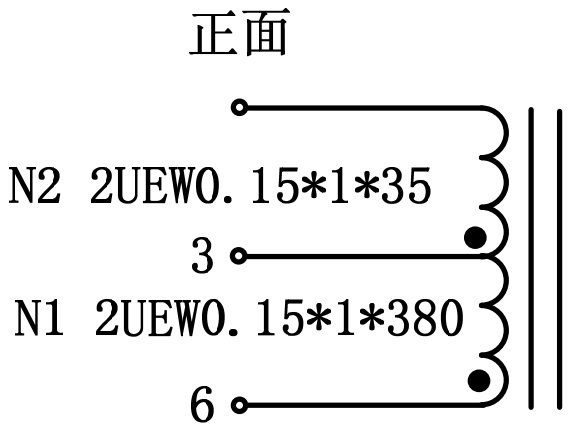
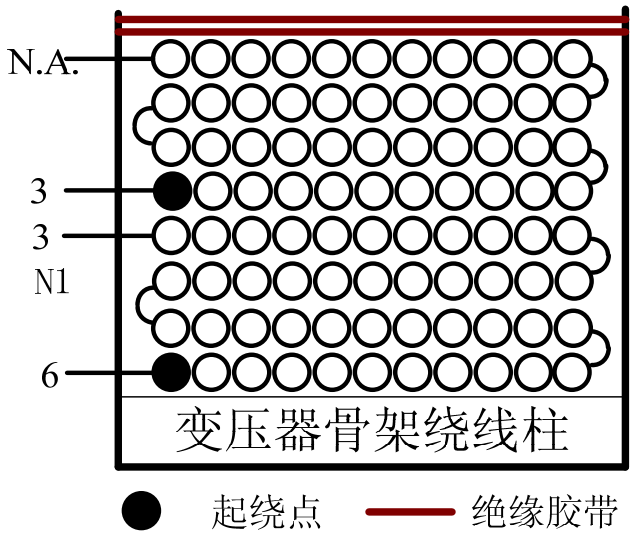
7.2 线路图：



7.3 绕法示意图：



7.4 绕组结构：

Winding No. 组别	Margin Tape 挡墙	Pin 脚位	Wire&Wire Copper 线径&股数	Turns 圈数	Tape Layer 胶带层数	Tube 套管	Winding Tape 绕线方式
N1	N.A.	6～3	2UEW0.15*1	380	2	N.A.	密绕
N2	N.A.	3～N.A.	2UEW0.15*1	35	2	N.A.	密绕

备注： 1. 剪掉 Pin1，2，5,8；
2. 电感的调整需磨磁芯中柱，不能垫磁芯两边；
3. 含浸；

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7.5 电气特性：

Test Item 测试项目	Test Location 测试位置	Test Condition 测试条件	Test Spec. 测试规格
Primart Inductance 电感	6～3	10KHz，1V	7.00mH

8. 电源输入输出特性和工作波形

备注：效率测试：需室温**满载持续工作20Min以**上，稳定后再测试；

负载分别采用电子负载和LED测试；同时满载热机

波形测试：输出负载采用LED 灯丝灯，灯串电压约152V；

负载为电子负载测试结果如下

Vin	Vo(V)	Io(mA)	Pin(W)	Po(W)	η
85V/63Hz	150	29.70	5.179	4.455	86.02%
	140	30.10	4.870	4.214	86.53%
	130	30.00	4.513	3.900	86.42%
	120	30.00	4.144	3.600	86.88%
150V/60Hz	150	29.90	5.092	4.485	88.08%
	140	29.90	4.732	4.186	88.47%
	130	30.10	4.425	3.913	88.43%
	120	30.00	4.086	3.600	88.10%
230V/50Hz	150	29.40	5.042	4.410	87.46%
	140	29.70	4.770	4.158	87.18%
	130	29.50	4.357	3.835	88.02%
	120	29.70	4.103	3.564	86.86%
265V/47Hz	150	29.20	5.049	4.380	86.76%
	140	29.30	4.776	4.102	85.88%
	130	29.10	4.376	3.783	86.44%
	120	29.20	4.078	3.504	85.92%

负载为LED测试结果如下

Vin(Vac)	85V/63Hz	115V/60Hz	230V/50Hz	265V/47Hz
Vo(V)	151.7	152.0	152.0	151.8
Io(mA)	29.90	30.40	30.30	30.00
Pin(W)	5.371	5.363	5.303	5.279
Po(W)	4.536	4.621	4.606	4.554
η	84.45%	86.16%	86.85%	86.27%

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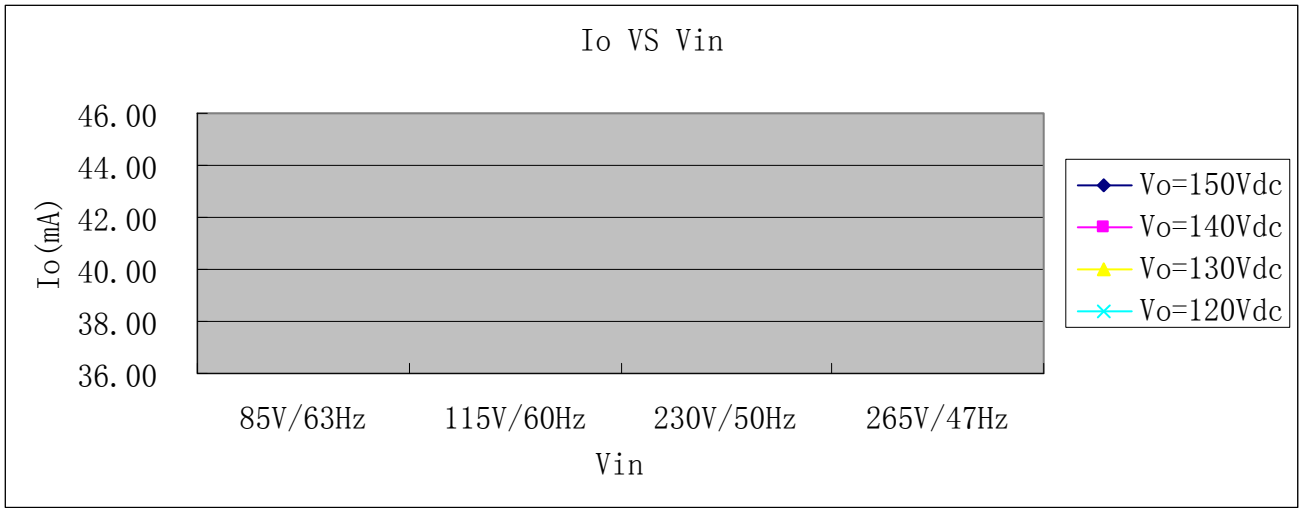
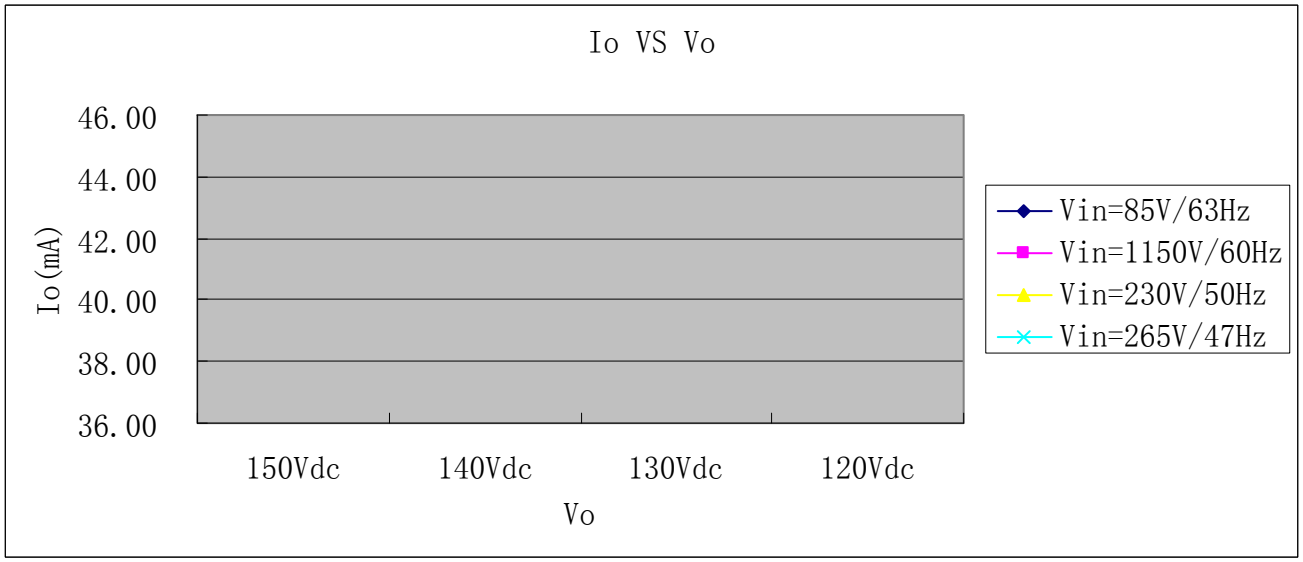
1) 调整率

负载（Vo）	输出电流(mA)					
	85V/63Hz	115V/60Hz	230V/50Hz	265V/47Hz	Max.-Min.	线性调整率
150Vdc	29.70	29.90	29.40	29.20	0.70	±1.18%
140Vdc	30.10	29.90	29.70	29.30	0.80	±1.34%
130Vdc	30.00	30.10	29.50	29.10	1.00	±1.68%
120Vdc	**30.00**	30.00	29.70	29.20	0.80	±1.34%
Max.-Min.	0.40	0.20	0.30	0.20		
负载调整率	±0.66%	±0.33%	±0.50%	±0.34%		

系统线性调整率和负载调整率均小于±2%；





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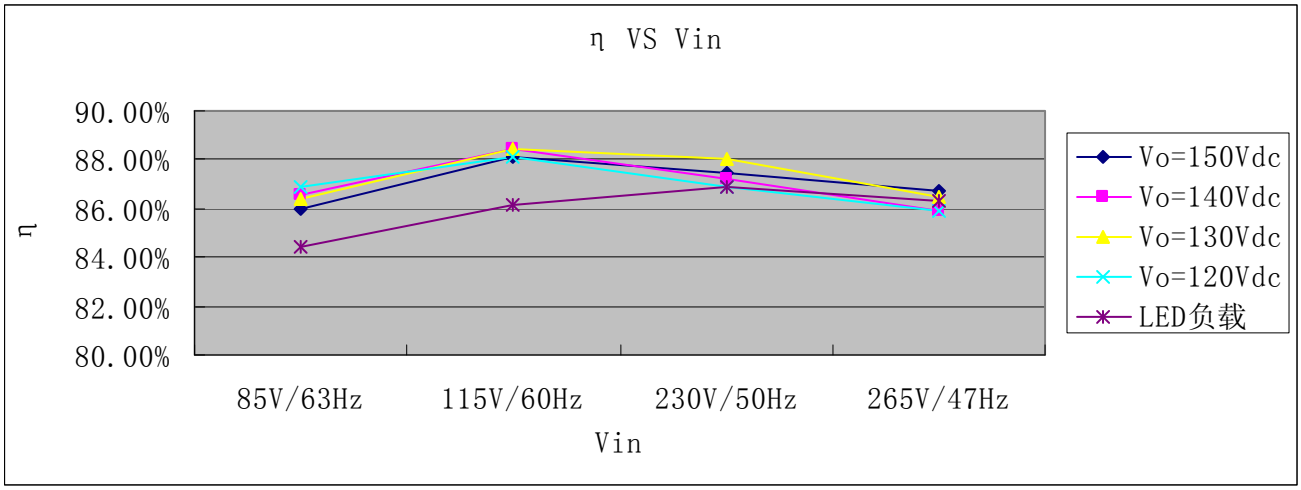
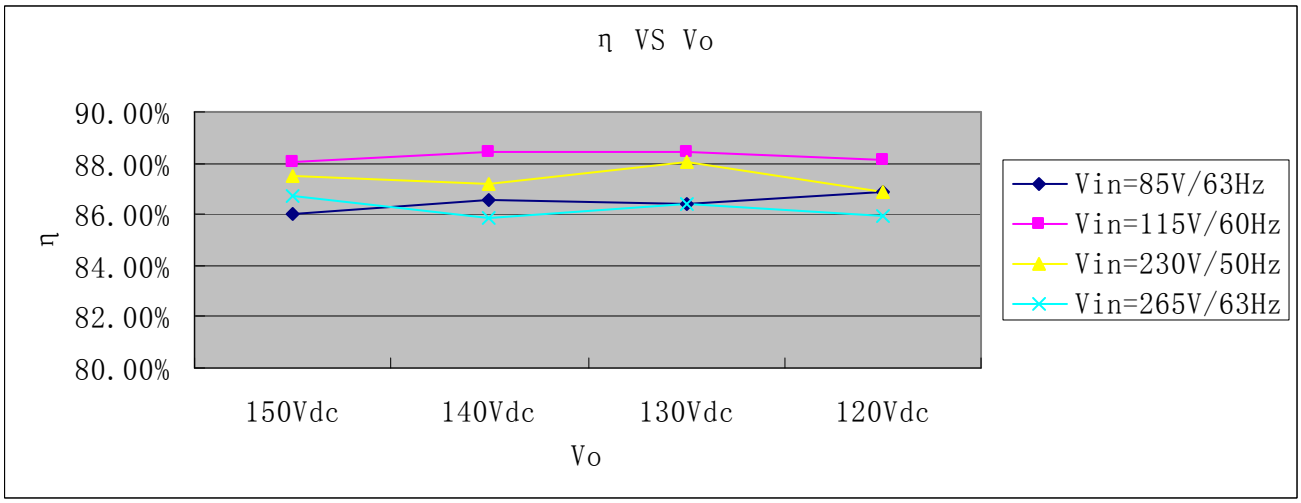
2) Efficiency

Note: 用电子负载CV模式模拟LED负载

负载 (Vo)	η 效率			
	85V/63Hz	115V/60Hz	230V/50Hz	265V/47Hz
150Vdc	86.02%	88.08%	87.46%	86.76%
140Vdc	86.53%	88.47%	87.18%	85.88%
130Vdc	86.42%	88.43%	88.02%	86.44%
120Vdc	86.88%	88.10%	86.86%	85.92%
灯丝灯	84.45%	86.16%	86.85%	86.27%

备注：可以看出采用LED做负载和比采用电子负载效率低约1~2%，特别是低压输入时差异较大；同时效率会随输入电压升高而升高；





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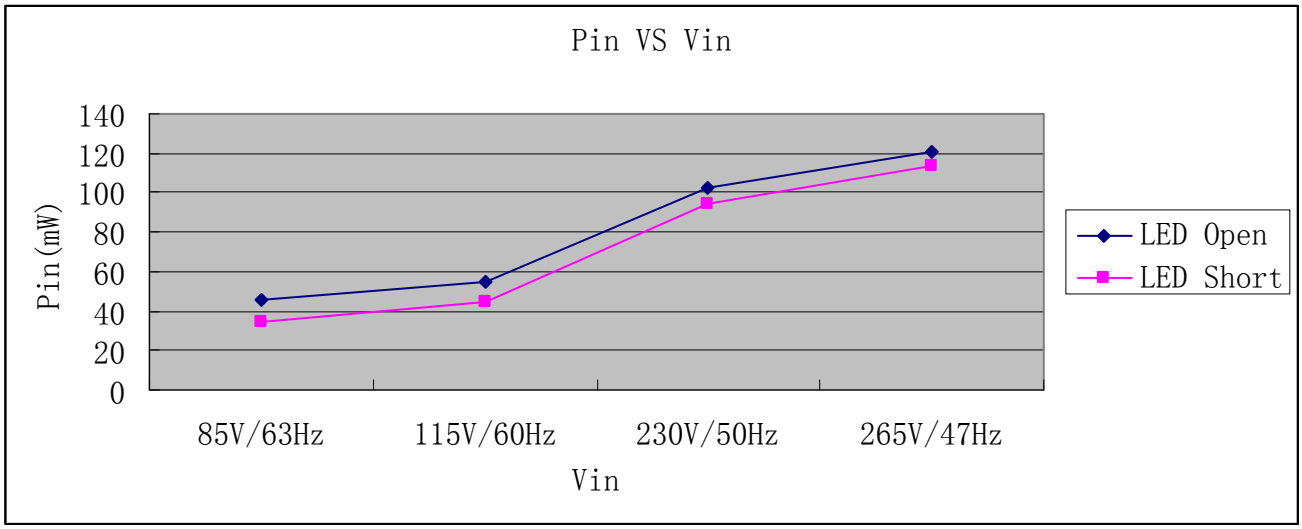
3） Input power when LED open Or Short

Vin	LED Open		LED Short
	Pin(mW)	Vo_max(V)	Pin(mW)
85V/60Hz	55	209	31
100V/60Hz	65	203	41
110V/60Hz	66	221	38
135V/60Hz	70	205	60

LED 开路电压为尖峰电压(见后续工作波形图 7)，实际采用万用表测试时电压有效值不到 100V；



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5) Startup （负载灯丝灯）

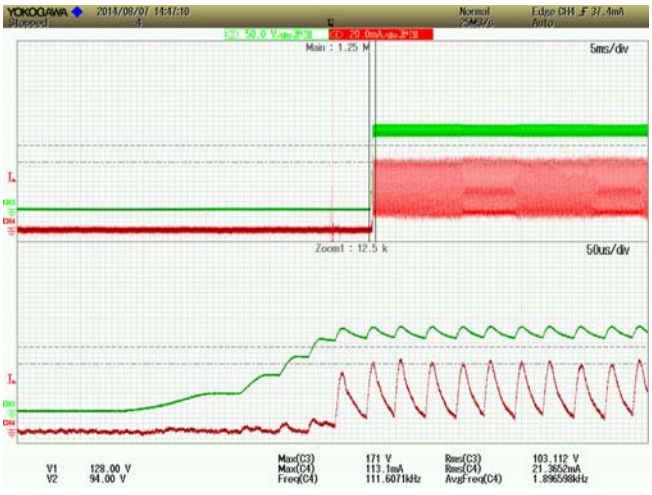
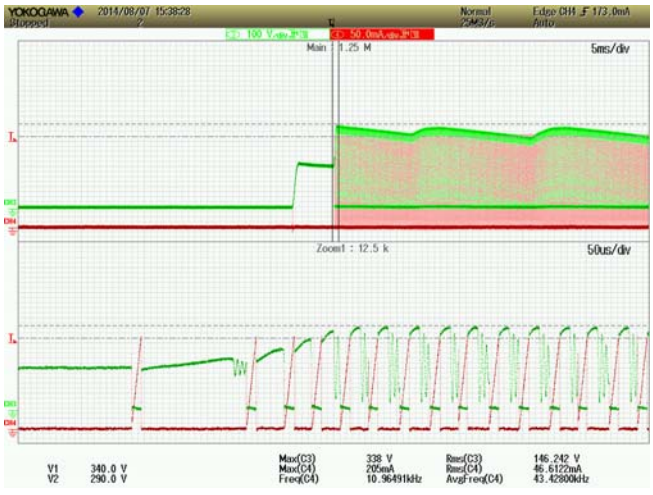
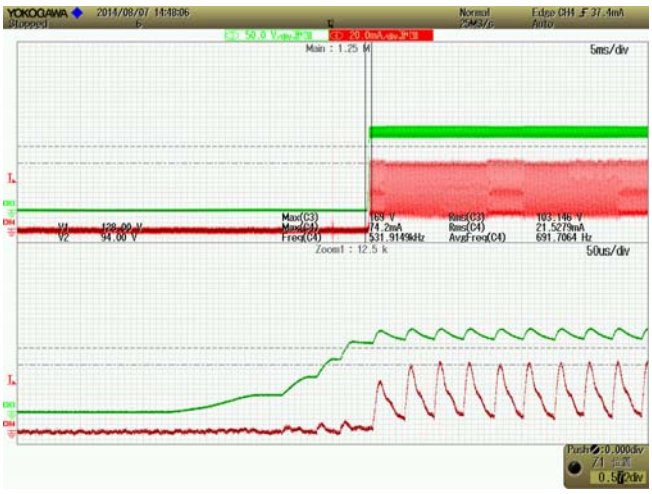
Figure 1. VIN = 115 VAC, startup			Figure 2. VIN = 115 VAC, startup		
					
Vo	–CH3 trace	50V/div	Vds	–CH3 trace	100V/div
Io	– CH4 trace	20mA/div	Ids	– CH4 trace	50mA/div
5ms/Zoom 50uS			5ms/Zoom 50uS		
Vds_max=338V 系统在 100mS 内启动					

Figure 3. VIN = 230 VAC, startup			Figure 4. VIN = 230 VAC, startup		
					
Vo	–CH3 trace	50V/div	Vds	–CH3 trace	100V/div
Io	– CH4 trace	20mA/div	Ids	– CH4 trace	50mA/div
5ms/Zoom 50uS			5ms/Zoom 50uS		
Vds_max=494V 系统在 100mS 内启动					

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6) Power off （负载灯丝灯）

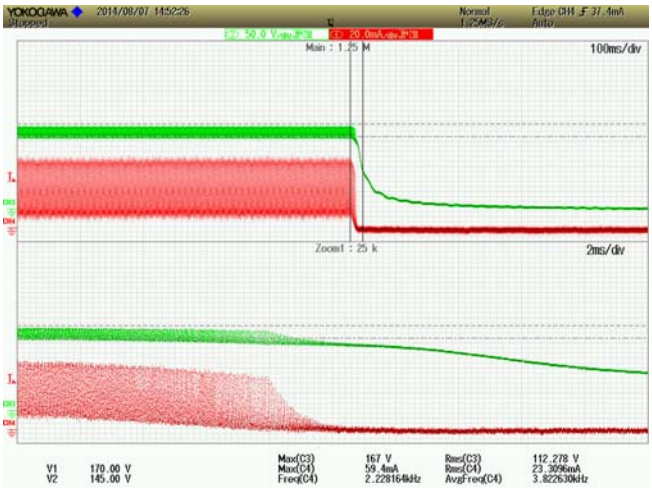
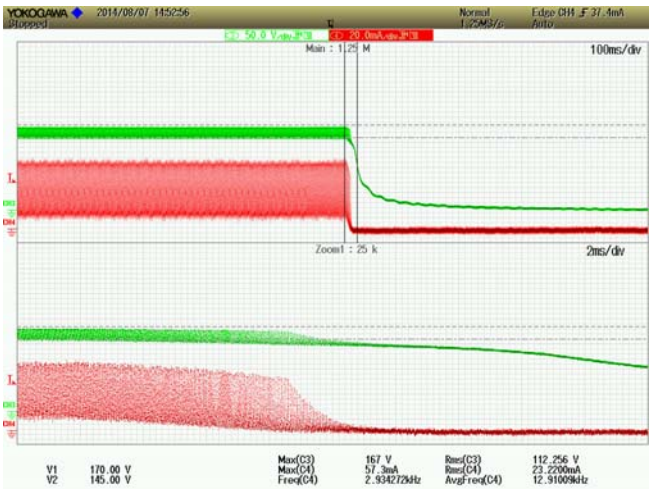
Figure 5. VIN = 115 VAC, Power off			Figure 6. VIN = 115 VAC, Power off		
					
Vo	–CH3 trace	50V/div	Vds	–CH3 trace	100V/div
Io	– CH4 trace	20mA/div	Ids	– CH4 trace	50mA/div
100ms/Zoom 2mS			100ms/Zoom 2mS		
断电无回闪					

Figure 7. VIN = 230 VAC, Power off			Figure 8. VIN = 230 VAC, Power off		
					
Vo	–CH3 trace	50V/div	Vds	–CH3 trace	100V/div
Io	– CH4 trace	20mA/div	Ids	– CH4 trace	50mA/div
100ms/Zoom 2mS			100ms/Zoom 2mS		
断电无回闪					

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7) Operating waveforms （负载灯丝灯）

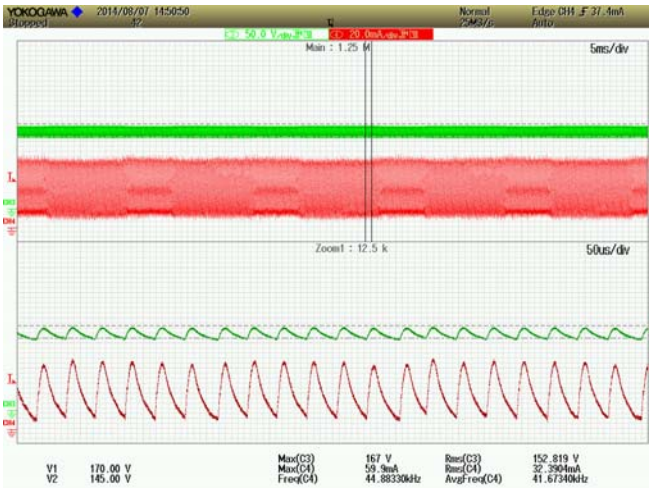
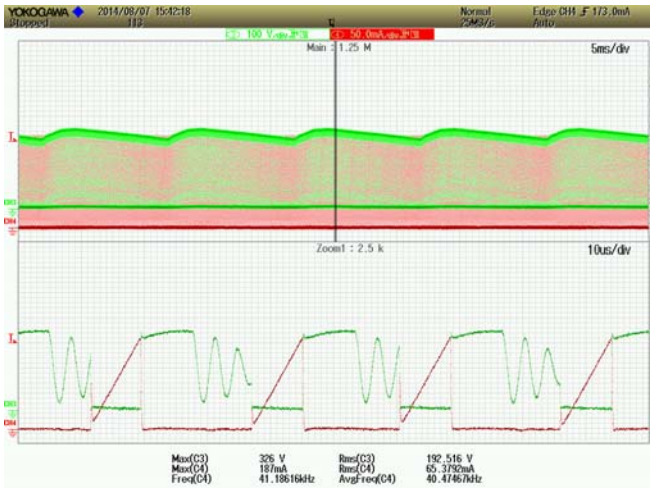
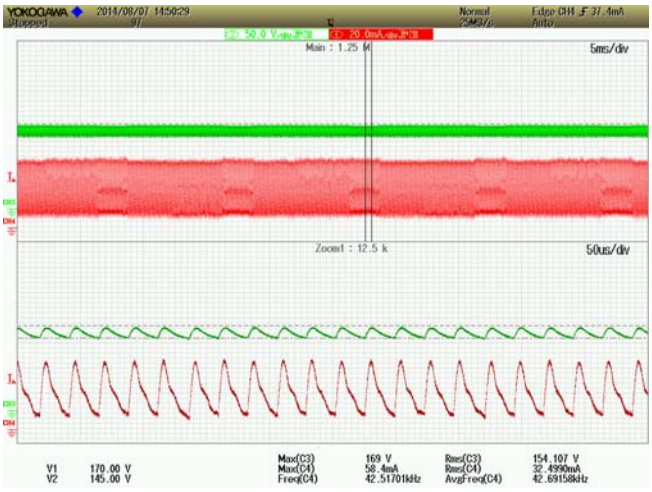
Figure 9. VIN = 115 VAC, Operating Waveform			Figure 10. VIN = 115 VAC, Operating Waveform		
					
Vo	–CH3 trace	50V/div	Vds	–CH3 trace	100V/div
Io	– CH4 trace	20mA/div	Ids	– CH4 trace	50mA/div
5ms/Zoom 50uS			5ms/Zoom 10uS		
Vds_max=326V					

Figure 11. VIN = 230 VAC, Operating Waveform			Figure 12. VIN = 230 VAC, Operating Waveform		
					
Vo	–CH3 trace	50V/div	Vds	–CH3 trace	100V/div
Io	– CH4 trace	20mA/div	Ids	– CH4 trace	50mA/div
5ms/Zoom 50uS			5ms/Zoom 10uS		
Vds_max=490V					

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8) LED Open Protection （负载灯丝灯）

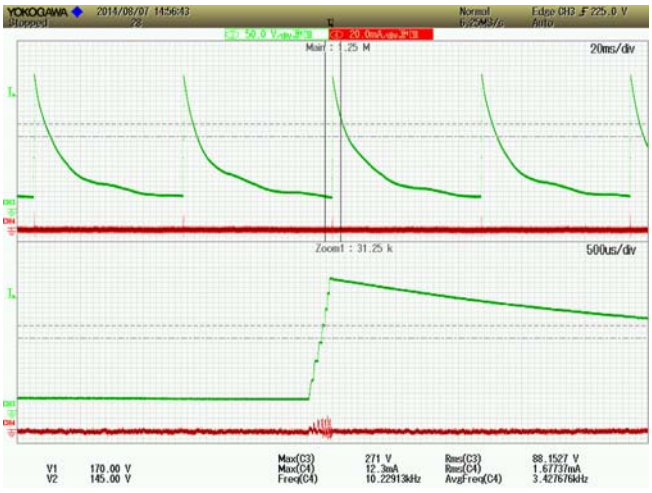
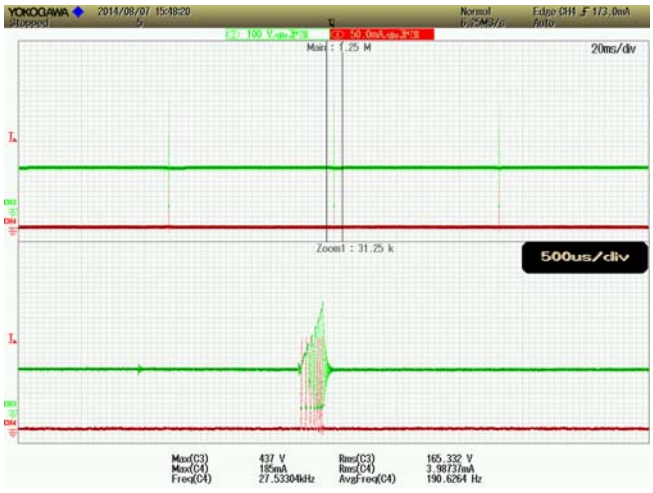
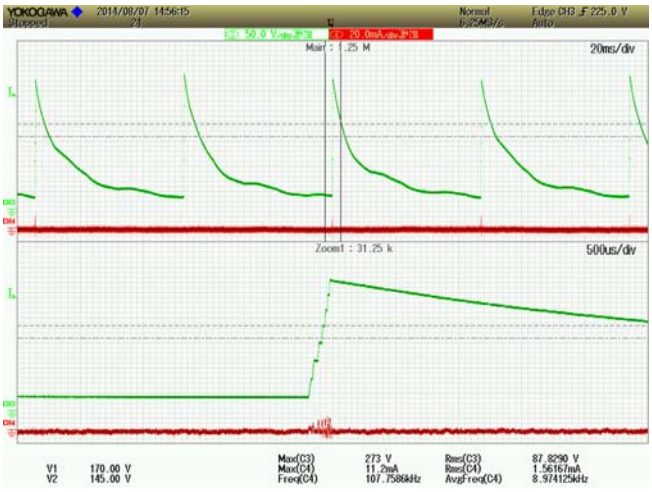
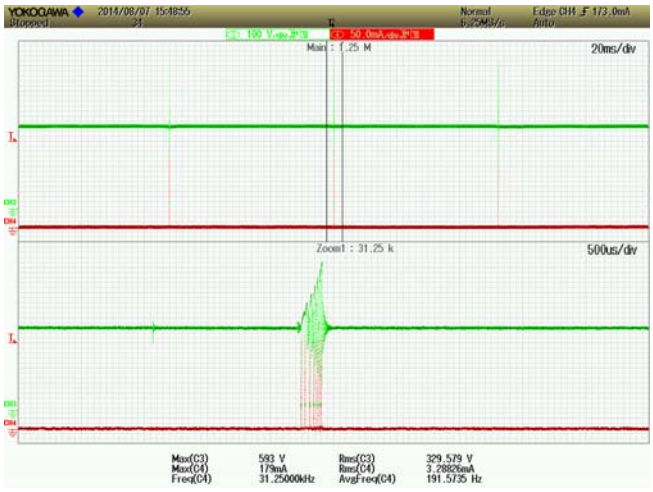
Figure 13. VIN = 115 VAC, LED Open			Figure 14. VIN = 115 VAC, LED Open		
					
Vo	–CH3 trace	50V/div	Vds	–CH3 trace	100V/div
Io	– CH4 trace	20mA/div	Ids	– CH4 trace	50mA/div
20ms/Zoom 500uS			20ms/Zoom 500uS		
LED 开路时系统进入打嗝保护：Vo_max=271V（有效值 88.1527V），Vds_max=437V					

Figure 15. VIN = 230 VAC, LED Open			Figure 16. VIN = 230 VAC, LED Open		
					
Vo	–CH3 trace	50V/div	Vds	–CH3 trace	100V/div
Io	– CH4 trace	20mA/div	Ids	– CH4 trace	50mA/div
20ms/Zoom 500uS			20ms/Zoom 500uS		
LED 开路时系统进入打嗝保护：Vo_max=273V（有效值 87.8290V），Vds_max=593V					

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9) LED Short Protection （负载灯丝灯）

Figure 17. VIN = 115 VAC,LED Short			Figure 18. VIN = 115 VAC,LED Short		
					
Vo	–CH3 trace	50V/div	Vds	–CH3 trace	100V/div
Io	– CH4 trace	20mA/div	Ids	– CH4 trace	50mA/div
20ms/Zoom 500uS			20ms/Zoom 500uS		
LED 短路时系统进入打嗝保护					

Figure 19. VIN = 230 VAC,LED Short			Figure 20. VIN = 230 VAC,LED Short		
					
Vo	–CH3 trace	50V/div	Vds	–CH3 trace	100V/div
Io	– CH4 trace	20mA/div	Ids	– CH4 trace	50mA/div
20ms/Zoom 500uS			20ms/Zoom 500uS		
LED 短路时系统进入打嗝保护					

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9. EMI 特性测试

9.1 传导测试

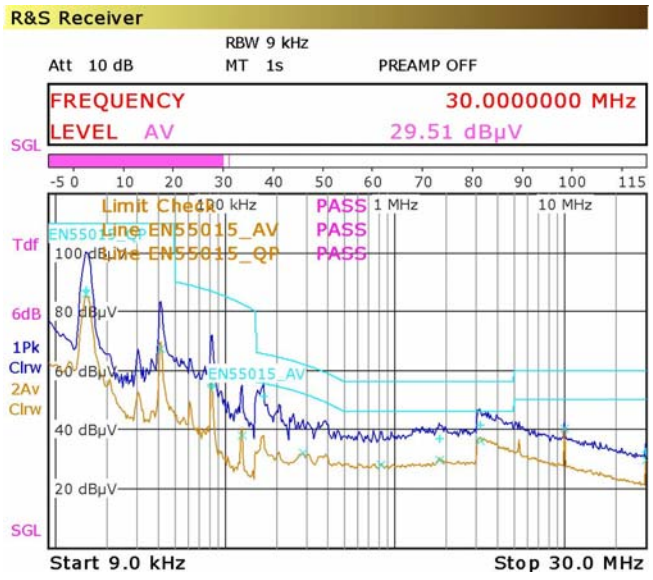
测试条件：Vin=115/230Vac，输出接 LED 灯丝灯，LED 压降约 150V

测试结果：裕量大于-4dB；

输入电压	传导测试结果	
	L	N
115V/60Hz	-9.46dB	-8.85dB
230V/50Hz	-9.00dB	-8.88dB

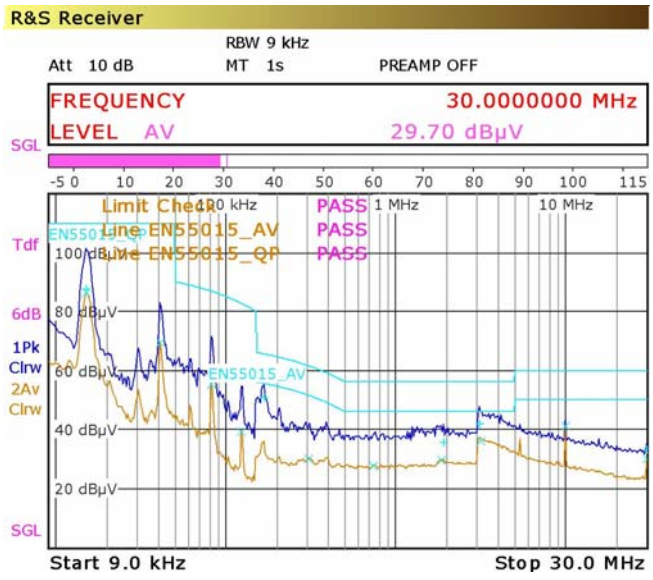
Vin=115Vac 测试结果

L 线测试波形



Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	15.0000 kHz	87.35	-22.65 dB
2 Average	15.0000 kHz	86.00	
2 Average	41.4000 kHz	67.49	
2 Average	82.2000 kHz	56.20	
1 Quasi Peak	82.6000 kHz	54.38	-32.36 dB
2 Average	123.8000 kHz	37.87	
1 Quasi Peak	166.0000 kHz	51.12	-14.42 dB
2 Average	286.0000 kHz	32.01	-20.10 dB
2 Average	814.0000 kHz	27.71	-18.29 dB
1 Quasi Peak	1.8260 MHz	36.64	-19.36 dB
2 Average	1.8260 MHz	29.38	-16.62 dB
1 Quasi Peak	3.1440 MHz	41.81	-14.19 dB
2 Average	3.1440 MHz	35.97	-10.03 dB
2 Average	10.0000 MHz	40.54	-9.46 dB
1 Quasi Peak	30.0000 MHz	32.35	-27.65 dB

N 线测试波形



Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	15.0000 kHz	87.81	-22.19 dB
2 Average	15.0000 kHz	86.48	
2 Average	41.0000 kHz	69.36	
2 Average	82.2000 kHz	55.50	
2 Average	123.4000 kHz	39.37	
1 Quasi Peak	166.0000 kHz	50.71	-14.83 dB
2 Average	306.0000 kHz	30.09	-21.45 dB
2 Average	734.0000 kHz	27.65	-18.35 dB
2 Average	1.8340 MHz	29.50	-16.50 dB
1 Quasi Peak	1.9060 MHz	35.75	-20.25 dB
1 Quasi Peak	3.1080 MHz	41.88	-14.12 dB
2 Average	3.1320 MHz	35.99	-10.01 dB
2 Average	10.0000 MHz	41.15	-8.85 dB
1 Quasi Peak	30.0000 MHz	32.96	-27.04 dB
2 Average	30.0000 MHz	29.70	-20.30 dB

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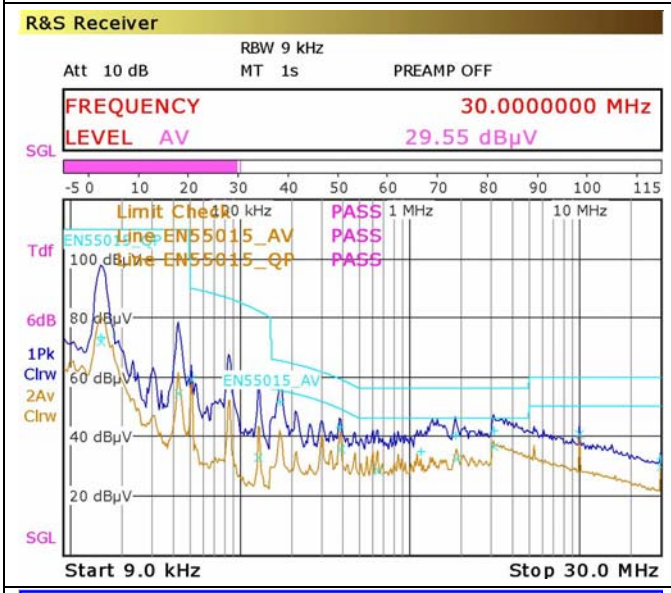
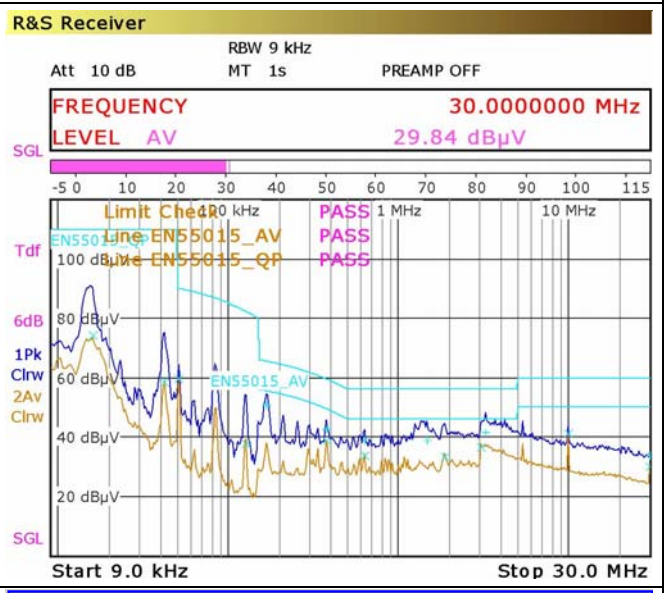
Vin=230Vac 测试结果

L 线测试波形



Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	15.0000 kHz	73.36	-36.64 dB
2 Average	15.0000 kHz	71.77	
2 Average	42.6000 kHz	54.68	
2 Average	51.4000 kHz	59.58	
2 Average	127.4000 kHz	32.86	
1 Quasi Peak	170.0000 kHz	51.79	-13.64 dB
1 Quasi Peak	382.0000 kHz	43.38	-15.99 dB
2 Average	386.0000 kHz	35.49	-13.77 dB
2 Average	642.0000 kHz	28.15	-17.85 dB
1 Quasi Peak	1.1500 MHz	34.93	-21.07 dB
1 Quasi Peak	1.8380 MHz	40.57	-15.43 dB
2 Average	1.8580 MHz	32.15	-13.85 dB
2 Average	3.0720 MHz	36.37	-9.63 dB
1 Quasi Peak	3.0760 MHz	42.20	-13.80 dB
2 Average	10.0000 MHz	41.00	-9.00 dB

N 线测试波形



Trace/Detector	Frequency	Level dBµV	DeltaLimit
2 Average	15.8000 kHz	74.28	
2 Average	41.8000 kHz	58.77	
2 Average	51.0000 kHz	59.65	
2 Average	125.8000 kHz	37.59	
1 Quasi Peak	166.0000 kHz	51.05	-14.49 dB
1 Quasi Peak	378.0000 kHz	42.85	-16.64 dB
2 Average	378.0000 kHz	38.88	-10.61 dB
1 Quasi Peak	630.0000 kHz	38.88	-17.12 dB
2 Average	630.0000 kHz	33.68	-12.32 dB
1 Quasi Peak	1.4620 MHz	38.75	-17.25 dB
2 Average	1.8660 MHz	32.94	-13.06 dB
2 Average	3.0440 MHz	36.55	-9.45 dB
1 Quasi Peak	3.2240 MHz	41.74	-14.26 dB
2 Average	10.0000 MHz	41.12	-8.88 dB
1 Quasi Peak	30.0000 MHz	33.43	-26.57 dB

9.2 辐射测试

测试条件：Vin=115/230Vac，输出接 LED 灯丝灯，LED 压降约 150V

测试结果：裕量大于-4dB；

输入电压	传导测试结果	
	H	V
115V/60Hz	-8.9dB(PK)	-9.9dB(QP)
230V/50Hz	-9.3dB(PK)	-7.0dB(QP)

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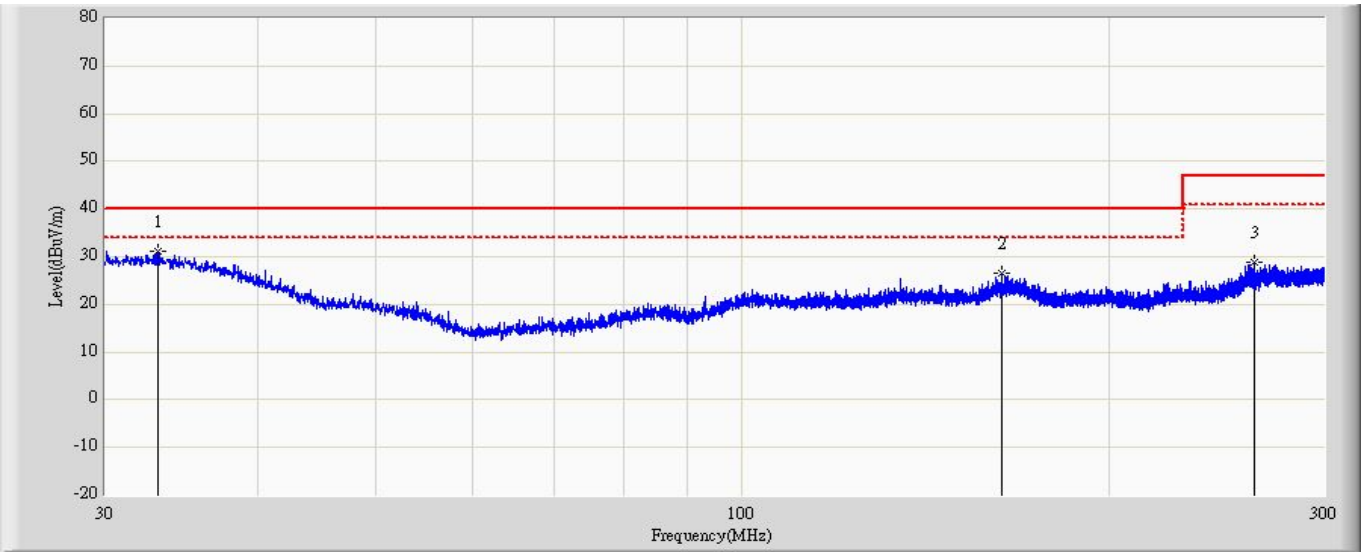
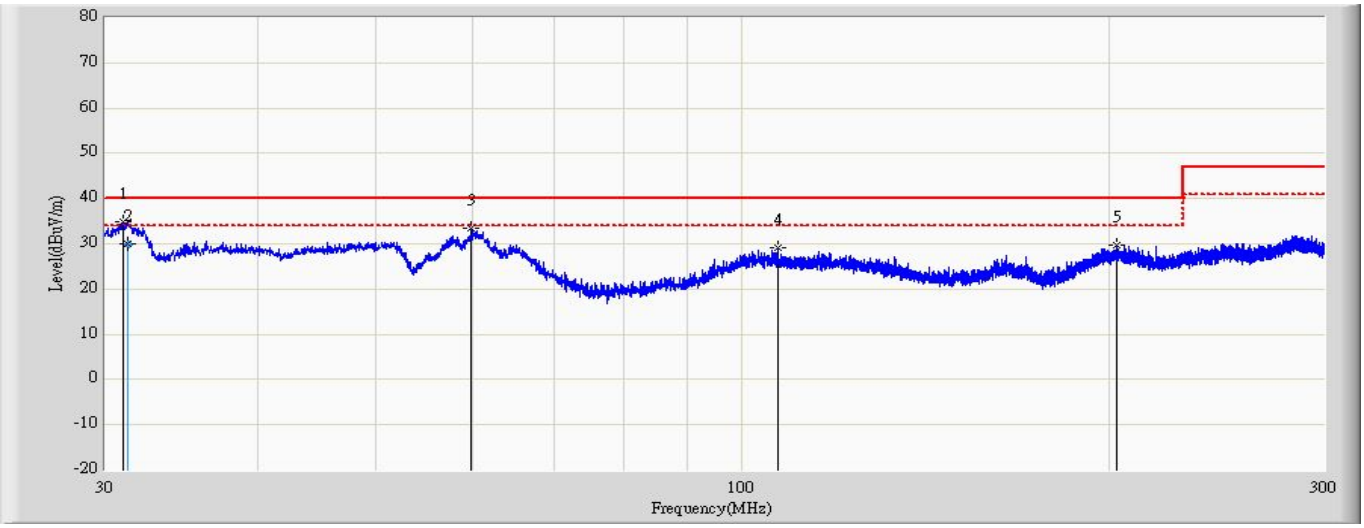
110V 输入水平方向



No	Mark	Frequency (MHz)	Measure Level (dBuV/m)	Reading Level (dBuV)	Over Limit (dB)	Limit (dBuV/m)	Probe (dB/m)	Cable (dB)	Amp (dB)	Ant Pos (cm)	Table Pos (deg)	Type
1	*	33.139	31.022	5.456	-8.978	40.000	19.103	6.462	0.000	0	0	PK
2		163.076	26.642	7.821	-13.358	40.000	11.691	7.130	0.000	0	0	PK
3		262.909	28.879	8.213	-18.121	47.000	13.194	7.471	0.000	0	0	PK

110V 输入垂直水平方向



No	Mark	Frequency (MHz)	Measure Level (dBuV/m)	Reading Level (dBuV)	Over Limit (dB)	Limit (dBuV/m)	Probe (dB/m)	Cable (dB)	Amp (dB)	Ant Pos (cm)	Table Pos (deg)	Type
1	*	31.080	34.868	10.865	-5.132	40.000	17.552	6.451	0.000	0	0	PK
2		31.335	30.002	6.100	-9.998	40.000	17.448	6.454	0.000	100	359	QP
3		59.936	33.305	16.046	-6.695	40.000	10.619	6.640	0.000	0	0	PK
4		106.950	29.266	5.810	-10.734	40.000	16.560	6.897	0.000	0	0	PK
5		202.631	29.784	5.087	-10.216	40.000	17.427	7.270	0.000	0	0	PK

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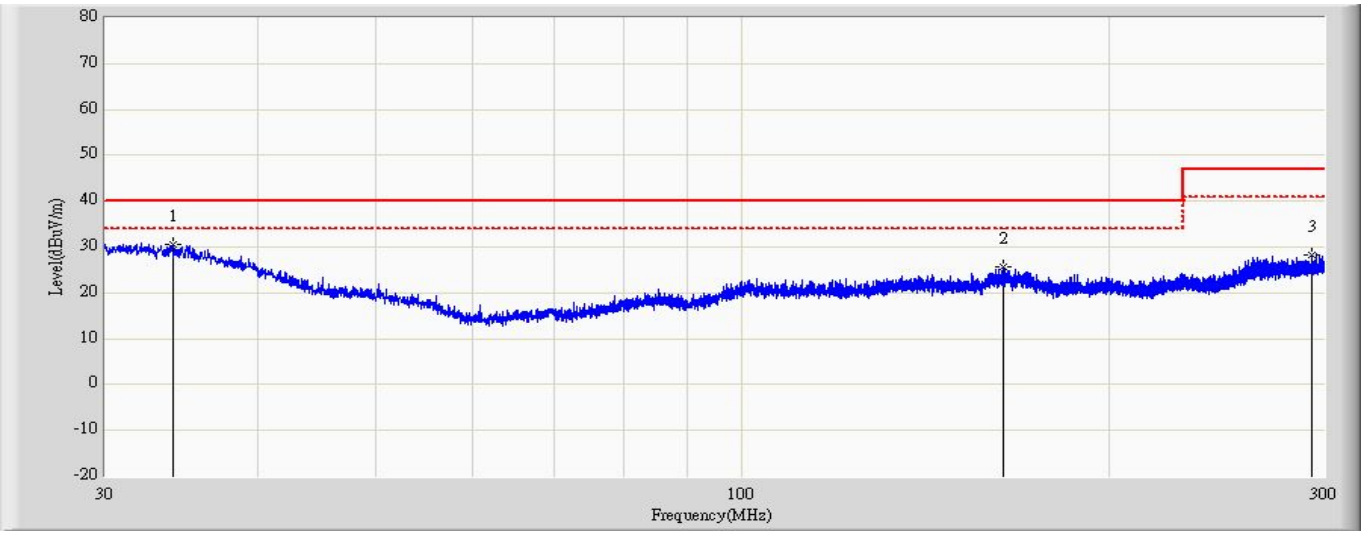
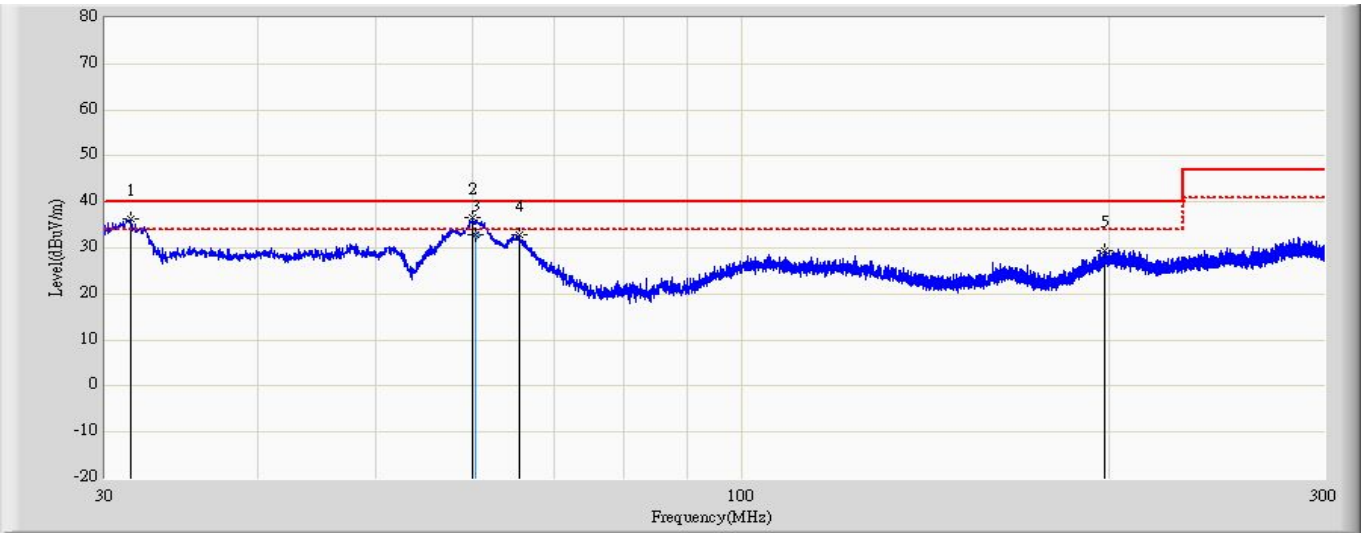
230V 输入水平方向



No	Mark	Frequency (MHz)	Measure Level (dBuV/m)	Reading Level (dBuV)	Over Limit (dB)	Limit (dBuV/m)	Probe (dB/m)	Cable (dB)	Amp (dB)	Ant Pos (cm)	Table Pos (deg)	Type
1	*	34.084	30.658	5.100	-9.342	40.000	19.086	6.472	0.000	0	0	PK
2		163.583	25.772	6.912	-14.228	40.000	11.730	7.130	0.000	0	0	PK
3		293.554	28.375	5.885	-18.625	47.000	14.913	7.577	0.000	0	0	PK

230V 输入垂直方向



No	Mark	Frequency (MHz)	Measure Level (dBuV/m)	Reading Level (dBuV)	Over Limit (dB)	Limit (dBuV/m)	Probe (dB/m)	Cable (dB)	Amp (dB)	Ant Pos (cm)	Table Pos (deg)	Type
1		31.451	36.443	12.587	-3.557	40.000	17.401	6.455	0.000	0	0	PK
2	*	60.037	36.575	19.322	-3.425	40.000	10.613	6.640	0.000	0	0	PK
3		60.331	32.950	15.700	-7.050	40.000	10.608	6.643	0.000	100	0	QP
4		65.539	32.805	15.686	-7.195	40.000	10.443	6.676	0.000	0	0	PK
5		198.176	29.442	5.018	-10.558	40.000	17.160	7.264	0.000	0	0	PK

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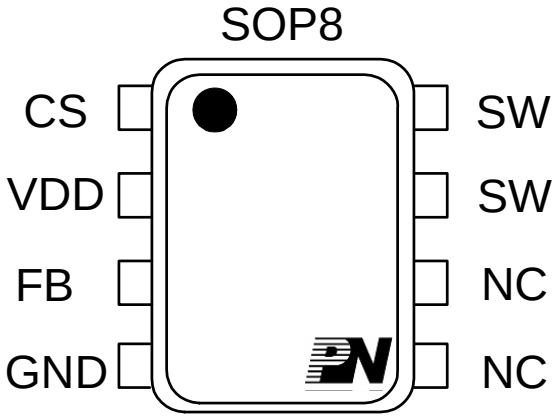
10. 附件 ：IC 封装图

PN8371 封装和脚位配置图：



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