设计范例报告

标题	***使用HiperTFS™-2 TFS7703H设计的190 W 连续功率、280 W峰值功率DC-DC正激式转换器，待机工作频率为132 kHZ***
规格	380 VDC输入；12 V，15 A主输出和12 V，0.83 A待机输出
应用	一体机（AIO）PC电源
作者	应用工程部
文档编号	DER-368
日期	2013年11月12日
修订版本	7.1

特色概述

- 高效率集成式主转换器及待机转换器
- 集成的高端驱动器
- 内置的主及待机欠压锁存
- 伏秒限制为主变压器提供保护
- 单一的待机功率限制与输入电压变化关系
- 132 kHz的工作频率允许使用较小的主变压器(EF25)
- >91%的高效率主转换器

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重要说明：
虽然本电路板的设计满足安全隔离要求，但工程原型尚未获得机构认证。

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1 简介

本文档是介绍一款190 W连续功率、280 W峰值功率电源的初步测试的工程报告，该电源由一个双管正激主转换器和一个反激待机转换器构成，它采用工作频率为132 kHz 的TFS7703H IC设计而成。一个EF25变压器用于主输出电源，一个EE16变压器用于待机电源。测试的目的是为了确定一个用于PC电源（仅）12 V输出“一体化”解决方案的评估板所能实现的最大输出功率（带风冷）。
主转换器在300 VDC至420 VDC的输入电压范围内进行工作。待机转换器的输入工作电压范围则为120 VDC至420 VDC。在典型系统中，高压DC输入通常由PFC级提供。

本文档包括电源规格、电路原理图、物料清单、变压器规格文件、测试设置说明及性能数据。

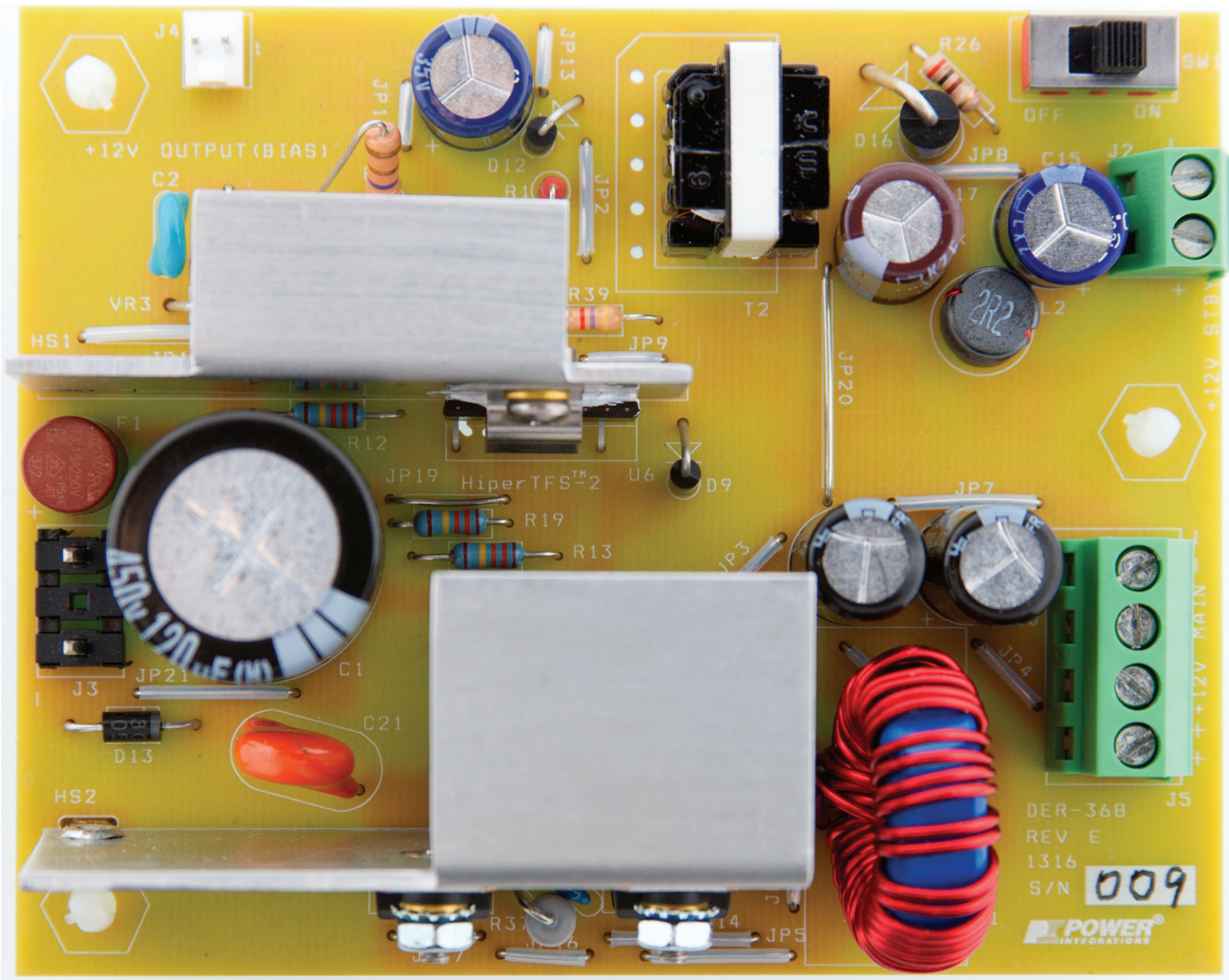

Figure 1 – DER-368 Populated Circuit Board Photograph, Top View.

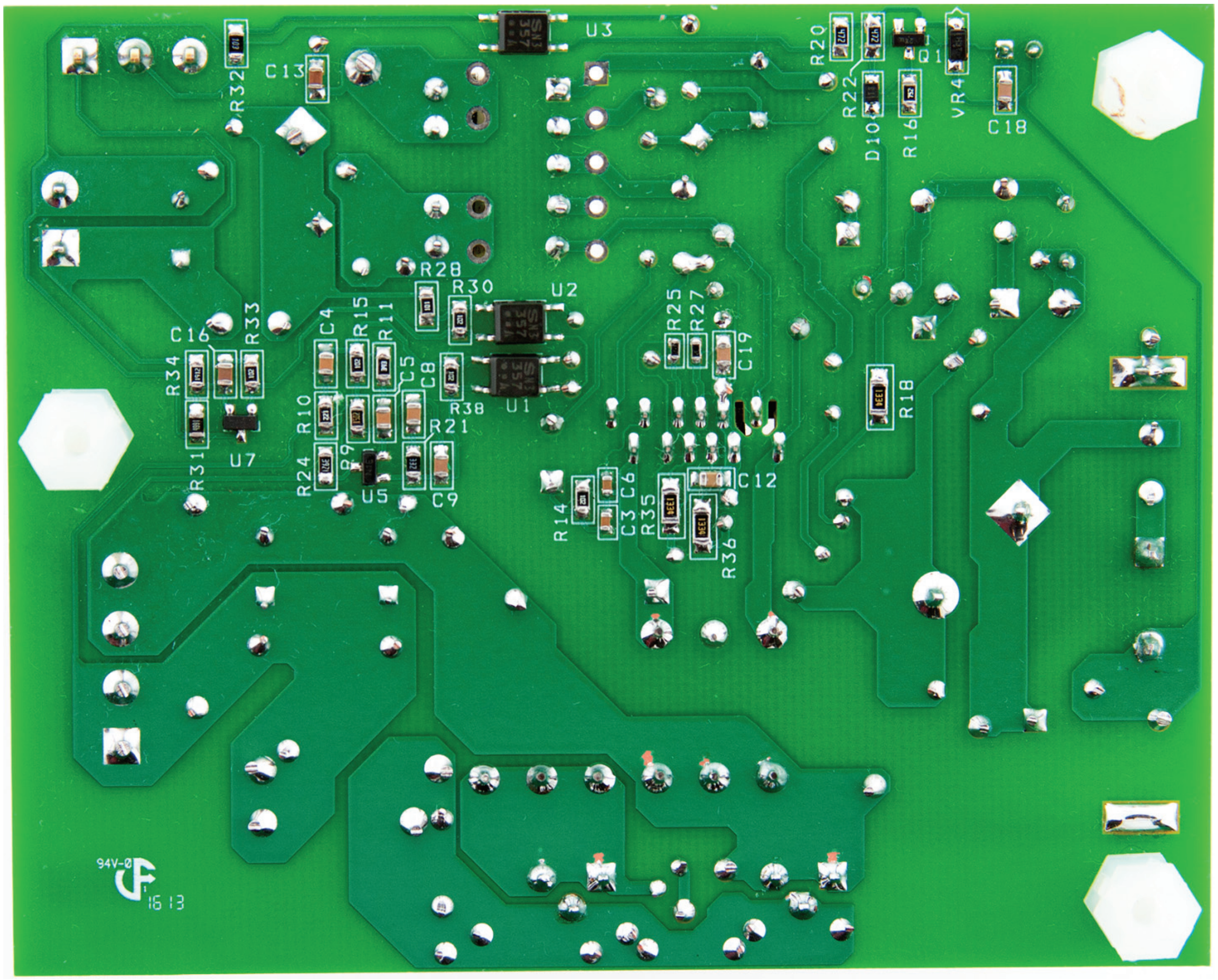

Figure 2 – DER-368 Populated Circuit Board Photograph, Bottom View.

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2 电源规格

下表所列为设计的最低可接受性能。实际性能可参考测量结果部分。

说明	符号	最小值	典型值	最大值	单位	备注
输入						
直流总线电压	V_{IN}	300	380	420	VDC	仅直流输入
空载输入功率(380 VDC)			0.3		W	
启动电压	V_{START}		340		VDC	
关断电压	V_{STOP}		285		VDC	
输出						
输出1电压	V_{OUT1}	11.4	12	12.6	V	±5%
输出1峰-峰值纹波电压	$V_{RIPPLE1}$			120	mV	20 MHz带宽
输出1电流	I_{OUT1}	0		15	A	22.5 A峰值
输出2电压	V_{OUT2}	11.4	12	12.6	V	±5%
输出2峰-峰值纹波电压	$V_{RIPPLE2}$			120	mV	20 MHz带宽
输出2电流	I_{OUT2}	0	0.83		A	
总输出功率						
连续输出功率	P_{OUT}		190		W	
峰值输出功率	P_{OUT_PEAK}			280	W	（主12 V输出上的峰值负载为22.5 A）
效率						在25°C、380 VDC输入下测得
20%负载	η		86		%	
50%负载	η		90		%	
100%负载	η		90		%	
尺寸		109 x 84 x 33			mm	长x宽x高
环境温度	t_{AMB}	0		40	°C	强制风冷

3 电路原理图

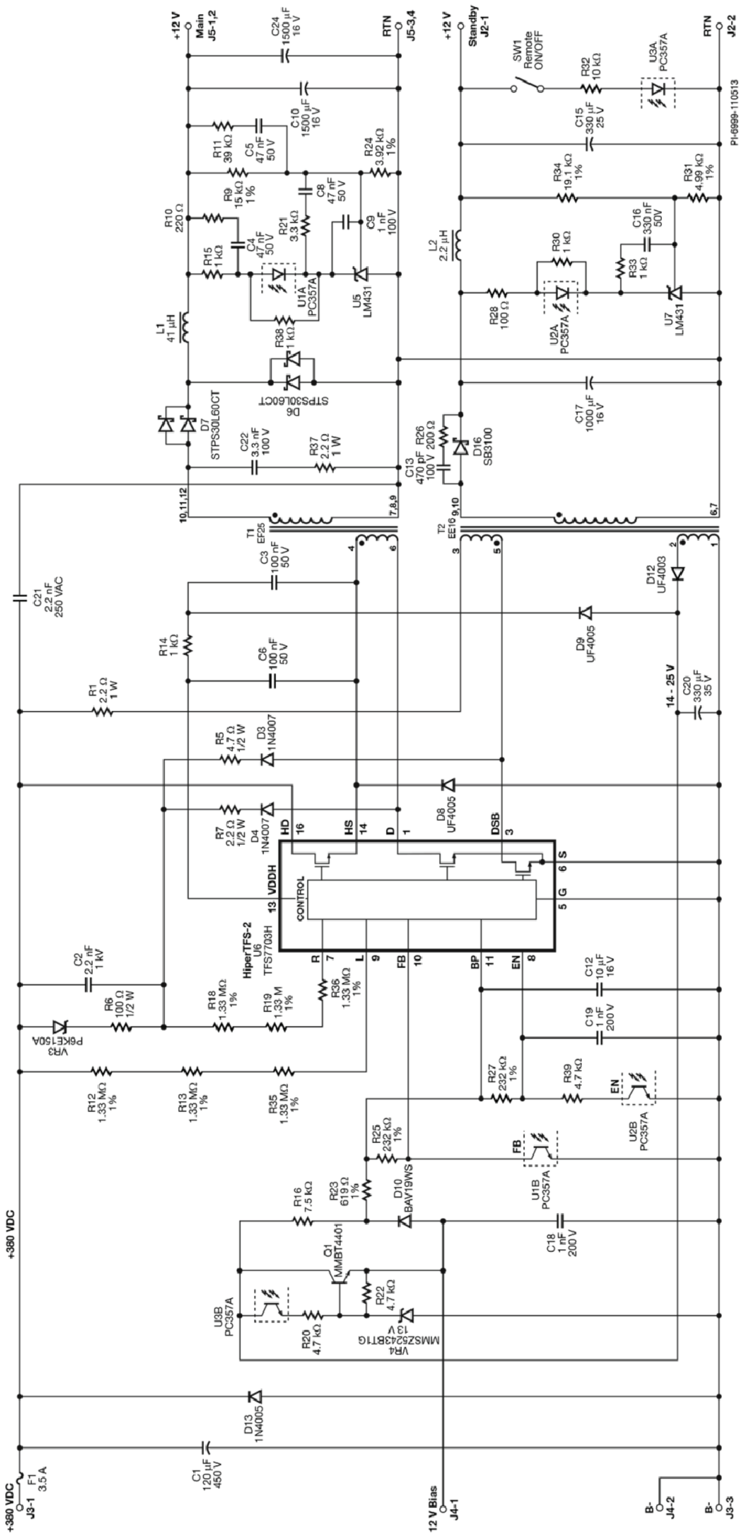

Figure 3 – Schematic.

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4 电路描述

图3中的电路原理图描述的是使用TFS7703H实现的一个12 V、15 A正激DC-DC转换器和一个12 V、0.83 A反激待机/初级偏置电源。

HiperTFS-2 TFS7703H以高成本效益的方式将一个下管725 V主MOSFET、一个上管530 V主MOSFET和一个725 V待机MOSFET、主及待机控制器、一个上管驱动器以及热关断和其他故障保护和控制电路集成到同一个封装内。该器件非常适合具有主及待机转换器（如PC电源）的高功率应用。待机转换器可以在宽输入电压范围内进行工作。主转换器用于接受来自功率因数校正级的升压输入电压，通常在300 VDC至385 VDC的电压范围内进行工作。

4.1 功率输入和滤波电路

本电路适用于主输出功率最高达180 W的PC电源。二极管D13可使保险丝F1在反向输入电压连接时断开，从而避免发生严重故障。电容C1为大容量储能元件。

4.2 初级侧

元件C2、R6和VR3形成一个关断箝位电路，用于限制待机转换器漏极和主正激转换器下管MOSFET漏极共用的U6的漏极电压。齐纳二极管VR3提供限定的箝位电压，并维持电容C2上的最大电压(150 V)。大部分漏感能量和磁化能量都会返回转换器，这是因为阻断二极管D3和D4具有慢恢复特性。主转换器与待机转换器共用一个复位/漏感尖峰箝位电路，有助于减少元件数。待机转换器通过二极管D3和电阻R5连接到箝位电路，主转换器通过D8、D4及R7连接到箝位电路。在复位时，主转换器会连接到一个远高于V_{IN}的复位电压，因此主转换器的工作占空比可以超出50%以上，这样能在不影响维持时间的情况下降低RMS开关电流。

旁路(BP)引脚与电容C12为HiperTFS-2控制器提供一个去耦工作电压。C12的值(10 μF)还可以将主转换器的工作频率选定在132 kHz。启动时，旁路电容从IC U6内部的电流源进行充电。当BP引脚电压达到5.8 V时，待机转换器可以开始开关，+12 V待机输出和初级侧偏置电压将开始升高。偏置/辅助供电绕组的输出端由二极管D12进行整流，并由电容C20进行滤波。偏置绕组的输出端用来在仅待机工作条件下通过电阻R16向HiperTFS-2 BP引脚供电。当远程ON开关SW1使能U3A和U3B且命令Q1进入ON状态时，Q1和D10会从初级偏置电源提供额外的电流。在完整的PC电源应用中，该电压用来通过J4连接器向PFC控制器提供偏置电源。所选取的R16值可维持流入BP引脚所需的700 μA最小电流（用来抑制HiperTFS-2高压电流源），从而降低空载功耗。电容C12连接到U6的BP引脚，为内部稳压的5.85 V电源提供去耦。齐纳二极管VR4为Q1提供电压参考，使门极-发射极电压稳定到12.4 V，进而使稳定的6 mA电流流入BP引脚；此外，齐纳二极管VR4还能为PFC级（如使用）提供稳压电源。

使能(EN)引脚是待机控制器的反馈引脚。在启动之前，会对一个从EN连接到BP的电阻R27进行检测，以便选择待机转换器多个内部限流值中的其中一个。在启动时，与EN引脚一样，反馈(FB)引脚电阻R25用来选择三个主限流值中的一个。R27可以采用四个不同的电阻值，用来选择待机转换器四个内部限流配置中的一个，R25可以采用三个不同的电阻值，用来选择主转换器三个内部限流配置中的一个。此处所示的电路采用R27 (232 kΩ)来实现650 mA的待机I_{LIM}，采用232 kΩ的R25来实现3.1 A的主I_{LIM}。

FB引脚为主转换器提供反馈。从FB引脚到接地电流吸收的增大将导致工作占空比的降低。

二极管D9用于在启动期间为自举充电C3和C6提供初始电源。在此期间，上管MOSFET HS引脚被暂时拉至源极12 ms。正常工作情况下，C6的额定电压被并联调节至约12 V。有必要始终确保电容C3上有一个最低为13 V的电压。

电阻R18、R19和R36用于将最大可用OFF时间复位电压转换为R引脚的电流，并与L引脚电流进行比较，以计算最大允许占空比，从而避免饱和，同时确定作为峰值导通时间通量的函数的最大允许占空因数。

线电压检测(L)引脚提供输入体电压线电压检测功能。该信息被欠压和过压检测电路同时用于主及待机转换器。该引脚也可被拉低至源极，以同时对待机及主电源实施远程ON/OFF控制。电阻R12、R13和R35用于将输入电压转换为L引脚的电流。

4.3 输出整流

对于待机转换器，输出整流由二极管D16提供。具有低ESR值的电容C17提供低纹波滤波。电感L2和电容C15形成一个后级滤波器，进一步降低输出端的开关纹波和噪声。

对于主转换器，二极管D7在主导通时间期间进行整流，二极管D6是在主关断时间期间为输出电感L1提供电流放电通路的箝位二极管。电感L1与电容C10和C24一起构成主转换器的输出滤波器，对开关输出纹波和噪声进行滤波。

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4.4　输出反馈

对于待机转换器，电阻R34和R31形成一个反馈分压网络。电源的输出电压被分压，并馈入误差放大器U7的输入端。U2A的阴极电压由U7内的放大器控制，以将分压器电压维持在2.5 V ±2%。阴极电压的变化会导致流经U2A内的光耦二极管的电流发生变化，进而改变流经U2B内的晶体管的电流。电容C19为EN引脚提供噪声抑制。当从EN引脚吸收的电流超出EN引脚阈值电流时，下一个开关周期将被禁止；当输出电压低于反馈阈值时，会使能一个开关周期。通过调整使能的周期数量来维持输出稳压。随负载的减轻，使能周期也随之减少，从而降低有效的开关频率，根据负载情况减低开关损耗。因此能够在负载极轻时提供恒定的效率，易于满足能效标准的要求。

对于主转换器，电阻R9和R24用来为U5误差放大器提供DC参考。以类似的方式，U5可以控制用于通过从FB引脚吸入的电流来调整工作占空比的光耦器U1，主要差异是FB引脚电流以线性方式控制主转换器的占空比，而待机转换器是采用整个周期On/Off控制。元件C4、C8-9、R10和R21对主12 V控制环路提供补偿。元件C5与R11形成“软结束”网络，用来防止启动时的输出过冲。

电阻R15为控制环路设置增益，电阻R10、R21和电容C4、C8和C9形成控制环路的响应，以实现所需的环路增益交叉频率和相位裕量。电阻R38和R30提供IC U5和U7各自所要求的偏置电流。

5 PCB布局

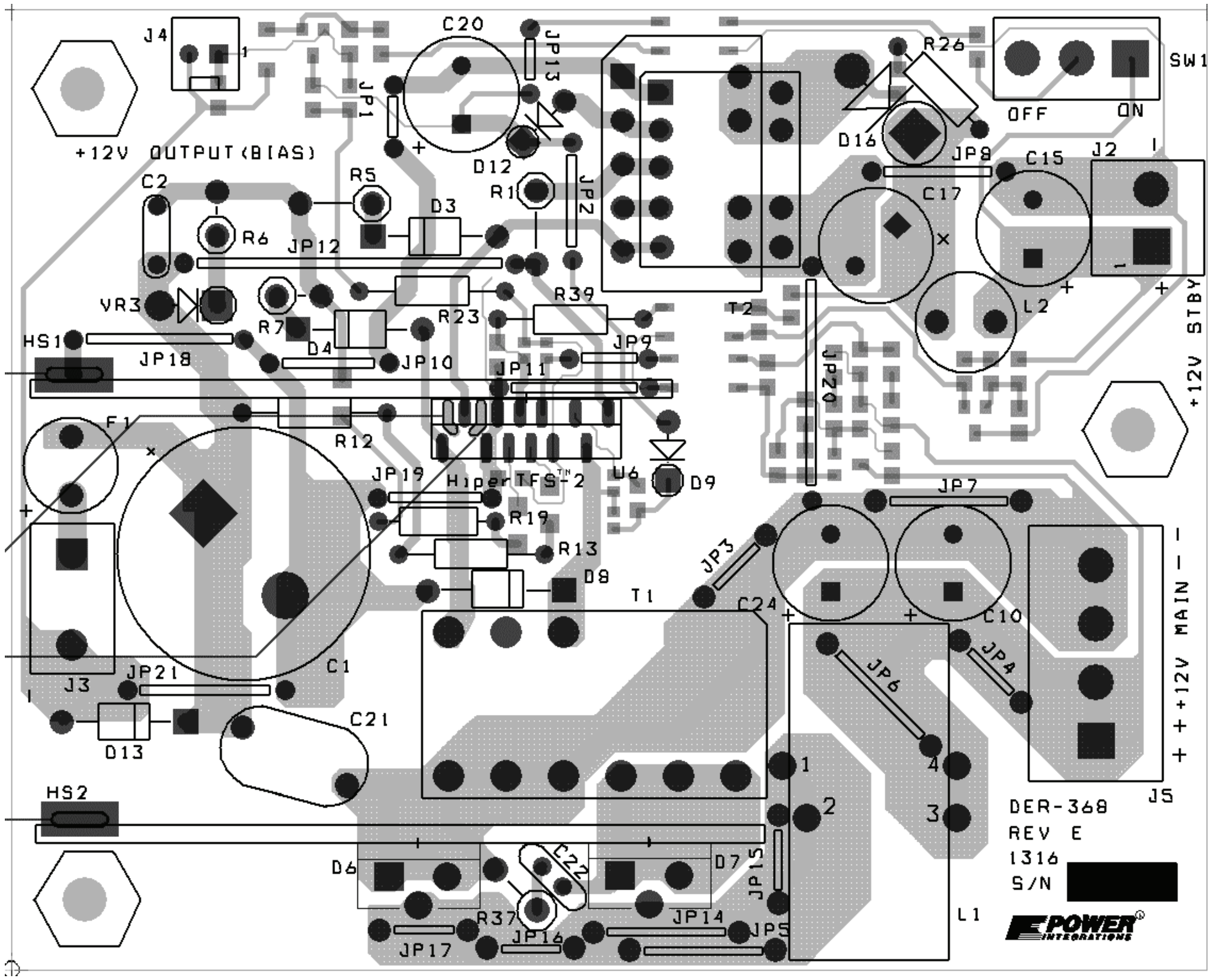

Figure 4 – DER-368 PCB Layout, Top View.

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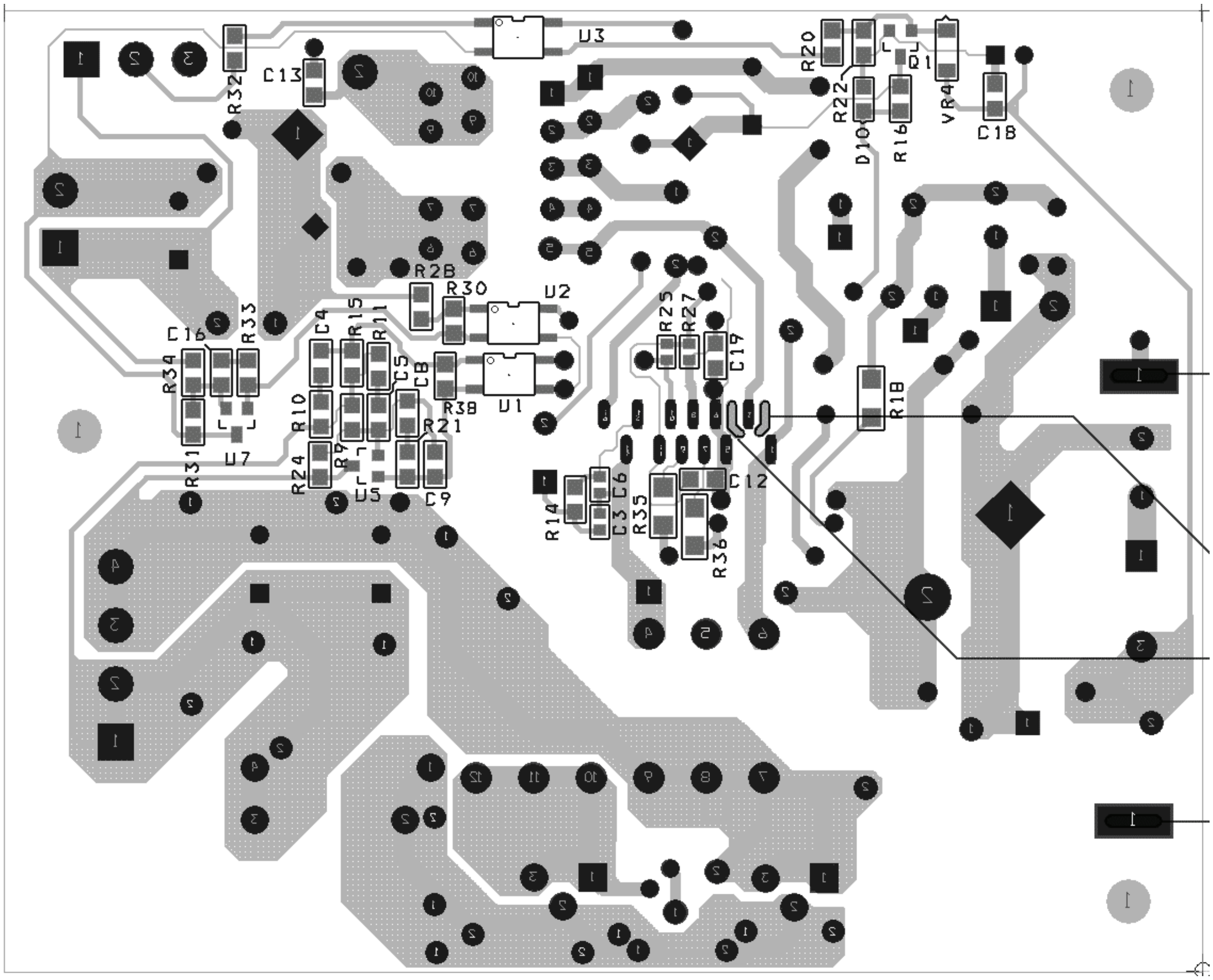

Figure 5 – DER-368 PCB Layout, Bottom View.

6 物料清单(BOM)

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	C1	120 μF, 450 V, Electrolytic, (22 x 30)	ESMQ451VSN121MP30S	United Chemi-con
2	1	C2	2.2 nF, 1 KV, Ceramic, SL, 0.2" L.S.	DEBB33A222KA2B	Murata
3	2	C3 C6	100 nF 50 V, Ceramic, X7R, 0603	C1608X7R1H104K	TDK
4	3	C4 C5 C8	47 nF, 50 V, Ceramic, X7R, 0805	GRM21BR71H473KA01L	Murata
5	3	C9 C18 C19	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
6	2	C10 C24	1500 μF, 16 V, Electrolytic, Low ESR, 10 x 20)	EEU-FR1C152	Panasonic
7	1	C12	10 μF, 16 V, Ceramic, X5R, 0805	GRM21BR61C106KE15L	Murata
8	1	C13	470 pF, 100 V, Ceramic, X7R, 0805	08051C471KAT2A	AVX
9	1	C15	330 μF, 25 V, Electrolytic, Low ESR, 90 mΩ, (10 x 12.5)	ELXZ250ELL331MJC5S	Nippon Chemi-Con
10	1	C16	330 nF, 50 V, Ceramic, X7R, 0805	GRM219R71H334KA88D	Murata
11	1	C17	1000 μF, 16 V, Electrolytic, Very Low ESR, 23 mΩ, (10 x 20)	EKZE160ELL102MJ20S	Nippon Chemi-Con
12	1	C20	330 μF, 35 V, Electrolytic, Low ESR, 68 mΩ, (10 x 16)	ELXZ350ELL331MJ16S	Nippon Chemi-Con
13	1	C21	2.2 nF, Ceramic, Y1	440LD22-R	Vishay
14	1	C22	3.3 nF, 100 V, Ceramic, X7R, Radial	FK18X7R2A332K	TDK
15	2	D3 D4	1000 V, 1 A, Rectifier, DO-41	1N4007-E3/54	Vishay
16	2	D6 D7	60 V, 30 A, Dual Schottky, TO-220AB	STPS30L60CT	ST
17	2	D8 D9	600 V, 1 A, Ultrafast Recovery, 75 ns, DO-41	UF4005-E3	Vishay
18	1	D10	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
19	1	D12	200 V, 1 A, Ultrafast Recovery, 50 ns, DO-41	UF4003-E3	Vishay
20	1	D13	600 V, 1 A, Rectifier, DO-41	1N4005-T	Diodes, Inc.
21	1	D16	100 V, 3 A, Schottky, DO-201AD	SB3100-T	Diodes, Inc.
22	1	ESIP CLIP1	Heat sink Hardware, Edge Clip 20.76 mm L x 8 mm W	NP975864	Aavid Thermalloy
23	1	F1	3.15 A, 250V, Slow, TR5	37213150411	Wickman
24	2	HS PAD1 HS PAD2	HEAT SINK PAD, TO-220, Sil-Pad 1000	1009-58	Bergquist
25	1	HS1	HEAT SINK, DER-368, Primary-		Custom
26	1	HS2	HEAT SINK, DER-368, Secondary		Custom
27	1	J2	2 Position (1 x 2) header, 5 mm (0.196) pitch, Vertical	1715022	Phoenix Contact
28	1	J3	CONN HEADER 3POS (1x3).156 VERT TIN (PULL PIN 2)	26-48-1031	Molex
29	1	J4	2 Position (1 x 2) header, 0.1 pitch, Vertical	22-23-2021	Molex
30	1	J5	CONN TERM BLOCK 5MM 4POS	1711042	Phoenix Contact
31	2	JP1 JP13	Wire Jumper, Non-Insulated, #22 AWG, 0.2 in	298	Alpha
32	6	JP2 JP3 JP4 JP15 JP16 JP17	Wire Jumper, Non-Insulated, #22 AWG, 0.3 in	298	Alpha
33	5	JP5 JP6 JP7 JP8 JP9 JP14	Wire Jumper, Non Insulated, #22 AWG, 0.5 in	298	Alpha
34	1	JP6	Wire Jumper, Insulated, TFE, #22 AWG, 0.5 in	C2004-12-02	Alpha
35	2	JP10	Wire Jumper, insulated, TFE, #22 AWG, 0.4 in	C2004-12-02	Alpha
36	1	JP11	Wire Jumper, insulated, TFE, #22 AWG, 0.3 in	C2004-12-02	Alpha
37	1	JP12	Wire Jumper, Non-insulated, #22 AWG, 1.0 in	298	Alpha
38	3	JP18 JP19 JP21	Wire Jumper, Non-insulated, #22 AWG, 0.3 in	298	Alpha
39	1	JP20	Wire Jumper, Non-insulated, #22 AWG, 0.7 in	298	Alpha
40	1	JP22	Wire Jumper, Non-insulated, #22 AWG, 0.4 in	298	Alpha
41	1	L1	41 μH, Inductor Toroidal, Sendust		

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42	1	L2	2.2 µH, 6.0 A	RFB0807-2R2L	Coilcraft
43	2	NUT1 NUT2	Nut, Hex, Kep 4-40, S ZN Cr3 plating RoHS	4CKNTZR	Any RoHS Compliant Mfg.
44	3	POST-CRKT_BRD_6-32_HEX1 POST-CRKT_BRD_6-32_HEX2 POST-CRKT_BRD_6-32_HEX3	Post, Circuit Board, Female, Hex, 6-32, snap, 0.375L, Nylon	561-0375A	Eagle Hardware
45	1	Q1	NPN, Small Signal BJT, GP SS, 40 V, 0.6 A, SOT-23	MMBT4401LT1G	Diodes, Inc.
46	1	R1	2.2 Ω, 5%, 1 W, Metal Film, Fusible	NFR0100002208JR500	Vishay
47	1	R5	4.7 Ω, 5%, 1/2 W, Carbon Film	CFR-50JB-4R7	Yageo
48	1	R6	100 Ω, 5%, 1/2 W, Carbon Film	CFR-50JB-100R	Yageo
49	1	R7	2.2 Ω, 5%, 1/2 W, Carbon Film	CFR-50JB-2R2	Yageo
50	1	R9	15 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1502V	Panasonic
51	1	R10	220 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ221V	Panasonic
52	1	R11	39 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ393V	Panasonic
53	3	R12 R13 R19	1.33 MΩ, 1%, 1/4 W, Metal Film	MF1/4DCT52R1334F	KOA Speer
54	3	R18 R35 R36	1.33 MΩ, 1%, 1/4 W, Thick Film, 1206	RC1206FR-071M33L	Yageo
55	5	R14 R15 R30 R33 R38	1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ102V	Panasonic
56	1	R16	7.5 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ752V	Panasonic
57	2	R20,R22	4.7 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ472V	Panasonic
58	1	R21	3.3 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ332V	Panasonic
59	1	R22	4.7 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ472V	Panasonic
60	1	R23	619Ω, 1%, 1/4 W, Metal Film	MFR-25FBF-619R	Yageo
61	2	R25,R27	232 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2323V	Panasonic
62	1	R26	200 Ω, 5%, 1/4 W, Carbon Film	CFR-25JB-200R	Yageo
63	1	R28	100 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6EGYJ101V	Panasonic
64	1	R31	4.99 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF4991V	Panasonic
65	1	R32	10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
66	1	R34	19.1 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1912V	Panasonic
67	1	R37	Resistor, Metal Oxide, 2.2 Ω, 1 W, 5%	RSF-100JB-2R2	Yageo
68	1	R39	4.7 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-4K7	Yageo
69	1	RTV1	Thermally conductive Silicone Grease	120-SA	Wakefield
70	2	SCREW1 SCREW2	SCREW PHIL Flat head, undercut 4-40 X .3750 (3/8) SST		Any RoHS Compliant Mfg.
71	1	SCREW3	SCREW MACHINE PHIL 4-40 X 5/16 SS	PMSSS 440 0031 PH	Building Fasteners
72	1	SW1	SLIDE MINI SPDT PC MNT AU	1101M2S3CBE2	C&K Components
73	1	T1	Transformer, DER-368 Main, EF25, Vertical		
74	1	T2	Transformer, DER-368 Standby, EE16, Vertical	Custom	
75	3	U1 U2 U3	Optocoupler, 80 V, CTR 80-160%, 4-Mini Flat	PC357N1TJ00F	Sharp
76	2	U5 U7	IC, REG ZENER SHUNT ADJ SOT-23	LM431AIM3/NOPB	National Semi
77	1	U6	HiperTFS-2, ESIP16/12	TFS7703H	Power Integrations
78	1	VR3	150 V, 5 W, 5%, TVS, DO204AC (DO-15)	P6KE150A	LittleFuse
79	1	VR4	13 V, 5%, 500 mW, SOD-123	MMSZ5243BT1G	ON Semi
80	3	WASHER1 WASHER2 WASHER3	WASHER FLAT #4 Zinc, OD 0.219, ID 0.125, Thk 0.032, Yellow Chromate Finish	5205820-2	Tyco
81	2	WASHER6 WASHER7	Washer Nylon Shoulder #4	3049	Keystone

7 设计表格

HiperTFS2_Two-switch_Forward_041613; Rev.1.0; Copyright Power Integrations 2013	**INPUT**	**INFO**	**OUTPUT**	**UNIT**	**HiperTFS2_041613_Rev1-0.xls; Two-switch Forward Transformer Design Spreadsheet**
Hiper-TFS MAIN OUTPUT (TWO-SWITCH FORWARD STAGE)					
OUTPUT VOLTAGE AND CURRENT					
VMAIN	12.00			V	Main output voltage
IMAIN	15.00			A	Main output current
VOUT2				V	Output2 voltage - enter zero if none
IOUT2				A	Output2 current - enter zero if none
POST REGULATED OUTPUT					
Post Regulator	NONE	*Info*			!!!! Info. No Selection for post-regulator - select 'NONE' if not using post-regulator
V_SOURCE				V	Select source of input voltage for post regulator. Enter None if Post regulator not used.
VOUT3			0	V	Enter postregulator output voltage
IOUT3			0	A	Enter post regulator output current
n_PR			1		Enter postregulator efficiency (Buck only)
COUPLED-INDUCTOR (LOW POWER) DERIVED OUTPUT					
VOUT4				V	Coupled-Inductor derived (low power) output voltage (typically -12 V)
IOUT4				A	Coupled-Inductor derived (low power) output current
POUT(Main)			180.0	W	Total output power (Main converter)
POUT_PEAK(Main)			180.0	W	Peak Output power(Main converter). If there is no peak power requirement enter value equal to continuous power
POUT(Standby)			10.3	W	Continuous output power from Standby power supply
POUT_PEAK(Standby)			10.0	W	Peak output power from Standby section
POUT(System Total)			**190.3**	**W**	**Total system continuous output power**
POUT_PEAK(System Total)			190.0	W	Total system peak output power
VBIAS	17.00			V	DC bias voltage from main transformer aux winding
INPUT VOLTAGE AND UV/OV					
CIN	120.00		120	uF	Input Capacitance. To increase CMIN, increase T_HOLDUP
T_HOLDUP			20	ms	Holdup time
CIN	120.00		120	uF	Select Bulk Capacitor
CIN_ESR			0.55	ohms	Bulk capacitor ESR
IRMS_CIN			0.67	A	RMS current through bulk capacitor
PLOSS_CIN			0.25	W	Bulk capacitor ESR losses
VMIN			300.0	V	Minimum input voltage to guarantee output regulation
VNOM			380.0	V	Nominal input voltage
VMAX			420.0	V	Maximum DC input voltage
RR			3.92	M-ohm	
RL			3.92	M-ohm	Minimum undervoltage On-Off threshold

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UV / OV / UVOV					Minimum undervoltage Off-On threshold (turn-on)
VUV OFF (min)			181.8	V	Minimum overvoltage Off-On threshold
VUV ON (min)			295.5	V	Minimum overvoltage On-Off threshold (turn-off)
VOV ON (min)			526.7	V	R pin resistor
VOV OFF (min)			526.7	V	Line Sense resistor value (L-pin) - goal seek (VUV OFF) for std 1% resistor series
VUV OFF (max)			225.0	V	
VUV ON (max)			326.9	V	
ENTER DEVICE VARIABLES					
Device	**TFS7703**		TFS7703		Selected HiperTFS device
Select Frequency mode	**f**		f		Select Frequency mode. "H" indicates 66 kHz selection, "F" indicates 132 kHz selection
ILIMIT_MIN			3.01	A	Device current limit (Minimum)
ILIMIT_TYP			3.24	A	Device current limit (Typical)
ILIMIT_MAX			3.47	A	Device current limit (Maximum)
fSMIN			124000	Hz	Device switching frequency (Minimum)
fS			132000	Hz	Device switching frequency (Typical)
fSMAX			140000	Hz	Device switching frequency (Maximum)
KI	1.0		1.0		Select Current limit factor (KI=1.0 for default ILIMIT, or select KI=0.9 or KI=0.7)
R(FB)			232.0	k-ohms	Feedback Pin Resistor value
ILIMIT SELECT			3.01	A	Selected current limit
RDS(ON)			5.00	ohms	Rds(on) at 100'C
DVNOM_GOAL			0.45		Target duty cycle at nominal input voltage (VNOM)
VDS			5.07	V	HiperTFS average on-state Drain to Source Voltage
Main MOSFET losses					
RDSON_LOWER			3.60	ohm	RDSON for low side MOSFET
RDSON_UPPER			1.40	ohm	RDSON for high side MOSFET
PCOND_LOWER			2.6	W	Conduction losses in lower MOSFET
PCOND_UPPER			1.0	W	Conduction losses in upper MOSFET
COSS_LOWER			35	pF	COSS for low side MOSFET
COSS_UPPER			110	pF	COSS for high side MOSFET
V_Coss upper FET			150	V	Voltage across upper MOSFET during turn off
P_Coss lower FET			0.12	W	Switching loss in upper MOSFET
P_Coss upper FET			0.16	W	Switching loss in lower MOSFET
lower FET crossoever loss			0.72	W	Crossover loss in lower MOSFET
TOTAL_MOSFET_LOSS			6.92		Total loss in MOSFET (upper + lower)
Clamp Section					
Clamp Selection	**CLAMP TO RAIL**				Select either "CLAMP TO RAIL" (default) or "CLAMP TO GND"
VCLAMP			150.00	V	Asymmetric Clamp Voltage
VDSOP			570.00	V	Maximum Hiper-TFS Drain voltage (at VOVOFF_MAX)
DIODE Vf SELECTION					
VDMAIN	0.40		0.4	V	Main output diodes forward voltage drop
VDOUT2			0.5	V	Secondary output diodes forward voltage drop

VDOUT3			0.5	V	3rd output diodes forward voltage drop
VDB			0.7	V	Bias diode forward voltage drop
TRANSFORMER CORE SELECTION					
Core Type	**Auto**		**EF25**		Selected core type
AE			0.518	cm^2	Core Effective Cross Sectional Area
LE			5.78	cm	Core Effective Path Length
AL			2000	nH/T^2	Ungapped Core Effective Inductance
BW			15.6	mm	Bobbin Physical Winding Width
B_HT			4.60	mm	Height of bobbin (to calculate fit)
B_WA			0.72	cm^2	Bobbin Winding area
M			4.5	mm	Bobbin safety margin tape width (2 * M = Total Margin)
LG_MAX			0.002	mm	Maximum zero gap tolerance, default 2um
LMAG_MAX			20	mH	Maximum magnetizing inductance of transformer. Do not exceed this value
LMAG	9.4		9	mH	Actual magnetizing inductance (measured) of transformer
FRES_TRF			173.04	kHz	Measured Primary winding self resonant frequency
C_TRF			90	pF	Estimated primary winding capacitance
L			3.00		Transformer primary layers (split primary recommended)
NMAIN	5.0		5.0		Main rounded turns
NS2			0.0		2nd output number of turns
NBIAS	0		0		VBias rounded turns (forward bias winding)
VOUT2 ACTUAL			0.0	V	Approximate Output2 voltage of with NS2 = 0 turns (AC stacked secondary)
VBIAS_ACTUAL			-0.7	V	Approximate Forward Bias Winding Voltage at VMIN with NB = 0 turns
TRANSFORMER DESIGN PARAMETERS					
NP			64		Primary rounded turns
BM_MAX			2548	Gauss	Max positive operating flux density at minimum switching frequency
BM PK-PK			3861	Gauss	Max peak-peak operating flux density at minimum switching frequency
BP_MAX			3229	Gauss	Max positive flux density at Vmax (limited by DVMAX clamp)
BP PK-PK			4892	Gauss	Max peak-peak flux density at Vmax (limited by DVMAX clamp)
IMAG			0.136	A	Peak magnetizing current at minimum input voltage
OD_P			0.31	mm	Primary wire outer diameter
AWG_P			29	AWG	Primary Wire Gauge (rounded to maximum AWG value)
TRANSFORMER LOSSES AND FIT ESTIMATE					
Core loss			*12.4*		
Core material	Auto		PC95		Select core material
BAC_pp			3627	gauss	Peak to peak flux density
core_loss_multiplier			2.04E-03		Core Loss constant
f_coeff			1.80		Frequency co-efficient
BAC_coeff			2.56		AC flux density co-efficient
specific core loss			995.50	mW/cc	Core loss per unit volume
core volume			3.02	cm^3	Volume of core
core loss			3.01	W	Core loss

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PRI WINDING FIT AND LOSSES					
OD_PRI			0.45	mm	Primary winding diameter
FILAR_PRI			1.00	strands	Number of parallel strands of wire (primary)
MLT_PRI			5.28	cm	Mean length per turn
DCR_PRI			465.19	milli-ohm	DC resistance of primary winding
PCOND_PRI			0.34	W	Conduction loss in primary winding
FILL_PRI			14	%	Fill factor (primary only)
SEC WINDING 1 (lower winding when AC stacked)					
VOUT			12	V	
NS1			5.0	turns	Number of turns
IRMS_SEC1			11.62	A	RMS current through winding
Foil/Wire	FOIL		FOIL	foil/wire	Select FOIL or WIRE for winding
OD/Thickness			0.125	mm	Wire diameter or Foil thickness
FILAR_SEC1			N/A	strands	Number of parallel strands (wire selection only)
SEC1_WIDTH			18	mm	Foil Width (Applicable if FOIL winiding used)
SEC1_MLT			5.28	cm	Mean length per turn
DCR_SEC1			2.59	milli-ohms	DC resistance of secondary winding
PCOND_SEC1			0.35	W	Conduction loss in secondary winding
FILL_SEC1			16	%	Fill factor (secondary 1 only)
SEC WINDING 2 (upper winding AC stacked)					
VOUT			0	V	
NS2			0.0	turns	Number of turns
IRMS_SEC2			0.00	A	RMS current through winding
Foil/Wire	FOIL		FOIL	foil/wire	Select FOIL or WIRE for winding
OD/Thickness			0.125	mm	Wire diameter or Foil thickness
FILAR_SEC2			N/A	strands	Number of parallel strands (wire selection only)
SEC2_WIDTH			18	mm	Foil Width (Applicable if FOIL winiding used)
SEC2_MLT			5.28	cm	Mean length per turn
DCR_SEC2			0.00	milli-ohms	DC resistance of secondary winding
PCOND_SEC2			0.00	W	Conduction loss in secondary winding
FILL_SEC2			0	%	Fill factor (secondary 1 only)
Total main transformer					
FILL_TOTAL			30	%	Total transformer fill factor
TOTAL_CU_LOSS			0.7	W	Total copper losses in transformer
TOTAL_CORE_LOSS			3.0	W	Total core losses in transformer
TOTAL_TRF_LOSS			3.7	W	Total losses in transformer
DUTY CYCLE VALUES (REGULATION)					
DVMIN			0.57		Duty cycle at minimum DC input voltage
DVNOM			0.45		Duty cycle at nominal DC input voltage
DVMAX			0.41		Duty cycle at maximum DC input voltage
DOVOFF MIN			0.32		Duty cycle at overvoltage DC input voltage(DOVOFF_MIN)
MAXIMUM DUTY CYCLE VALUES					
DMAX_UVOFF_MIN			0.65		Max duty cycle clamp at VUVOFF_MIN
DMAX_VMIN			0.60		Max duty clamp cycle at VMIN
DMAX_VNOM			0.56		Max duty clamp cycle at VNOM
DMAX_VMAX			0.51		Max duty clamp cycle at VMAX

DMAX_OVOFFMIN			0.41		Max duty clamp cycle at VOVOFF_MAX
CURRENT WAVESHAPE PARAMETERS					
IP			1.49	A	Maximum peak primary current at maximum DC input voltage
IP_PEAK			1.49	A	Peak primary current at Peak Output Power and max DC input voltage
IPRMS(NOM)			0.85	A	Nominal primary RMS current at nominal DC input voltage
OUTPUT INDUCTOR OUTPUT PARAMETERS					
KDI_ACTUAL			0.31		Current ripple factor of combined Main and Output2 outputs
Core Type	**Kool Mu 125u**		Kool Mu 125u		Select core type
Core	**77350(O.D)=24.3**		77350(O.D)=24.3		Coupled Inductor - Core size
AE			38.80	mm^2	Core Effective Cross Sectional Area
LE			58.80	mm	Core Effective Path Length
AL			105.00	nH/T^2	Ungapped Core Effective Inductance
BW			43.26	mm	Bobbin Physical Winding Width
VE			2280.00	mm^3	Volume of core
Powder cores (Sendust and Powdered Iron) Cores					
MUR			125.00		Relative permeability of material
H			55.49	AT/cm	Magnetic field strength
MUR_RATIO			0.29		Percent of permeability as compared to permiability at H = 0 AT/cm
LMAIN_ACTUAL			**12.1**	**uH**	**Estimated inductance of main output at full load**
LMAIN_0bias			42.00	uH	Estimated inductance of main output with 0 DC bias
LOUT2			0.00	uH	Estimated inductance of auxiliary output at full load
BM_IND			2534.69	Gauss	DC component of flux density
BAC_IND			388.82	Gauss	AC component of flux density
Turns					
INDUCTOR TURNS MULTIPLIER			3.00		Multiplier factor between main number of turns in transformer and inductor (default value = 3)
NMAIN_INDUCTOR	20		20.00		Main output inductor number of turns
NOUT2_INDUCTOR			0.00		Output 2 inductor number of turns
NOUT4_INDUCTOR			N/A		Bias output inductor number of turns (for bias or control circuit VDD supply)
Ferrite Cores					
LMAIN_ACTUAL			**N/A**	**uH**	**Estimated inductance of main output**
LOUT2			N/A	uH	Estimated inductance of aux output
LG			N/A	mm	Gap length of inductor cores
Target BM			N/A	Gauss	Target maximum flux density
BM_IND			N/A	Gauss	Estimated maximum operating flux density
BAC_IND			N/A	Gauss	AC flux density
Turns					
NMAIN_INDUCTOR			N/A		Main output inductor number of turns
NAUX_INDUCTOR			N/A		Aux output inductor number of turns
N_BIAS			N/A		Aux output inductor number of turns
Wire Parameters					
Total number of layers			1.03		Total number of layers for chosen toroid
IRMS_MAIN			15.02	A	RMS current through main inductor windings
IRMS_AUX			0.00	A	RMS current through aux winding

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AWG_MAIN	18		18.00	AWG	Main inductor winding wire gauge
OD_MAIN			1.09	mm	Main winding wire gauge outer diameter
FILAR_MAIN			2.00		Number of parallel strands for main output
RDC_MAIN			6.74	mohm	Resistance of wire for main inductor winding
AC Resistance Ratio (Main)			3.78		Ratio of total resistance (AC + DC) to the DC resistance (using Dowell curves)
CMA_MAIN			216.57	CMA	Cir mils per amp for main inductor winding
J_MAIN			15.96	A/mm^2	Current density in main inductor winding
AWG_AUX			0.00	AWG	Aux winding wire gauge
OD_MAIN			N/A	mm	Auxiliary winding wire gauge outer diameter
FILAR_AUX			2.00		Number of parallel strands for aux output
RDC_AUX			0.00	mohm	Resistance of wire for aux inductor winding
AC Resistance Ratio (Aux)			0.00		Ratio of total resistance (AC + DC) to the DC resistance (using Dowell curves)
CMA_AUX		*Info*	0.00	CMA	!!! Info. Low CMA may cause overheating. Verify acceptable temperature rise
J_AUX			0.00	A/mm^2	Current density in auxiliary winding
Estimated Power Loss					
PCOPPER_MAIN			1.52	W	Copper loss in main inductor winding
PCOPPER_AUX			0.00	W	Copper loss in aux inductor windings
PCORE			0.43	W	Total core loss
PTOTAL_IND			1.95	W	Total losses in output choke
SECONDARY OUTPUT PARAMETERS					
ISFWDRMS			11.62	A	Max. fwd sec. RMS current (at DVNOM)
ISFWD2RMS			0.00	A	Max. fwd sec. RMS current (at DVNOM)
ISCATCHRMS			12.83	A	Max. catch sec. RMS current (at DVNOM)
ISCATCH2RMS			0.00	A	Max. catch sec. RMS current (at DVNOM)
IDAVMAINF			8.59	A	Maximum average current, Main rectifier (single device rating)
IDAVMAINC			8.90	A	Maximum average current, Main rectifier (single device rating)
IDAVOUT2F			0.00	A	Maximum average current, Main rectifier (single device rating)
IDAVOUT2C			0.00	A	Maximum average current, Main rectifier (single device rating)
IRMSMAIN			1.33	A	Maximum RMS current, Main output capacitor
IRMSOUT2			0.00	A	Maximum RMS current, Out2 output capacitor
PD_LOSS_MAIN			6	W	main diode loss
PD_LOSS_OUT2			0	W	output 2 diode loss
	% Derating				
VPIVMAINF	100%		44.5	V	Main Forward Diode peak-inverse voltage (at VDSOP)

VPIVMAINC	100%		32.8	V	Main Catch Diode peak-inverse voltage (at VOVOFF_MAX)
VPIVOUT2F	100%		0.0	V	Output2 Forward Diode peak-inverse voltage (at VDSOP)
VPIVOUT2C	100%		0.0	V	Output2 Catch Diode peak-inverse voltage (at VOVOFF_MAX)
VPIVB	100%		0.0	V	Bias output rectifier peak-inverse voltage (at VDSOP)
Hiper-TFS STANDBY SECTION (FLYBACK STAGE)					
ENTER APPLICATION VARIABLES					
VACMIN	85			V	Minimum AC Input Voltage
VACMAX	265			V	Maximum AC Input Voltage
fL	50			Hz	AC Mains Frequency
VO_SB	12.00			V	Output Voltage (at continuous power)
IO_SB	0.83			A	Power Supply Output Current (corresponding to peak power)
IO_SB_PK	0.83				Peak output current
POUT_SB			9.96	W	Continuous Output Power
POUT_SB_TOTAL			10.28	W	Total Standby power (Includes Bias winding power)
POUT_SB_PK			9.96	W	Peak Standby Output Power
n	0.80				Efficiency Estimate at output terminals. Under 0.7 if no better data available
Z	0.50				Z Factor. Ratio of secondary side losses to the total losses in the power supply. Use 0.5 if no better data available
tC	3.00			ms	Bridge Rectifier Conduction Time Estimate
ENTER Hiper-TFS STANDBY VARIABLES					
Select Current Limit	**STD**		Standard Current Limit		Enter "LOW" for low current limit, "RED" for reduced current limit (sealed adapters), "STD" for standard current limit or "INC" for increased current limit (peak or higher power applications)
ILIM_MIN			0.605	A	Minimum Current Limit
ILIM_TYP			0.650	A	Typical Current Limit
ILIM_MAX			0.696	A	Maximum Current Limit
R(EN)			232.0	k-ohms	Enable pin resistor
fSmin			124000	Hz	Minimum Device Switching Frequency
I^2fmin			50.19	A^2kHz	I^2f (product of current limit squared and frequency is trimmed for tighter tolerance)
VOR	100.00		100	V	Reflected Output Voltage (VOR < 135 V Recommended)
VDS			10	V	Hiper-TFS Standby On State Drain to Source Voltage
VD_SB			0.7	V	Output Winding Diode Forward Voltage Drop
KP			1.55		Ripple to Peak Current Ratio (KP < 6)
KP_TRANSIENT			1.27		Transient Ripple to Peak Current Ratio. Ensure KP_TRANSIENT > 0.25
ENTER BIAS WINDING VARIABLES					
VB			16.00	V	Bias Winding Voltage
IB			20.00	mA	Bias winding Load current
PB			0.32	W	Bias winding power

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VDB			0.70	V	Bias Winding Diode Forward Voltage Drop
NB			15.00		Bias Winding Number of Turns
VZOV			22.00	V	Overvoltage Protection zener diode voltage.
UVLO VARIABLES					
RLS			3.92	M-Ohms	Line sense resistor (from Main converter section)
V_UV_ACTUAL			100	V	Typical DC start-up voltage
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**EE16**		**EE16**		Enter Transformer Core
AE			0.192	cm^2	Core Effective Cross Sectional Area
LE			3.5	cm	Core Effective Path Length
AL			1140	nH/T^2	Ungapped Core Effective Inductance
BW			8.6	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	3.00		3		Number of Primary Layers
NS_SB	11		11		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN_SB			114.01	V	Minimum DC Input Voltage
VMAX_SB			374.77	V	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX_SB			0.36		Duty Ratio at full load, minimum primary inductance and minimum input voltage
IAVG			0.12	A	Average Primary Current
IP_SB			0.6045	A	Minimum Peak Primary Current
IR_SB			0.6045	A	Primary Ripple Current
IRMS_SB			0.24	A	Primary RMS Current
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP_SB			491.12	uH	Typical Primary Inductance. +/- 10% to ensure a minimum primary inductance of 446 uH
LP_TOLERANCE			10	%	Primary inductance tolerance
NP_SB			87		Primary Winding Number of Turns
ALG			65	nH/T^2	Gapped Core Effective Inductance
BM			2054	Gauss	Maximum Operating Flux Density, BM<3000 is recommended
BAC			1027	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1654		Relative Permeability of Ungapped Core
LG			0.35	mm	Gap Length (Lg > 0.1 mm)
BWE			25.8	mm	Effective Bobbin Width
OD			0.298	mm	Maximum Primary Wire Diameter including insulation
INS			0.05	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.246	mm	Bare conductor diameter
AWG			31	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			81	Cmils	Bare conductor effective area in circular mils
CMA			334	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PARAMETERS					
Lumped parameters					
ISP			4.76	A	Peak Secondary Current

ISRMS			2.03	A	Secondary RMS Current
IRIPPLE			1.85	A	Output Capacitor RMS Ripple Current
CMS			406	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			24	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
VOLTAGE STRESS PARAMETERS					
VDRAIN			605	V	Maximum Drain Voltage Estimate (Assumes 20% zener clamp tolerance and an additional 10% temperature tolerance)
PIVS			60	V	Output Rectifier Maximum Peak Inverse Voltage
Other Losses					
PCB trace losses			0.27	W	Estimated PCB trace losses
Forward DC-DC System efficiency					
TOTAL_MOSFET_LOSS			6.9	W	HiperTFS losses
TOTAL_TRF_LOSS			**3.69**	W	Main transformer losses
Output diode losses			**6.00**	W	Output diode losses
PLOSS_CIN			0.25	W	Bulk capacitor ESR losses
PTOTAL_IND			**1.95**	W	Output choke losses
Other Losses			**0.27**	W	Other losses (includes PCB traces, clamp loss, standby loss, magamp loss etc.)
Efficiency			90.4%		Total system efficiency

Note: Main transformer outer limbs were gapped by using a 3M 74 tape in order to avoid the pulse skipping issue. Magnetizing inductance was brought down to 3.4 mH from 9 mH. Refer to main transformer specification section for details.

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8 主变压器(T1)规格

8.1 电气原理图

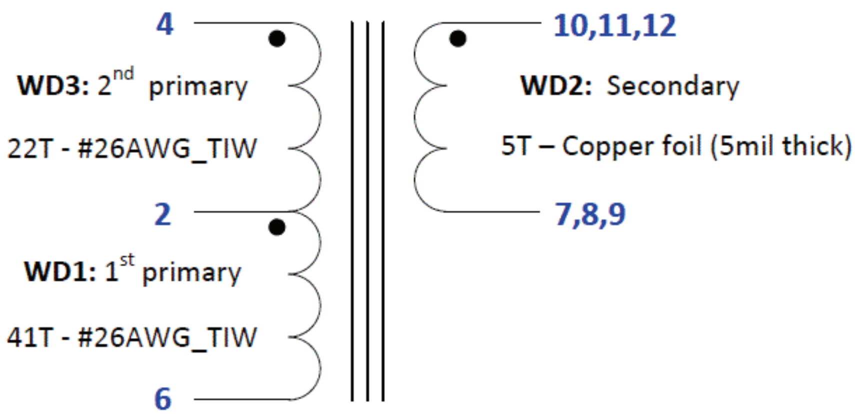

Figure 6 – Main 12 V Transformer (T1) Electrical Diagram.

8.2 电气规格

Electrical Strength	1 second, 60 Hz, from pins 4-6 to pins 7-12.	3000 VAC
Primary Inductance	Pins 4-6, all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	3.4 mH ±10%
Resonant Frequency	Pins 4-6, all other windings open.	450 kHz (Min.)
Primary Leakage Inductance	Pins 4-6, with pins 7-12 shorted, measured at 100 kHz, 0.4 V_{RMS}.	16 μH max

8.3 材料

Item	Description
[1]	Core Pair: EF25, TDK PC44 material or equivalent, ungapped.
[2]	Bobbin: EF25-Vertical, 12 pins (6/6). Taiwan Shulin Enterprise TF-2554.
[3]	Tape: Polyester Film, 3M 1350F-1 or equivalent, 14.9 mm wide.
[4]	Tape: Polyester Film, 3M 1350F-1 or equivalent, 22 mm wide.
[5]	Copper Foil, 0.005” thick, 0.7” wide.
[6]	Tinned Solid Copper Bus Wire, #20 AWG.
[7]	Triple Insulated Wire, Furukawa Tex-E or equivalent, 26 #AWG.
[8]	Tape: Polyester Film, 3M 74, 0.5 mil thick, or equivalent. Cut into size: 7.0 mm x 3.5 mm.
[9]	Varnish: Dolph BC-359, or equivalent.

8.4 结构图

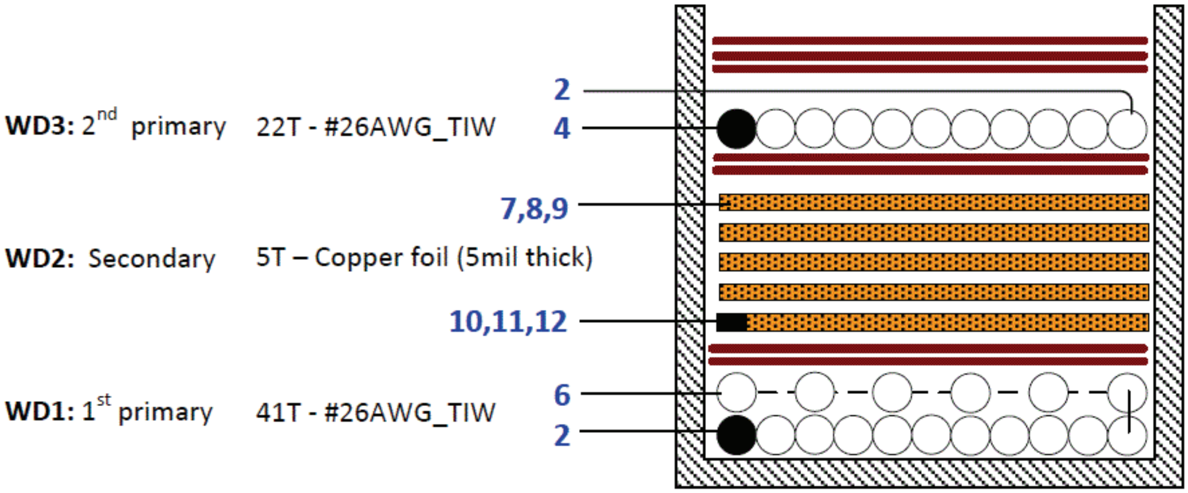

Figure 7 – Main Transformer Build Diagram.

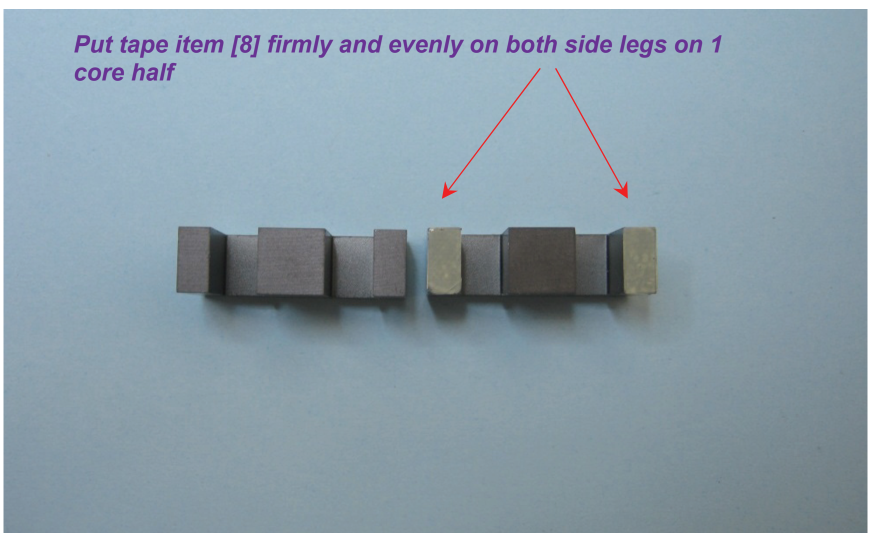

Figure 8 – Making Core Gap.

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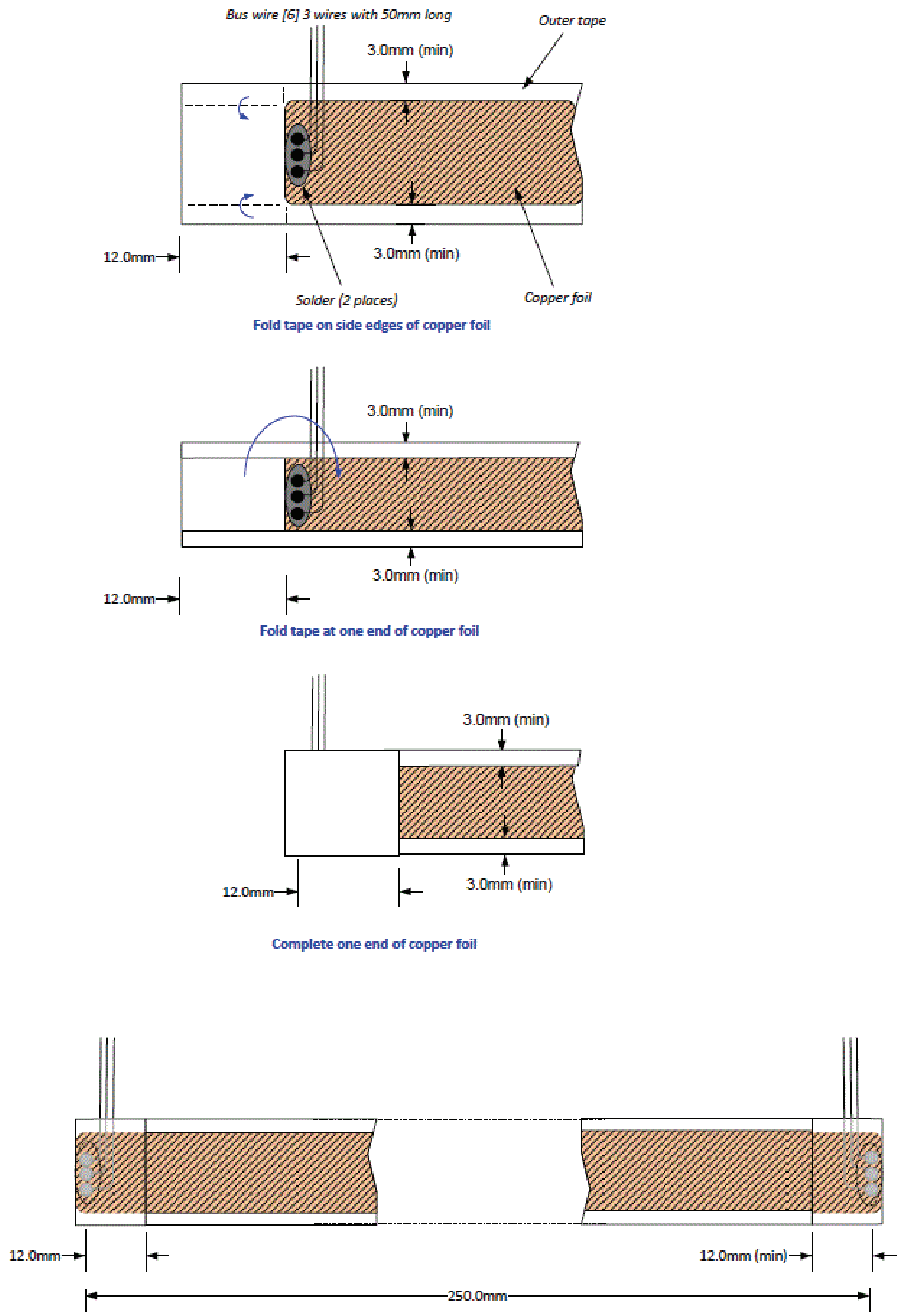

Figure 9 – Transformer Output Foil Construction Drawing.

8.5 制作说明

Assembly Step	Winding Instructions
Primary (WDG1)	Starting at pin 2, wind 41T of triple insulated wire (Item [7] in two layers. Finish at pin 6.
Insulation	Insulate using 2 layers of tape (item [3]).
Secondary (WDG2)	Using Items [4], [5], and [6], construct a 250 mm long cuffed foil assembly per Figure 8. Starting at pins 10, 11, and 12, wind 5 turns of foil, finishing at pins 7, 8, and 9.
Insulation	Apply 2 layers of tape (item [3]) for insulation.
Primary (WDG3)	Starting at pin 4, wind 22 turns of triple insulated wire (item [7]) in a single layer, finishing at pin 2.
Insulation	Apply three layers of tape (item [3]) for finish wrap.
Final Assembly	Use 2 pieces of tape item [8] press firmly, evenly on both side legs on 1 core half to create 0.5 mil core gap. (see Figure 8 above).

Note: If without transformer gapping, in this design it has been found there is a high-side driver pulse skipping issue. In this design, it happens at >400 VDC input and <3.5 A load on main 12 V channel, when there is a snubber circuit at the main transformer secondary output. Pulse skipping is avoided by gapping outer limbs of the transformer with the help of 0.5 mil thick tape.

Pulse skipping is caused due to drop in VDDH pin voltage. When there is not enough magnetizing current, high side source voltage doesn't reach ground during core reset period and bootstrap diode cannot charge high side VDDH bootstrap capacitor. With insufficient voltage on the VDDH pin, high side driver could skip pulses.

Pulse skipping is not necessarily present in all the designs. Depending on the load levels and snubber values, the conditions to have pulse skipping issue will vary as well.

Pulse skipping can be avoided by doing one of following options:

1. By providing gap on center limb of the transformer in order to reduce the magnetizing inductance (as used in this design).
2. By adding a high side bias winding.
3. Remove the secondary snubber and use high voltage diodes on the secondary.

Option 1 may result in slight efficiency degradation, especially on lighter load. Option 2 should not affect efficiency but it adds transformer cost. In option 3, if a snubber is not used, the output diode needs to have a higher voltage rating. This results in lower efficiency at full load.

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9 输出电感(L1)规格

9.1 电气原理图

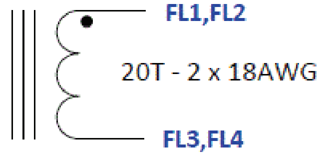

Figure 10 – Output Inductor Schematic Diagram.

9.2 电气规格

Inductance	Pins FL1-FL2, all other windings open, measured at 100 kHz, 0.4 $V_{RMS.}$	41 µH ±15%

9.3 材料

Item	Description
[1]	Sendust Toroidal Core, 125µ: Magnetics, Inc. 77350-A7 or equivalent.
[2]	Magnet wire: #18 AWG Solderable Double Coated.

10 待机电源变压器(T2)规格

10.1 电气原理图

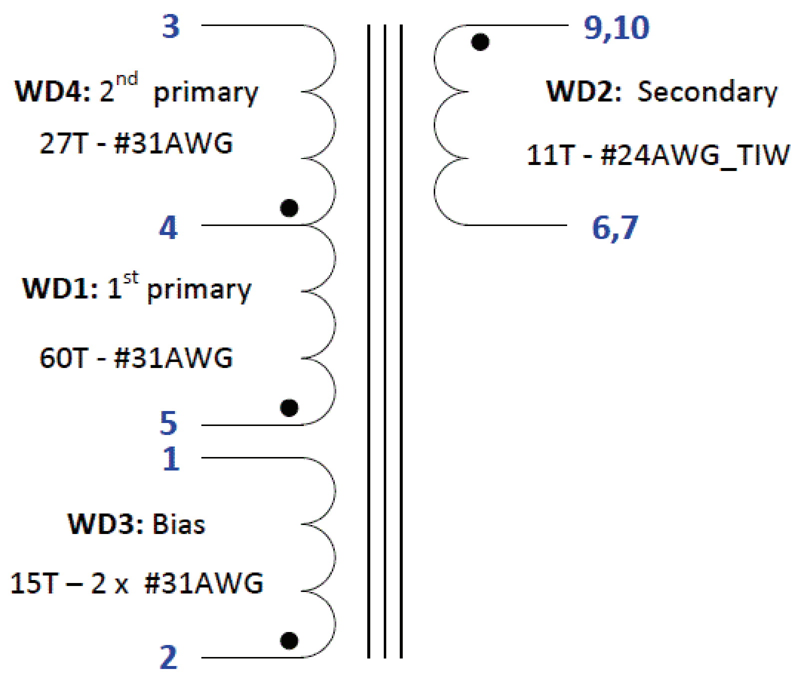

Figure 11 – Standstandby Transformer Electrical Diagram.

10.2 电气规格

Electrical Strength	1 second, 60 Hz, from pins 1-5 to pins 5-10.	3000 VAC
Primary Inductance	Pins 3-5, all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	491 µH ±10%
Resonant Frequency	Pins 3-5, all other windings open.	1 MHz (Min.)
Primary Leakage Inductance	Pins 3-5, with pins 6, 7, 9, 10 shorted, measured at 100 kHz, 0.4 V_{RMS}.	13 µH (Max)

10.3 材料

Item	Description
[1]	Core: EE16, TDK PC44 material or equivalent, gapped for ALG 96 nH/T^2.
[2]	Bobbin: EE16, Vertical, 10 pins (5/5). Yh Hwa YW-527-00B.
[3]	Tape: 3M 1350 F1 or equivalent, 10.8 mm wide.
[4]	Magnet wire: #31 AWG, double coated.
[5]	Triple Insulated Wire: Furukawa Tex-E or equivalent, #24 AWG.
[6]	Varnish: Dolph BC-359, or equivalent.

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10.4 结构图

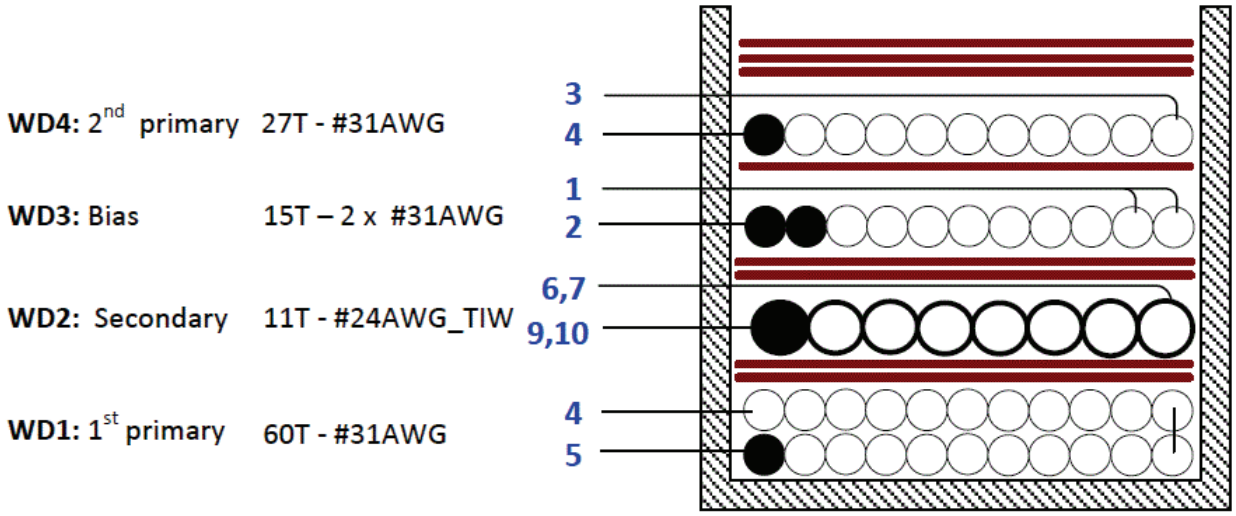

Figure 12 – Build Diagram for Standby Transformer.

10.5 制作说明

Assembly Step	Winding Instructions
Primary (WDG1)	Starting at pin 5, wind 60 T of wire (Item [4] in two layers. Finish at pin 4.
Insulation	Insulate using 2 layers of tape (item [3]).
Secondary (WDG2)	Starting at pins 9 and 10, wind 11 turns of triple insulated wire (item [5]), finishing at pins 6 and 7.
Insulation	Apply 2 layers of tape (item [3]) for insulation.
Primary Bias (WDG3)	Starting at pin 2, wind 15 bifilar turns of wire (item [4]) in a single layer, finishing at pin 1.
Insulation	Apply one turn of tape (item [3]) for insulation.
Primary (WDG4)	Starting at pin 4, wind 27 turns of triple insulated wire (item [8]), finishing at pin 3.
Insulation	Apply three layers of tape (item [3]) for finish wrap.
Final Assembly	Grind core gap to specified inductance coefficient. Assemble bobbin and core halves, secure cores. Dip varnish (item [6]).

11 散热片组件

11.1 初级金属散热片

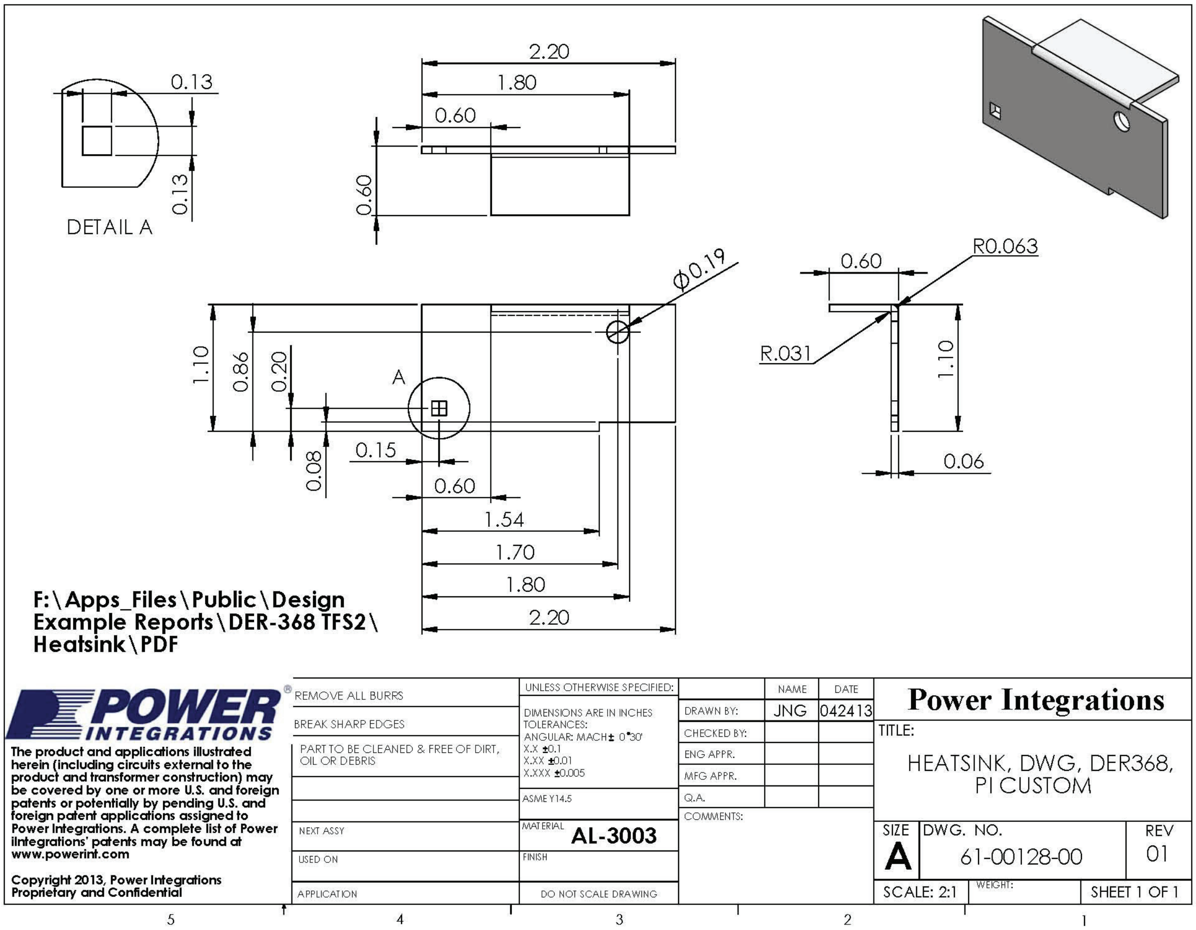

Figure 13 – Primary Heat Sink Sheet Metal Drawing.

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11.2 完成的初级散热片

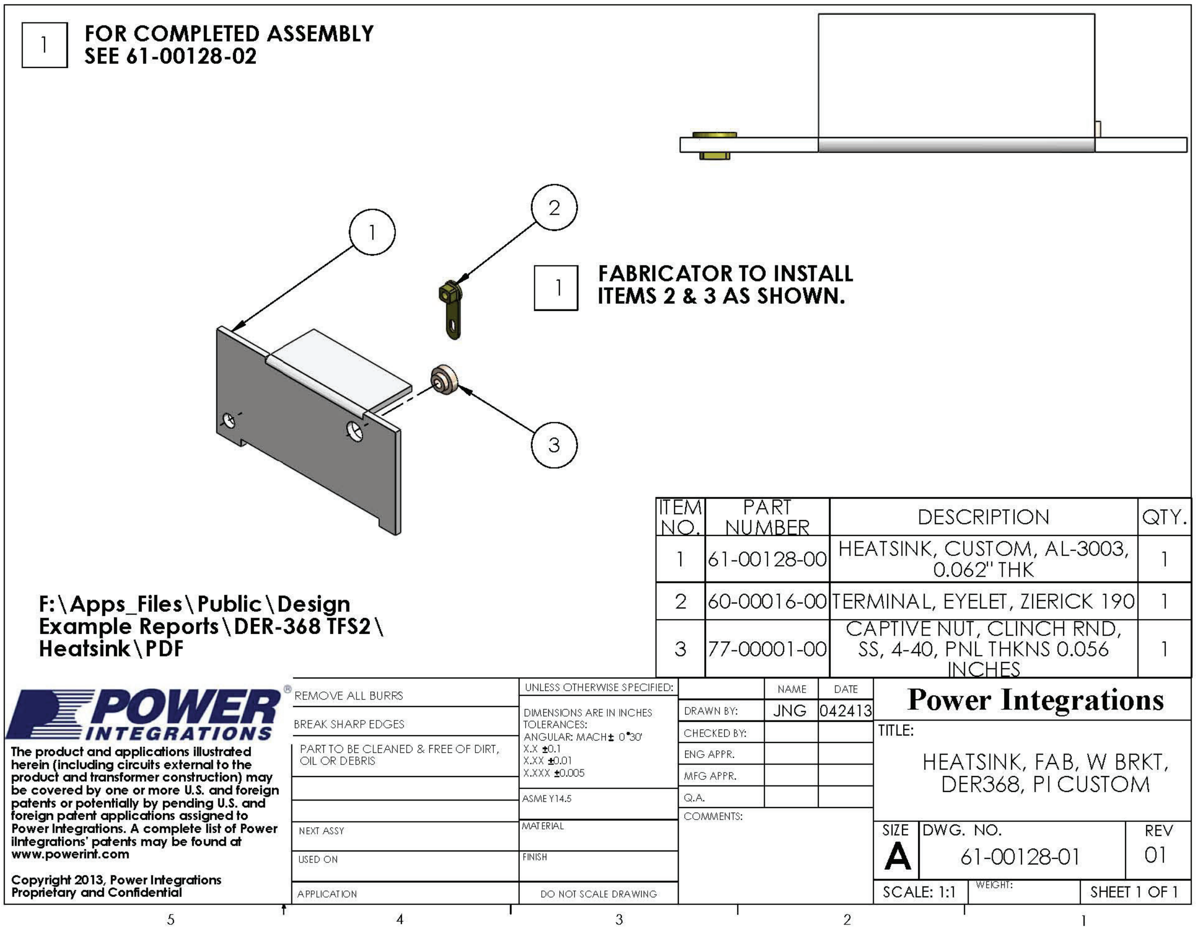
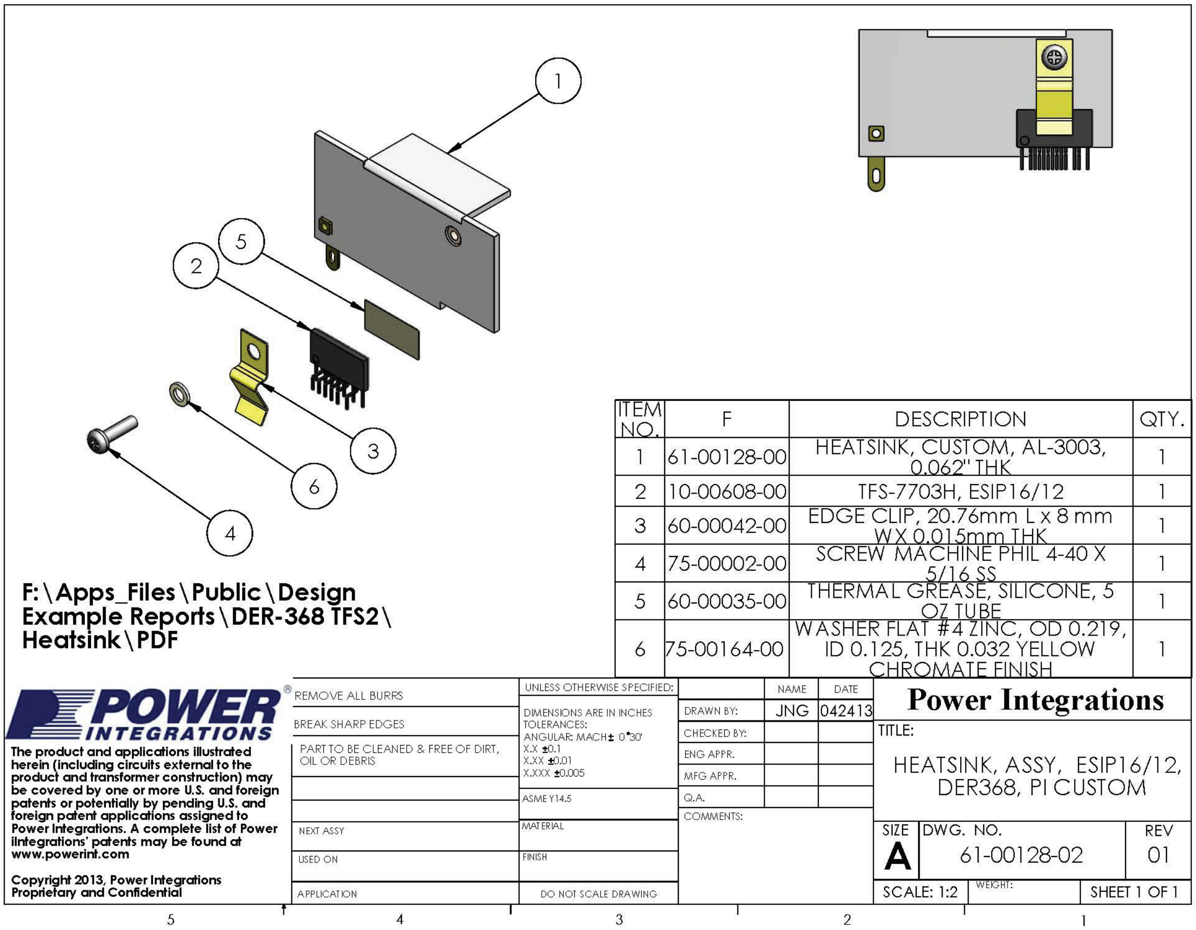


Figure 14 – Completed Primary Heat Sink.

11.3 初级散热片装配



ITEM NO.	F	DESCRIPTION	QTY.
1	61-00128-00	HEATSINK, CUSTOM, AL-3003, 0.062" THK	1
2	10-00608-00	TFS-7703H, ESIP16/12	1
3	60-00042-00	EDGE CLIP, 20.76mm L x 8 mm W X 0.015mm THK	1
4	75-00002-00	SCREW MACHINE PHIL 4-40 X 5/16 SS	1
5	60-00035-00	THERMAL GREASE, SILICONE, 5 OZ TUBE	1
6	75-00164-00	WASHER FLAT #4 ZINC, OD 0.219, ID 0.125, THK 0.032 YELLOW CHROMATE FINISH	1

Figure 15 – Primary Heat Sink Assembly.

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11.4 次级金属散热片

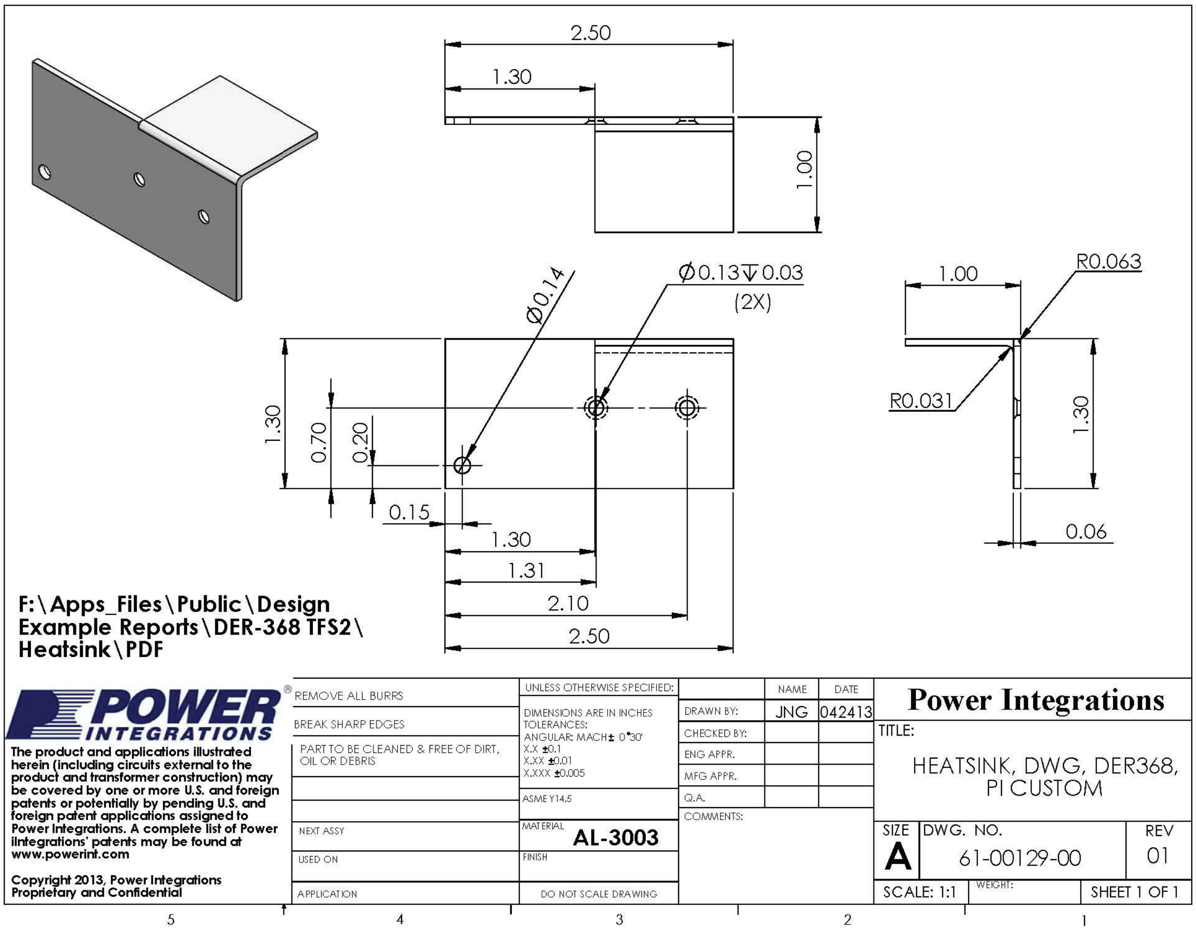

Figure 16 – Secondary Heat Sink Sheet Metal Drawing.

11.5 完成的次级散热片

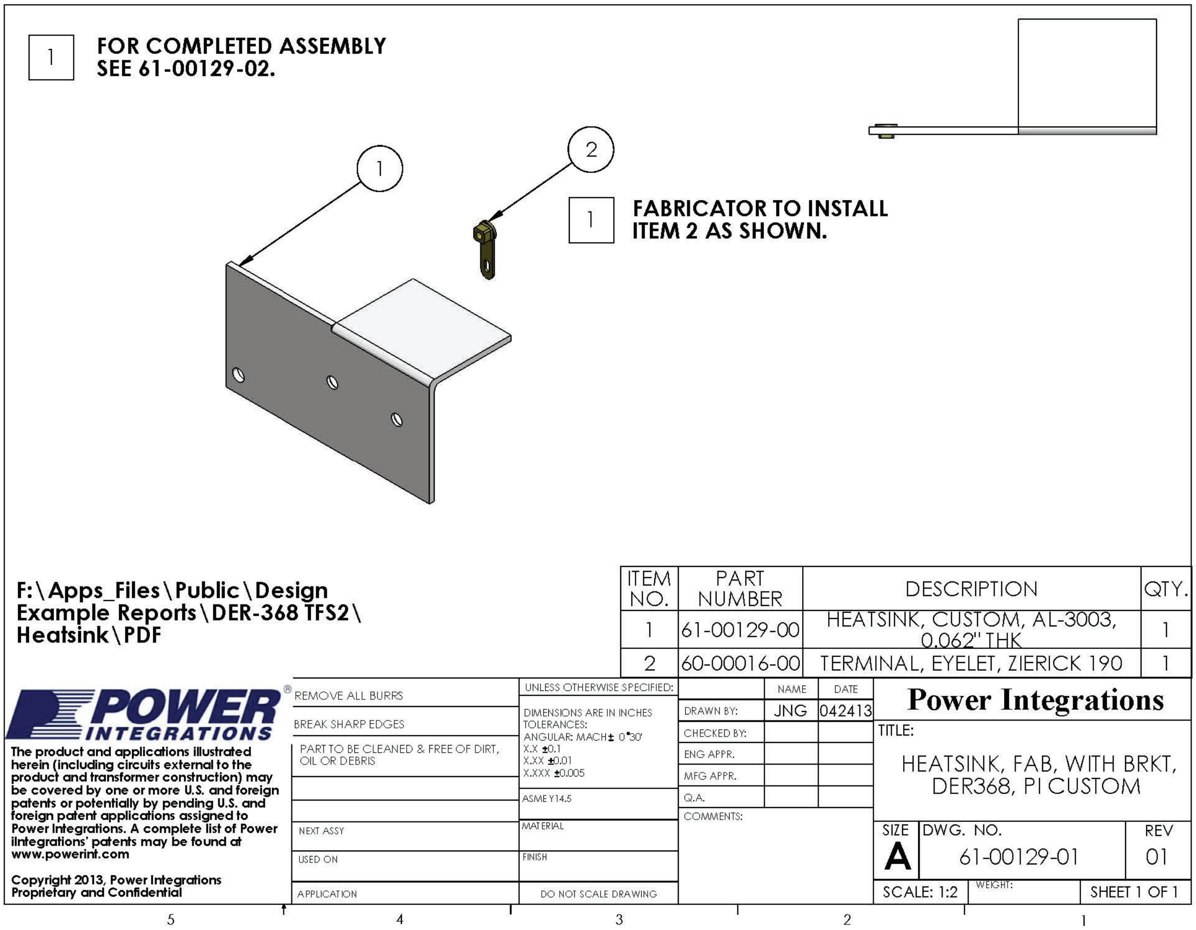

Figure 17 – Completed Secondary Heat Sink.

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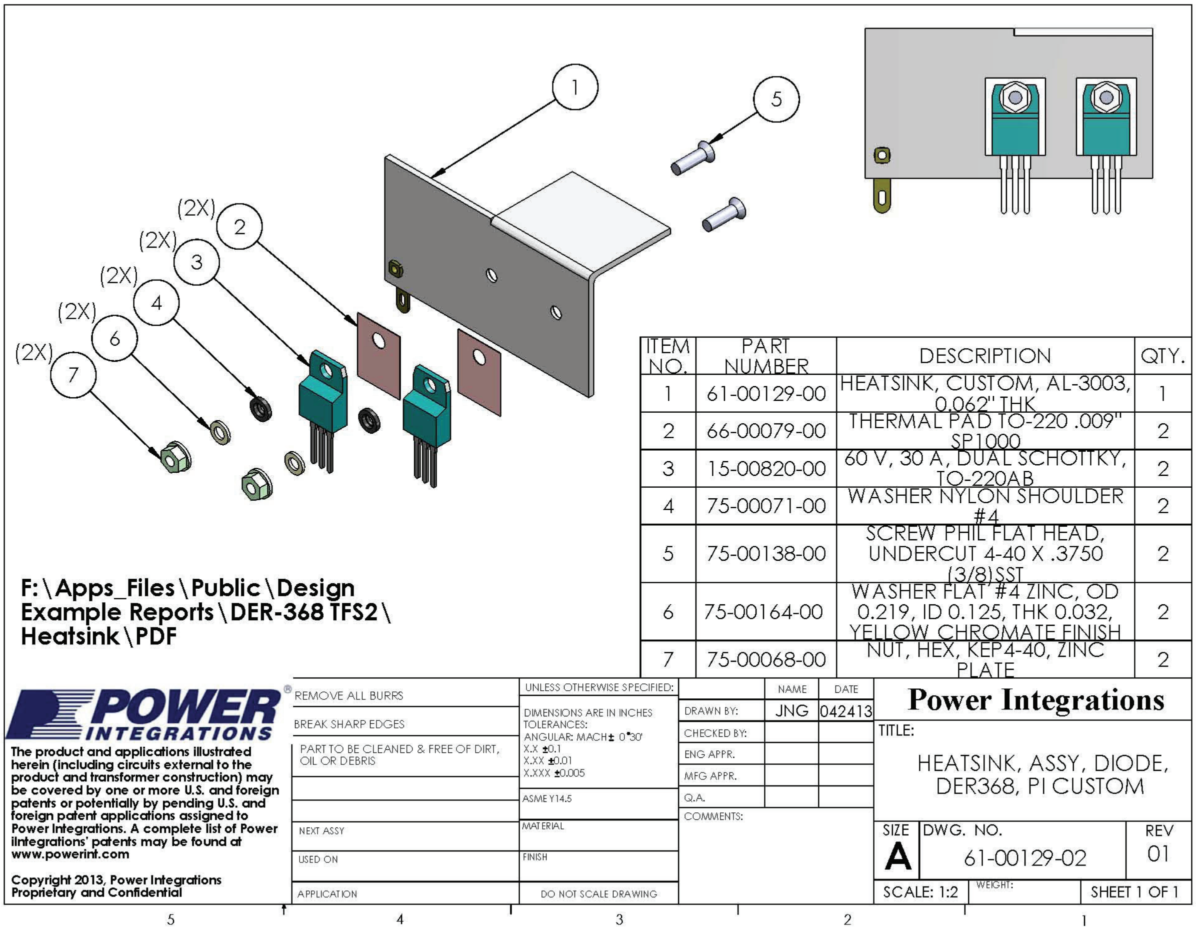
11.6 次级散热片装配



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	61-00129-00	HEATSINK, CUSTOM, AL-3003, 0.062" THK	1
2	66-00079-00	THERMAL PAD TO-220 .009" SP1000	2
3	15-00820-00	60 V, 30 A, DUAL SCHOTTKY, TO-220AB	2
4	75-00071-00	WASHER NYLON SHOULDER #4	2
5	75-00138-00	SCREW PHIL FLAT HEAD, UNDERCUT 4-40 X .3750 (3/8)SST	2
6	75-00164-00	WASHER FLAT #4 ZINC, OD 0.219, ID 0.125, THK 0.032, YELLOW CHROMATE FINISH	2
7	75-00068-00	NUT, HEX, KEP4-40, ZINC PLATE	2

Figure 18 – Secondary Heat Sink Assembly.

12 性能测量

12.1 效率

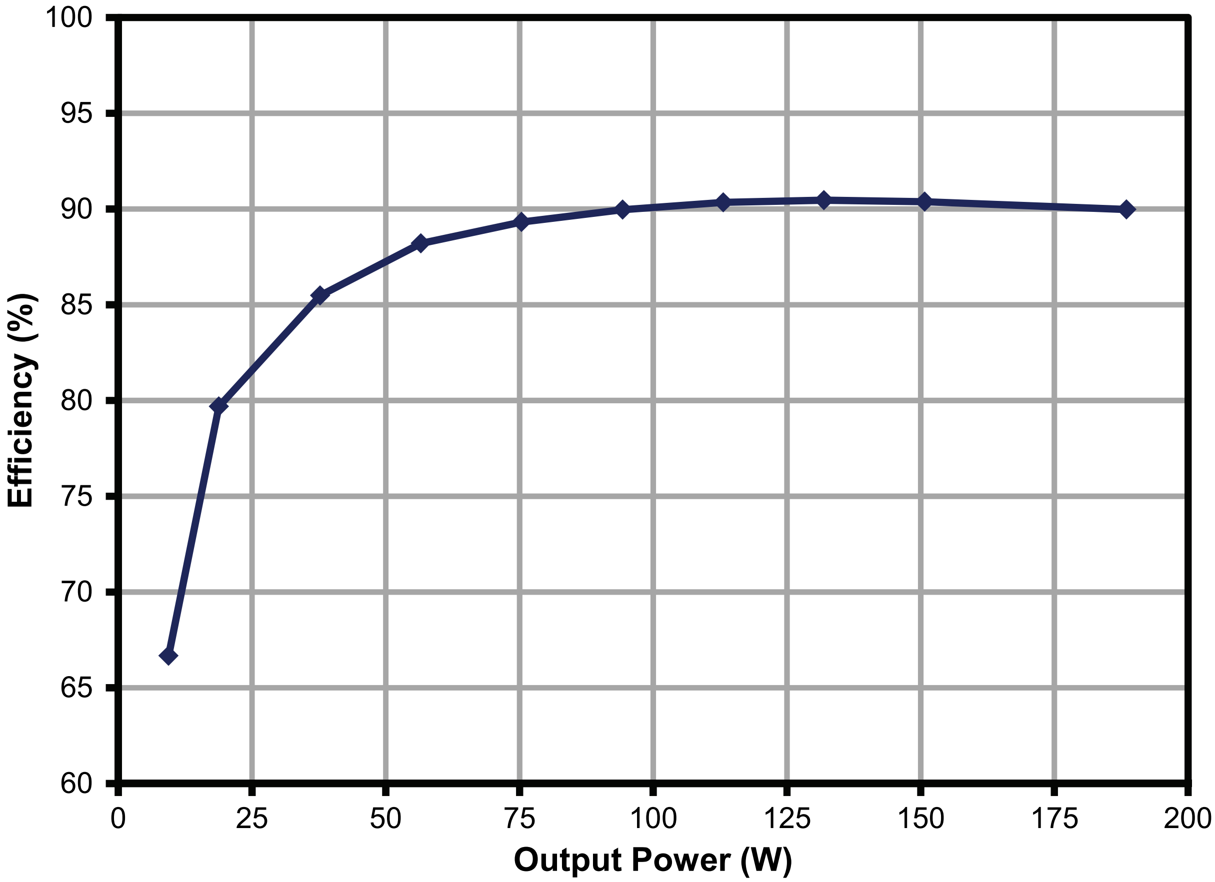


Figure 19 – Efficiency vs. Output load Percentage, Main + Standby Outputs.

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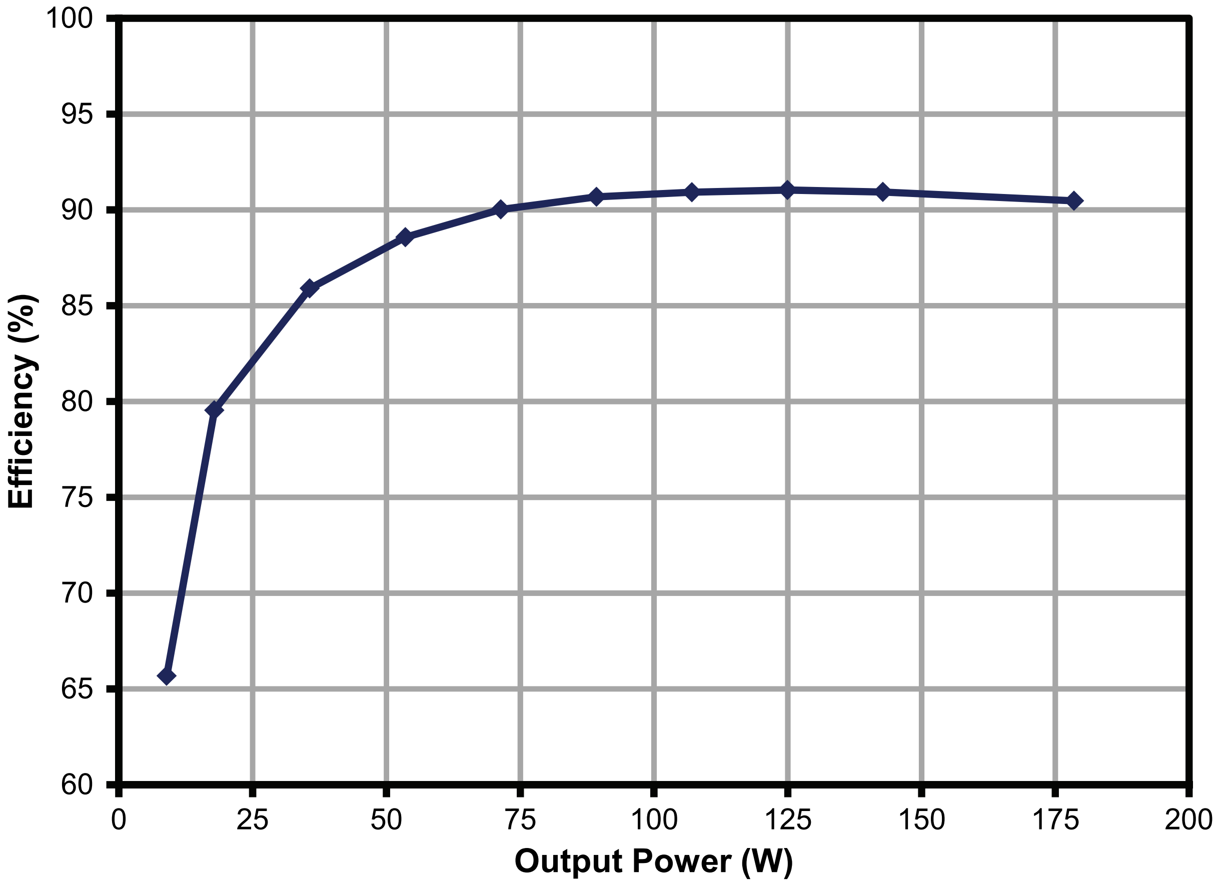

Figure 20 – Main 12 V Output Efficiency vs. Output Power, 380 VDC Input, Standby Output Unloaded.

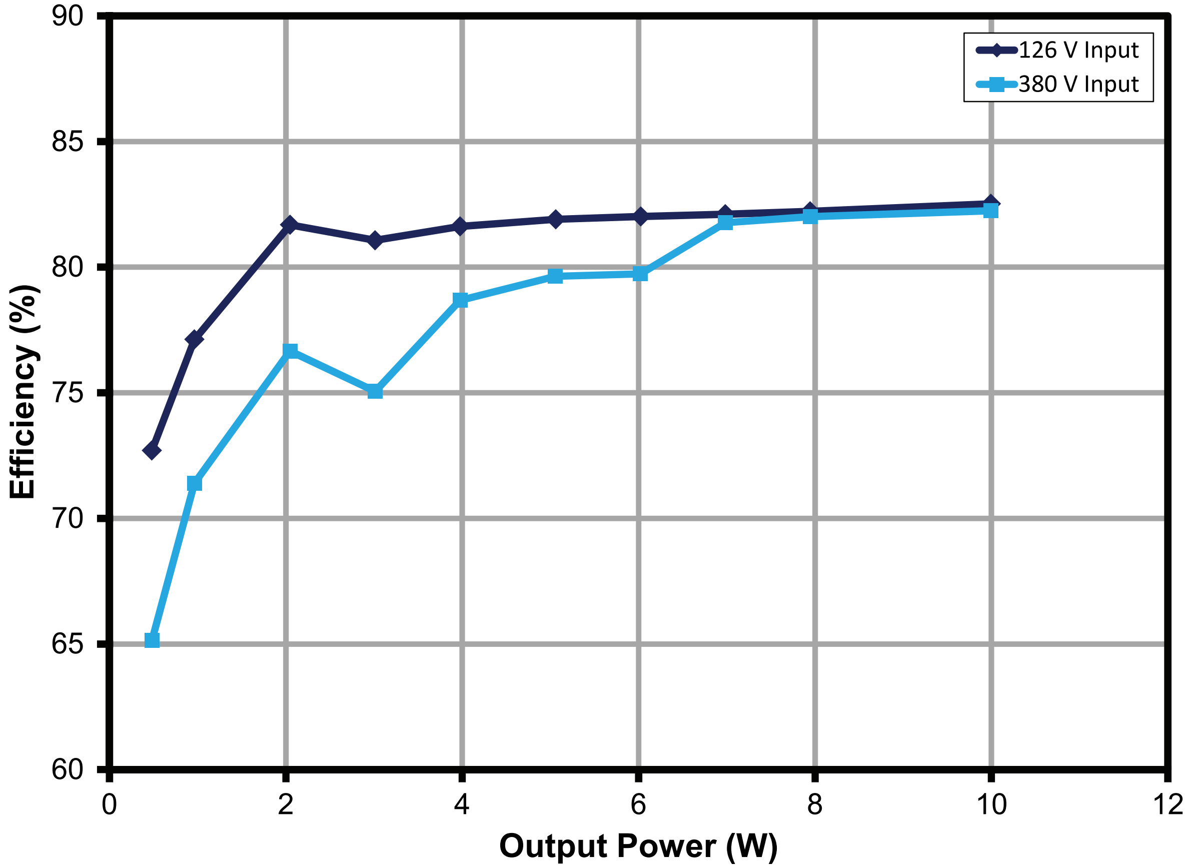

Figure 21 – Standby Efficiency vs. Load.

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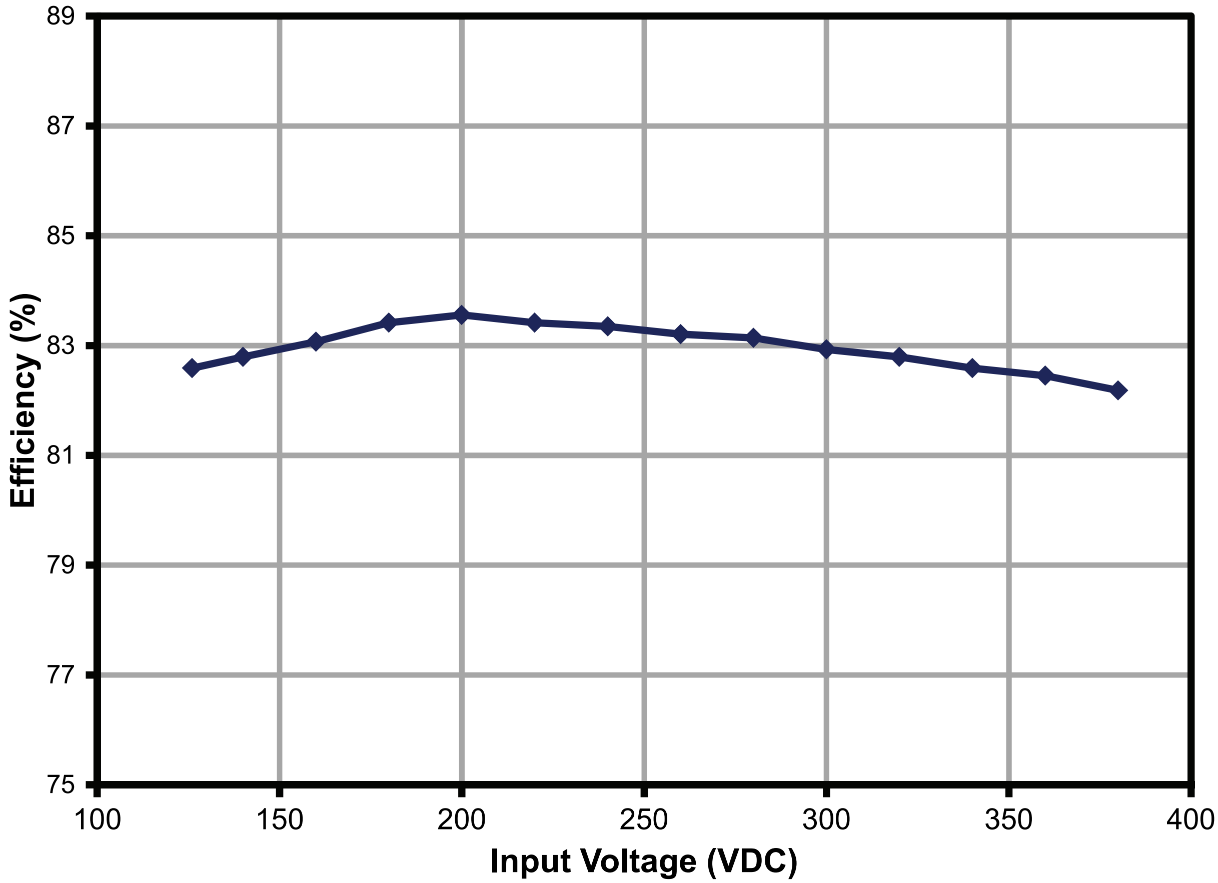

Figure 22 – Standby Efficiency vs. Input Voltage, 100% Load.

12.2 待机空载输入功率

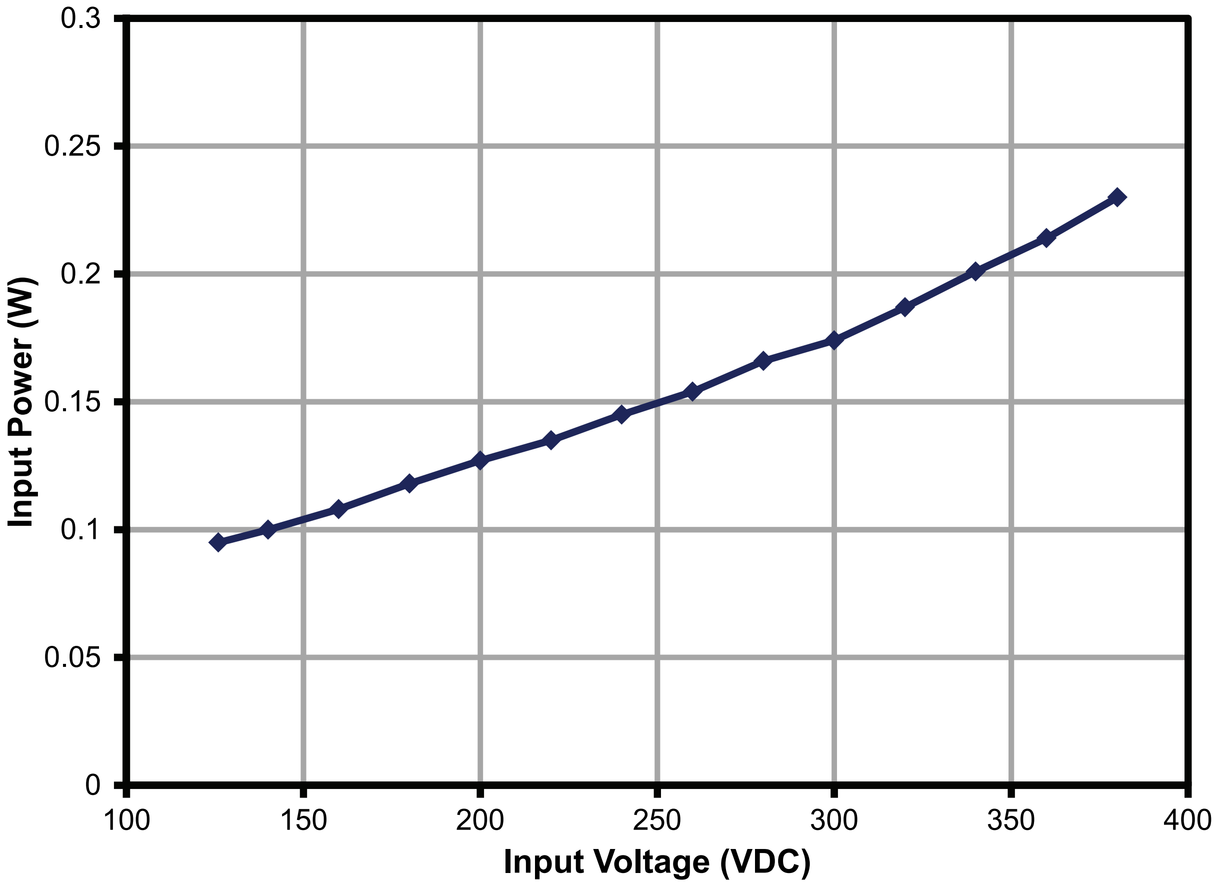

Figure 23 – Standby No-Load Input Power vs. Input Voltage.

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12.3 调整

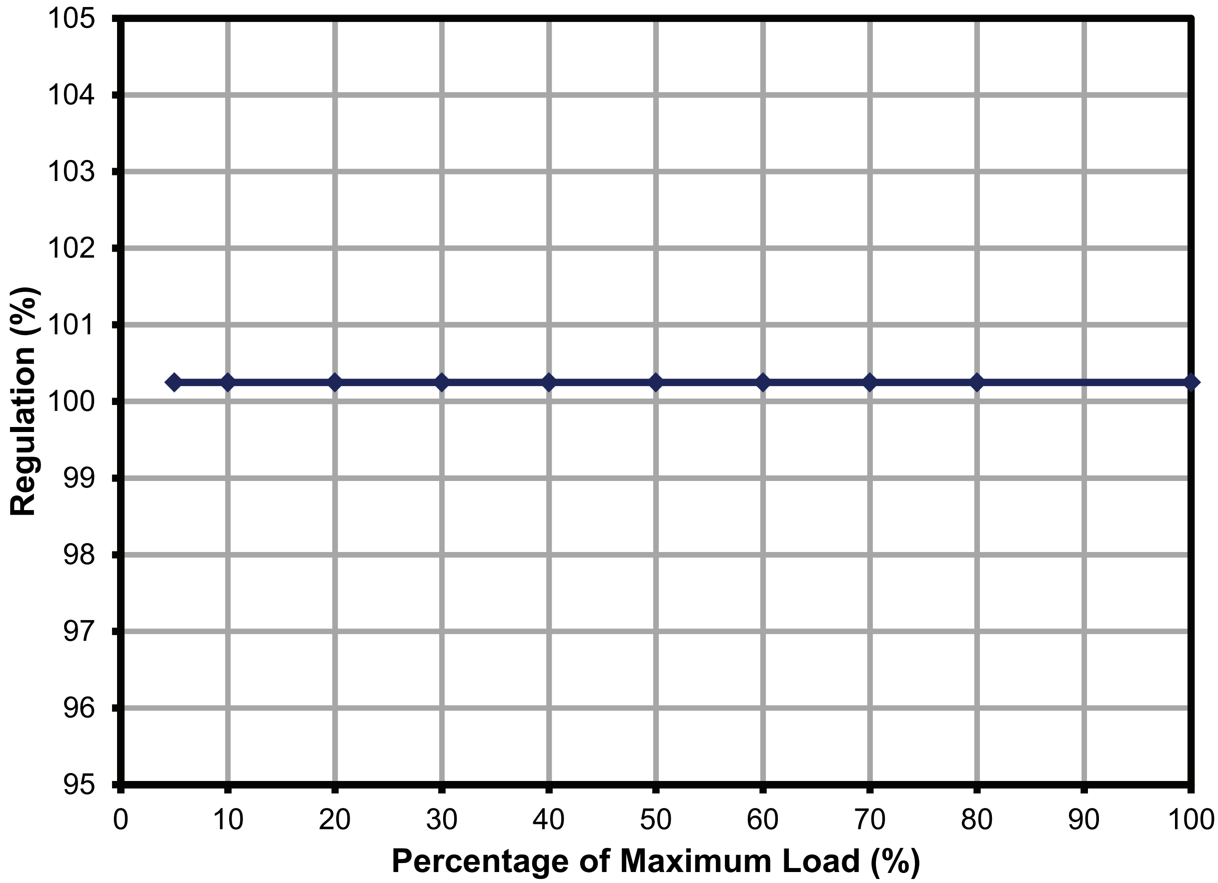

Figure 24 – Standby Supply Load Regulation, 380 VDC Input.

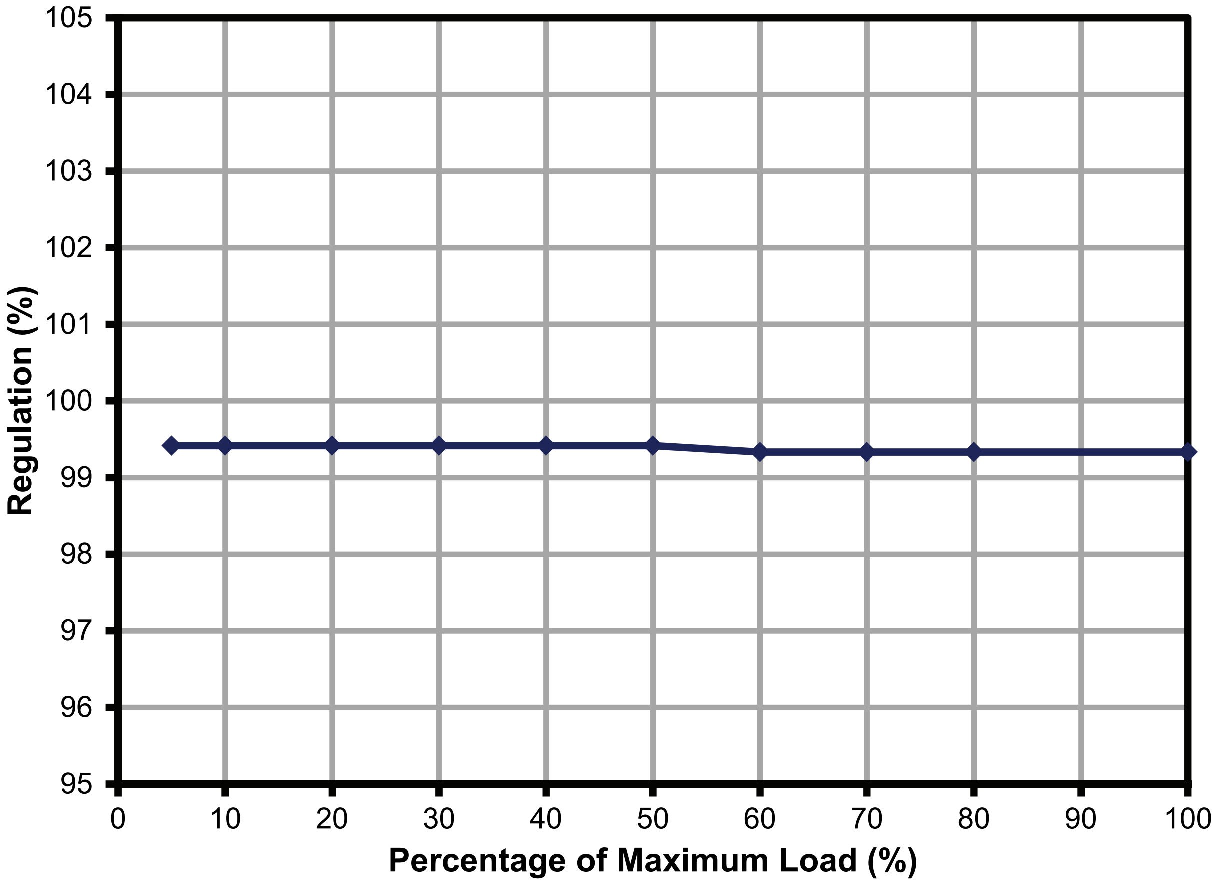

Figure 25 – Main Output Load Regulation, 380 VDC Input.

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12.4 波形

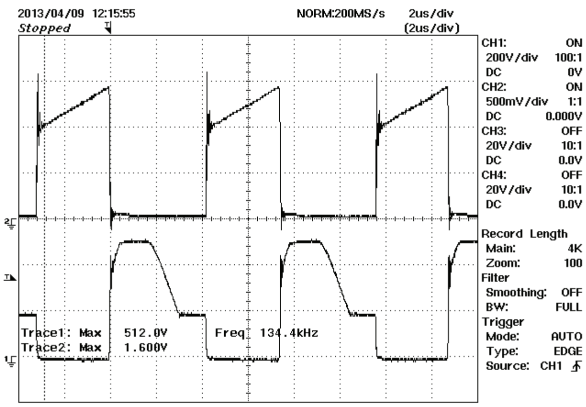

Figure 26 – Main Output Drain Voltage and Current, Full Load, 380 VDC Input.
Upper: I_{DRAIN}, 0.5 A / div.
Lower: V_{DRAIN}, 200 V, 2 μs / div.

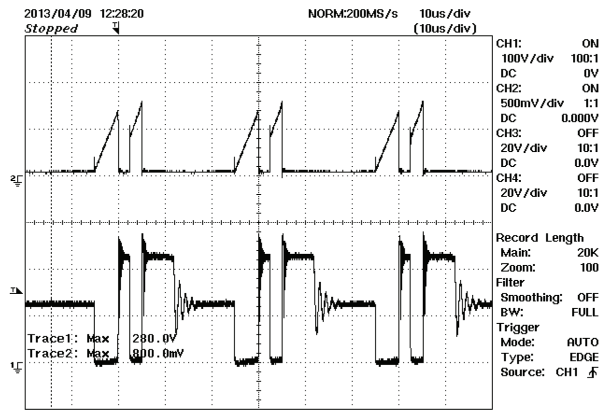

Figure 27 – Standby Output Drain Voltage and Current, Full Load, 126 VDC (90 VAC equiv.) Input.
Upper: I_{DRAIN}, 0.5 A / div.
Lower: V_{DRAIN}, 100 V, 10 μs / div.

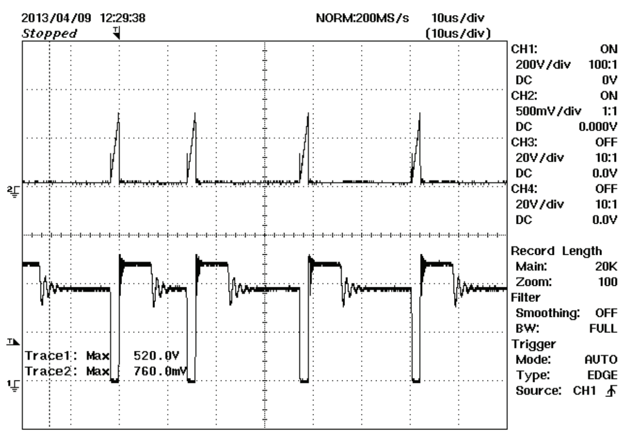

Figure 28 – Standby Output Drain Voltage and Current, Full load, 380 VDC Input.
Upper: I_{DRAIN}, 0.5 A / div.
Lower: V_{DRAIN}, 200 V, 10 μs / div.

12.5 主输出二极管峰值反向电压

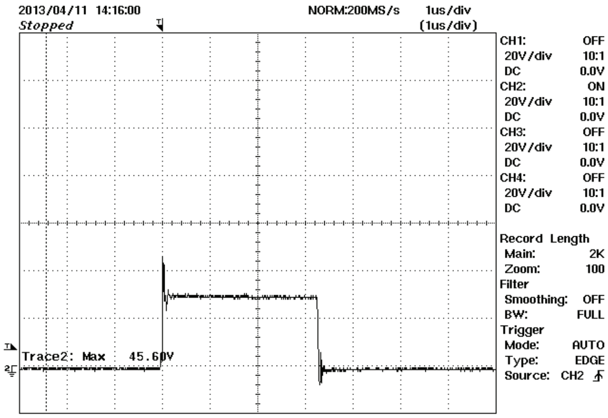

Figure 29 – Main Output Catch Diode (D6) Reverse Voltage, 380 VDC Input, Full Load, 20 V, 1 μs / div.

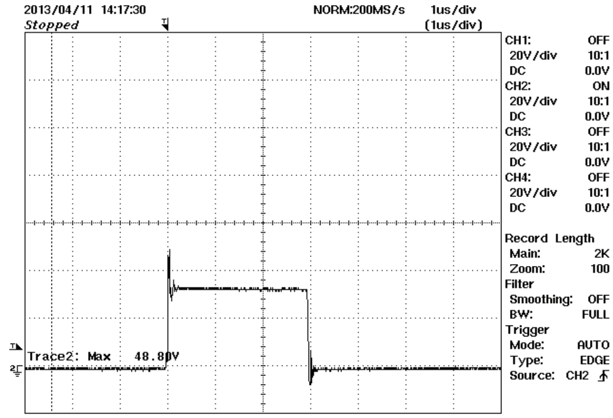

Figure 30 – Main Output Catch Diode (D6) Reverse Voltage, 420 VDC Input, Full Load, 20 V, 1 μs / div.

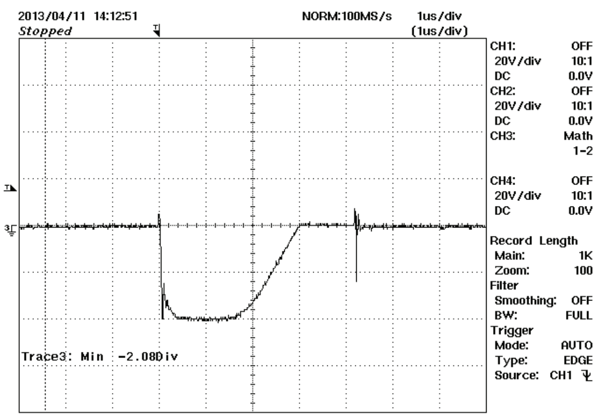

Figure 31 – Main Output Forward Diode (D7) Reverse Voltage, 380 VDC Input, Full Load, 20 V, 1 μs / div. PRV = 2.08 div. X 20 V / div. = 41.6 V

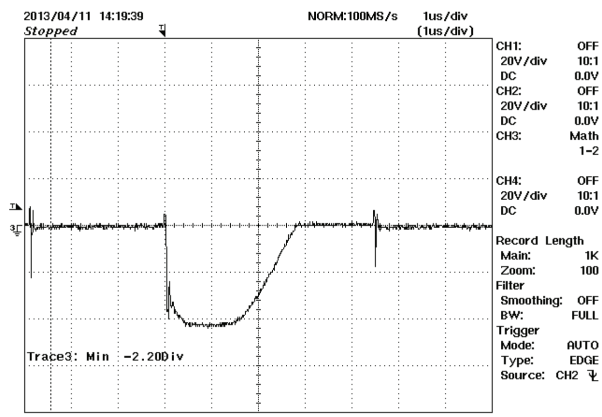

Figure 32 – Main Output Forward Diode (D7) Reverse Voltage, 420 VDC Input, Full Load, 20 V, 1 μs / div. PRV = 2.2 div. X 20 V / div. = 44 V

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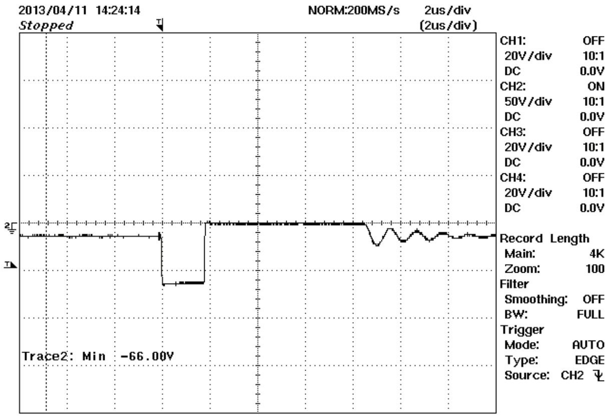

Figure 33 – Standby Output Rectifier Diode (D16) Reverse Voltage, 380 VDC Input, Full Load, 50 V, 2 µs / div.

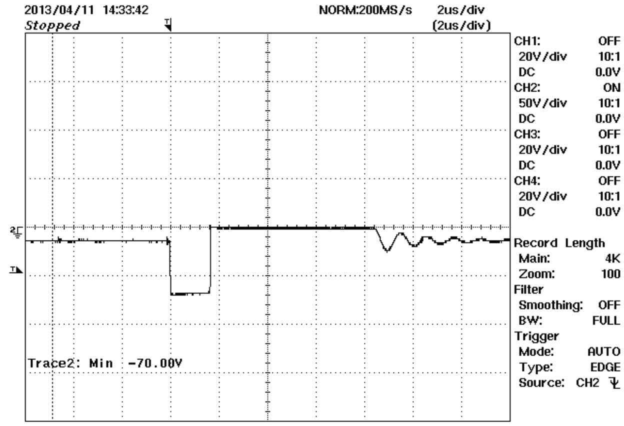

Figure 34 – Standby Output Rectifier Diode (D16) Reverse Voltage, 420 VDC Input, Full Load, 50 V, 2 µs / div.

12.6 启动和维持

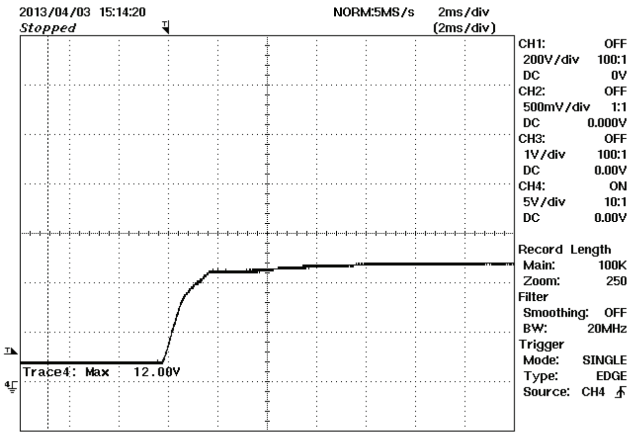

Figure 35 – 12 V Main Output Start-up, Full Load, 380 VDC Input, Resistive Load, 5 V, 2 ms / div.

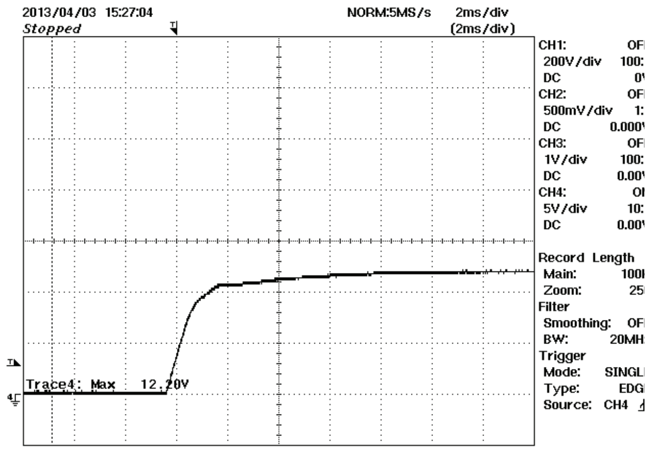

Figure 36 – 12 V Main Output Start-up, 3% Load, 380 VDC Input, Resistive Load, 5 V, 2 ms / div.

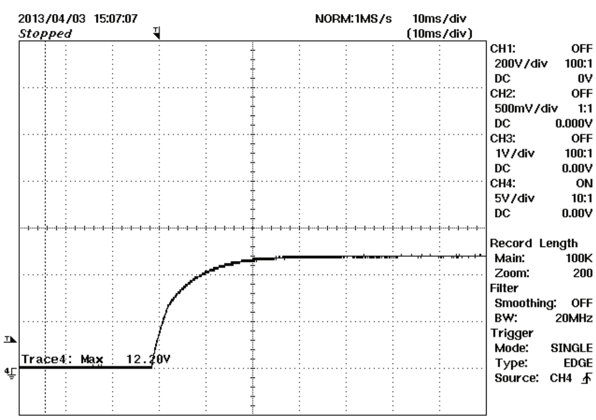

Figure 37 – 12 V Aux Output Start-up, 126 VDC Input, Zero Load, 5 V, 10 ms / div.

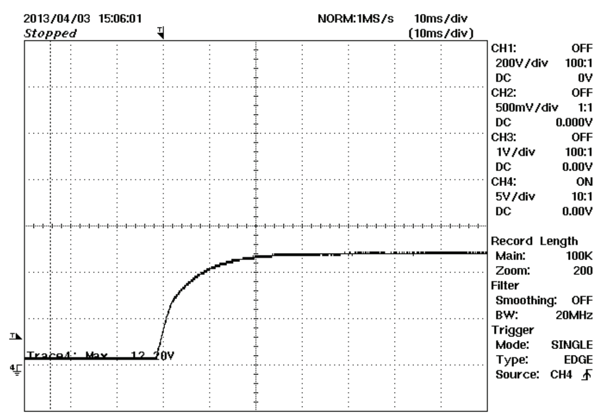

Figure 38 – 12 V Aux Output Start-up, 126 VDC Input, Full Load, 5 V, 10 ms / div.

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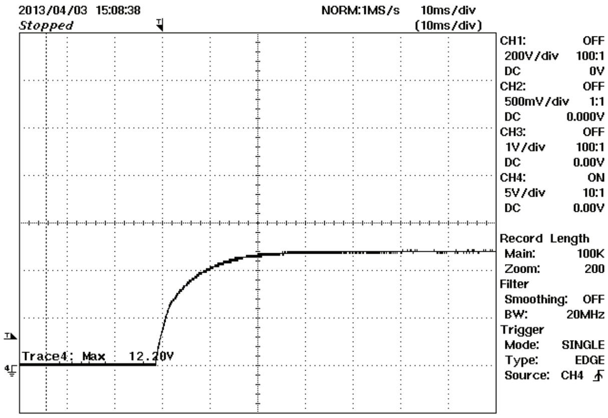

Figure 39 – 12 V Aux Output Start-up, 380 VDC Input, Zero Load, 5 V, 10 ms / div.

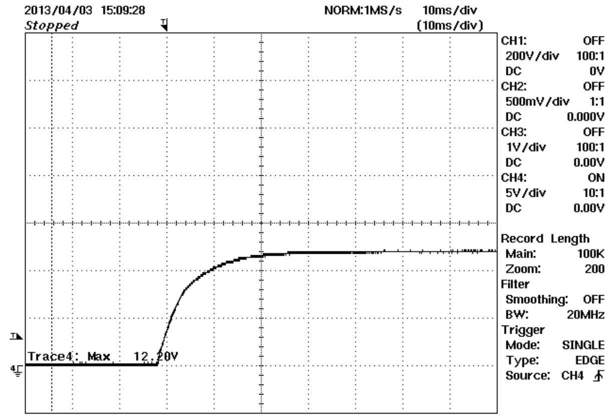

Figure 40 – 12 V Aux Output Start-up, 380 VDC Input, Full Load, 5 V, 10 ms / div.

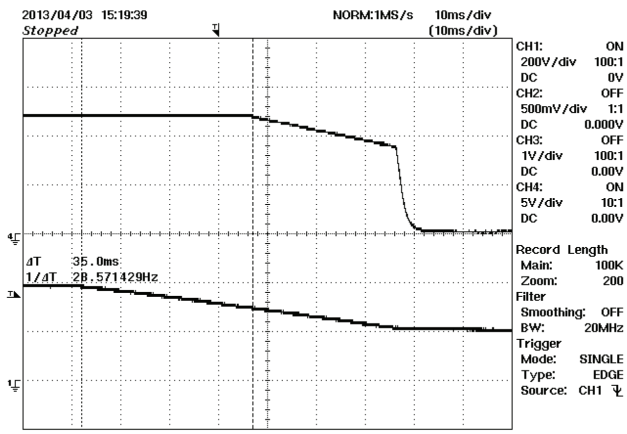

Figure 41 – Main Output Hold-up Time, Full Load.
Upper: V_{OUT}, 5 V / div.
Lower: B+ Voltage, 200 V, 10 ms / div.

12.7 纹波

12.7.1 纹波测量方法

For DC output ripple measurements, a modified oscilloscope test probe must be utilized in order to reduce spurious signals due to noise pickup. Details of the probe modification are provided in the figures below.

The 4987BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 μF / 50 V ceramic type and one (1) 1.0 μF / 50 V aluminum electrolytic. The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).

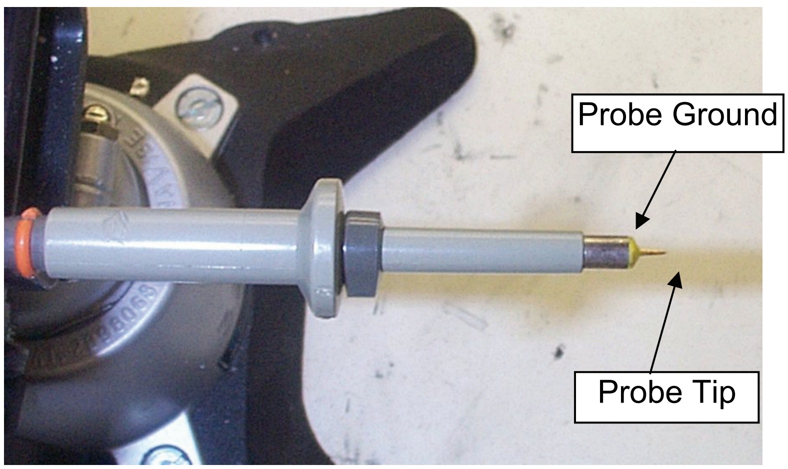

Figure 42 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

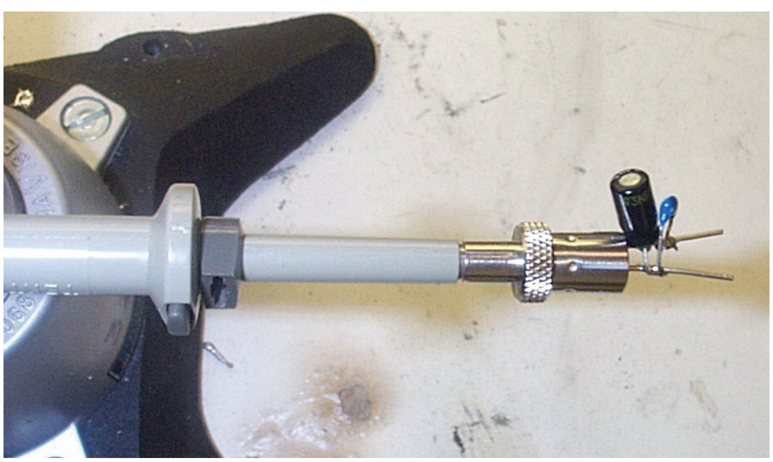

Figure 43 – Oscilloscope Probe with Probe Master (www.probemaster.com) 4987A BNC Adapter. (Modified with Wires for Ripple Measurement, and Two Parallel Decoupling Capacitors added)

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12.7.2 纹波测量结果

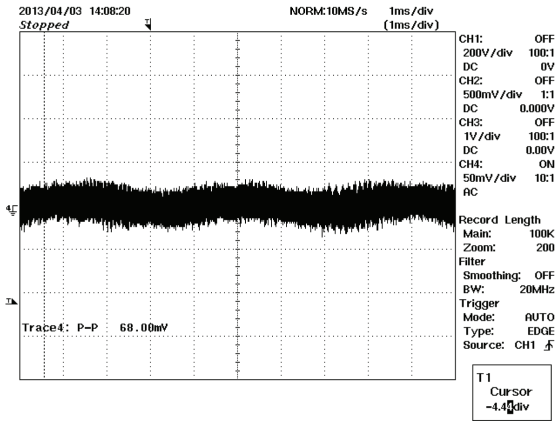

Figure 44 – Ripple, 12 V Main Output, Full Load, 380 VDC Input. 50 mV, 1 ms / div.

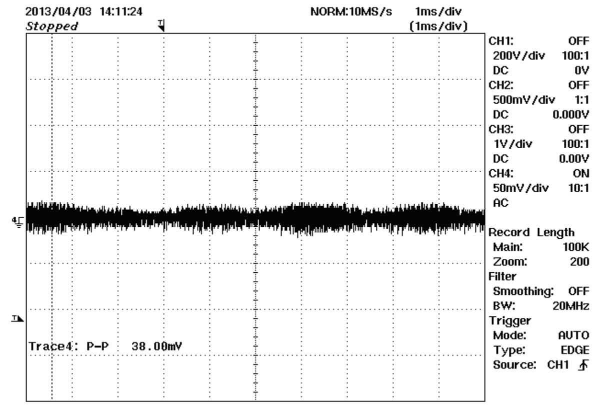

Figure 45 – Ripple, 12 V Standby Output, Full Load, 126 VDC Input 50 mV, 1 ms / div.

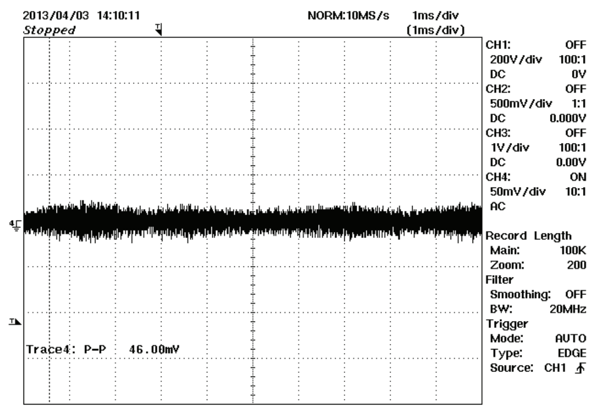

Figure 46 – Ripple, 12 V Standby Output, Full Load, 380 VDC Input 50 mV, 1 ms / div.

12.8 瞬态响应

In Figures 47-48, and 51-52, data was collected with the oscilloscope set to averaging mode, so that events non-synchronous with the load step (such as high frequency output ripple, are average out, leaving a clear view of the response to the step load change.

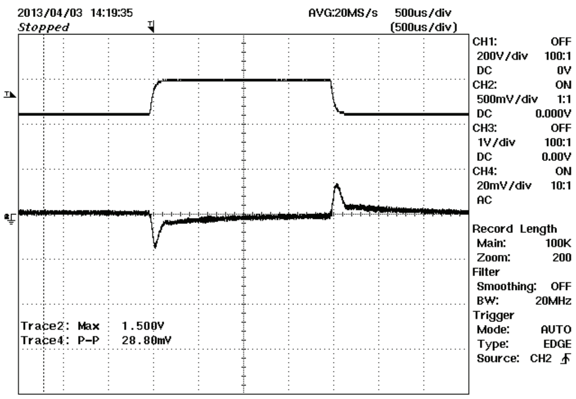

Figure 47 – 12 V Main Output Load Transient Response, 75% - 100% - 75% Load Step, 380 VDC Input.
Upper: I_{OUT}, 5 A / div.
Lower: V_{OUT}, 20 mV, 500 μs / div.

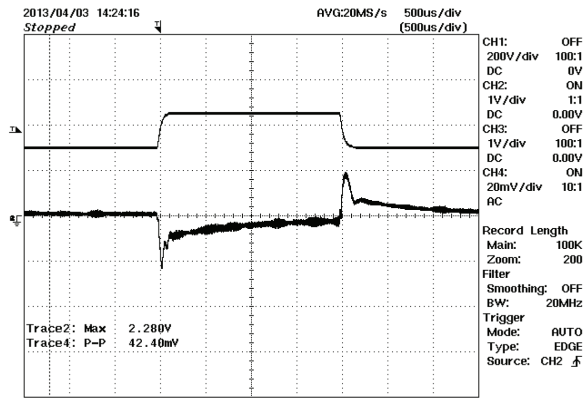

Figure 48 – 12 V Main Output Load Transient Response, 100% – 180% – 100% Load Step, 380 VDC Input.
Upper: I_{OUT}, 10 A / div.
Lower: V_{OUT}, 20 mV, 500 μs / div.

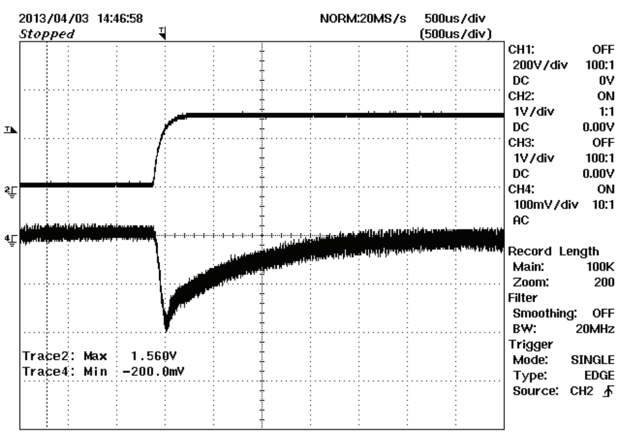

Figure 49 – 12 V Main Output Load Transient Response, 3% - 100% - Load Step, 380 VDC Input.
Upper: I_{OUT}, 5 A / div.
Lower: V_{OUT}, 100 mV, 500 μs / div.

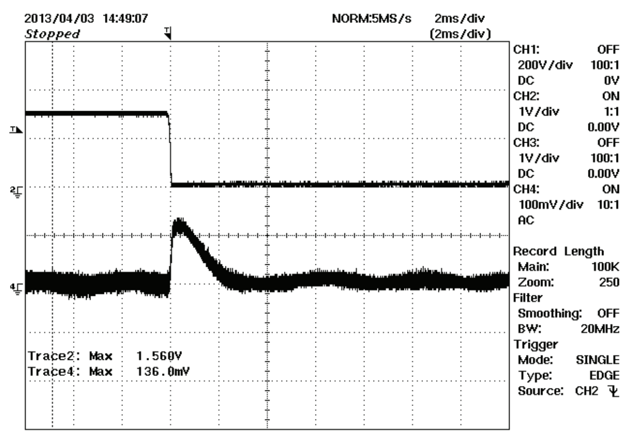

Figure 50 – 12 V Main Output Load Transient Response, 100% - 3% Load Step, 380 VDC Input.
Upper: I_{OUT}, 5 A / div.
Lower: V_{OUT}, 100 mV, 2 ms / div.

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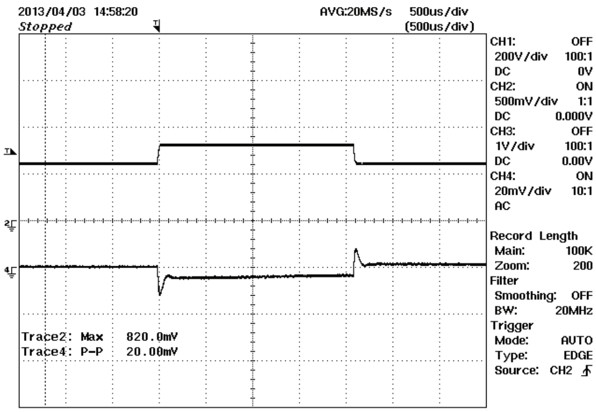

Figure 51 – 12 V Standby Output Load Transient Response, 75% - 100% - 75% Load Step, 126 VDC Input.
Upper: I_{OUT}, 0.5 A / div.
Lower: V_{OUT}, 20 mV, 500 μs / div.

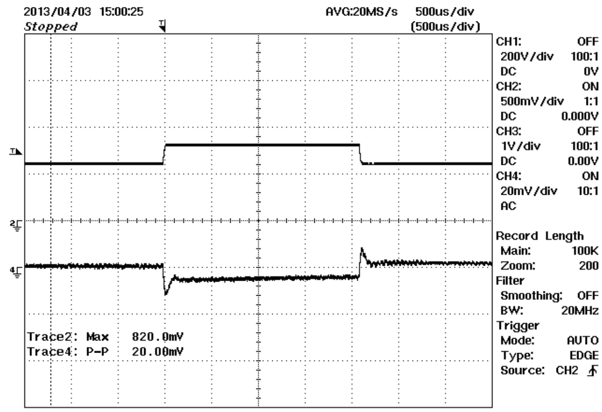

Figure 52 – 12 V Standby Output Load Transient Response, 75% - 100% - 75% Load Step, 380 VDC Input.
Upper: I_{OUT}, 0.5 A / div.
Lower: V_{OUT}, 20 mV, 500 μs / div.

13 热测试

The test setup for evaluating component temperature with forced air cooling is shown below. A cardboard shroud was constructed to approximate the size of a typical power supply, and fitted with a 12 V, 50 mm, 0.27 A fan (Yate Loon D50SH-12C), driven by an external DC supply. The fan was oriented to exhaust from the box. Fan voltage was set to 8 VDC for the measurements shown below. The back side of the box was left open to facilitate measurements with a thermal camera. The main output diodes (D6 and D7) and the output diode snubber resistor (R37) were not accessible to the thermal camera, so these were fitted with #30 AWG type T thermocouples soldered to the device mounting tabs for thermal measurements, or in the case of the resistor, attached to the resistor body using thermal epoxy. Results are shown in Section 13.2.

Figure 53 – Test Set-up Showing Fan.

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13.1 热图片

Figure 54 – Standby Transformer T2, Visible Light View.

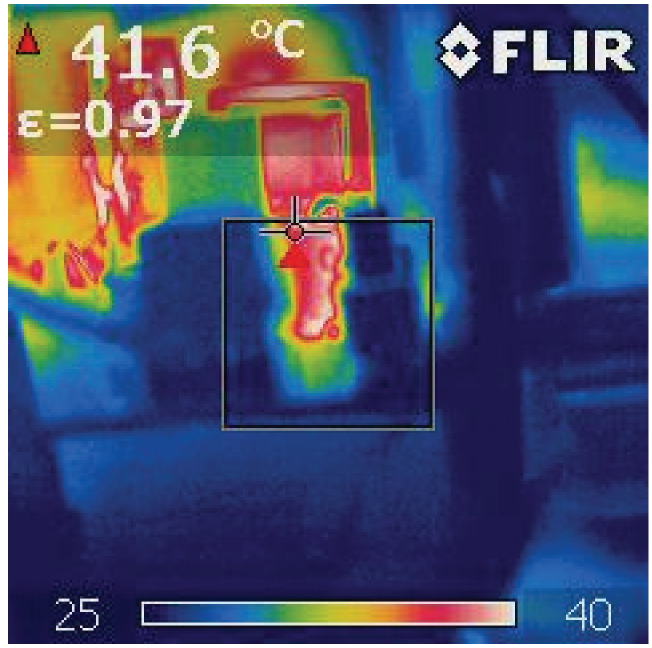

Figure 55 – Standby Transformer T2 Thermal Image, Full Load, Room Temperature.

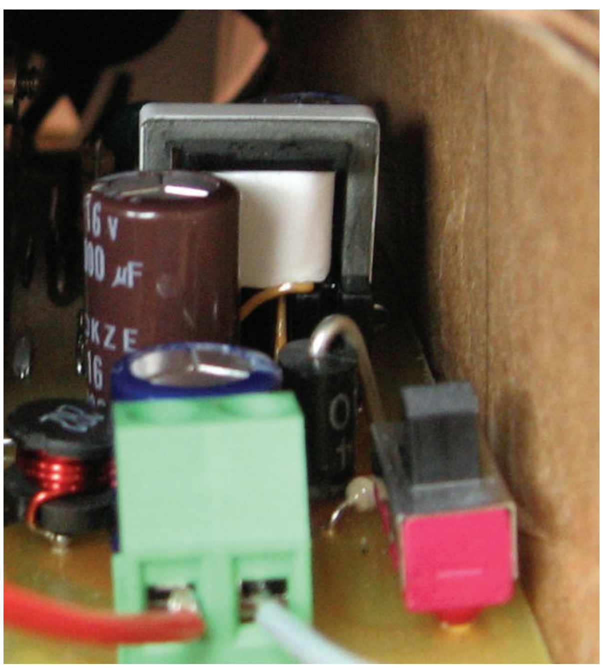

Figure 56 – Standby Output Rectifier D16, Visible Light View.

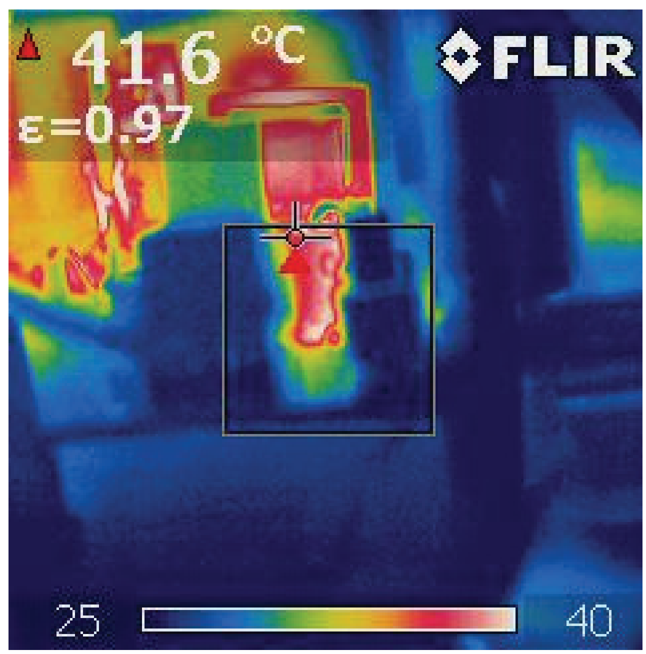

Figure 57 – Standby Output Rectifier D16 Thermal Image, Full Load, Room Temperature.

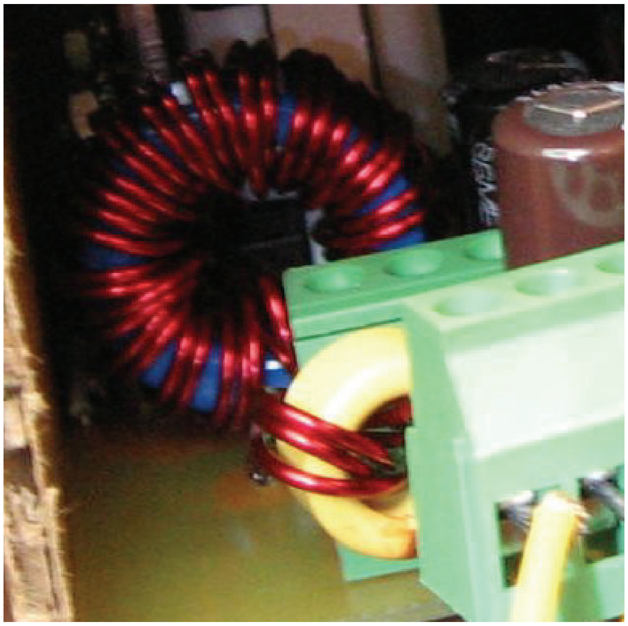

Figure 58 – Main Output Choke L1, Visible Light View.

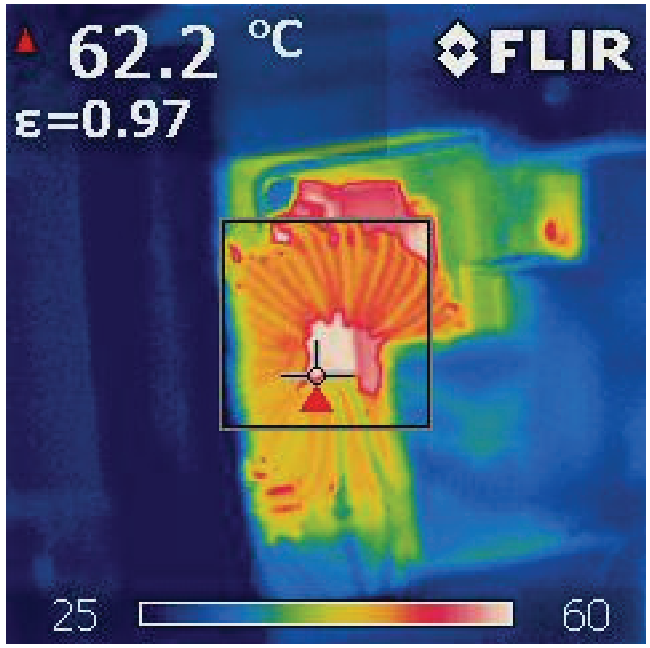

Figure 59 – Main Output Choke L1 Thermal Image, Full Load, Room Temperature.

Figure 60 – Main Output Transformer T1, Visible Light View.

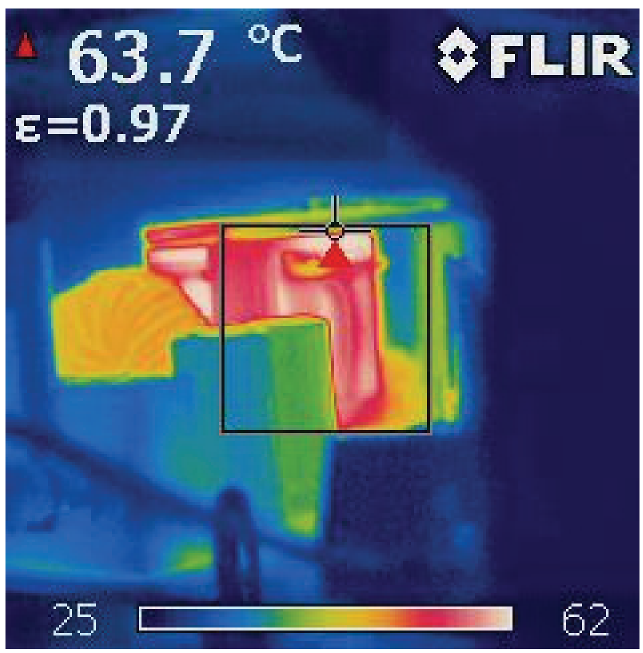

Figure 61 – Main Output Transformer T1 Thermal Image, Full Load, Room Temperature.

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Figure 62 – HiperTFS-2 IC U6 , Visible Light View.

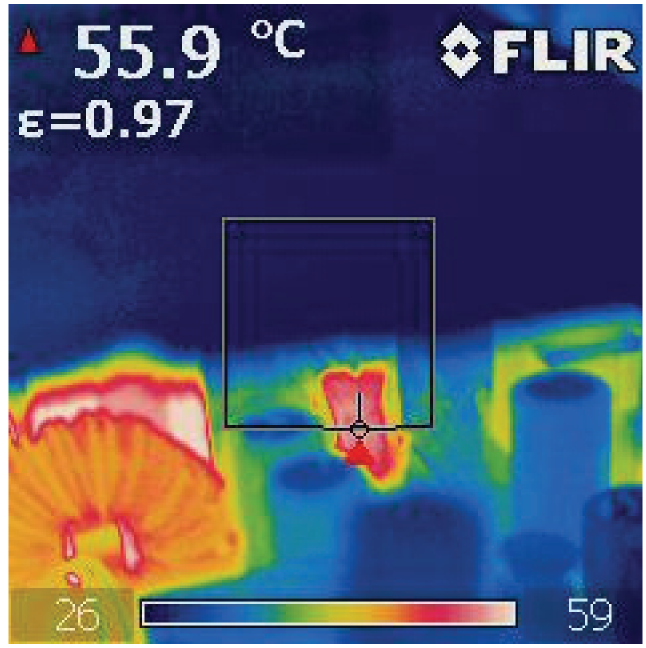

Figure 63 – HiperTFS-2 IC U6 Thermal Image, Full Load, Room Temperature.

13.2 主输出整流管的热电耦测量

Position	THM1 (D7)	THM2 (D6)	THM3 (R37)	THM4 (AMB)
Temperature	63 °C	64 °C	62 °C	25 °C

14 增益相位图

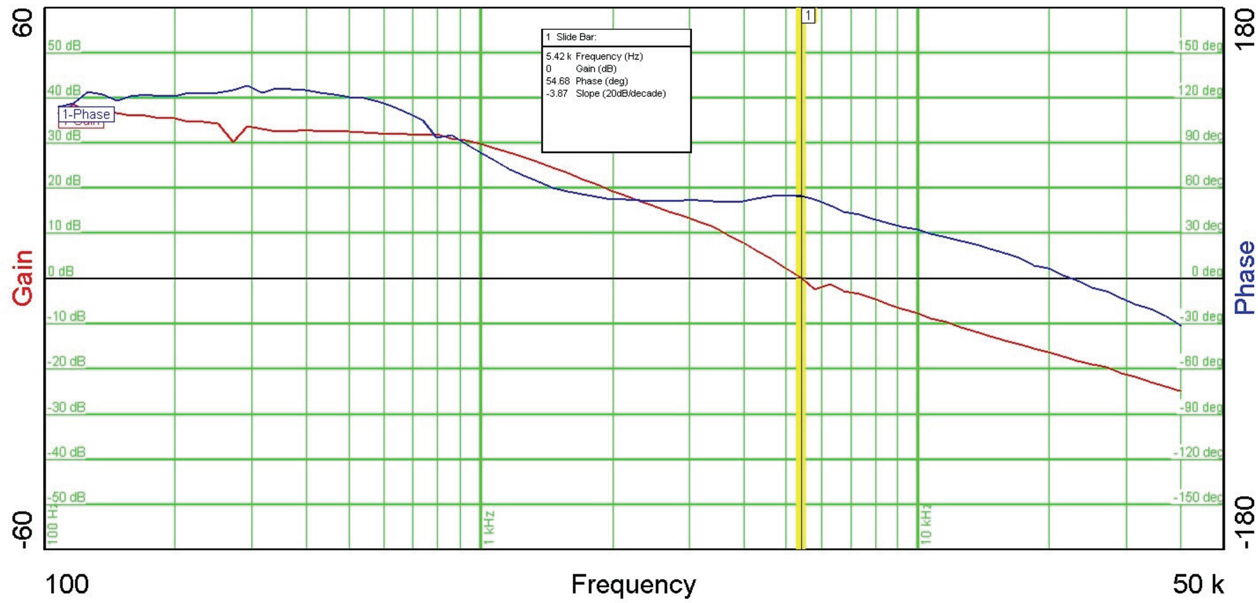

Figure 64 – Main Output Control Loop, 380 VDC Input, Full Load. Gain Crossover is at 5.42 kHz, with 54.7º Phase Margin.

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15 版本历史

Date	Author	Revision	Description and Changes	Reviewed
12-Nov-13	SS	7.1	Initial Release	Apps & Mktg

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