設計範例報告

標題	***190 W 連續功率，280 W 峰值功率 DC-DC 順向式轉換器，在 132 kHZ 下待機運作，使用 HiperTFS™-2 TFS7703H***
規格	380 VDC 輸入；12 V、15 A 主電源和 12 V、0.83 A 待機輸出
應用	整合式電腦電源供應器
作者	應用工程部門
文件編號	DER-368
日期	2013 年 11 月 12 日
修訂	7.1

摘要與功能

- 高效率整合式主電源和待機轉換器
- 整合式高側驅動器
- 嵌入式主電源和待機欠壓保護
- 伏特-秒限制保護主變壓器
- 平板待機功率限制與輸入電壓
- 132 kHz 工作頻率適用於小型主變壓器 (EF25)
- >91% 高效率主電源轉換器

專利資訊

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目錄

重要事項：
雖然此電路板的設計符合安全隔離要求，但工程原型尚未取得安規機構之認證。

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1 簡介

本文件是一份工程報告，說明由雙開關順向式主電源轉換器和返馳式待機轉換器 (採用以 132 kHz 運作的 TFS7703H IC) 組成的 190 W 連續功率，280 W 峰值功率電源供應器的初步測試。EF25 變壓器用於主輸出電源供應器，EE16 變壓器用於待機電源供應器。本測試的目的旨在確定電腦電源供應器的 12 V (僅) 輸出「整合式」解決方案的評估板是否可實現最大輸出功率 (含風扇冷卻)。

主電源轉換器在 300 VDC 至 420 VDC 的輸入電壓範圍內運作。待機轉換器在 120 VDC 至 420 VDC 範圍內運作。典型系統中的高壓 DC 輸入可從 PFC 架構供應。

本文件內容涵蓋電源供應器的規格、電路圖、物料表、變壓器文件、測試設定說明和效能資料。

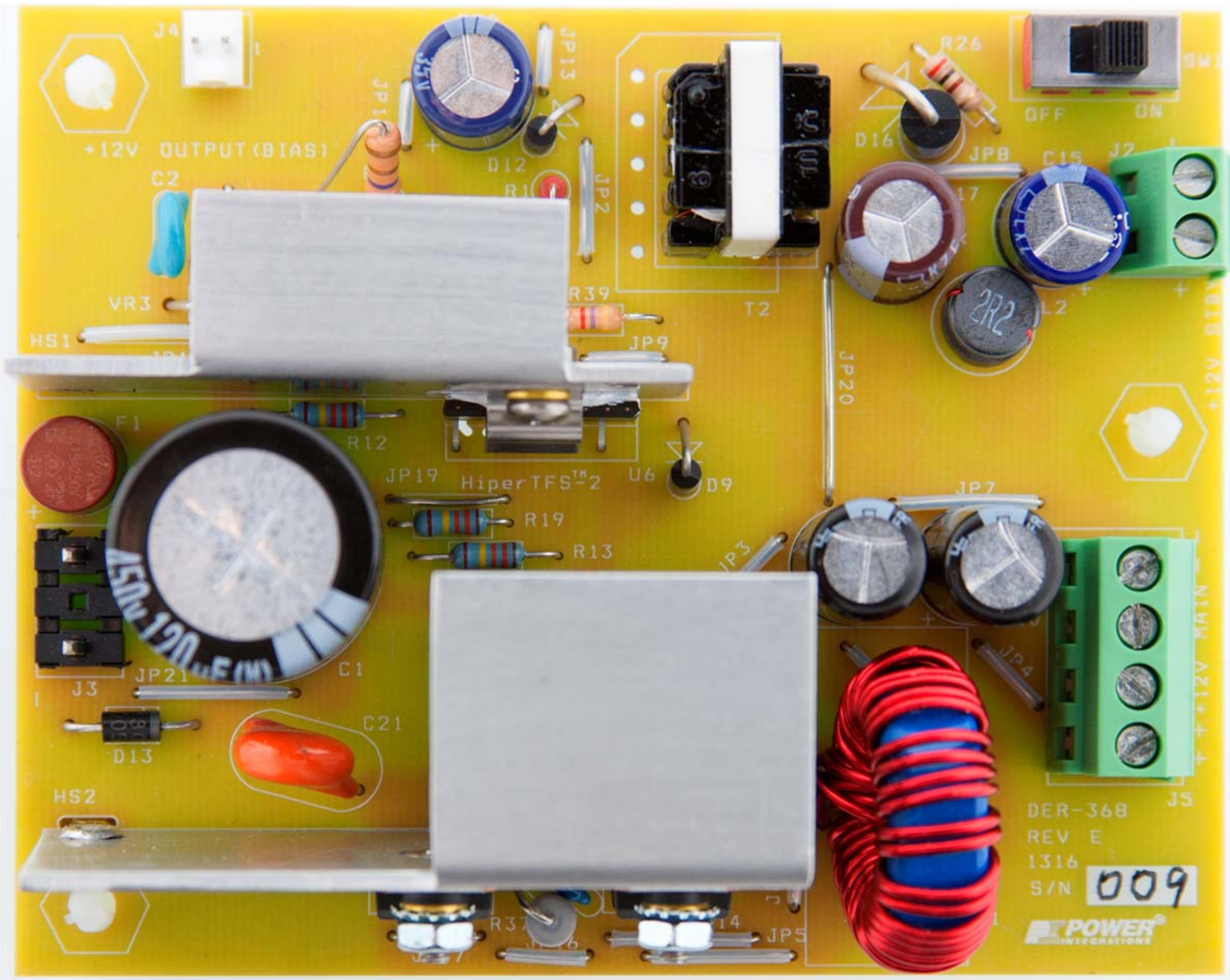

Figure 1 – DER-368 Populated Circuit Board Photograph, Top View.

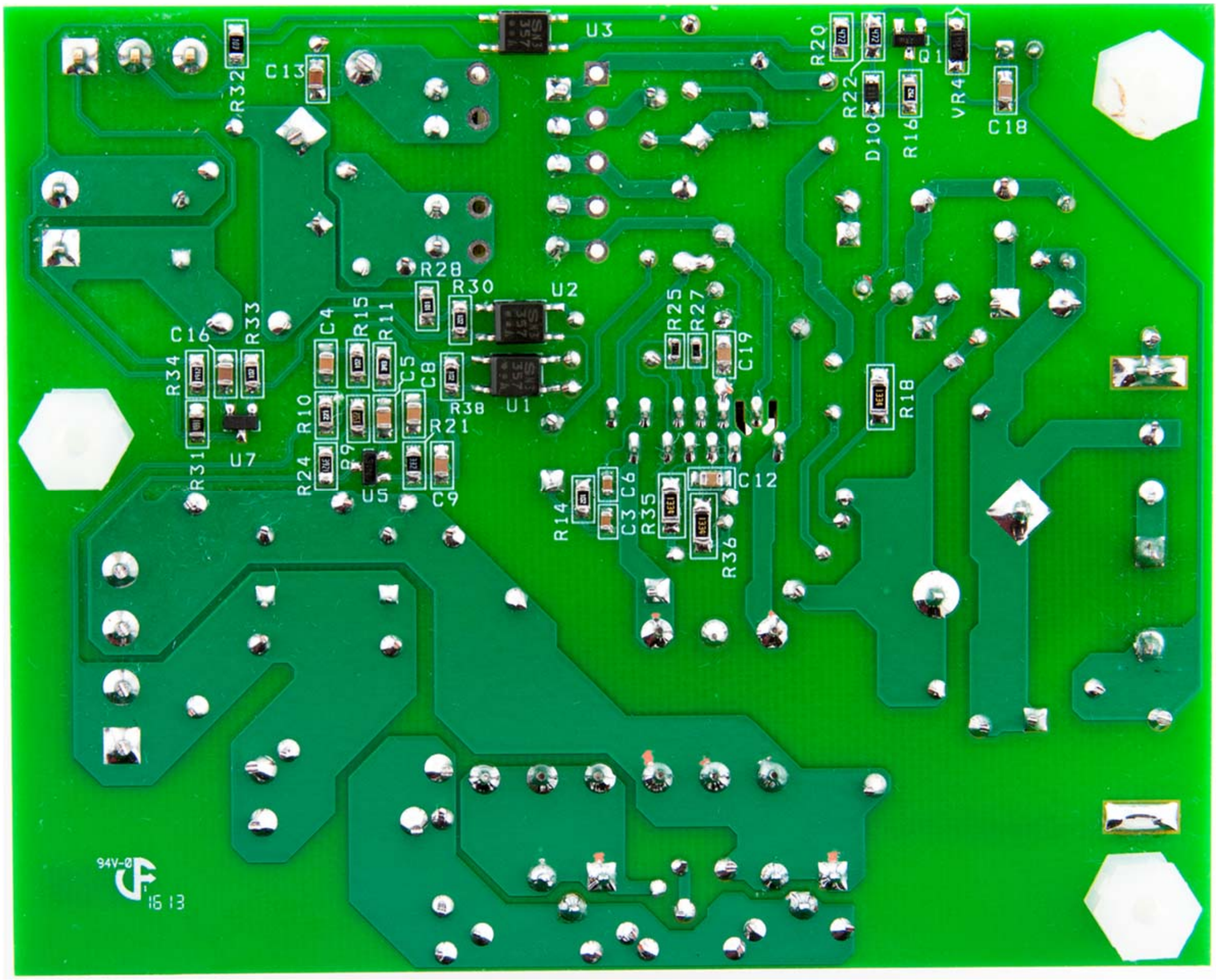

Figure 2 – DER-368 Populated Circuit Board Photograph, Bottom View.

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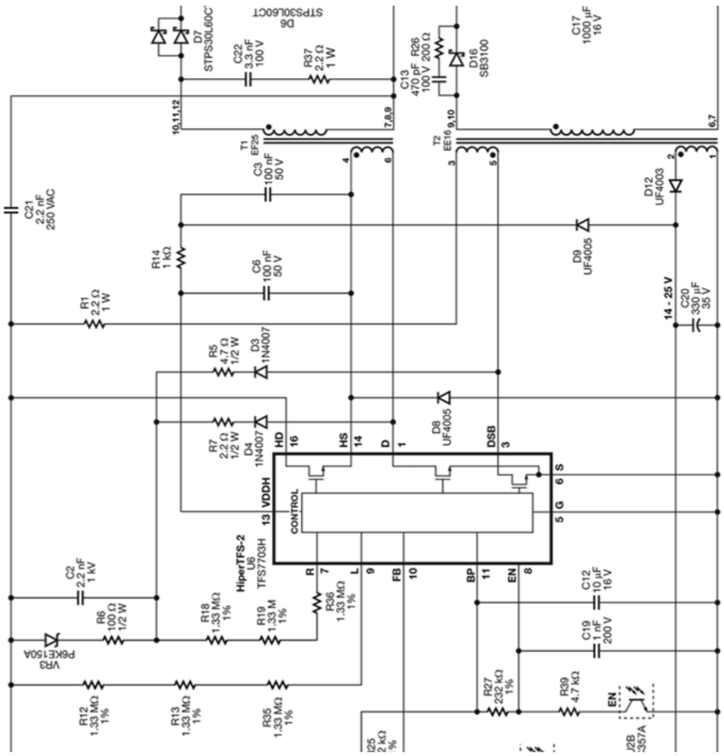
2 電源供應器規格

下表列出此設計可接受的最低效能。實際效能列在結果部分。

說明	符號	最小值	典型值	最大值	單位	註解
輸入						
DC 匯流排電壓	**V_{IN}**	300	380	420	VDC	僅限 DC 輸入。
無負載輸入功率 (380 VDC)			0.3		W	
啓動電壓	**V_{START}**		340		VDC	
關機電壓	**V_{STOP}**		285		VDC	
輸出						
輸出 1 電壓	**V_{OUT1}**	11.4	12	12.6	V	±5%
輸出 1 P-P 漣波電壓	**$V_{RIPPLE1}$**			120	mV	20 MHz 頻寬
輸出 1 電流	**I_{OUT1}**	0		15	A	22.5 A 峰值
輸出 2 電壓	**V_{OUT2}**	11.4	12	12.6	V	±5%
輸出 2 P-P 漣波電壓	**$V_{RIPPLE2}$**			120	mV	20 MHz 頻寬
輸出 2 電流	**I_{OUT2}**	0	0.83		A	
總輸出功率						
連續輸出功率	**P_{OUT}**		190		W	
峰值輸出功率	**P_{OUT_PEAK}**			280	W	(在主電源 12 V 輸出上有 22.5 A 的峰值負載)
效率						在 25 °C、380 VDC 輸入下測得
20% 負載	η		86		%	
50% 負載	η		90		%	
100% 負載	η		90		%	
尺寸		109 x 84 x 33			mm	長 x 寬 x 高
環境溫度	t_{AMB}	0		40	?C	強制氣冷

3 電路圖



3Figure

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SEQ Figure * ARABIC

4 電路說明

圖 3 中的電路圖說明使用 TFS7703H 實作的 12 V、15 A 順向式 DC-DC 轉換器和 12 V、0.83 A 返馳式待機/一次側偏壓電源供應器。

HiperTFS-2 TFS7703H 極具成本效益，因爲它將低壓側 725 V 主 MOSFET、高壓側 530 V 主 MOSFET 和 725 V 待機 MOSFET、主電源和待機控制器、高壓側驅動器、過熱關機保護和其他故障保護以及其他控制電路整合在單一封裝內。此裝置非常適用於具有主電源和待機轉換器的高功率應用 (例如電腦電源供應器)。待機可在廣泛的輸入電壓範圍內運作。主電源轉換器用於接收來自功率因數修正階段的輸入電壓升壓，且通常在 300 VDC 至 385 VDC 範圍內運作

4.1 功率輸入和濾波器

此電路是專爲主輸出功率高達 180 W 的電腦電源供應器設計的。二極體 D13 可在反向輸入電壓連接時開啓保險絲 F1，以防止發生嚴重故障。電容器 C1 是大能量儲存元件。

4.2 一次側

組件 C2、R6 和 VR3 元件構成關斷箝位電路，可限制主電源順向式轉換器的待機轉換器汲極和低壓側 MOSFET 汲極的 U6 汲極電壓。積納二極體 VR3 提供定義的箝位電壓，並保持箝位電容器 C2 的最大電壓 (150 V)。由於使用慢速恢復的阻隔二極體 D3 和 D4，大多數漏電和磁化能量會返回轉換器。主電源和待機轉換器之間共用的重設/漏感突波箝位可減少元件數目。待機是透過二極體 D3 和電阻器 R5 連接到箝位，而主電源部分則是透過二極體 D8、D4 及電阻器 R7 連接到箝位。在重設時，主電源部分會連接到高出 V_{IN} 甚多的重設電壓，因此主電源轉換器的操作工作週期可延長 50% 以上，可降低 RMS 切換電流而不會有額外的維持時間。

BYPASS (BP) 接腳加上電容器 C12，爲 HiperTFS-2 控制器提供去耦合工作電壓。C12 的值 (10 µF) 也選取 132 kHz 作爲主電源轉換器的工作頻率。當啓動時，旁路電容器會從 IC U6 內部的電流源充電。當 BP 接腳的電壓達到 5.8 V，待機轉換器會開始交換，而 +12 V 待機輸出和一次側偏壓電壓將開始升高。偏壓/輔助供電繞組的輸出會由二極體 D12 進行整流，並且由電容器 C20 進行濾波。在僅待機操作期間，偏壓繞組的輸出用於透過電阻器 R16 向 HiperTFS-2 BP 接腳供電。當遠端開啓切換開關 SW1 啓動 U3A 和 U3B 且命令 Q1 進入開啓狀態時，Q1 和 D10 會從一次側偏壓電源供應器提供額外電流。在完整的電腦電源供應器應用中，此電壓可用於透過 J4 連接器爲 PFC 控制器提供偏壓。R16 的值被選取用來維持輸入到 BP 接腳所需的最低 700 µA，以抑制內部 HiperTFS-2 高壓電流源，從而降低無負載功耗。電容器 C12 連接到 U6 的 BP 接腳，可爲內部穩壓的 5.85 V 供電提供去耦合。積納二極體 VR4 可爲 Q1 提供電壓參考來將射極間電壓調節爲 12.4 V，以輸入穩定的 6 mA 到 BP 接腳，並爲 PFC 架構(若使用) 提供穩壓供電。

啓用 (EN) 接腳是待機控制器部分的回饋接腳。在啓動之前，會偵測從 EN 連接到 BP 的電阻器 R27，以針對待機部分選取數種內部限電流之一。回饋 (FB) 接腳電阻器 R25 用於在啓動時使用與 EN 接腳相同的方式選取三種主電源限電流之一。R27 有四種不同的電阻器值可用，可針對待機部分選取四種內部限電流配置之一，而 R27 有三種不同的電阻器值可用，可針對主電源部分選取三種限電流配置之一。此處展示的電路，在 650 mA 的待機 ILIM 使用 R27 (232 kΩ)，而在 3.1 A 的主電源 ILIM 使用 R25 的 232 kΩ。

FB 接腳爲主電源轉換器提供回饋。增加從 FB 接腳到接地降低的電流，會導致減少操作工作週期。

二極體 D9 用於在啓動期間爲升壓充電 C3 和 C6 提供初始功率。在此期間，高壓側 MOSFET HS 接腳會短暫拉出到源極 12 毫秒。在正常操作期間，C6 上的標準電壓會分流調整爲大約 12 V。這是必要的，可確保電容器 C3 在任何時候都至少有 13 V。

電阻器 R18、R19 和 R36 是用來將最大可用關閉時間重設電壓轉換成 R 接腳的電流，並將其與 L 接腳比較來計算允許的最大工作週期以避免飽和，並確定允許的最大工作係數是否可作爲開啓時間峰值磁通的函數。

線路感測 (L) 接腳提供輸入大電壓線路感測功能。本資訊是供主電源和待機部分的欠壓和過壓偵測電路使用。此接腳也可向下拉至源極來同時實作待機和主電源供應器的遠端開/關。電阻器 R12、R13 和 R35 用於將輸入電壓轉換成 L 接腳的電流。

4.3 輸出整流

針對待機部分，輸出整流是由二極體 D16 提供。低 ESR 電容器 C17 提供低漣波濾波。電感器 L2 和電容器 C15 構成後置濾波器，可進一步減少輸出中的切換漣波和雜訊。

針對主電源轉換器部分，二極體 D7 會在主電源開啓期間進行整流，而二極體 D6 是箝位二極體，可在主電源關閉期間爲輸出電感器 L1 提供電流放電路徑。電感器 L1 與電容器 C10 和 C24 構成主電源轉換器的輸出濾波器，可過濾切換輸出漣波和雜訊。

4.4 輸出回授

針對待機部分，電阻器 R34 和 R31 構成回授分壓網絡。電源供應器的輸出電壓會被分割並饋送至誤差放大器 U7 的輸入端上。U2A 的陰極端電壓是由 U7 內部的放大器控制，以將分壓電壓保持在 2.5 V ±2%。改變陰極端電壓會導致改變流經 U2A 內部光耦合器二極體的電流，進而改變流經 U2B 內部電晶體的電流。電容器 C19 爲 EN 接腳提供雜訊抑制。當 EN 接腳的電流降低幅度超過 EN 接腳的臨界值電流時，會禁止下一個切換週期，並且，當輸出電壓降至回授臨界值以下時，會允許發生導通週期。透過調整啓用週期的數目，可維持輸出調節。當負載減少時，啓用週期的數目會減少，進而降低有效切換頻率並調整有負載時的切換損失。這可提供極輕負載下幾乎恆定的效率，是符合節能要求的理想之選。

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針對主電源部分，採用電阻器 R9 和 R24 爲 U5 誤差放大器提供 DC 參考。U5 利用類似方式來控制光耦合器 U1，U1 用於透過 FB 接腳的電流降低來調整操作工作週期，其主要差別在於 FB 接腳電流是以線性方式來控制主電源轉換器的工作週期，與待機轉換器的整個週期開/關控制不同。元件 C4、C8-9、R10 和 R21 用於補償主電源 12 V 控制迴路。元件 C5 和 R11 構成「軟關閉」網路，用於避免啓動時輸出過衝。

電阻器 R15 設定控制迴路的增益，電阻器 R10、R21 和電容器 C4、C8 和 C9 形成控制迴路的回應，以達到所需的迴路增益交越頻率和相位餘裕。電阻器 R38 和 R30 分別爲 IC U5 和 U7 提供所需的偏壓電流。

5 PCB 佈局

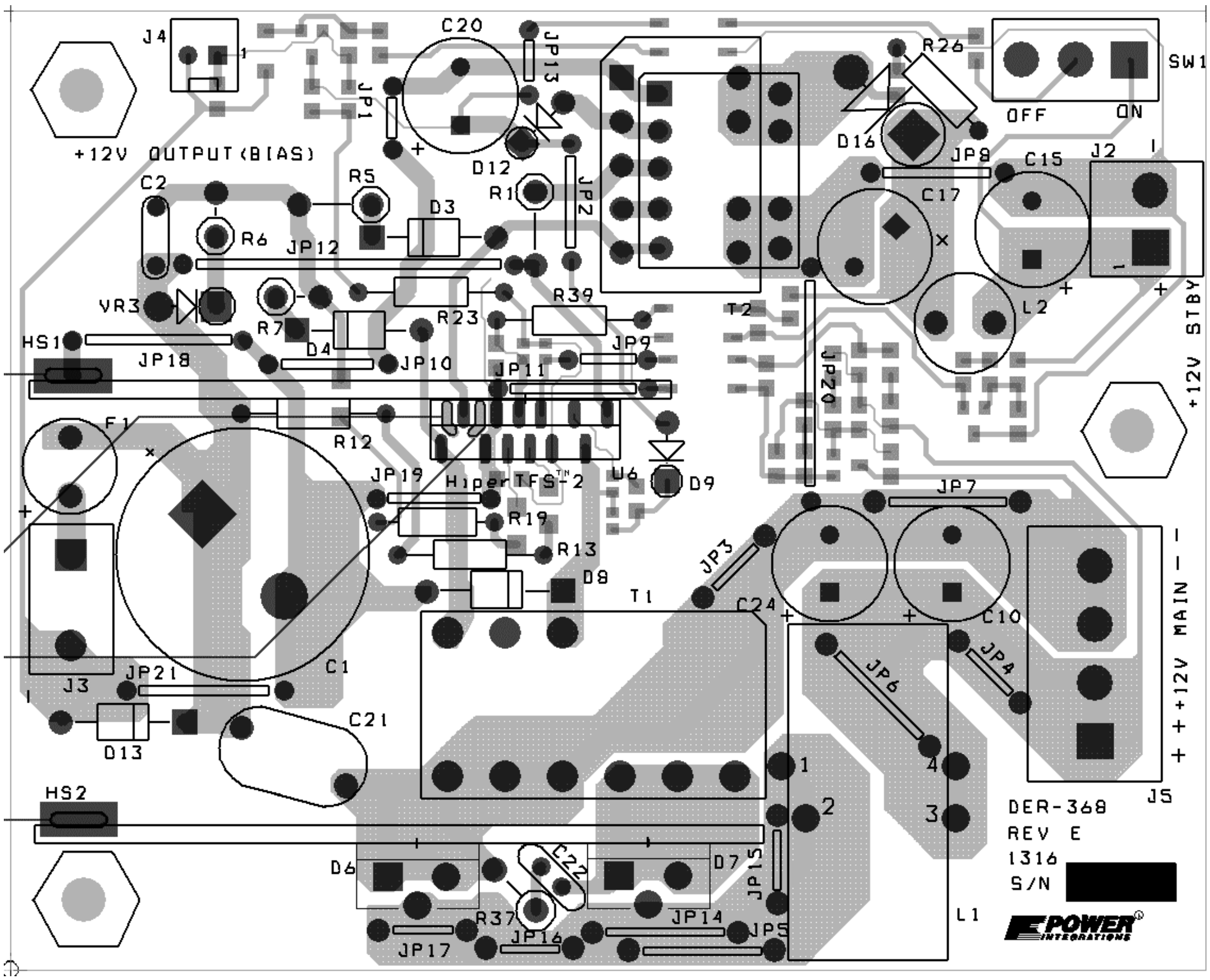

Figure 4 – DER-368 PCB Layout, Top View.

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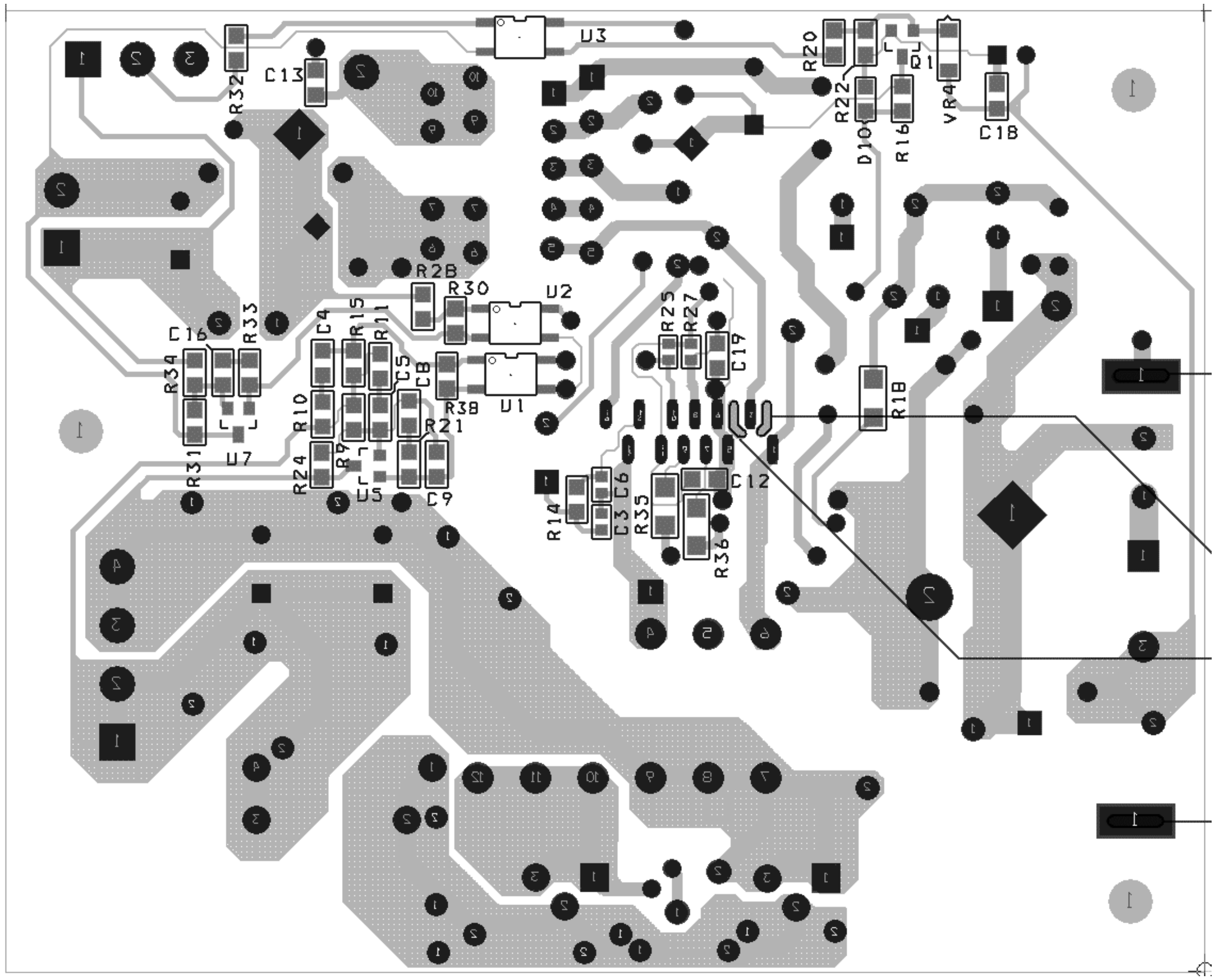

Figure 5 – DER-368 PCB Layout, Bottom View.

6 物料清單

Item	Qty	Ref Des	說明	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		
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

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					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 設計試算表

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
UV / OV / UVOV					Minimum undervoltage Off-On threshold (turn-on)

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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
PRI WINDING FIT AND LOSSES					
OD_PRI			0.45	mm	Primary winding diameter

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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
AWG_MAIN	18		18.00	AWG	Main inductor winding wire gauge
OD_MAIN			1.09	mm	Main winding wire gauge outer diameter

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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	連續輸出功率
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
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

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					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.)
效率			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 主變壓器 (T1) 規格

8.1 電氣圖

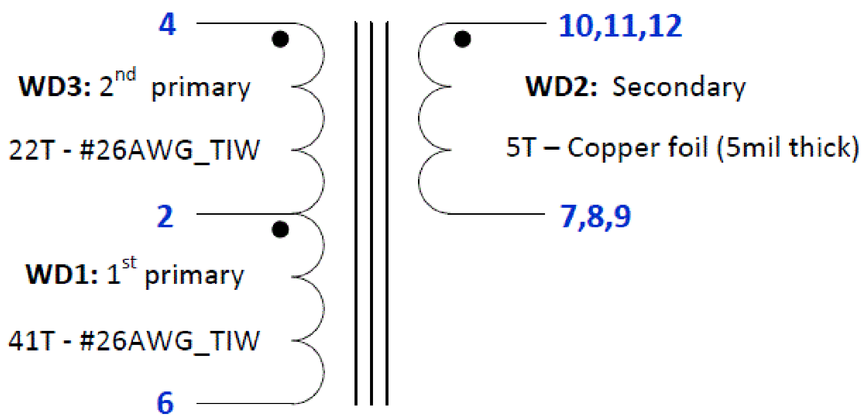

Figure 6 – Main 12 V Transformer (T1) Electrical Diagram.

8.2 電氣規格

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 建構圖

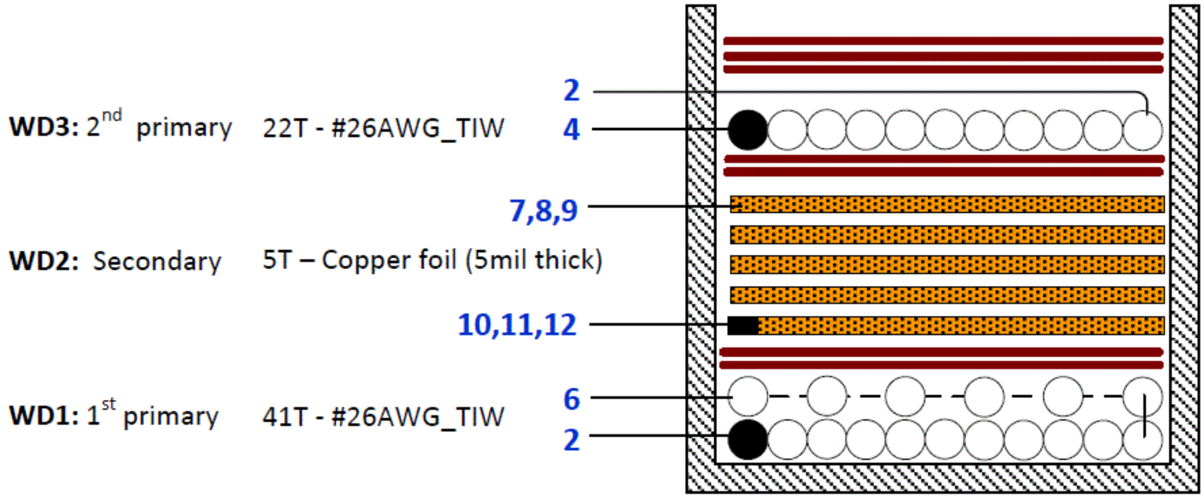

Figure 7 – Main Transformer Build Diagram.

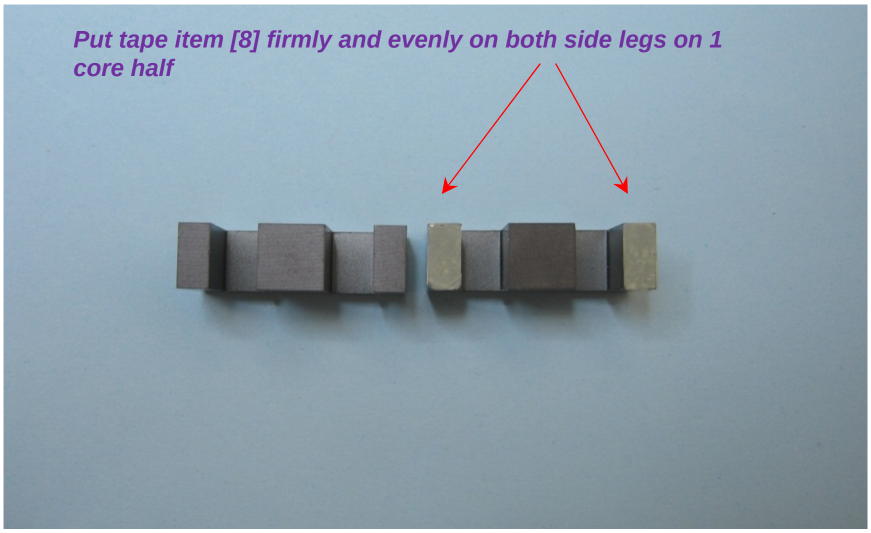

Figure 8 – Making Core Gap.

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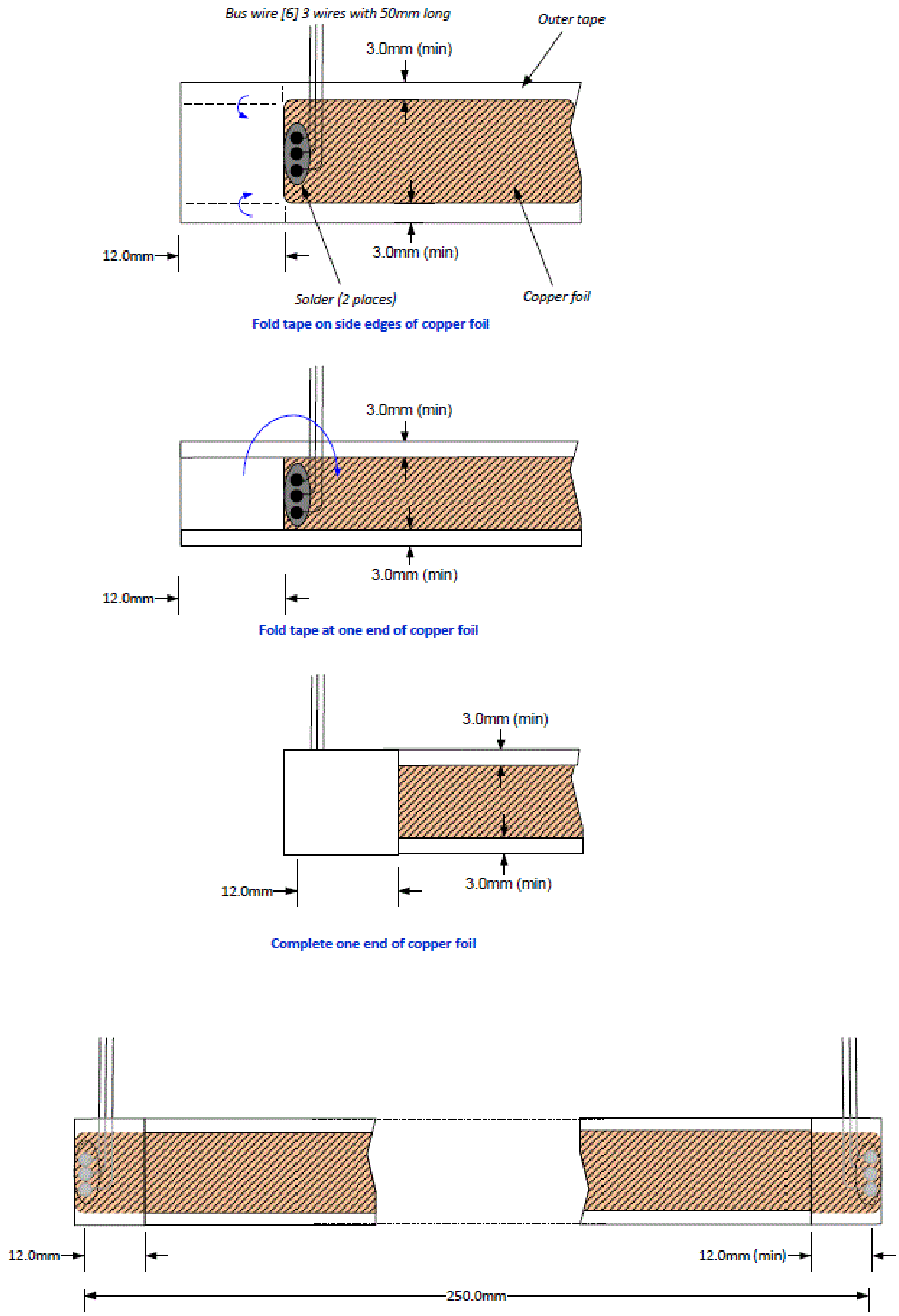

Figure 9 – Transformer Output Foil Construction Drawing.

8.5 建置指示

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 輸出電感器 (L1) 規格

9.1 電氣圖

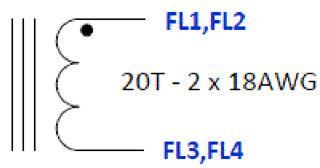

Figure 10 – Output Inductor Schematic Diagram.

9.2 電氣規格

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 待機電源供應器變壓器 (T2) 規格

10.1 電氣圖

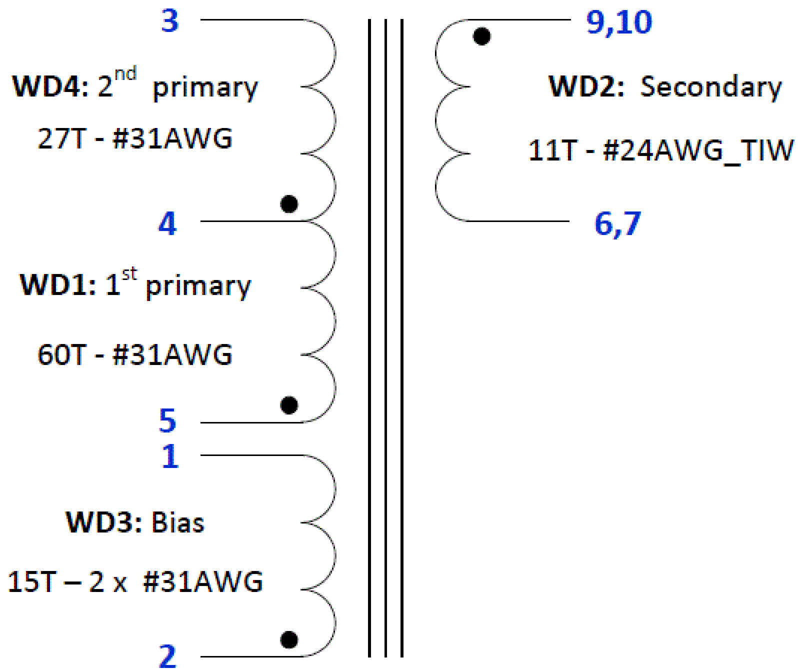

Figure 11 – Standby Transformer Electrical Diagram.

10.2 電氣規格

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 建構圖

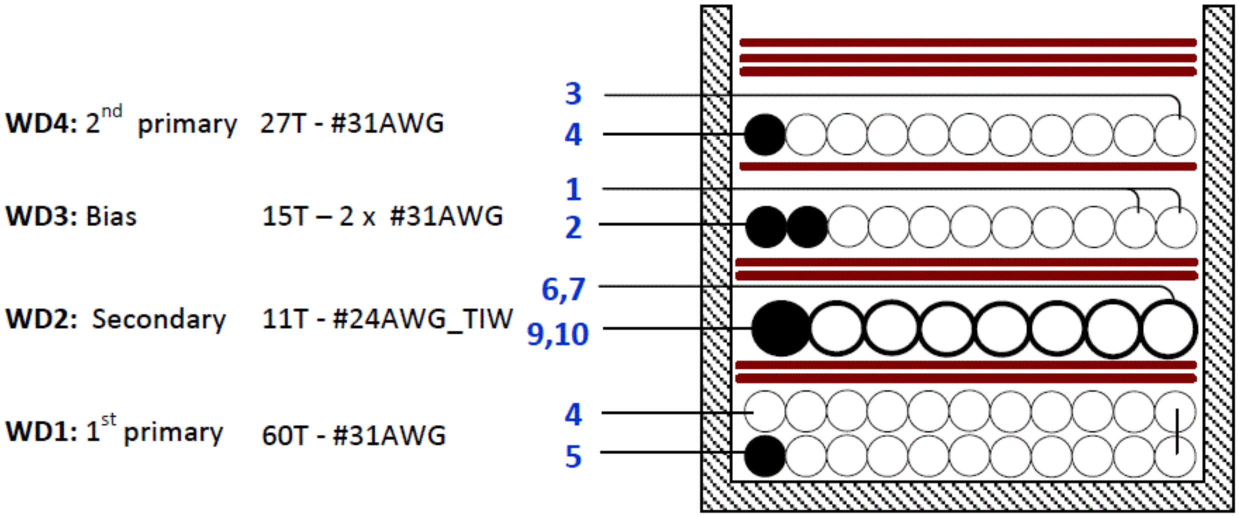

Figure 12 – Build Diagram for Standby Transformer.

10.5 建置指示

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 散熱片組裝

11.1 主要散熱片鋼板

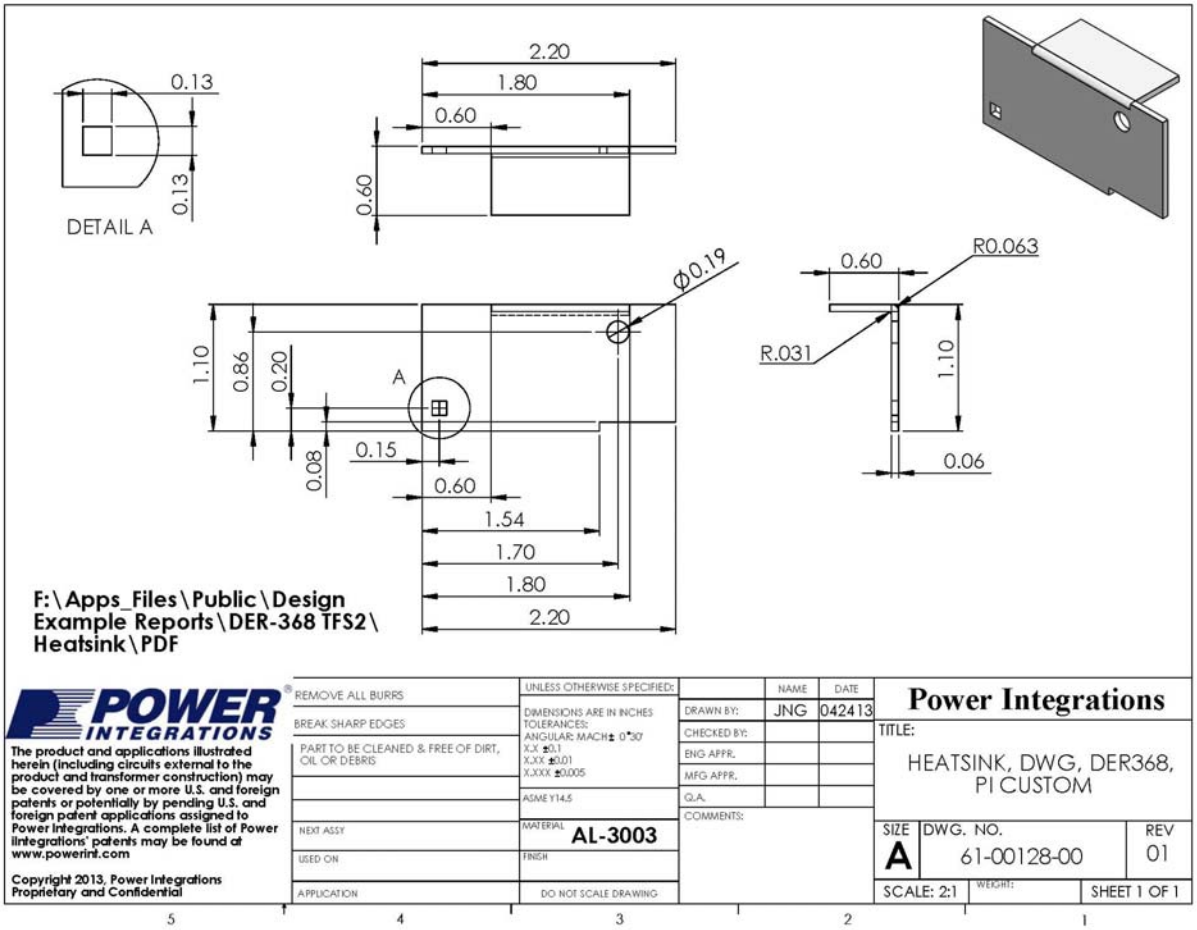

Figure 13 – Primary Heat Sink Sheet Metal Drawing.

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11.2 完成的主要散熱片

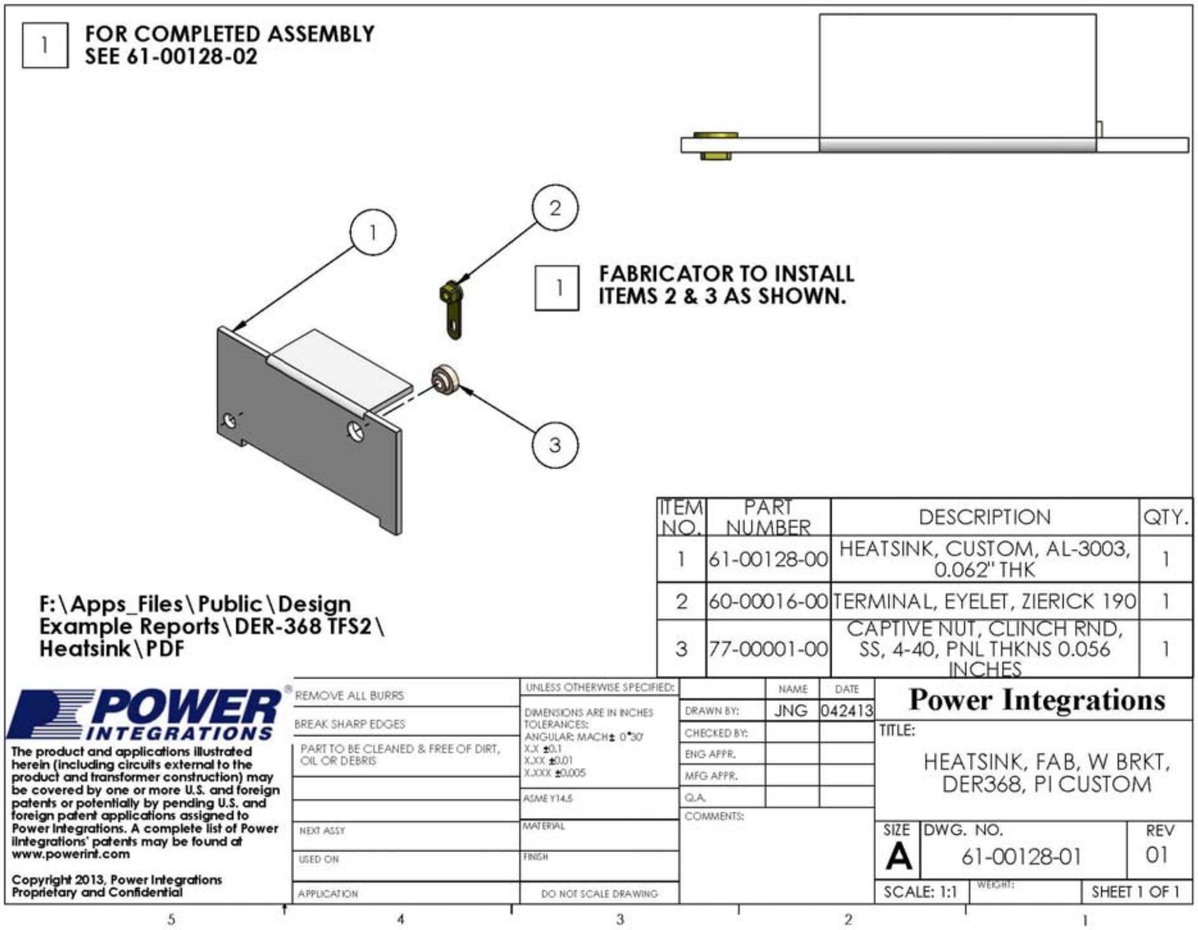

Figure 14 – Completed Primary Heat Sink.

11.3 主要散熱片組裝

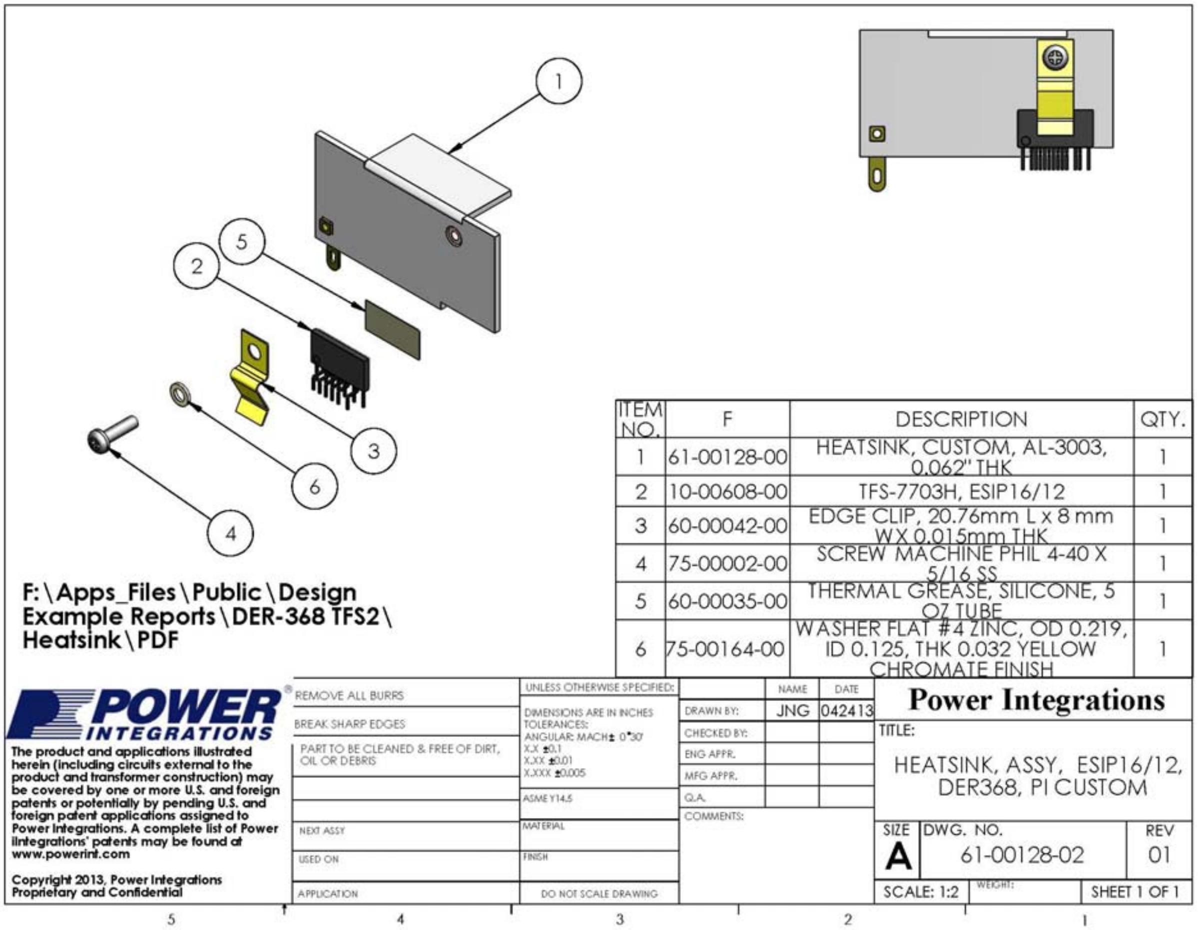

Figure 15 – Primary Heat Sink Assembly.

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11.4 次要散熱片鋼板

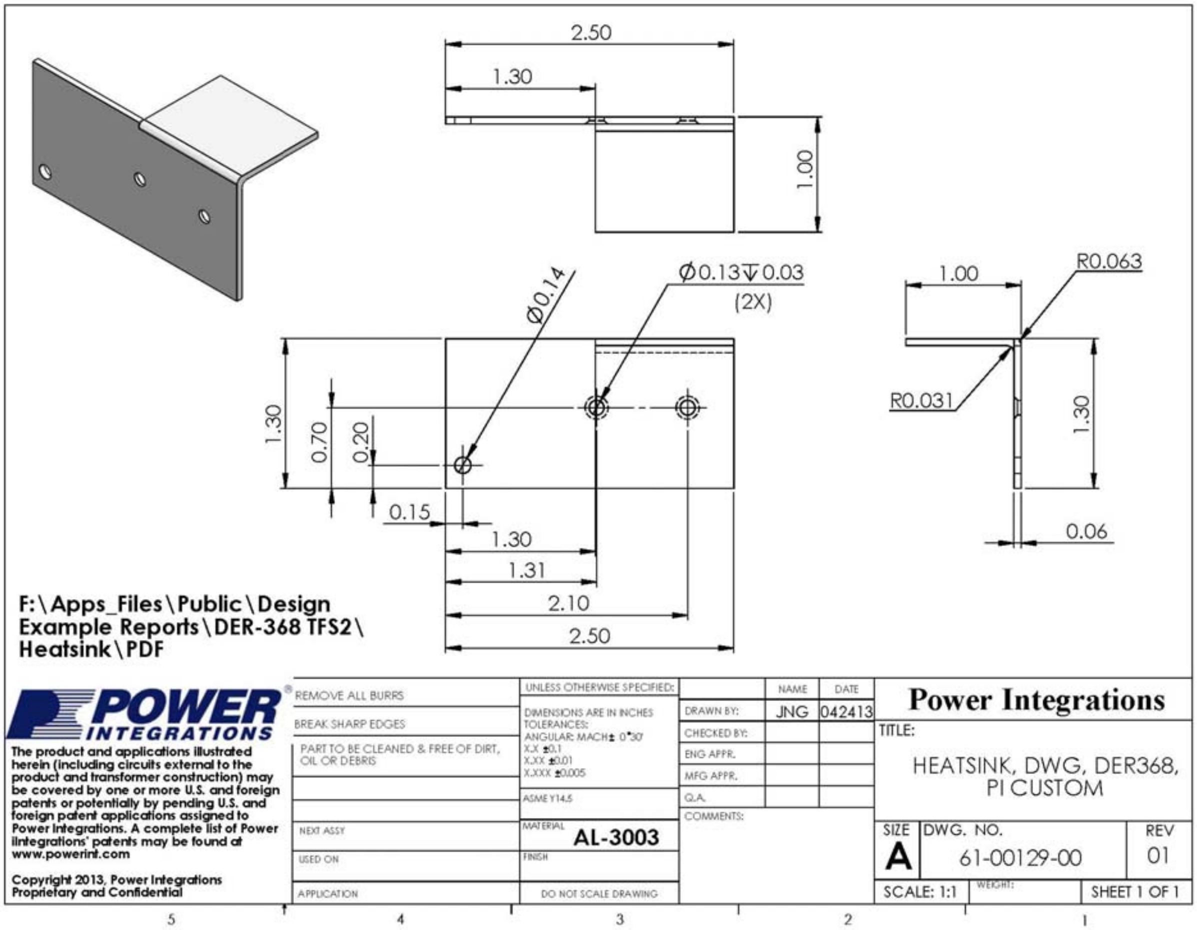

Figure 16 – Secondary Heat Sink Sheet Metal Drawing.

11.5 完成的次要散熱片

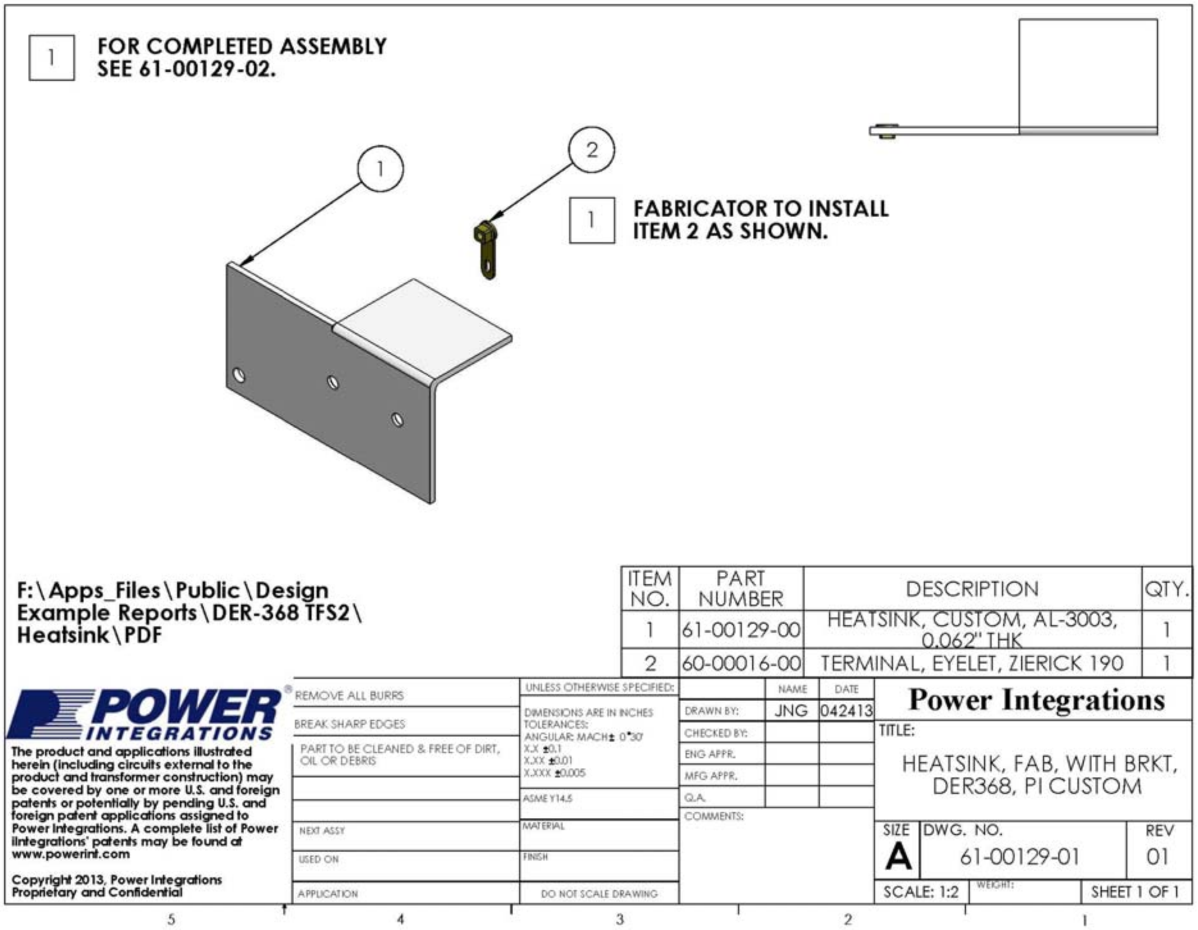

Figure 17 – Completed Secondary Heat Sink.

11.6 次要散熱片組裝

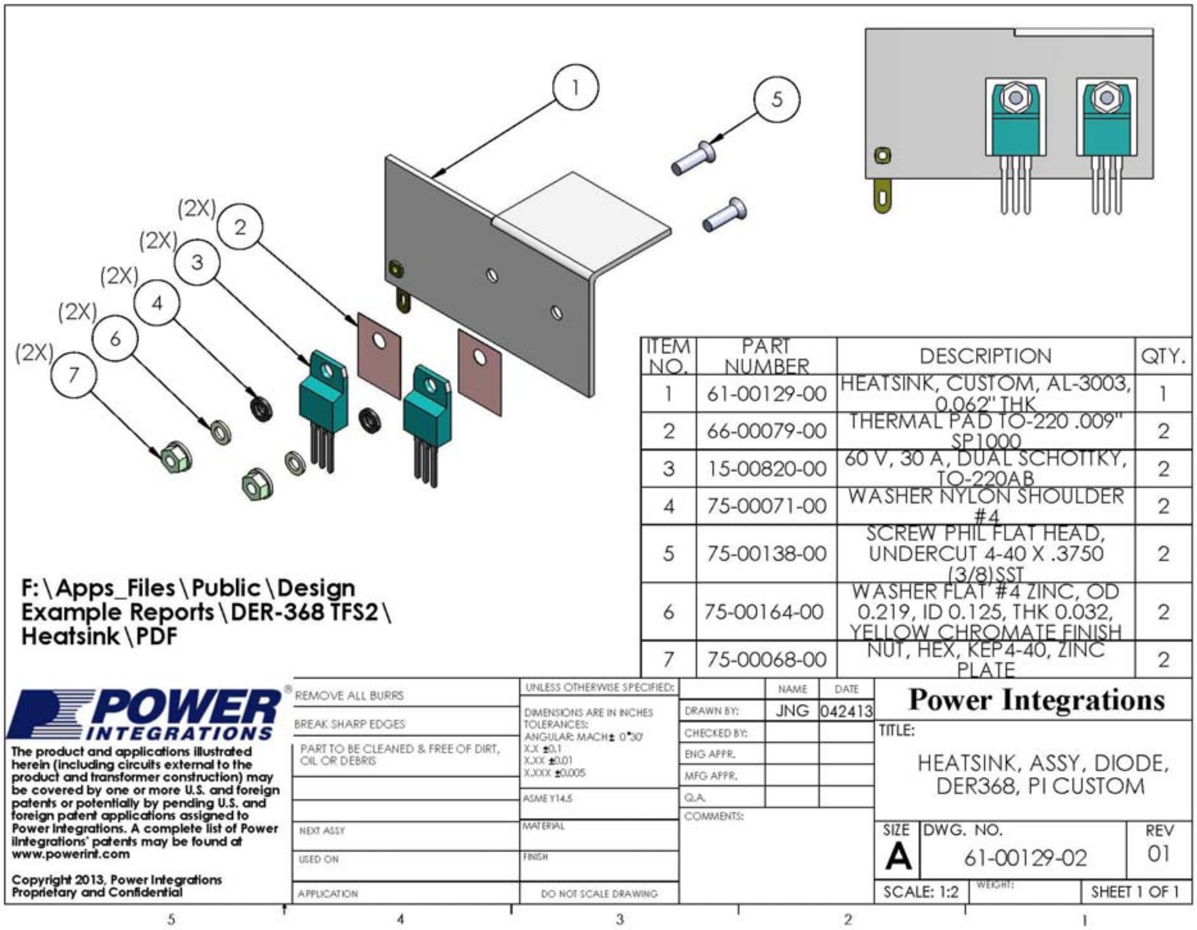

Figure 18 – Secondary Heat Sink Assembly.

12 效能測量

12.1 效率

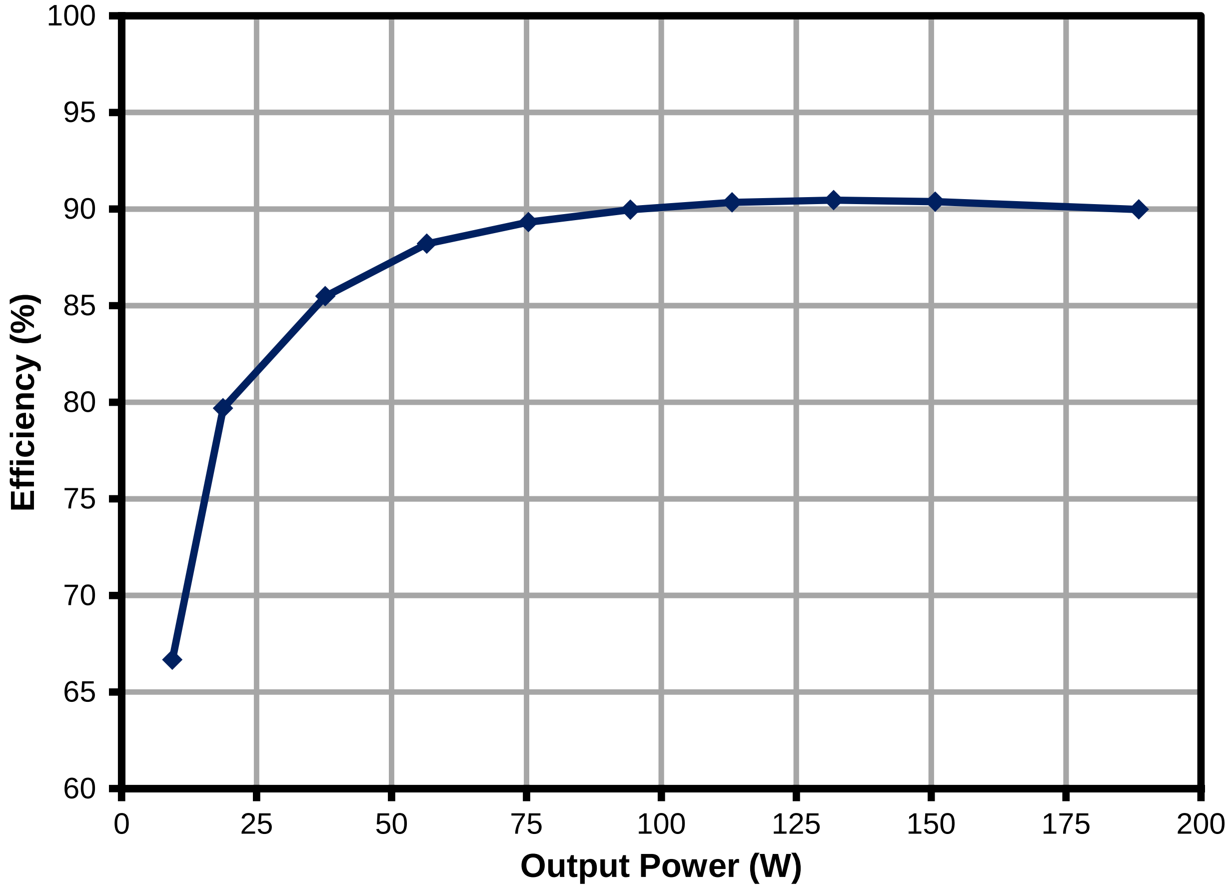

Figure 19 – Efficiency vs. Output load Percentage, Main + Standby Outputs.

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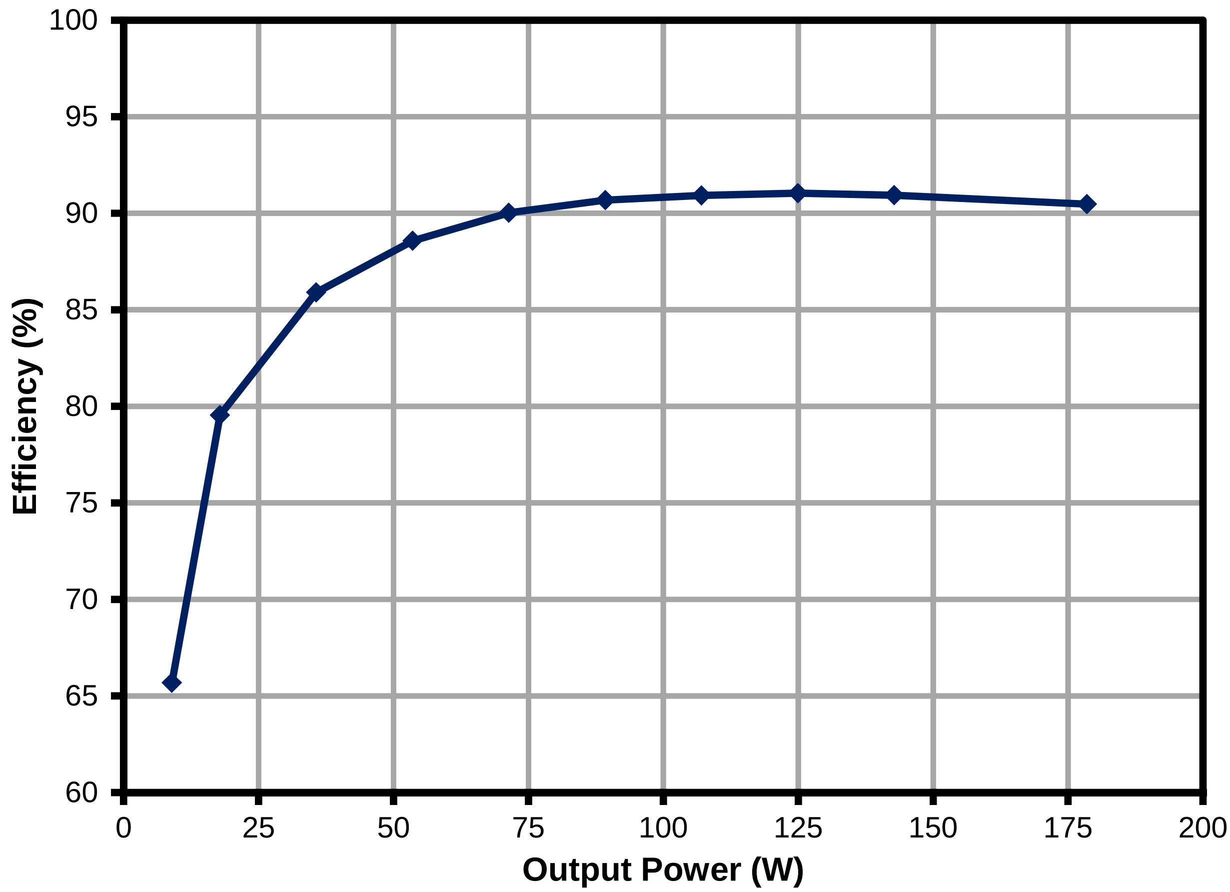

Figure 20 – Main 12 V Output Efficiency vs. Output Power, 380 VDC Input, Standby Output Unloaded.

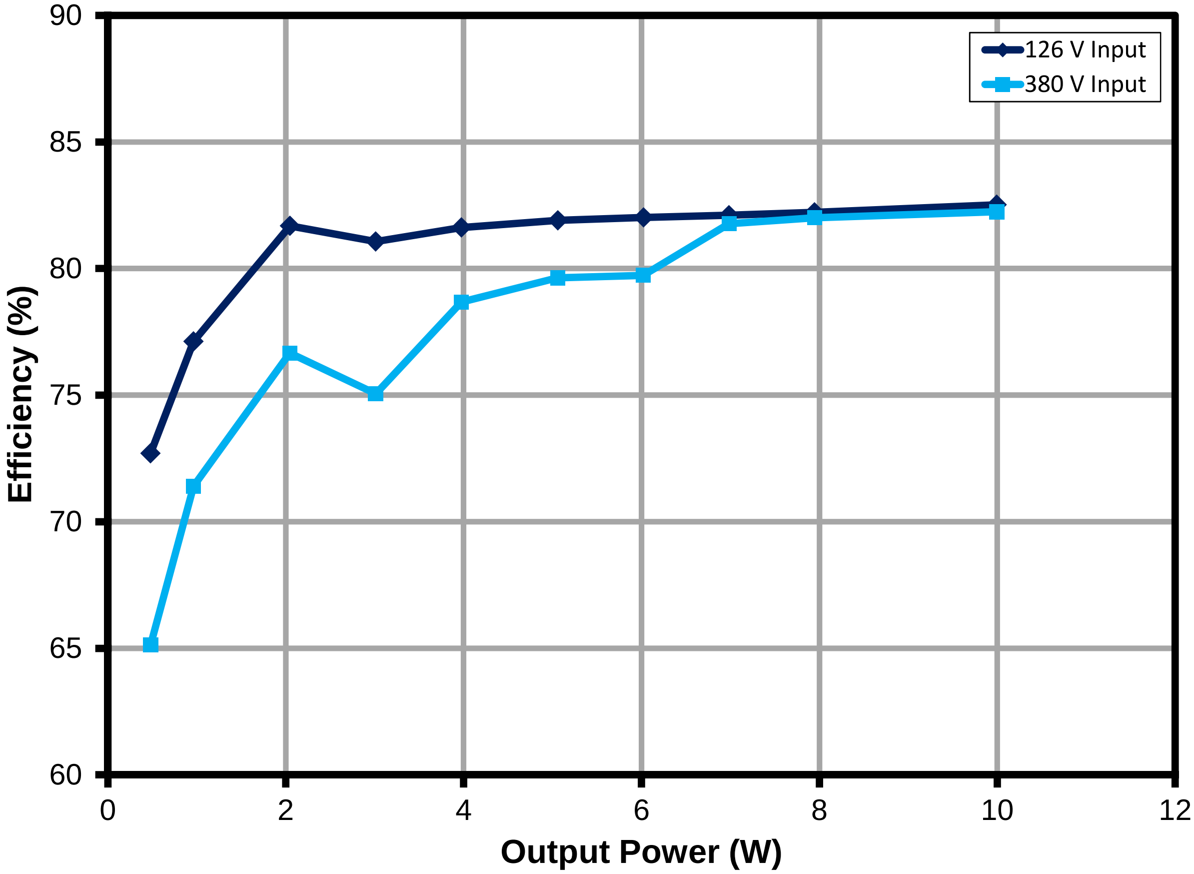

Figure 21 – Standby Efficiency vs. Load.

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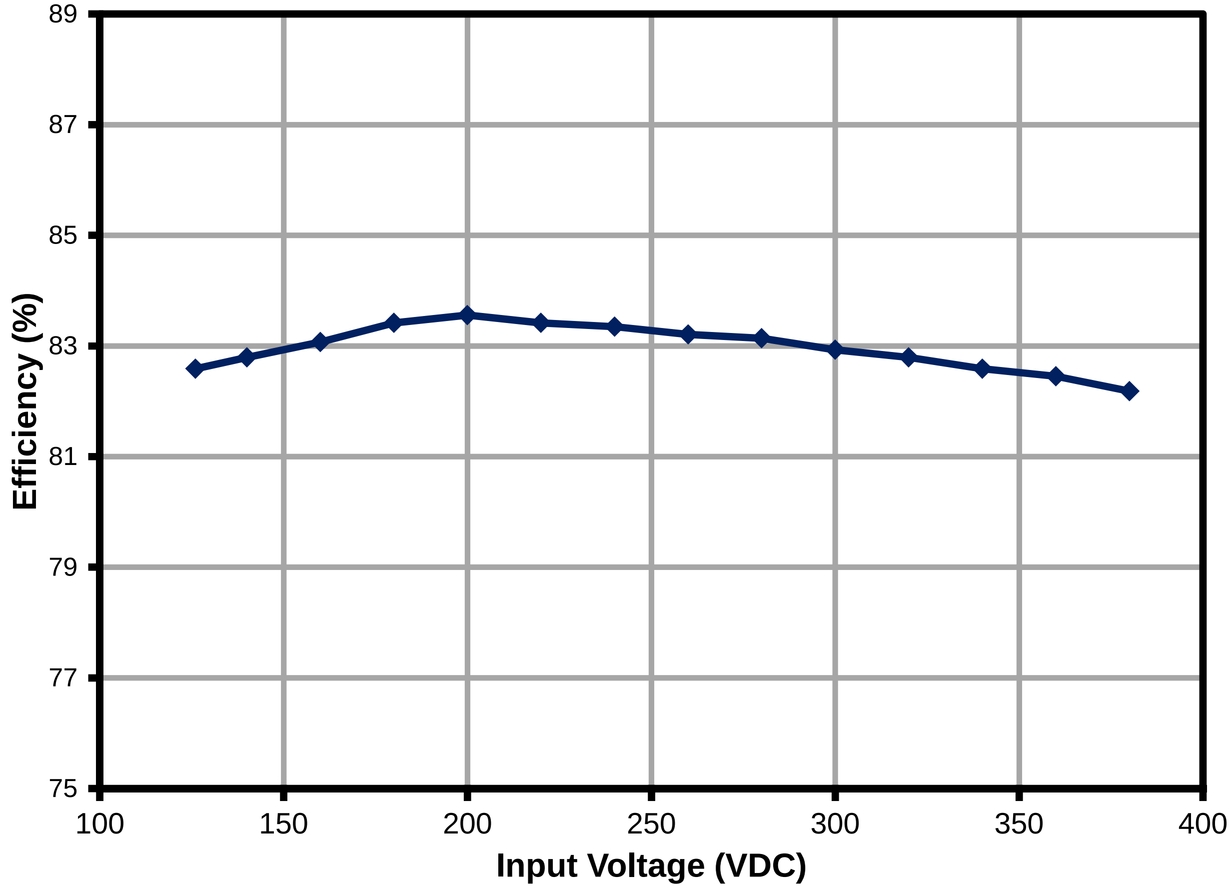

Figure 22 – Standby Efficiency vs. Input Voltage, 100% Load.

12.2 待機無負載輸入功率

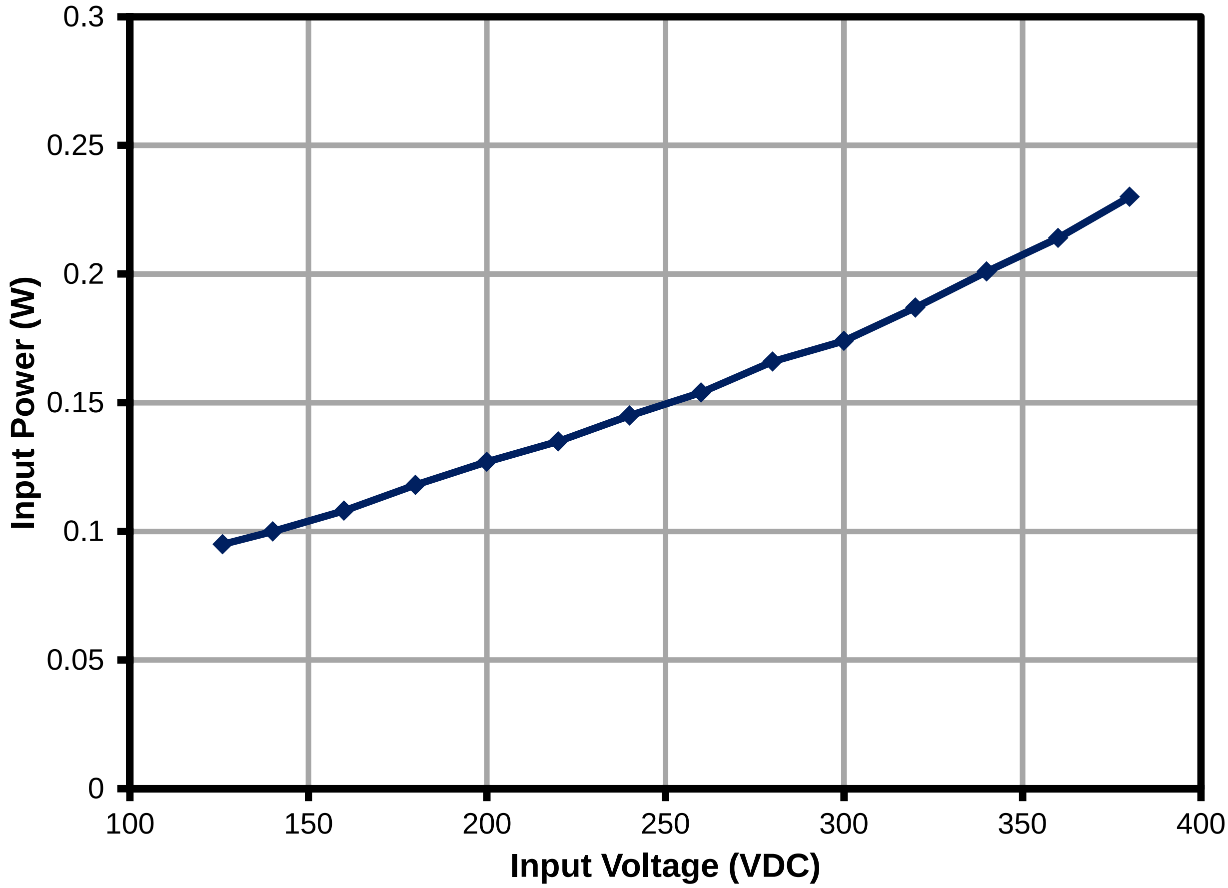

Figure 23 – Standby No-Load Input Power vs. Input Voltage.

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12.3 調節

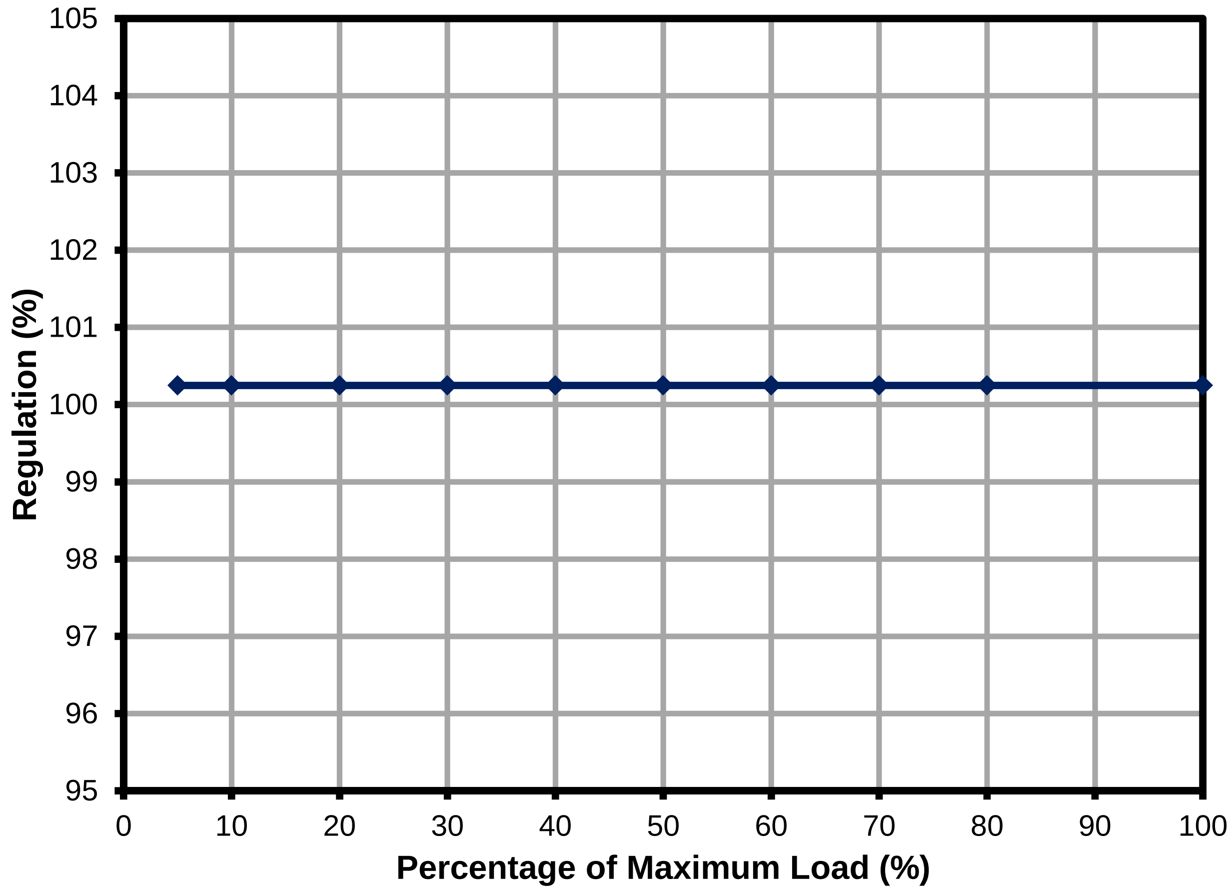

Figure 24 – Standby Supply Load Regulation, 380 VDC Input.

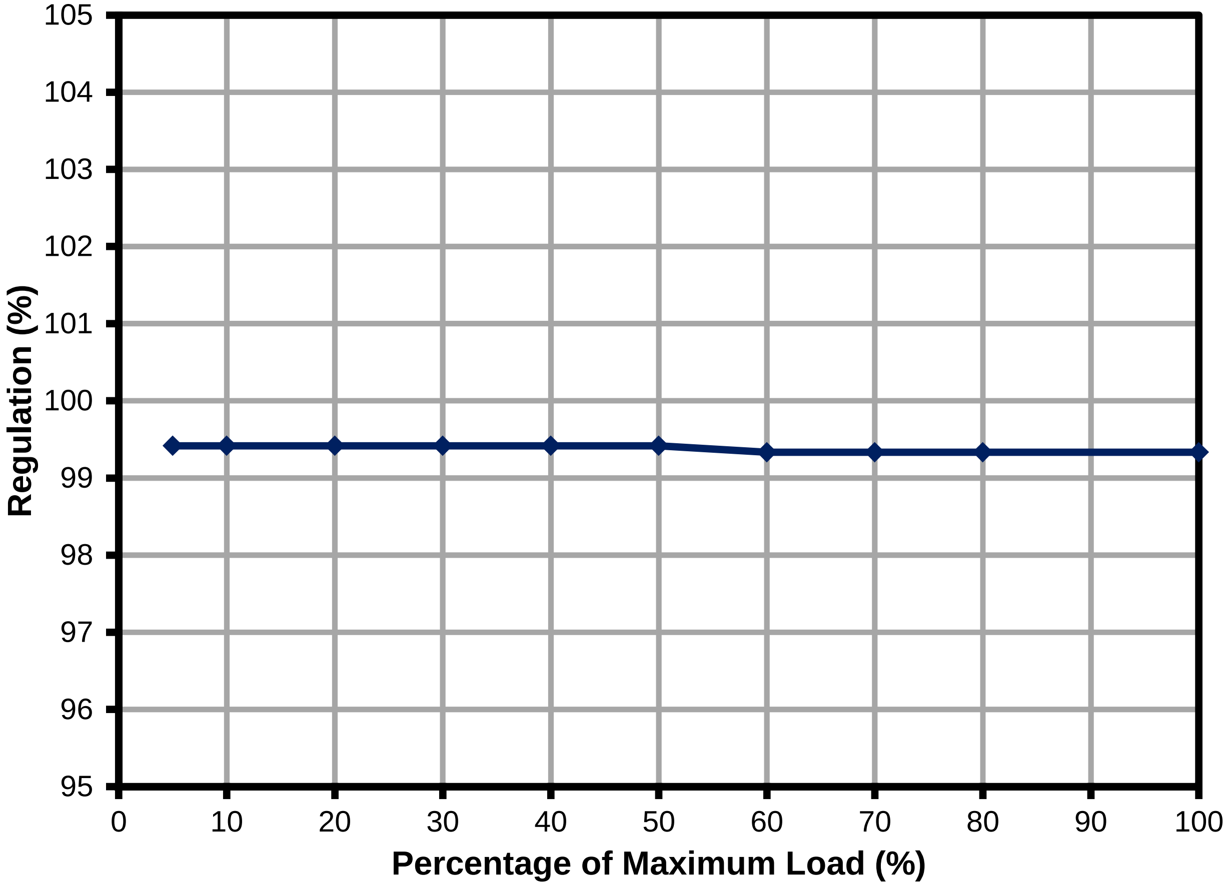

Figure 25 – Main Output Load Regulation, 380 VDC Input.

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12.4 波形

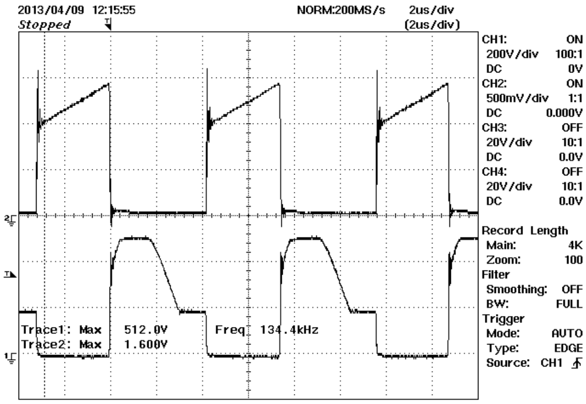

Figure 26 – Main Output Drain Voltage and Current, Full Load, 380 VDC Input.
Upper:I_{DRAIN}, 0.5 A / div.
Lower:V_{DRAIN}, 200 V, 2 μs / div.

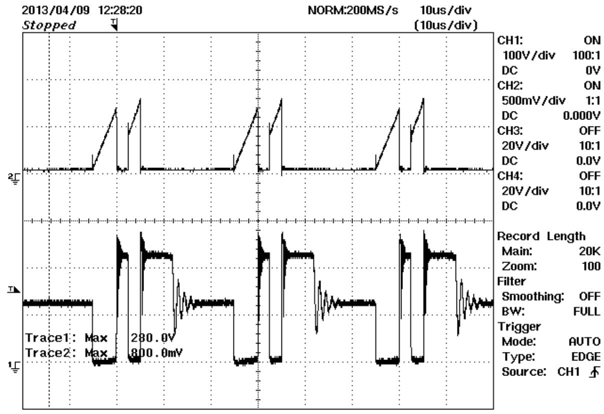

Figure 27 – Standby Output Drain Voltage and Current, Full Load, 126 VDC (90 VAC equiv.)Input.
Upper:I_{DRAIN}, 0.5 A / div.
Lower:V_{DRAIN}, 100 V, 10 μs / div.

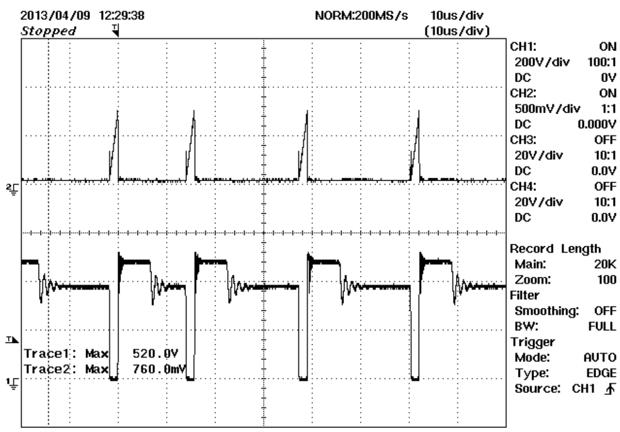

Figure 28 – Standby Output Drain Voltage and Current, Full load, 380 VDC Input.
Upper:I_{DRAIN}, 0.5 A / div.
Lower:V_{DRAIN}, 200 V, 10 μs / div.

12.5 主輸出二極體反向峰值電壓

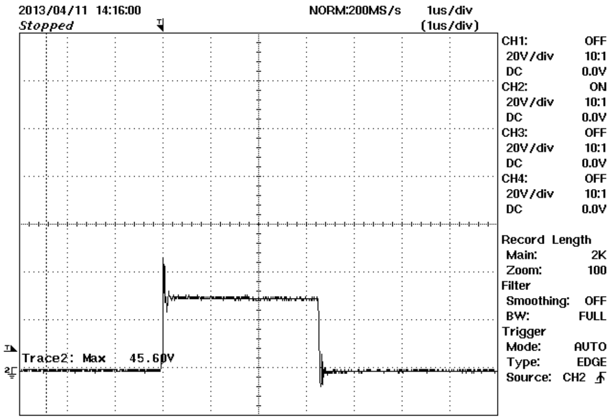

Figure 29 – Main Output Catch Diode (D6) Reverse Voltage, 380 VDC Input, Full Load, 20 V, 1 μs / div.

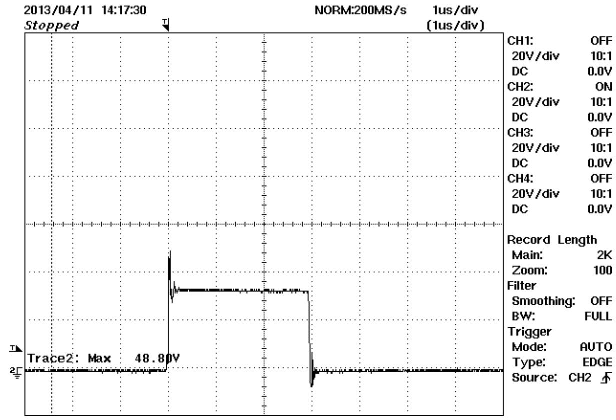

Figure 30 – Main Output Catch Diode (D6) Reverse Voltage, 420 VDC Input, Full Load, 20 V, 1 μs / div.

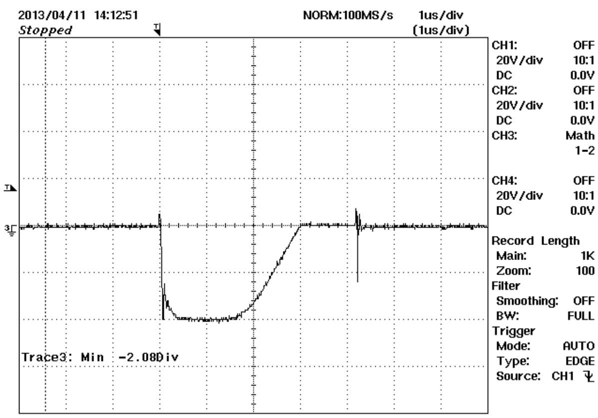

Figure 31 – Main Output Forward Diode (D7) Reverse Voltage, 380 VDC Input, Full Load, 20 V, 1 μs / div. PRV = 2.08 div. X 20 V / div. = 41.6 V

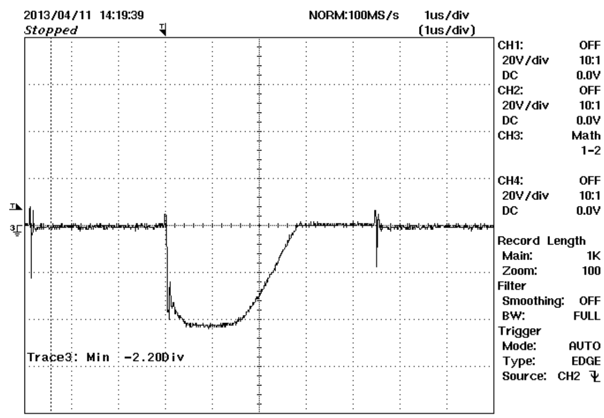

Figure 32 – Main Output Forward Diode (D7) Reverse Voltage, 420 VDC Input, Full Load, 20 V, 1 μs / div. PRV = 2.2 div. X 20 V / div. = 44 V

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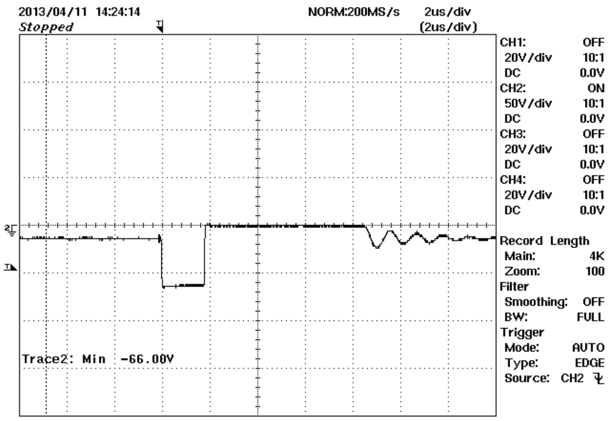

Figure 33 – Standby Output Rectifier Diode (D16) Reverse Voltage, 380 VDC Input, Full Load, 50 V, 2 μs / div.

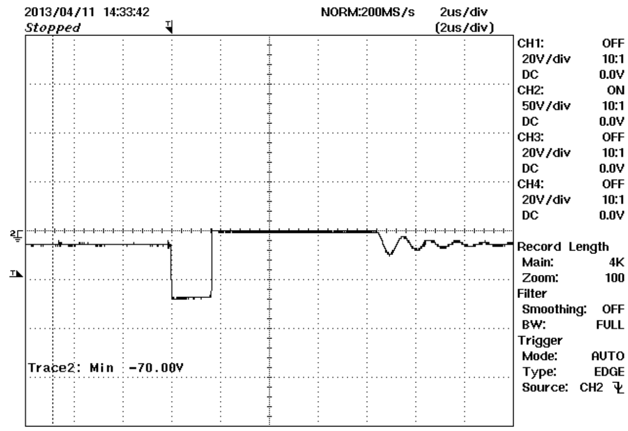

Figure 34 – Standby Output Rectifier Diode (D16) Reverse Voltage, 420 VDC Input, Full Load, 50 V, 2 μs / div.

12.6 啓動與維持

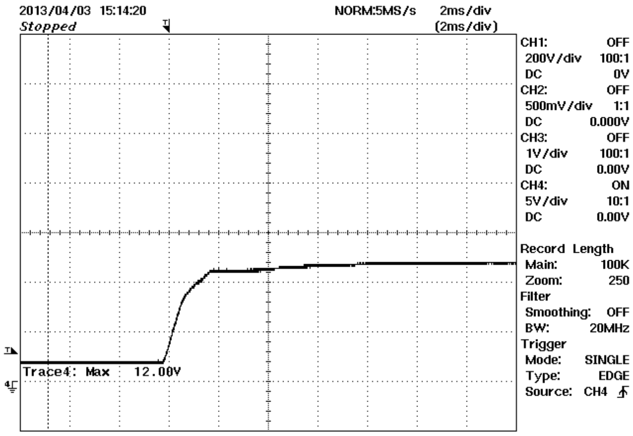

Figure 35 – 12 V Main Output Start-up, Full Load, 380 VDC Input, Resistive Load, 5 V, 2 ms / div.

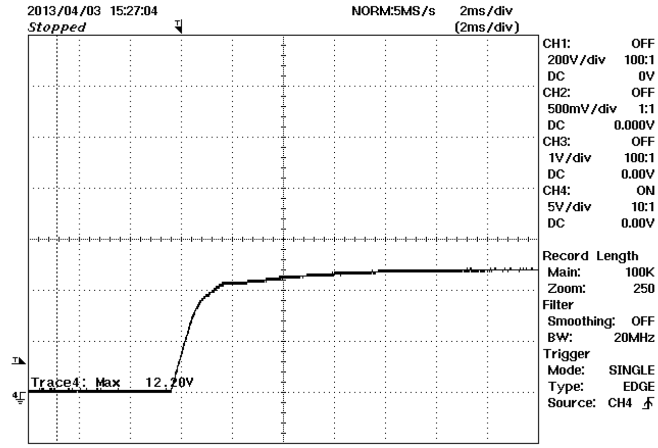

Figure 36 – 12 V Main Output Start-up, 3% Load, 380 VDC Input, Resistive Load, 5 V, 2 ms / div.

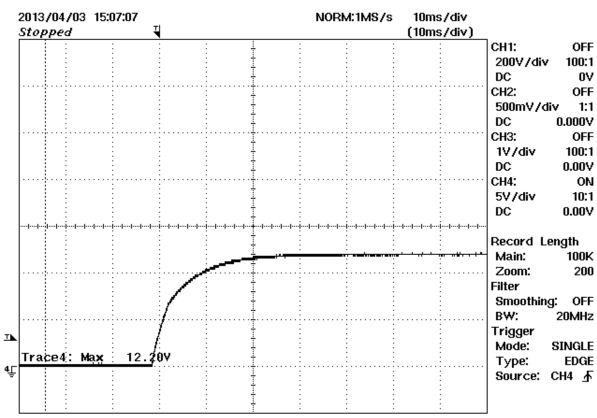

Figure 37 – 12 V Aux Output Start-up, 126 VDC Input, Zero Load, 5 V, 10 ms / div.

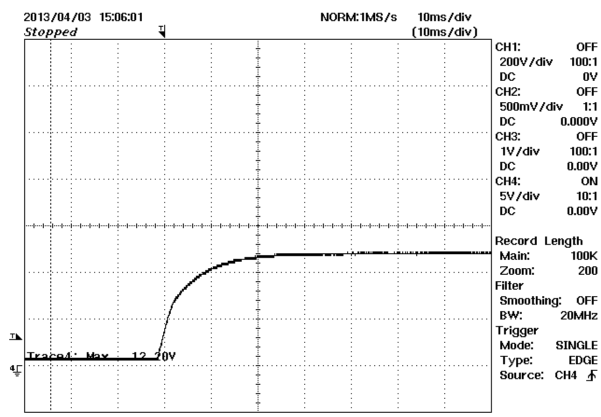

Figure 38 – 12 V Aux Output Start-up, 126 VDC Input, Full Load, 5 V, 10 ms / div.

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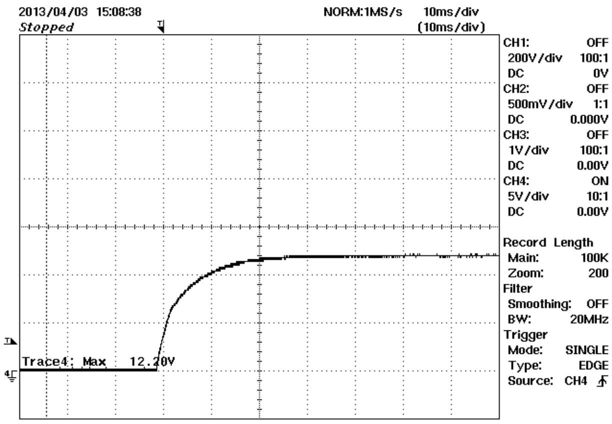

Figure 39 – 12 V Aux Output Start-up, 380 VDC Input, Zero Load, 5 V, 10 ms / div.

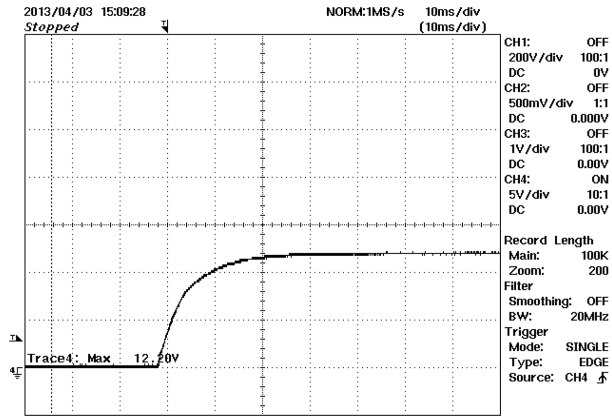

Figure 40 – 12 V Aux Output Start-up, 380 VDC Input, Full Load, 5 V, 10 ms / div.

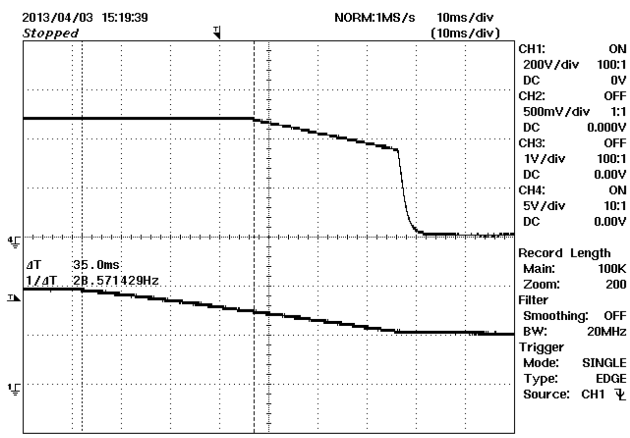

Figure 41 – Main Output Hold-up Time, Full Load.Upper:V_{OUT}, 5 V / div.
Lower:B+ Voltage, 200 V, 10 ms / div.

12.7 漣波

12.7.1 漣波測量技術

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).

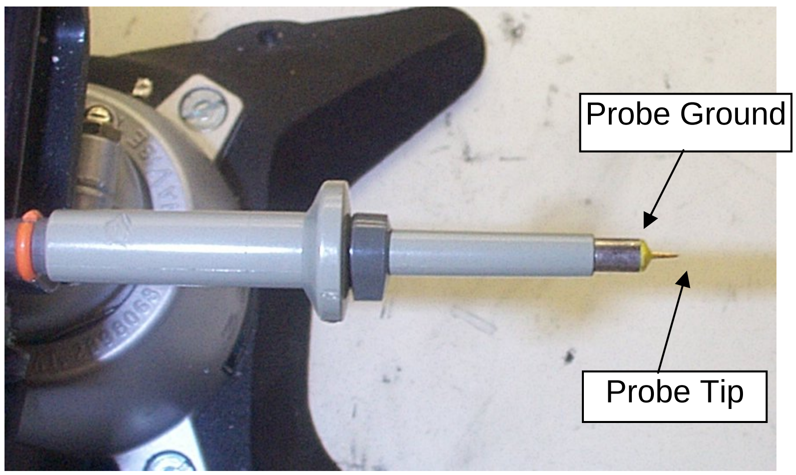

Figure 42 – Oscilloscope Probe Prepared for Ripple Measurement.(End Cap and Ground Lead Removed)

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 漣波測量結果

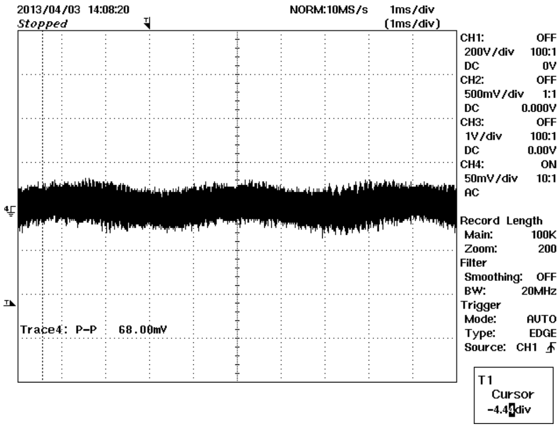

Figure 44 – Ripple, 12 V Main Output, Full Load, 380 VDC Input.50 mV, 1 ms / div.

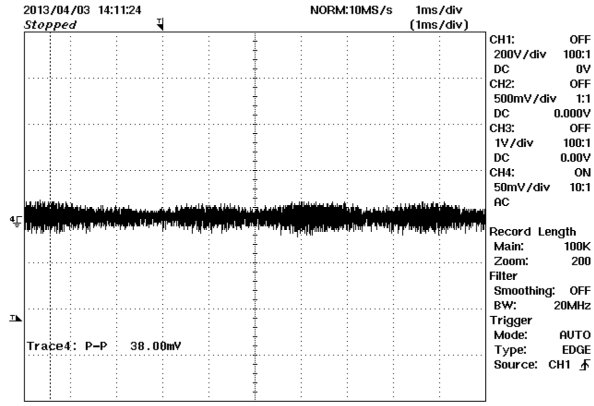

Figure 45 – Ripple, 12 V Standby Output, Full Load, 126 VDC Input 50 mV, 1 ms / div.

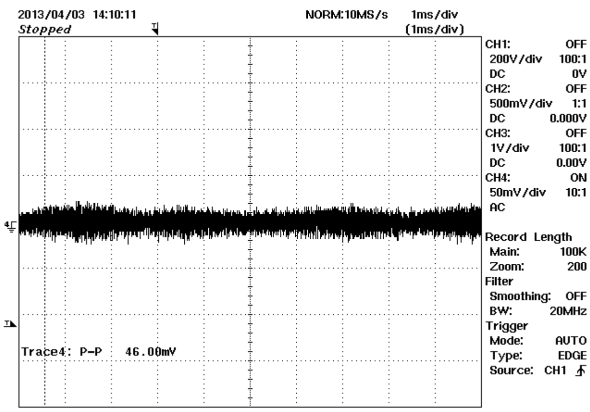

Figure 46 – Ripple, 12 V Standby Output, Full Load, 380 VDC Input 50 mV, 1 ms / div.

12.8 暫態反應

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.

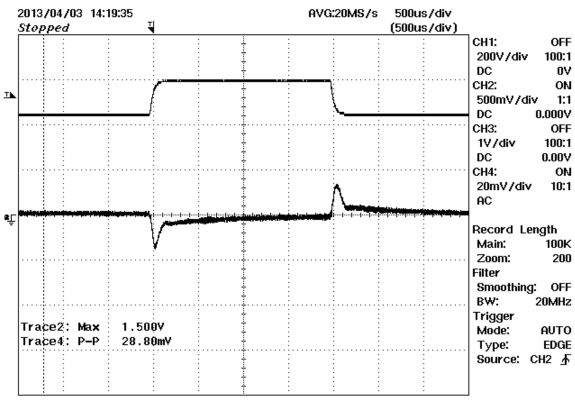

Figure 47 – 12 V Main Output Load Transient Response, 75% - 100% - 75% Load Step, 380 VDC Input.
Upper:I_{OUT}, 5 A / div.
Lower:V_{OUT}, 20 mV, 500 μs / div.

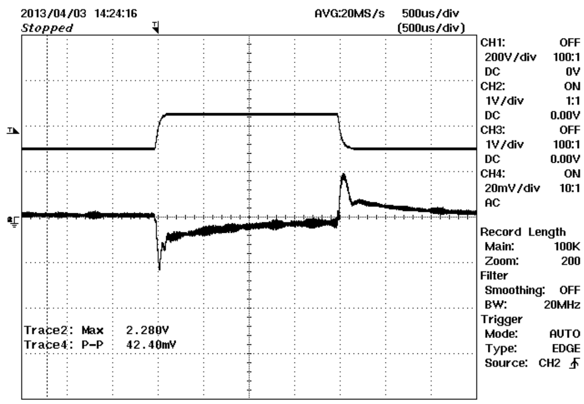

Figure 48 – 12 V Main Output Load Transient Response, 100% – 180% – 100% Load Step, 380 VDC Input.
Upper:I_{OUT}, 10 A / div.
Lower:V_{OUT}, 20 mV, 500 μs / div.

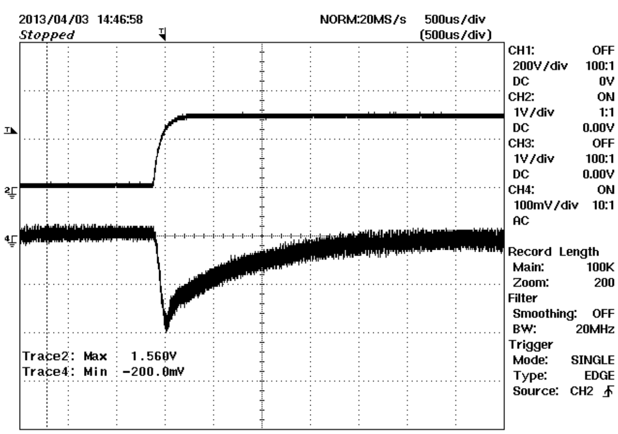

Figure 49 – 12 V Main Output Load Transient Response, 3% - 100% - Load Step, 380 VDC Input.
Upper:I_{OUT}, 5 A / div.
Lower:V_{OUT}, 100 mV, 500 μs / div.

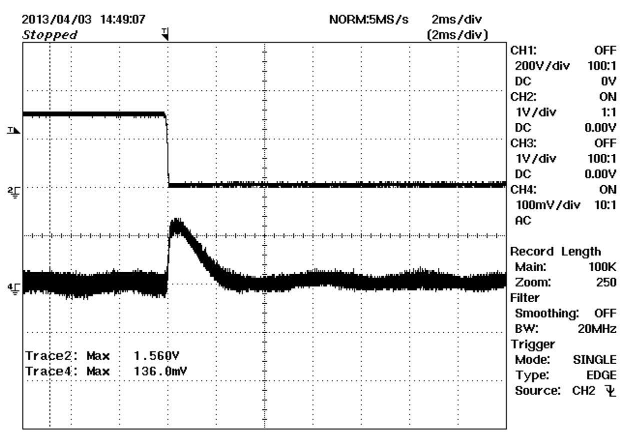

Figure 50 – 12 V Main Output Load Transient Response, 100% - 3% Load Step, 380 VDC Input.
Upper:I_{OUT}, 5 A / div.
Lower:V_{OUT}, 100 mV, 2 ms / div.

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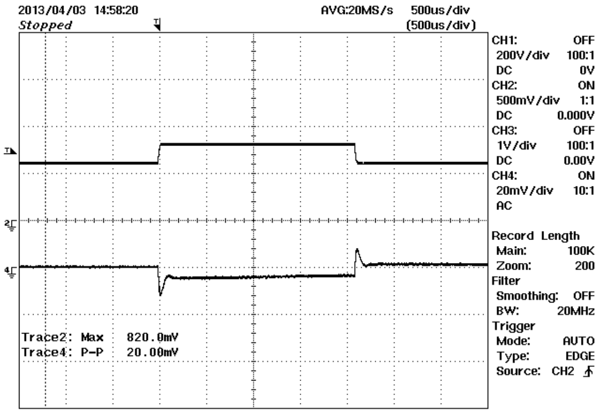

Figure 51 – 12 V Standby Output Load Transient Response, 75% - 100% - 75% Load Step, 126 VDC Input.
Upper:I_{OUT}, 0.5 A / div.
Lower:V_{OUT}, 20 mV, 500 μs / div.

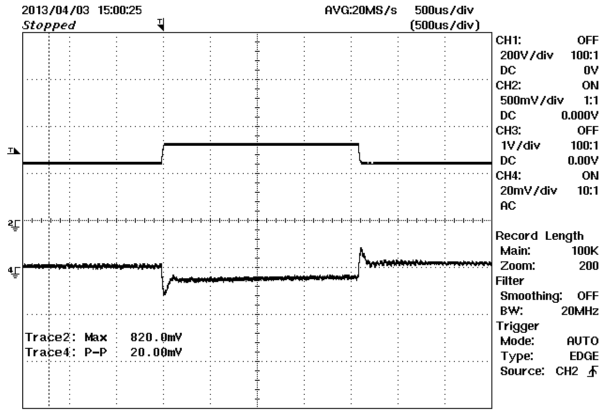

Figure 52 – 12 V Standby Output Load Transient Response, 75% - 100% - 75% Load Step, 380 VDC Input.
Upper:I_{OUT}, 0.5 A / div.
Lower:V_{OUT}, 20 mV, 500 μs / div.

13 熱測試

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.

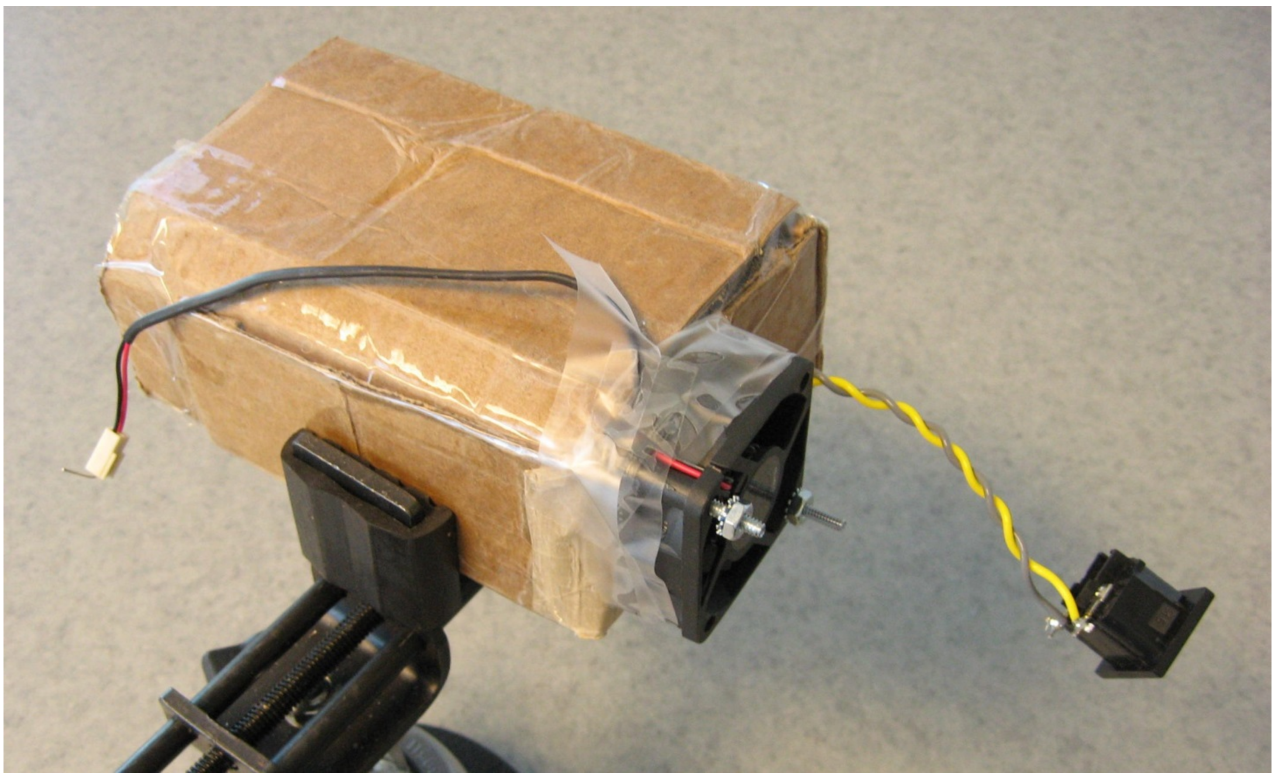

Figure 53 – Test Set-up Showing Fan.

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13.1 熱圖片

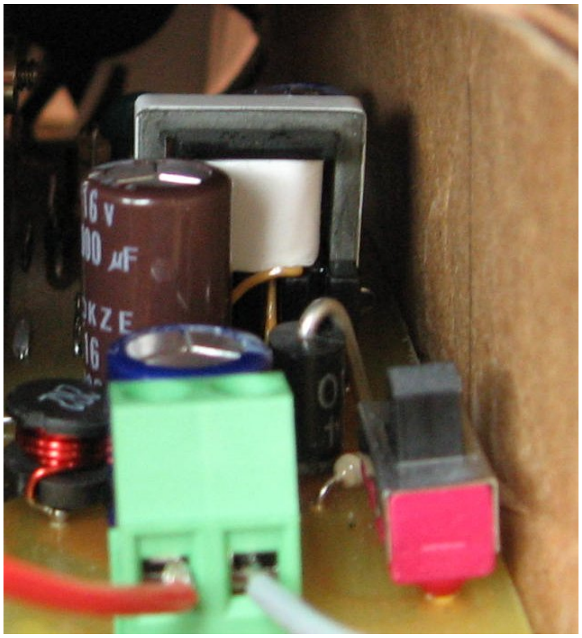

Figure 54 – Standby Transformer T2, Visible Light View.

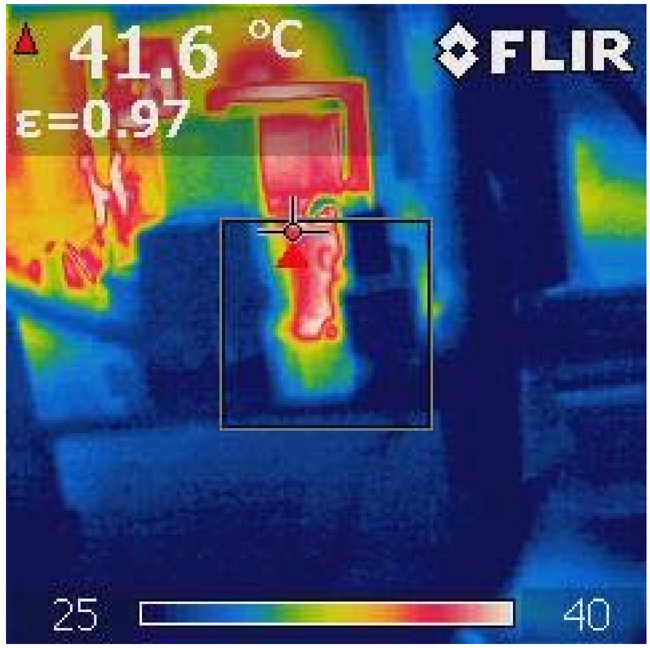

Figure 55 – Standby Transformer T2 Thermal Image, Full Load, Room Temperature.

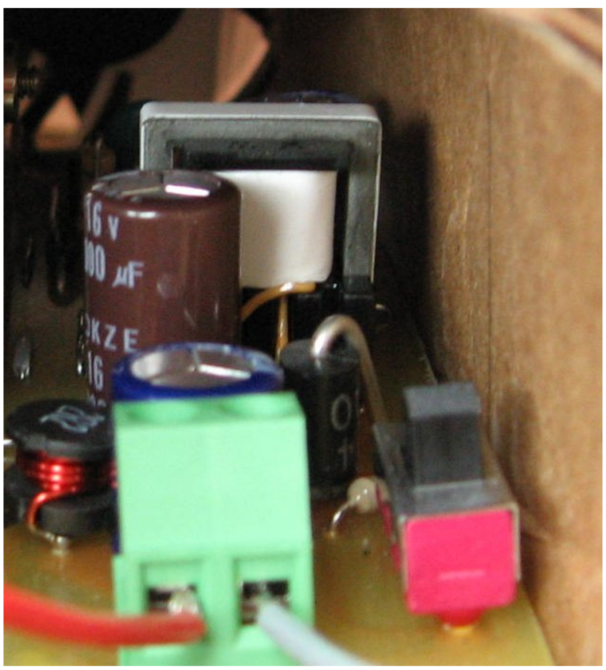

Figure 56 – Standby Output Rectifier D16, Visible Light View.

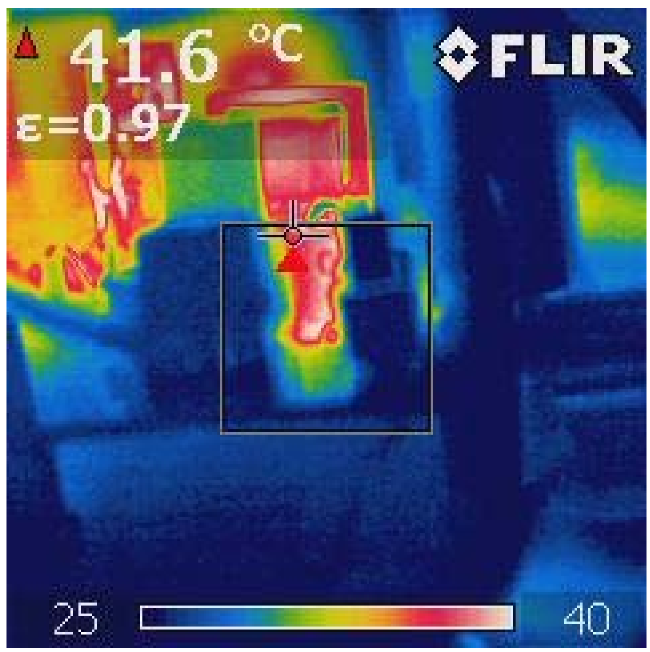

Figure 57 – Standby Output Rectifier D16 Thermal Image, Full Load, Room Temperature.

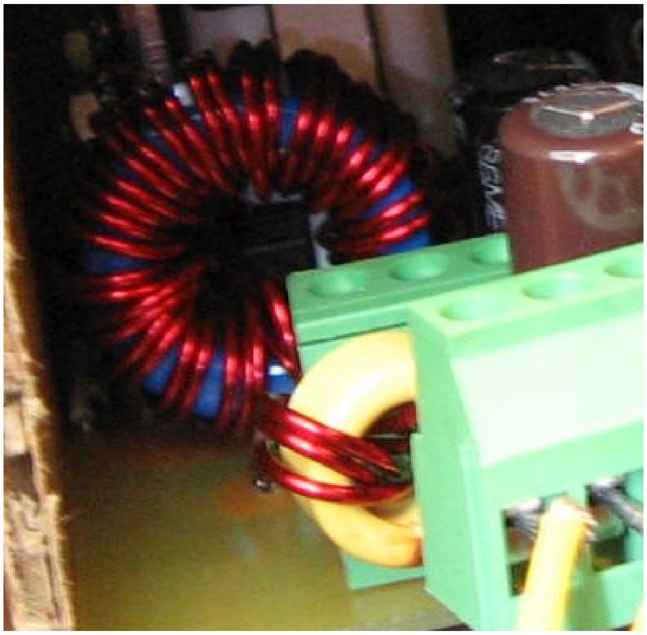

Figure 58 – Main Output Choke L1, Visible Light View.

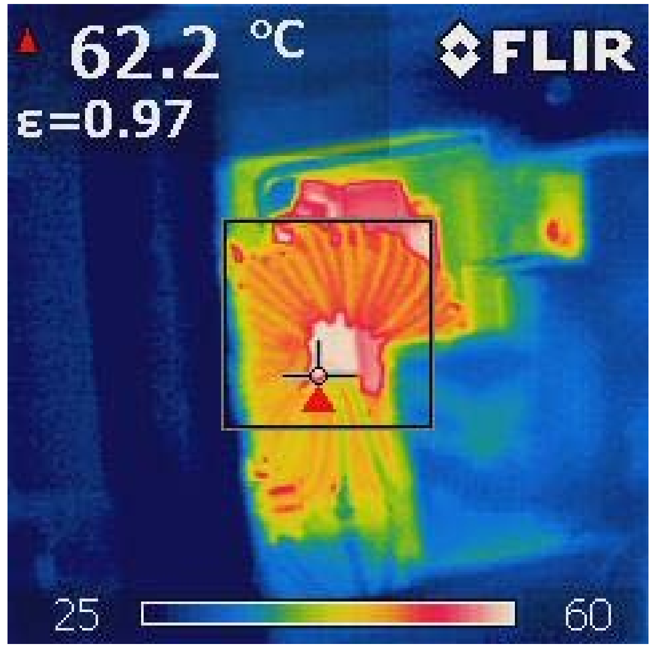

Figure 59 – Main Output Choke L1 Thermal Image, Full Load, Room Temperature.

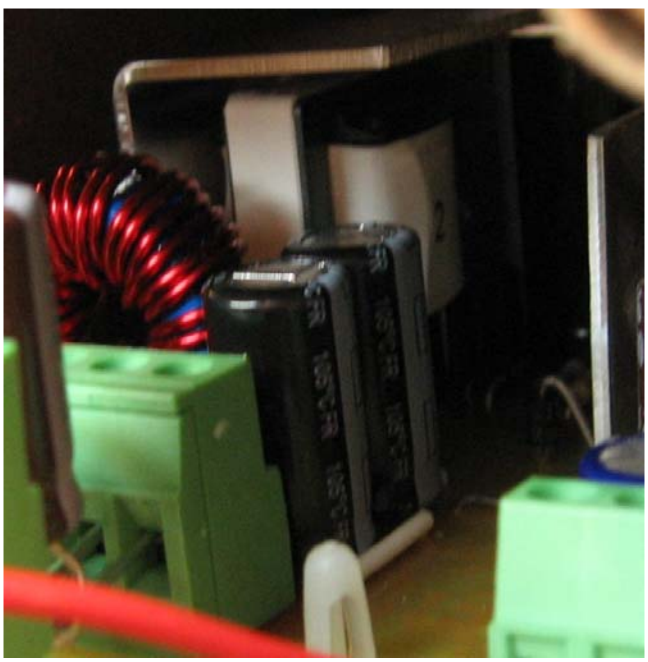

Figure 60 – Main Output Transformer T1, Visible Light View.

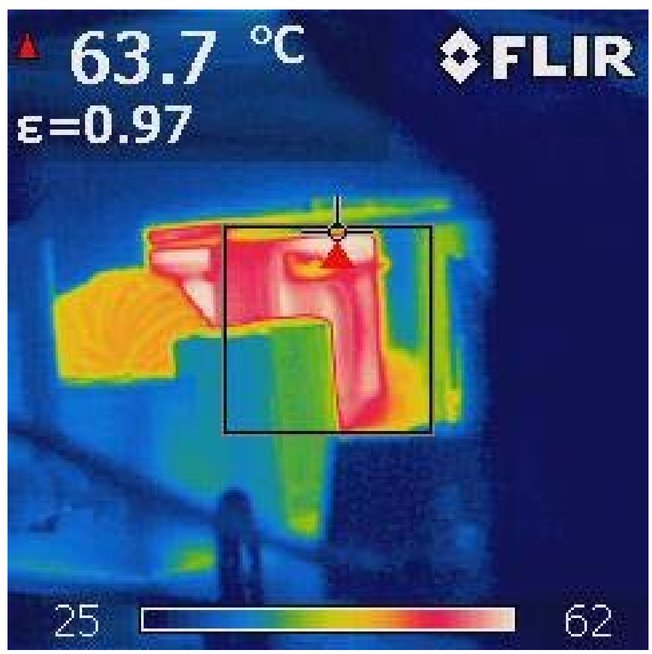

Figure 61 – Main Output Transformer T1 Thermal Image, Full Load, Room Temperature.

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

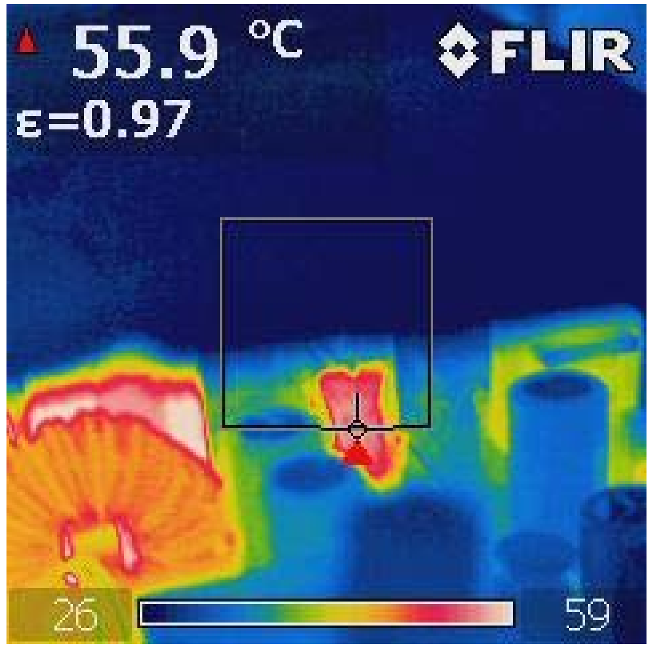
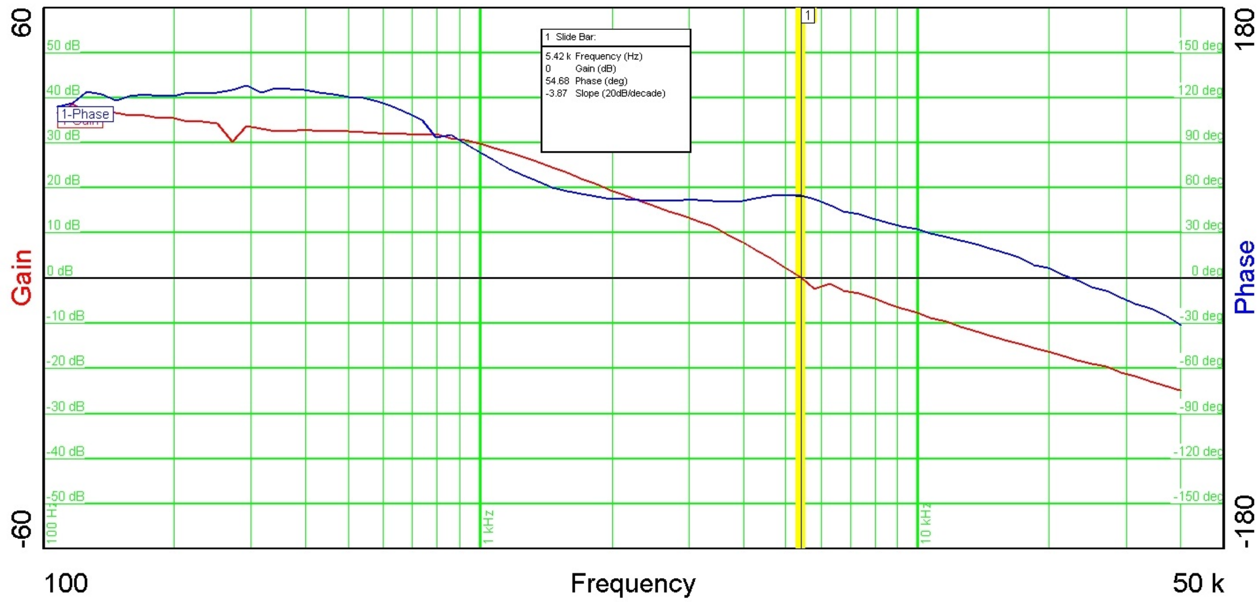


Figure 63 – HiperTFS-2 IC U6 Thermal Image, Full Load, Room Temperature.

13.2 *主輸出整流器的熱電偶測量*

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

14 增益-相位



64Figure

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SEQ Figure * ARABIC 64

15 修訂記錄

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

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