# 設計範例報告

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|---|---|
| **標題** | ***使用 LYTSwitch™ -4 LYT4324E* 的 20 W 高效率 (大於 86%) 可調光雙向閘流器 (TRIAC)、功率因數修正、隔離返馳式 LED 驅動器** |
| **規格** | 185 VAC – 265 VAC 輸入；<br>36 $V_{TYPICAL}$，550 mA 輸出 |
| **應用** | 替換 PAR38 燈泡 |
| **作者** | 應用工程部門 |
| **文件編號** | DER-396 |
| **日期** | 2013 年 9 月 1 日 |
| **修訂** | 1.0 |

## 摘要與功能

- Single-stage 功率因數修正結合精準的定電流 (CC) 輸出 (±5%)
- 230 VAC 時功率因數 (PF) 大於 0.9
- 230 VAC 時電壓諧波失真率 (%A THD) 小於 20%
- 不同生產和溫度範圍的調光效能一致
- 成本低、所需元件極少且 PCB 佔位面積設計小
- 高度節能，在 230 VAC 輸入條件下效率大於 86 %
- 快速啓動 (小於 250 ms) – 無可感延遲
- 順利的單向啓動 - 無輸出閃爍
- 整合式保護與信賴度特性
  - 無負載保護，短路保護
  - 具有高磁滯時間的自動恢復回復過溫保護，同時保護元件和 PCB
  - 在線間電壓關閉情況下，不會發生任何損壞
- 符合 IEC 2.5 kV 振盪波、500 V 線差動電壓突波和 EN55015 傳導性 EMI 規範



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# 目錄

**重要事項：**
雖然此電路板的設計符合非隔離式 LED 驅動器的安全要求，但工程原型尚未取得相關機構之認證。因此，執行所有測試應使用隔離變壓器才能提供 AC 輸入給原型板。


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# 1 簡介

本工程報告文件說明採用 LYTSwitch-4 高線間電壓裝置系列之 LYT4324E 的隔離式功率因數 (PF) 可調光 LED 驅動器 (電源供應器)。

DER-396 提供 185 至 265 VAC 輸入電壓範圍內單一 20 W (36 $V_{TYPICAL}$) 可調光 550 mA 定電流輸出。

主要設計目標是提升到最高效率和完成最小尺寸。這使得驅動器可安裝在 PAR38 尺寸的燈具內，並盡可能接近可供生產的成品設計。

LYTSwitch-4 IC 可讓您實作具有成本效益、所需元件少且同時符合功率因數 (PF) 及諧波限值的 LED 驅動器。LYTSwitch-4 驅動器 IC 將 PFC 功能與二次側輸出定電流控制電路整合成一個切換階段。

使用的架構是以連續導通模式工作的隔離返馳式。完全從一次側完成輸出電流調節，而不再需要二次側回授元件。由於這是在 IC 內執行，因此不需要在一次側感測外部電流，進而可降低元件成本並提升效率。內部控制器可調整功率 MOSFET 工作週期，利用高功率因數 (PF) 與低諧波電流控制維護正弦輸入電流。

LYT4324E 也提供精密的保護功能；在發生開路控制迴路與輸出短路狀況時，將會自動重新啓動。線電壓過壓可提高線路故障與突波承受度，輸出過壓可在負載斷路時保護電源供應器，而精確的磁滯回復過溫保護功能可確保在各種條件下都能有安全的 PCB 平均溫度。
在任何 LED 燈具裝置中，驅動器決定了許多足以影響使用者體驗的效能屬性，包括啓動時間、調光效能和元件間一致性。此設計經過最佳化，能夠使用廣泛的調光器在大調光範圍下正常運作。

本文件內容涵蓋電源供應器的規格、電路圖、物料清單、變壓器文件、印刷電路板佈局、設計試算表和效能資料。

## 2 植入的 PCB

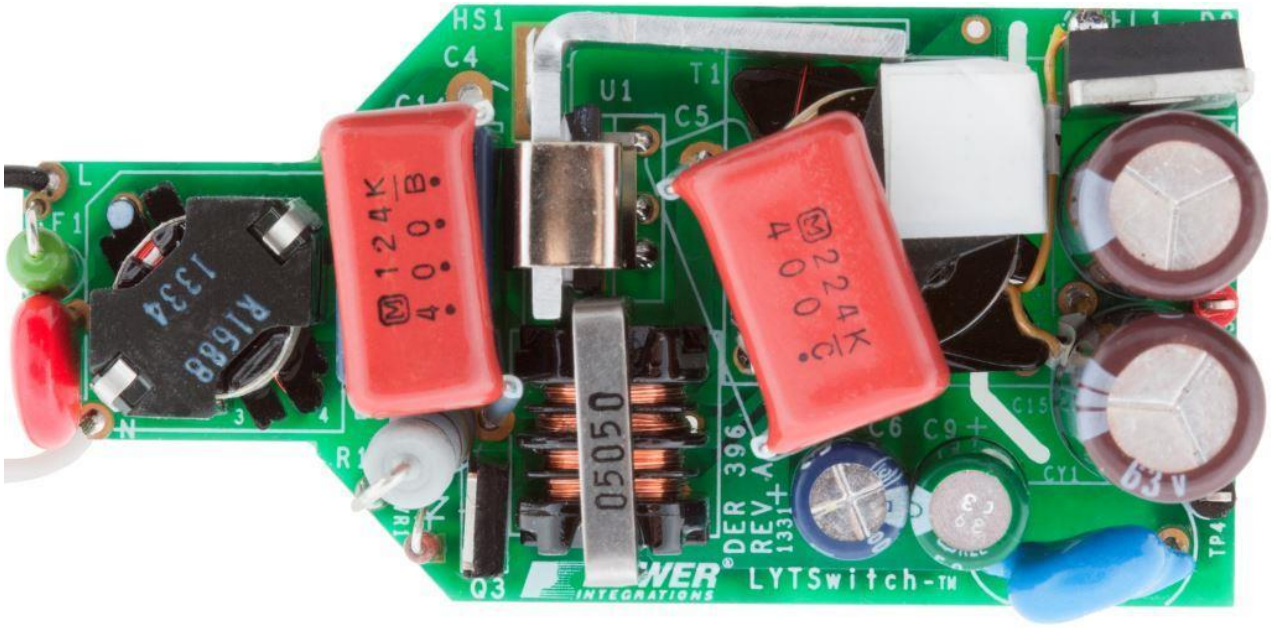


**Figure 1 –** Populated Circuit Board (Top Side).

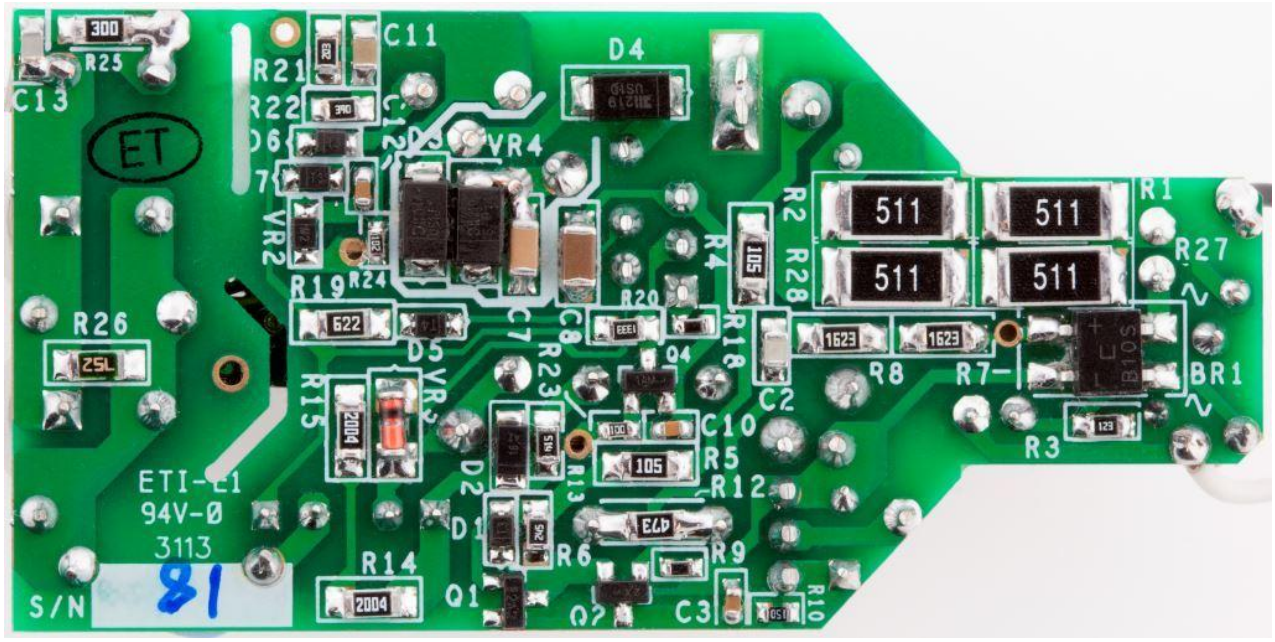


**Figure 2 –** Populated Circuit Board (Bottom Side).


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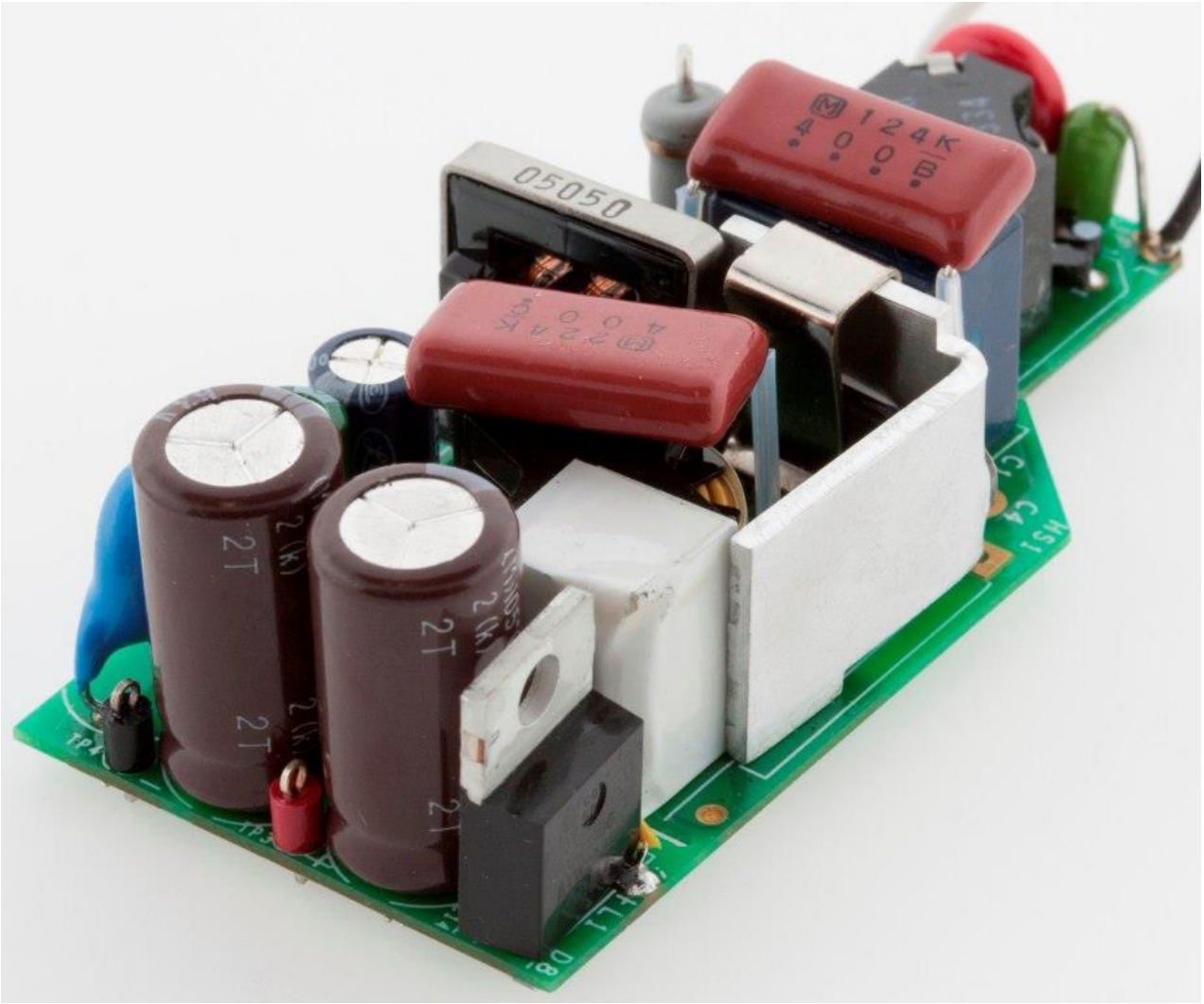


**Figure 3 –** Populated Circuit Board.
Dimensions:2.68 in [68.1 mm] L x 1.32 in [33.6 mm] W x 1 in [25.4 mm] H.

## 3 電源供應器規格

下表展示設計的最低可接受效能。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** | | | | | | |
| 電壓 | $V_{IN}$ | 185 | 230 | 265 | VAC | 雙線 – 無 P.E. |
| 頻率 | $f_{LINE}$ | 47 | 50/60 | 63 | Hz | |
| 功率因數 (PF) | | | 0.9 | | | 在 230 VAC |
| 電壓諧波失真率 (%ATHD) | | | | 17 | | |
| **輸出** | | | | | | |
| 輸出電壓 | $V_{OUT}$ | 33 | 36 | 39 | V | |
| 輸出電流 | $I_{OUT}$ | 522 | 550 | 577 | mA | 在 230 VAC |
| **總輸出功率** | | | | | | |
| 連續輸出功率 | $P_{OUT}$ | | 20 | | W | |
| **效率** | | | | | | |
| 標準 | η | | 86 | | % | 於 $P_{OUT}$ 25 °C、230 VAC 條件下測量 |
| **環境** | | | | | | |
| 傳導性 EMI | | 符合 CISPR22B / EN55015 標準 | | | | |
| 線電壓突波 差模 (L1-L2) | | | 500 | | V | 1.2/50 µs 突波，IEC 1000-4-5，串聯阻抗：差模： 2 Ω |
| 振盪波 (100 kHz) 差模 (L1-L2) | | | 2.5 | | kV | 2 Ω 短路串聯阻抗 |



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## *3.1 Schematic*

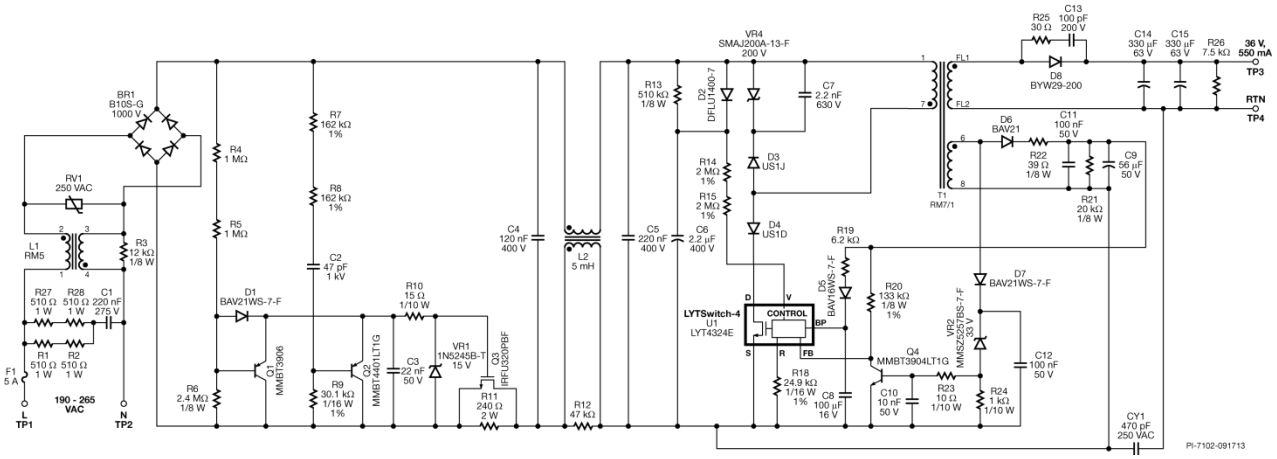


**Figure 4 –** Schematic for 36 V, 550 mA Replacement Lamp.

# 4 電路說明

LYTSwitch-4 (U1) 是高度整合的功率 IC 系列，主要設計用於 LED 驅動器應用。LYTSwitch-4 可在 Single-stage 轉換架構中提供高功率因數 (PF)，同時還能跨輸入範圍 (185 VAC 至 265 VAC) 調節輸出電流和 LED 驅動器應用環境中常見的典型輸出電壓變化。

## *4.1 輸入階段*

保險絲 F1 可防止元件發生故障。爲了避免保險絲在線間突波期間發生開路，所以需要快速的 5 A 額定值。電阻器 RV1 會提供箝位以限制線差動電壓突波事件期間的最大電壓。選取 275 VAC 額定部分，其稍微高於指定的最大工作電壓 (265 VAC)。LYTSwitch-4 的快斷型線電壓過壓偵測加上搭配使用 D2 和 C6 峰值偵測器電容器，可提供箝位以限制 IC 的功率 MOSFET 上的最大電壓應力。此外，在線差動電壓突波事件期間，透過 RC 高通濾波器 R7、R8 和 C2、Q2 偵測的高電壓微分值將會關閉 Q3，而與在阻尼電阻器 R11 中產生的輸入電流成正比的電壓會從輸入中減去。這會限制 U1 的汲極上的電壓應力。電阻器 R9 會洩漏 C2 的電荷，從而確保 Q2 在正常操作期間處於關閉狀態。

差模電感器 L1 是前端 EMI 濾波器，用於抑制雜訊。在必要時，電阻器 R3 會抑制 EMI 濾波器的諧振。

AC 輸入是 BR1 整流後的全波，以達到良好的功率因數 (PF) 和低總諧波失真 (THD)。

電容器 C4、C5 和共模電感器 L2 在橋式整流器後方構成 EMI 濾波器。濾波器電容會受到限制，以維持高功率因數 (PF)。這個輸入 π 濾波器網路加上 LYTSwitch-4 的頻率抖動功能，可符合 B 級輻射量限值。必要時，電阻器 R12 會抑制 EMI 濾波器的諧振，以防止系統中測量時 (驅動器加上機殼) EMI 頻中產生峰值。

## *4.2 阻尼階段*

爲了提供低成本的輸出調光功能，採用 TRIAC 的上升邊緣相位調光器在設計時有許多取捨。由於 LED 照明所消耗的功率小得多 (相較於傳統白熾燈泡)，因此燈具所汲取的電流會低於調光器內 TRIAC 的保持電流。這會導致發生不良情況，例如調光範圍受限及 (或) TRIAC 啓動不一致導致的閃爍。開啓 TRIAC 時，LED 燈具相對較大的阻抗會因對輸入電容充電的突波電流而導致大幅振盪。這同樣會引起不良狀況，因爲振盪可能導致 TRIAC 電流降至零 (並關閉 TRIAC)。爲了解決這些問題，採用了主動阻尼器和被動洩放器這兩個電路。這些電路的缺點是會增大功耗，進而降低電源供應器的效率。對於非調光應用，省略這些元件即可。

主動阻尼器包含元件 R4、R5、R6、R10、D1、Q1、C3、VR1 以及與 Q3 搭配使用的 R11。此電路透過串聯 R11，可在 TRIAC 開啓時，於導通期間的第 1 ms 內限制對 C3 充電的突波電流。約 1 ms 後，Q3 會開啓，從而使 R11 短路。這樣可維持R11 的功率消耗，並允許較大的值用於電流限制。電阻器 R4、R5、R6 和 C3 會在 TRIAC 導通後提供


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1 ms 延遲時間。TRIAC 未導通時，電晶體 Q1 會將 C3 放電，VR1 將 Q3 的閘極電壓箝制在 15 V，而 R10 則同時防止 MOSFET 振盪。Q3 會在未連接任何 TRIAC 調光器時保持開啓，藉此繞過 R11 達到更高的效率。

被動 RC 洩放器 (C1、R1、R2、R27 和 R28) 位於保險絲的正後方，可透過 EMI 電感器將調光期間的突波電流降至最低，藉此將可聞雜訊降至最低。採用四個洩放器電阻器來分擔功率損失 (特別是在調光器的 90º 導通角) 及達到小型外觀尺寸。此電路可在每個 AC 半週期內對應於驅動器的輸入電流增大時，保持輸入電流高於 TRIAC 的保持電流 (holding current)，防止 TRIAC 在每個導通角期間開始時開啓和關閉震盪。

### *4.3 LYTSwitch-4 一次側*

變壓器 (T1) 的一端會連接到 DC 匯流排，而另一端會連接到 LYTSwitch-4 IC 的汲極 (D) 接腳。電流會在功率 MOSFET 開啓期間逐漸增加一次側儲存能量，然後在功率 MOSFET 關閉期間傳輸至輸出。由於其電路板佔位面積小，因此選取 RM7 鐵芯尺寸。線軸不符合 230 VAC 操作所需的 6.2 mm 安全安規距離，而使用飛線讓二次側繞組終止於 PC 板。

爲了提供峰值線電壓資訊給 U1，輸入整流 AC 峰值電壓會透過 D2 爲 C6 充電。然後該電壓將以透過 R14 和 R15 的電流形式饋送至 U1 的電壓監測器 (V) 接腳。電阻器公差會導致不同元件有不同的 V 接腳電流，因此選擇 1% 電阻器類型以最小化此差異。裝置也會使用 V 接腳電流，來設定線間輸入過壓臨界值。電阻器 R13 爲 C6 提供放電路徑，時間常數遠大於整流 AC 的時間常數，防止以線間電壓頻率調變 V 接腳電流。

在內部使用 V 接腳電流和回授 (FB) 接腳電流，以控制平均輸出 LED 電流。在 R 接腳 (R18) 上使用了 24.9 kΩ 電阻器，同時在 V 接腳上使用 4 MΩ (R14+R15) 電阻器，以便使輸入電壓和輸出電流之間形成線性關係並最大化調光範圍。

在功率 MOSFET 開啓期間，需要使用二極體 D4，才能在 C5 上的電壓低於輸出反射電壓 ($V_{OR}$) 時防止反向電流流經 U1。在暫態操作期間，由於漏電感的影響，VRCD 突波吸收器二極體 D3、VR4 及 C7 會將汲極電壓箝制在安全等級。

二極體 D6、C9、C11、R21 及 R22 會從變壓器上的輔助繞組產生一次側偏壓供電。電容器 C8 會爲 U1 的 BYPASS (BP) 接腳 (內部控制器的供電接腳) 提供本機去耦合。在啓動期間，會從汲極接腳連接的內部高電壓電流源將 C8 充電至約 6 V。這樣，零件就可以在透過 R19 從偏壓供電元件提供操作供電電流時啓動切換。二極體 D5 會隔離 C8 的 BP 接腳，以防止一併爲 C9 與 C11 充電時增加啓動時間。

建議使用外部偏壓供電 (透過 D5 和 R19) 以提供最低的裝置消耗功率和最高效率，並提高調光效能。

電容器 C8 也可選取輸出功率模式，針對降低的功率模式選取的 100 μF 可讓裝置的消耗功率與散熱需求降至最低。雖然 47 μF 是建議的最低旁路電容器值，但在使用 SMD 陶瓷型電容器時，建議 68 μF – 100 μF / X5R 以允許電容公差。

### *4.4 輸出回授*

使用偏壓繞組電壓可間接感測輸出電壓，而不再需要二次側回授元件。偏壓繞組電壓與輸出電壓成正比 (由偏壓繞組和二次側繞組之間的圈數比設定)。

電阻器 R20 會將偏壓電壓轉換成電流，再將該電流饋送至 U1 的 FB 接腳。U1 的內部引擎會結合 FB 接腳電流、V 接腳電流及內部汲極電流資訊，以便提供恆定的輸出電流，同時維持高輸入功率因數 (PF)。

### *4.5 負載中斷保護*

參考設計受到意外 LED 負載中斷保護 (如生產中)。控制器將在自動重新啓動模式下運作，以便透過限制輸出電壓 (藉由電感器輔助繞組、D7 整流和 C12 峰值濾波的反射電壓) 來防止電路板上的輸出電容器損壞。當 Q4 從 FB 接腳帶出的電流開啓時，裝置會進入自動重新啓動模式，積納二極體 VR2 會設定過壓限制。

### *4.6 過載和短路保護*

樣品透過一次側限電流受到過載和短路保護。在短路期間，一次側電流會逐漸增加，直至達到限電流。如需更多說明，請參閱短路波形。


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# 5 PCB 佈局和外形

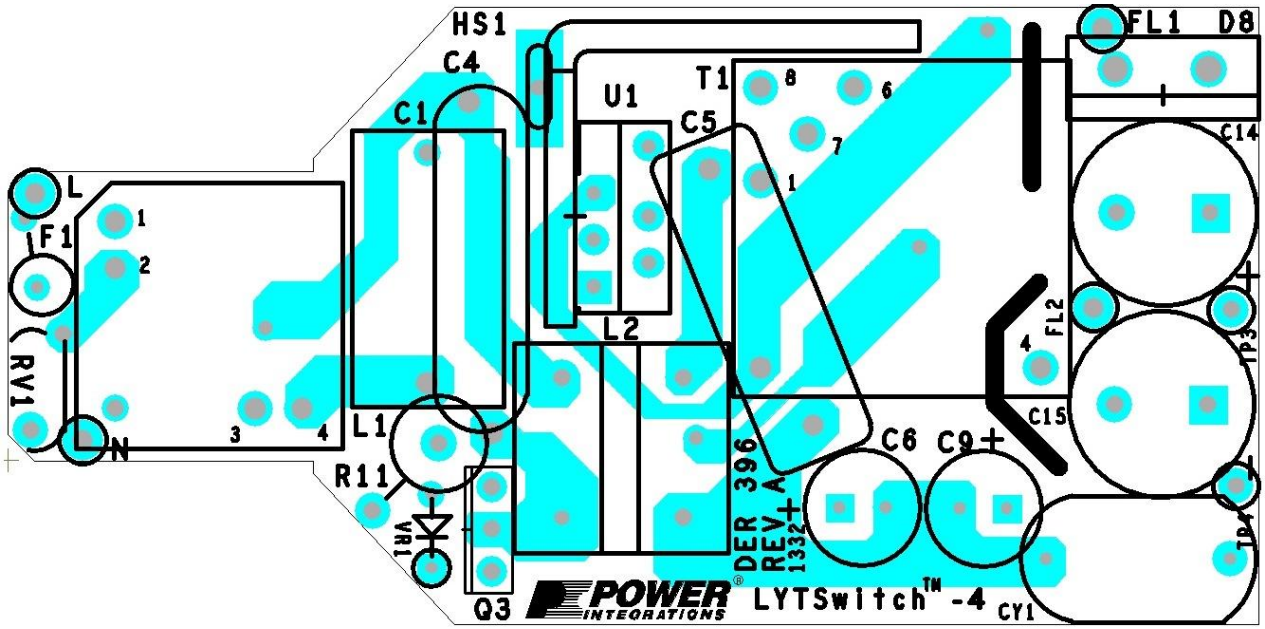


**Figure 5 –** Top Printed Circuit Layout.

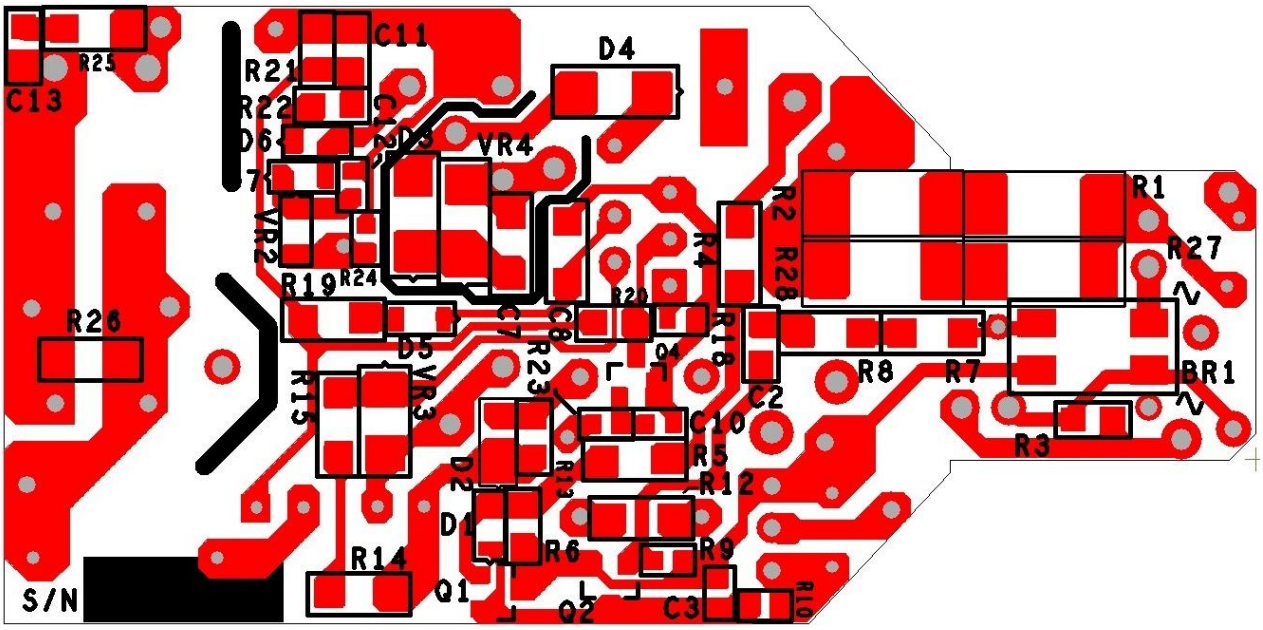


**Figure 6 –** Bottom Printed Circuit Layout.

# 6 物料清單

The table below is the reference design BOM.

| Item | Qty | Ref Des | Description | Mfg Part Number | Manufacturer |
|---|---|---|---|---|---|
| 1 | 1 | BR1 | 1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC | B10S-G | Comchip |
| 2 | 1 | C1 | 220 nF, 275 VAC, Film, X2 | LE224-M | OKAYA |
| 3 | 1 | C2 | 47 pF, 1000 V, Ceramic, NPO, 0805 | VJ0805A470JXGAT5Z | Vishay |
| 3 | 1 | C3 | 22 nF 50 V, Ceramic, X7R, 0603 | C1608X7R1H223K | TDK |
| 4 | 1 | C4 | 120 nF, 400 V, Film | ECQ-E4124KF | Panasonic |
| 5 | 1 | C5 | 220 nF, 400 V, Film | ECQ-E4224KF | Panasonic |
| 6 | 1 | C6 | 2.2 μF, 400 V, Electrolytic, (6.3 x 11) | TAB2GM2R2E110 | Ltec |
| 7 | 1 | C7 | 2.2 nF, 630 V, Ceramic, X7R, 1206 | C3216X7R2J222K | TDK |
| 8 | 1 | C8 | 100 μF, 16 V, X5R, 1206 | 3216X5R1C105M | TDK |
| 9 | 1 | C9 | 56 μF, 50 V, Electrolytic, Very Low ESR, 140 mΩ, (6.3 x 11) | EKZE500ELL560MF11D | Nippon Chemi-Con |
| 10 | 1 | C10 | 10 nF 50 V, Ceramic, X7R, 0603 | C0603C103K5RACTU | Kemet |
| 11 | 1 | C11 | 100 nF, 50 V, Ceramic, X7R, 0805 | CC0805KRX7R9BB104 | Yageo |
| 12 | 1 | C12 | 100 nF 50 V, Ceramic, X7R, 0603 | C1608X7R1H104K | TDK |
| 13 | 1 | C13 | 100 pF, 200 V, Ceramic, COG, 0805 | 08052A101JAT2A | AVX |
| 14 | 2 | C14 C15 | 330 μF, 63 V, Electrolytic, (10 x 20) | EKMG630ELL331MJ20S | United Chemi-con |
| 15 | 1 | CY1 | 470 pF, 250 VAC, Film, X1Y1 | CD95-B2GA471KYNS | TDK |
| 16 | 3 | D1 D6 D7 | 250 V, 0.2 A, Fast Switching, 50 ns, SOD-323 | BAV21WS-7-F | Diodes, Inc. |
| 17 | 1 | D2 | 400 V, 1 A, DIODE SUP FAST 1A PWRDI 123 | DFLU1400-7 | Diodes, Inc. |
| 18 | 1 | D3 | DIODE ULTRA FAST, SW 600 V, 1 A, SMA | US1J-13-F | Diodes, Inc. |
| 19 | 1 | D4 | DIODE ULTRA FAST, SW, 200 V, 1 A, SMA | US1D-13-F | Diodes, Inc. |
| 20 | 1 | D5 | 75 V, 0.15 A, Switching, SOD-323 | BAV16WS-7-F | Diodes, Inc. |
| 21 | 1 | D8 | 200 V, 8 A, Ultrafast Recovery, 25 ns, TO-220AC | BYW29-200G | On Semi |
| 22 | 1 | F1 | 5 A, 250 V, Fast, Microfuse, Axial | 0263005.MXL | Littlefuse |
| 23 | 1 | L1 | Custom, RM5, Vertical, 6 pins | SNX-R1688 | Santronics USA |
| 24 | 1 | L2 | 5 mH, 0.5 A, Common Mode Choke Vertical | SU9VF-05050 | Tokin |
| 25 | 1 | Q1 | PNP, Small Signal BJT, 40 V, 0.2 A, SOT-23 | MMBT3906LT1G | On Semi |
| 36 | 1 | Q2 | NPN, Small Signal BJT, GP SS, 40 V, 0.6 A, SOT-23 | MMBT4401LT1G | Diodes, Inc. |
| 26 | 1 | Q3 | 400 V, 3.1 A,N-Channel, TO-251AA | IRFU320PBF | Vishay |
| 27 | 1 | Q4 | NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23 | MMBT3904LT1G | On Semi |
| 28 | 4 | R1 R2 R27 R28 | 510 Ω, 5%, 1 W, Thick Film, 2512 | ERJ-1TYJ511U | Panasonic |
| 29 | 1 | R3 | 12 kΩ, 5%, 1/8 W, Thick Film, 0805 | ERJ-6GEYJ123V | Panasonic |
| 30 | 2 | R4 R5 | 1 MΩ, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ105V | Panasonic |
| 31 | 1 | R6 | 2.4 MΩ, 5%, 1/8 W, Thick Film, 0805 | ERJ-6GEYJ245V | Panasonic |
| 32 | 1 | R7 | 162 k, 1%, 1/4 W, Thick Film, 1206 | ERJ-8ENF1623V | Panasonic |
| 33 | 1 | R8 | 162 k, 1%, 1/4 W, Thick Film, 1206 | ERJ-8ENF1623V | Panasonic |
| 34 | 1 | R9 | 30.1 k, 1%, 1/16 W, Thick Film, 0603 | ERJ-3EKF3012V | Panasonic |
| 35 | 1 | R10 | 15 Ω, 5%, 1/10 W, Thick Film, 0603 | ERJ-3GEYJ150V | Panasonic |
| 36 | 1 | R11 | 240 Ω, 5%, 2 W, Metal Oxide | RSF200JB-240R | Yageo |
| 37 | 1 | R12 | 47 kΩ, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ473V | Panasonic |
| 38 | 1 | R13 | 510 kΩ, 5%, 1/8 W, Thick Film, 0805 | ERJ-6GEYJ514V | Panasonic |
| 39 | 2 | R14 R15 | 2.0 MΩ, 1%, 1/4 W, Thick Film, 1206 | ERJ-8ENF2004V | Panasonic |
| 40 | 1 | R17 | 200 kΩ, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ204V | Panasonic |
| 41 | 1 | R18 | 24.9 kΩ, 1%, 1/16 W, Thick Film, 0603 | ERJ-3EKF2492V | Panasonic |



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| Item | Qty | Ref Des | Description | Mfg Part Number | Manufacturer |
|---|---|---|---|---|---|
| 42 | 1 | R19 | 6.2 kΩ, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ622V | Panasonic |
| 43 | 1 | R20 | 133 kΩ, 1%, 1/8 W, Thick Film, 0805 | ERJ-6ENF1333V | Panasonic |
| 44 | 1 | R21 | 20 kΩ, 5%, 1/8 W, Thick Film, 0805 | ERJ-6GEYJ203V | Panasonic |
| 45 | 1 | R22 | 39 Ω, 5%, 1/8 W, Thick Film, 0805 | ERJ-6GEYJ390V | Panasonic |
| 46 | 1 | R23 | 10 Ω, 5%, 1/10 W, Thick Film, 0603 | ERJ-3GEYJ100V | Panasonic |
| 47 | 1 | R24 | 1 kΩ, 5%, 1/10 W, Thick Film, 0603 | ERJ-3GEYJ102V | Panasonic |
| 48 | 1 | R25 | 30 Ω, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ300V | Panasonic |
| 49 | 1 | R26 | 7.5 kΩ, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ752V | Panasonic |
| 50 | 1 | RV1 | 250 V, 21 J, 7 mm, RADIAL LA | V130LA20AP | Littlefuse |
| 51 | 1 | T1 | Custom, RM7/I, Vertical, 8 pins with mtg clip CLI/P-RM7 | SNX-R1689 | Santronics USA |
| 52 | 1 | U1 | LYTSwitch-4, eSIP-7C | LYT4324E | Power Integrations |
| 53 | 1 | VR1 | 15 V, 5%, 500 mW, DO-35 | 1N5245B-T | Diodes, Inc. |
| 54 | 1 | VR2 | 33 V, 5%, 200 mW, SOD-323 | MMSZ5257BS-7-F | Diodes, Inc. |
| 55 | 1 | VR4 | 200 V, 400 W, SMA | SMAJ200A-13-F | Diodes, Inc. |
| **Mechanical BOM** | | | | | |
| 1 | 1 | HS1 | Heat sink, Custom, Al, 3003, 0.062" Thk | Custom | Custom |
| 2 | 1 | POWER CLIP1 | Heat sink Hardware, Edge Clip 21N (4.7 lbs) 10 mm L x 7 mm W x 0.5 mm H | CLP212SG | Aavid Thermalloy |
| 3 | 6 | Insulation Tubing | 15 mm; PTTFE AWG #20 TW Tubing | TFT20-NT | Custom Cut |

# 7 變壓器 (T1) 規格

## *7.1 電氣圖*

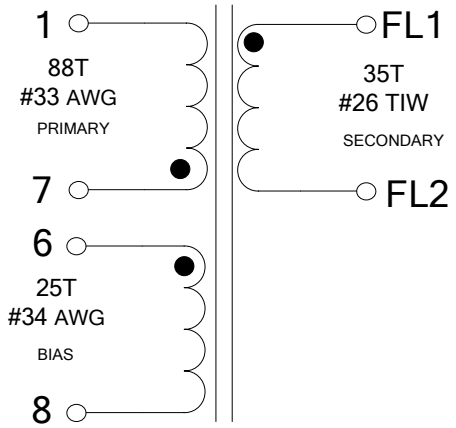


**Figure 7 –** Transformer Electrical Diagram.

## *7.2 電氣規格*

| | | |
|---|---|---|
| **Primary Inductance** | Pins 1-7, all other windings open, measured at 100 kHz, 0.4 $V_{RMS.}$ | 1 mH ±7% |
| **Resonant Frequency** | Pins 1-7, all other windings open. | 1000 kHz (Min.) |

## *7.3 材料*

| Item | Description |
|---|---|
| **[1]** | Core:RM7; 3F3. |
| **[2]** | Bobbin:Rm-7; 4/4 pin vertical. |
| **[3]** | Clip:EPCOS, KlammerRM7, Manufacture P/N:B65820B2001X. |
| **[4]** | Magnet Wire:#33 AWG, double coated. |
| **[5]** | Magnet Wire:#26 TIW, triple insulated. |
| **[6]** | Magnet Wire:#34 AWG, double coated. |
| **[7]** | Tape:3M 1298 Polyester Film, 7.0.mm wide, 2.0 mil thick or equivalent. |
| **[8]** | Tape:3M 1298 Polyester Film, 18.0.mm x 30.0.mm, 2.0.mil thick or equivalent. |
| **[9]** | Varnish:Dolph BC-359, or equivalent. |


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## *7.4 建構圖*

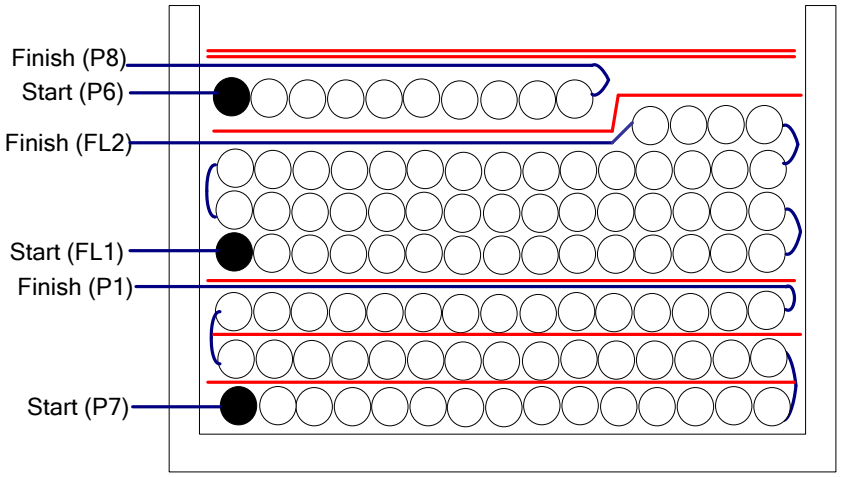


**Figure 8 –** Transformer Build Diagram.

## *7.5 構造*

| | |
|---|---|
| **Winding Preparation** | Note:pin-out of bobbin is designated as in picture below.<br>Place the bobbin item [1] on the mandrel with the pin side is on the left.<br>Winding direction is clockwise direction. |
| **Winding 1** | Start at pin 7, wind 31 turns of wire item [4] from left to right for the 1st layer and place 1 layer of tape item [6].Continue winding another 31 turns for the 2nd layer, from right to left and also place 1 layer of tape item [7].Then wind 26 turns for the 3rd layer from left to right, at the last turn bring the wire back to the left and terminate at pin 1. |
| **Insulation** | Place 1 layer of tape item [7]. |
| **Winding 2** | Use wire item [5], leave ~ 25 mm floating and place a piece of small tape to mark it as start lead FL1.Wind 32 turns of wire in 3 layers and 3 turns on the 4th layer on the right side of bobbin, at the last turn bring the wire back to the left and also leave ~ 25 mm floating as end lead FL2. |
| **Insulation** | Place 1 layer of tape item [7]. |
| **Winding 3** | Now wind 25 turns of wire item [6] on the left section of 4th layer from winding 2, start at pin 6 and end with pin 8. |
| **Insulation** | Place 2 layers of tape item [7] to secure windings. |
| **Final Assembly** | Grind core halves item [2] to get 1 mH and secure with clips item [3]<br>Cut short FL1 to 24 mm and FL2 to 12 mm.<br>Cut ground lead of clip item [3] on the left side of core halves, see picture below.<br>Prepare tape item [8].<br>Wrap 2 layers of tape item [8] on the left side of core halves for insulation.<br>Varnish with item [9].<br>Cut pin number 2, 3 and 5. |

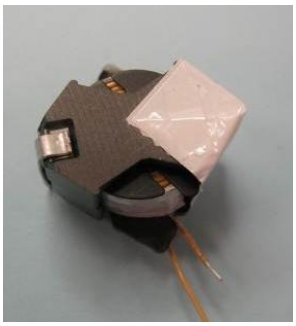

**Figure 9 –** Transformer Assembly Illustration.



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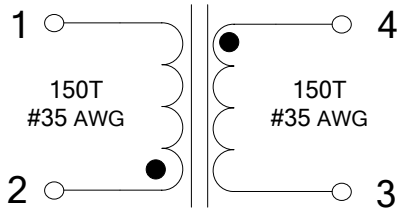
# 8 差模電感器 (L1) 規格

## *8.1 建構圖*




Follow the transformer pin
according to its data sheet

**Figure 10 –** Inductor Electrical Diagram.

## *8.2 電氣規格*

| | | |
|---|---|---|
| **Primary Inductance** | Pins 1-2, all other windings open, measured at 100 kHz, 0.4 $V_{RMS.}$ | 240 µH ±10% |

## *8.3 材料*

| Item | Description |
|---|---|
| **[1]** | Core:RM5 (3/3); N87. |
| **[2]** | Bobbin:RM-5; 3/3 pin vertical. |
| **[3]** | Magnet Wire:#35 AWG. |
| **[4]** | Tape:3M 1298 Polyester Film, 4.8 mm wide, 2.0 mil thick or equivalent. |
| **[5]** | Varnish:Dolph BC-359, or equivalent. |

## *8.4 建構圖*

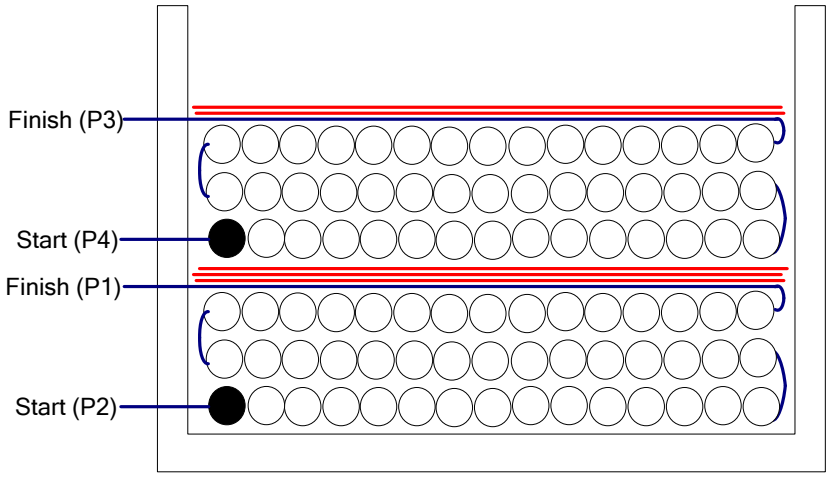



**Figure 11 –** Inductor Build Diagram.

## *8.5 構造*

| | |
|---|---|
| **Winding Preparation** | Note:pin-out of bobbin is designated as in picture below.<br>Place the bobbin item [1] on the mandrel with the pin side is on the left.<br>Winding direction is clockwise direction. |
| **Winding 1** | Start at pin 2, wind 150 turns of wire item [3] continuously then terminate at pin 1. |
| **Insulation** | Place 3 layer of tape item [4]. |
| **Winding 2** | Start at pin 4, wind 150 turns of wire item [3] continuously then terminate at pin 3. |
| **Insulation** | Place 2 layers of tape item [4] to secure windings. |
| **Final Assembly** | Grind core halves item [2] to get 1 mH and secure with clips.<br>Varnish with item [5].Cut pin 5 and 6. |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# 9 U1 散熱片

## *9.1 U1 散熱片製造圖*

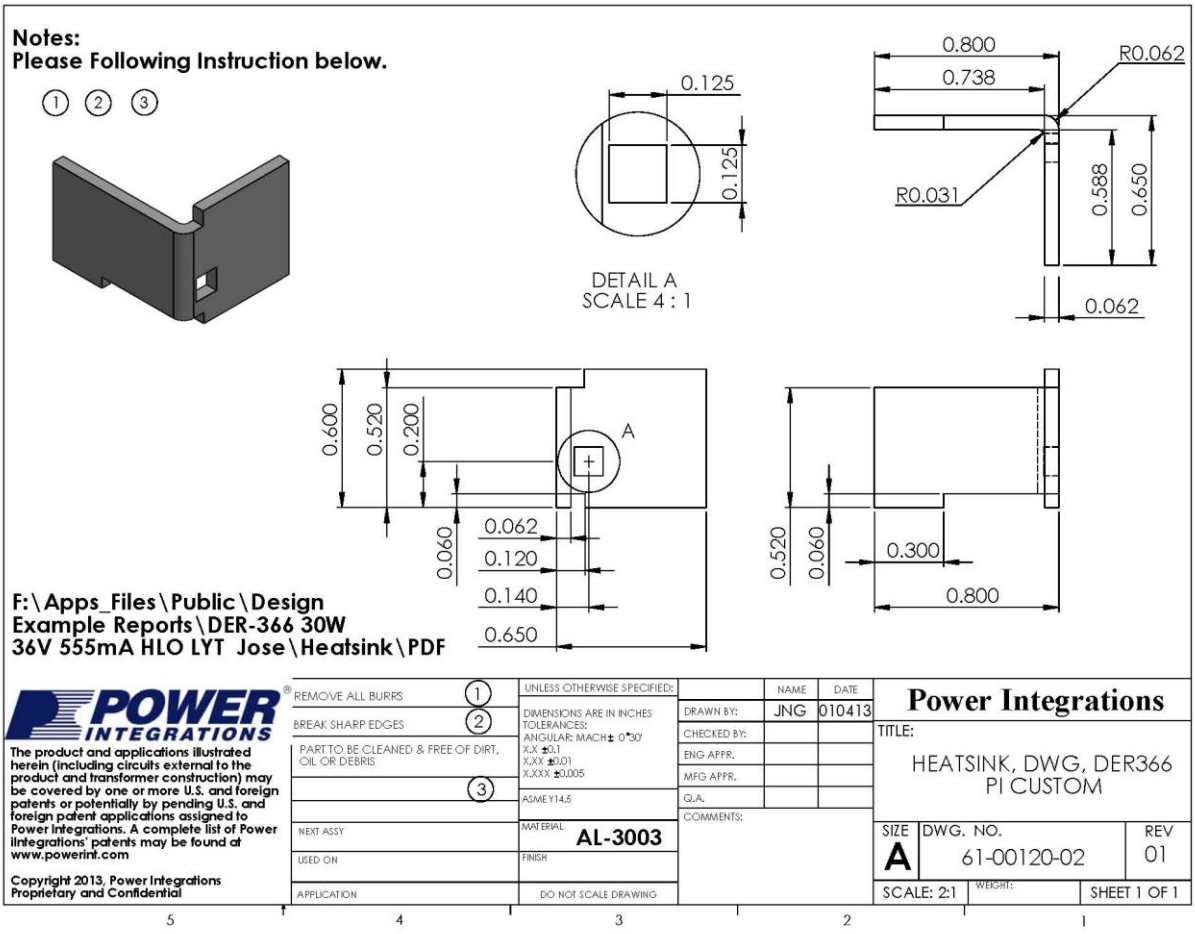


**Figure 12 –** U1 Heat Sink Fabrication Drawing.

## *9.2 U1 散熱片組裝圖*

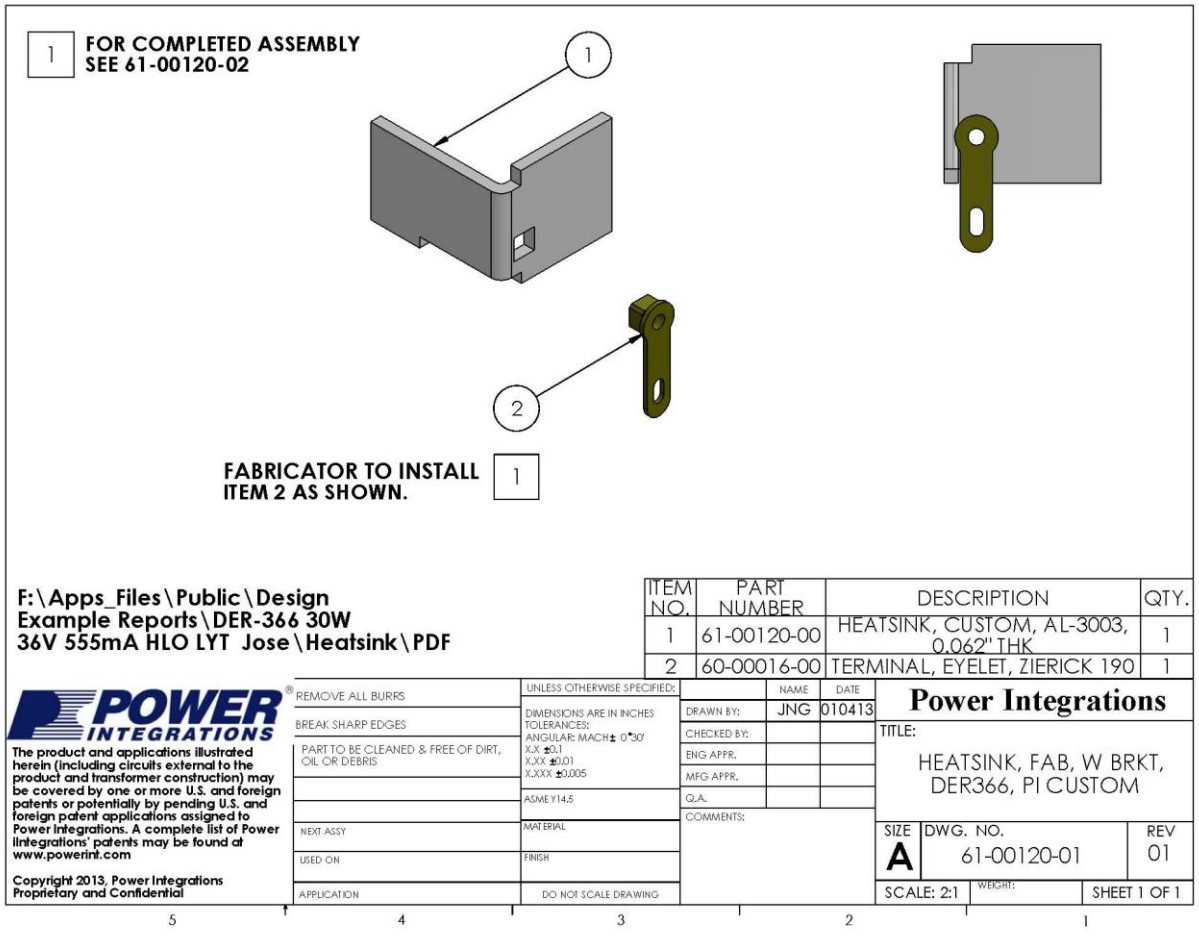


**Figure 13 –** U1 Heat Sink Assembly Drawing.


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## *9.3 散熱片和 U1 組裝圖*

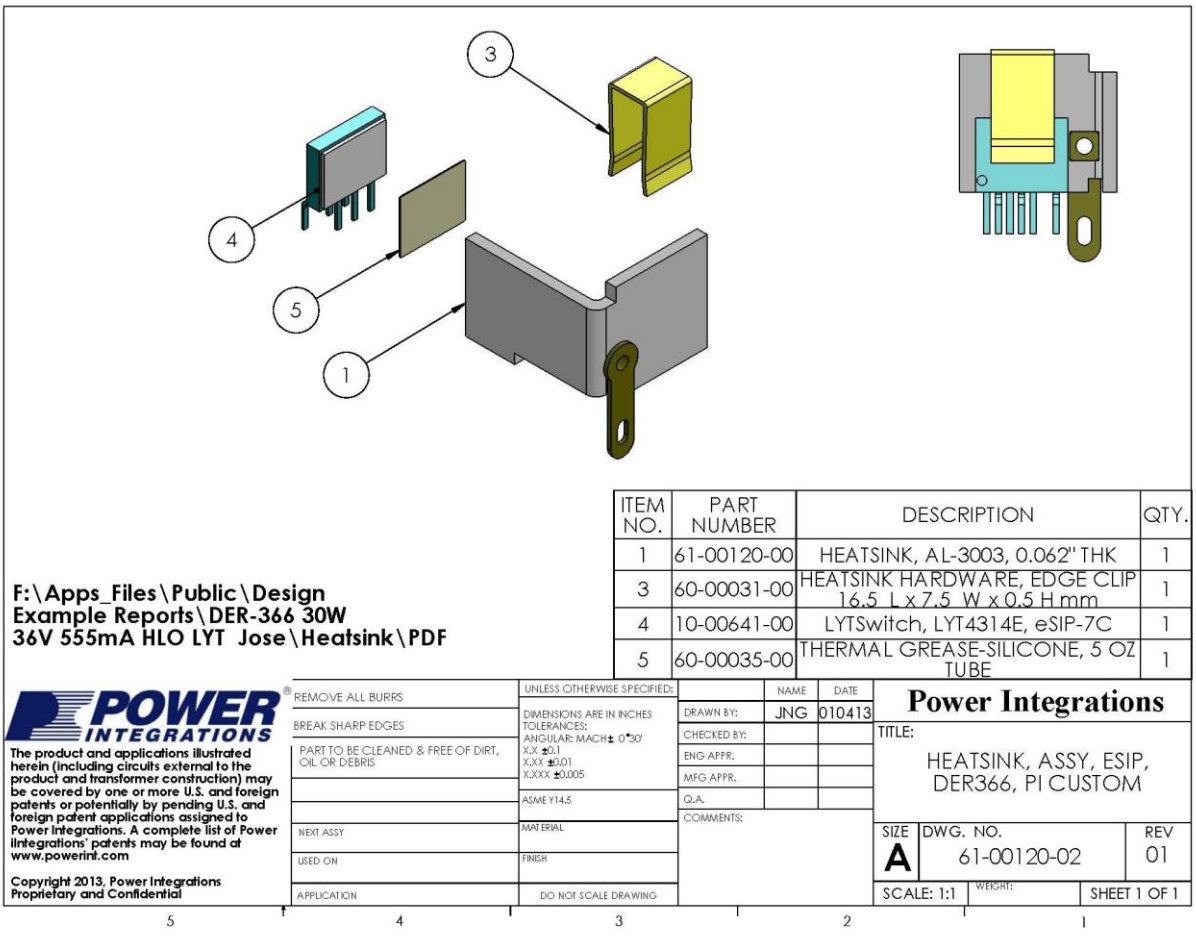


**Figure 14 –** Heat Sink and U1 Assembly Drawing.

## 10 變壓器設計試算表

| ACDC_LYTSwitch-4_HL_062013; Rev.1.0; Copyright Power Integrations 2013 | INPUT | INFO | OUTPUT | UNIT | LYTSwitch-4_HL_062013:Flyback Transformer Design Spreadsheet |
|---|---|---|---|---|---|
| **ENTER APPLICATION VARIABLES** | | | | | **DER-396** |
| Dimming required | 是 | | 是 | | Select 'YES' option if dimming is required.Otherwise select 'NO'. |
| VACMIN | 185 | | 185 | V | Minimum AC Input Voltage |
| VACMAX | | | 265 | V | Maximum AC input voltage |
| fL | | | 50 | Hz | AC Mains Frequency |
| VO | 36 | | 36 | V | Typical output voltage of LED string at full load |
| VO_MAX | | | 39.6 | V | Maximum expected LED string Voltage. |
| VO_MIN | | | 32.4 | V | Minimum expected LED string Voltage. |
| V_OVP | | | 42.47 | V | Over-voltage protection setpoint |
| IO | 0.55 | | 0.55 | A | Typical full load LED current |
| PO | | | 19.8 | W | Output Power |
| n | | | 0.8 | | Estimated efficiency of operation |
| VB | | | 25 | V | Bias Voltage |
| **ENTER LYTSwitch VARIABLES** | | | | | |
| LYTSwitch | Auto | | LYT4324 | | Selected LYTSwitch |
| Current Limit Mode | RED | | RED | | Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode |
| ILIMITMIN | | | 0.95 | A | Minimum current limit |
| ILIMITMAX | | | 1.11 | A | Maximum current limit |
| fS | | | 132000 | Hz | Switching Frequency |
| fSmin | | | 124000 | Hz | Minimum Switching Frequency |
| fSmax | | | 140000 | Hz | Maximum Switching Frequency |
| IV | | | 80.56727984 | uA | V pin current |
| RV | | | 4 | M-ohms | Upper V pin resistor |
| RV2 | | | 1E+12 | M-ohms | Lower V pin resistor |
| IFB | 178 | | 178 | uA | FB pin current (85 uA < IFB < 210 uA) |
| RFB1 | | | 123.5955056 | k-ohms | FB pin resistor |
| VDS | | | 10 | V | LYTSwitch on-state Drain to Source Voltage |
| VD | | | 0.5 | V | Output Winding Diode Forward Voltage Drop (0.5 V for Schottky and 0.8 V for PN diode) |
| VDB | | | 0.7 | V | Bias Winding Diode Forward Voltage Drop |
| **Key Design Parameters** | | | | | |
| KP | 0.7 | | 0.7 | | Ripple to Peak Current Ratio (For PF > 0.9, 0.4 < KP < 0.9) |
| LP | | | 998.2376383 | uH | Primary Inductance |
| VOR | 92 | | 92 | V | Reflected Output Voltage. |
| Expected IO (average) | | | 0.547777905 | A | Expected Average Output Current |
| KP_VNOM | | | 0.666138709 | | Expected ripple current ratio at VACNOM |
| TON_MIN | | | 1.493186757 | us | Minimum on time at maximum AC input voltage |
| PCLAMP | | | 0.159394306 | W | Estimated dissipation in primary clamp |
| **ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES** | | | | | |
| Core Type | RM7 | | RM7 | | Select Core Size |
| Custom Core | RM7 | | | | Enter Custom core part number (if applicable) |
| AE | 0.45 | | 0.45 | cm^2 | Core Effective Cross Sectional Area |
| LE | 3 | | 3 | cm | Core Effective Path Length |
| AL | 2500 | | 2500 | nH/T^2 | Ungapped Core Effective Inductance |
| BW | 6.9 | | 6.9 | mm | Bobbin Physical Winding Width |
| M | | | 0 | mm | Safety Margin Width (Half the Primary to Secondary Creepage Distance) |



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| | | | | | |
|---|---|---|---|---|---|
| L | 4 | | 4 | | Number of Primary Layers |
| NS | 35 | | 35 | | Number of Secondary Turns |
| **DC INPUT VOLTAGE PARAMETERS** | | | | | |
| VMIN | | | 261.629509 | V | Peak input voltage at VACMIN |
| VMAX | | | 374.766594 | V | Peak input voltage at VACMAX |
| **CURRENT WAVEFORM SHAPE PARAMETERS** | | | | | |
| DMAX | | | 0.267730208 | | Minimum duty cycle at peak of VACMIN |
| IAVG | | | 0.119116476 | A | Average Primary Current |
| IP | | | 0.826177997 | A | Peak Primary Current (calculated at minimum input voltage VACMIN) |
| IRMS | | | 0.231970815 | A | Primary RMS Current (calculated at minimum input voltage VACMIN) |
| **TRANSFORMER PRIMARY DESIGN PARAMETERS** | | | | | |
| LP | | | 998.2376383 | uH | Primary Inductance |
| LP_TOL | 10 | | 10 | | Tolerance of primary inductance |
| NP | | | 88.21917808 | | Primary Winding Number of Turns |
| NB | | | 24.64383562 | | Bias Winding Number of Turns |
| ALG | | | 128.2649294 | nH/T^2 | Gapped Core Effective Inductance |
| BM | | | 2077.457006 | Gauss | Maximum Flux Density at PO, VMIN (BM<3100) |
| BP | | | 2791.138572 | Gauss | Peak Flux Density (BP<3700) |
| BAC | | | 727.109952 | Gauss | AC Flux Density for Core Loss Curves (0.5 X Peak to Peak) |
| ur | | | 1326.288091 | | Relative Permeability of Ungapped Core |
| LG | | | 0.418255474 | mm | Gap Length (Lg > 0.1 mm) |
| BWE | | | 27.6 | mm | Effective Bobbin Width |
| OD | | | 0.312857143 | mm | Maximum Primary Wire Diameter including insulation |
| INS | | | 0.053423557 | mm | Estimated Total Insulation Thickness (= 2 * film thickness) |
| DIA | | | 0.259433586 | mm | Bare conductor diameter |
| AWG | | | 30 | AWG | Primary Wire Gauge (Rounded to next smaller standard AWG value) |
| CM | | | 101.5936673 | Cmils | Bare conductor effective area in circular mils |
| CMA | | | 437.9588334 | Cmils/Amp | Primary Winding Current Capacity (200 < CMA < 600) |
| **TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)** | | | | | |
| **Lumped parameters** | | | | | |
| ISP | | | 2.082421254 | A | Peak Secondary Current |
| ISRMS | | | 0.884132667 | A | Secondary RMS Current |
| IRIPPLE | | | 0.692235923 | A | Output Capacitor RMS Ripple Current |
| CMS | | | 176.8265334 | Cmils | Secondary Bare Conductor minimum circular mils |
| AWGS | | | 27 | AWG | Secondary Wire Gauge (Rounded up to next larger standard AWG value) |
| DIAS | | | 0.362522298 | mm | Secondary Minimum Bare Conductor Diameter |
| ODS | | | 0.197142857 | mm | Secondary Maximum Outside Diameter for Triple Insulated Wire |
| **VOLTAGE STRESS PARAMETERS** | | | | | |
| VDRAIN | | | 566.5923475 | V | Estimated Maximum Drain Voltage assuming maximum LED string voltage (Includes Effect of Leakage Inductance) |
| PIVS | | | 191.1564827 | V | Output Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike) |
| PIVB | | | 134.1846154 | V | Bias Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike) |
| **FINE TUNING (Enter measured values from prototype)** | | | | | |
| **V pin Resistor Fine Tuning** | | | | | |
| RV1 | | | 4 | M-ohms | Upper V Pin Resistor Value |

| | | | | | |
|---|---|---|---|---|---|
| RV2 | | | 1E+12 | M-ohms | Lower V Pin Resistor Value |
| VAC1 | | | 115 | V | Test Input Voltage Condition1 |
| VAC2 | | | 230 | V | Test Input Voltage Condition2 |
| IO_VAC1 | | | 0.55 | A | Measured Output Current at VAC1 |
| IO_VAC2 | | | 0.55 | A | Measured Output Current at VAC2 |
| RV1 (new) | | | 4.000604137 | M-ohms | New RV1 |
| RV2 (new) | | | 20911.63067 | M-ohms | New RV2 |
| V_OV | | | 319.5673531 | V | Typical AC input voltage at which OV shutdown will be triggered |
| V_UV | | | 66.34665276 | V | Typical AC input voltage beyond which power supply can startup |
| **FB pin resistor Fine Tuning** | | | | | |
| RFB1 | 133 | | 133 | k-ohms | Upper FB Pin Resistor Value |
| RFB2 | | | 1E+12 | k-ohms | Lower FB Pin Resistor Value |
| VB1 | | | 22.46520548 | V | Test Bias Voltage Condition1 |
| VB2 | | | 27.53479452 | V | Test Bias Voltage Condition2 |
| IO1 | | | 0.55 | A | Measured Output Current at Vb1 |
| IO2 | | | 0.55 | A | Measured Output Current at Vb2 |
| RFB1 (new) | | | 133 | k-ohms | New RFB1 |
| RFB2(new) | | | 1E+12 | k-ohms | New RFB2 |
| **Input Current Harmonic Analysis** | | | | | |
| Harmonic | | | Max Current (mA) | Limit (mA) | |
| 1st Harmonic | | | | | |
| 3rd Harmonic | | | 20.69736113 | 1666.17 | PASS.3rd Harmonic current content is lower than the limit |
| 5th Harmonic | | | 9.233940611 | 931.095 | PASS.5th Harmonic current content is lower than the limit |
| 7th Harmonic | | | 5.592928806 | 490.05 | PASS.7th Harmonic current content is lower than the limit |
| 9th Harmonic | | | 3.956638292 | 245.025 | PASS.9th Harmonic current content is lower than the limit |
| 11th Harmonic | | | 2.979917621 | 171.5175 | PASS.11th Harmonic current content is lower than the limit |
| 13th Harmonic | | | 2.264929473 | 145.103805 | PASS.13th Harmonic current content is lower than the limit |
| 15th Harmonic | | | 1.69769565 | 125.74683 | PASS.15th Harmonic current content is lower than the limit |
| | | | | | |
| THD | | | 23.53869833 | % | Estimated total Harmonic Distortion (THD) |

**Table 1 –** Sample Spreadsheet Calculation.



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## 11 效能資料

All measurements performed at 25 ºC room temperature, 60 Hz input frequency unless otherwise specified.

| 輸入 | | Input Measurement | | | | | LED Load Measurement | | | Efficiency (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| VAC ($V_{RMS}$) | Freq (Hz) | $V_{IN}$ ($V_{RMS}$) | $I_{IN}$ ($mA_{RMS}$) | $P_{IN}$ (W) | 功率因數 (PF) | 電壓諧波失真率 (%ATHD) | $V_{OUT}$ ($V_{DC}$) | $I_{OUT}$ ($mA_{DC}$) | $P_{OUT}$ (W) | |
| 185 | 50 | 184.85 | 140.39 | 24.969 | 0.962 | 15.62 | 39.1500 | 547.700 | 21.540 | 86.27 |
| 200 | 50 | 199.85 | 131.37 | 24.997 | 0.952 | 16.49 | 39.1100 | 549.800 | 21.610 | 86.45 |
| 220 | 50 | 219.90 | 121.59 | 25.016 | 0.936 | 17.59 | 39.0800 | 551.000 | 21.620 | 86.42 |
| 230 | 50 | 229.85 | 117.51 | 25.020 | 0.926 | 17.91 | 39.0500 | 551.000 | 21.610 | 86.37 |
| 240 | 50 | 239.88 | 113.83 | 25.028 | 0.917 | 18.01 | 39.0300 | 551.000 | 21.590 | 86.26 |
| 265 | 50 | 264.92 | 106.00 | 24.935 | 0.888 | 18.04 | 38.9900 | 547.000 | 21.410 | 85.86 |
| 185 | 50 | 184.84 | 130.63 | 23.130 | 0.958 | 15.76 | 35.9000 | 552.000 | 19.910 | 86.08 |
| 200 | 50 | 199.85 | 122.72 | 23.227 | 0.947 | 16.46 | 35.8900 | 555.000 | 20.030 | 86.24 |
| 220 | 50 | 219.91 | 114.31 | 23.363 | 0.929 | 17.27 | 35.8900 | 558.000 | 20.150 | 86.25 |
| 230 | 50 | 229.85 | 110.76 | 23.412 | 0.920 | 17.44 | 35.8900 | 559.000 | 20.170 | 86.15 |
| 240 | 50 | 239.88 | 107.35 | 23.399 | 0.909 | 17.55 | 35.8800 | 558.000 | 20.130 | 86.03 |
| 265 | 50 | 264.92 | 100.60 | 23.399 | 0.878 | 17.49 | 35.8600 | 556.000 | 20.030 | 85.60 |
| 185 | 50 | 184.85 | 122.49 | 21.580 | 0.953 | 16.09 | 33.2300 | 555.000 | 18.570 | 86.05 |
| 200 | 50 | 199.86 | 115.48 | 21.724 | 0.941 | 16.6 | 33.2100 | 560.000 | 18.720 | 86.17 |
| 220 | 50 | 219.91 | 107.91 | 21.887 | 0.922 | 17.17 | 33.1900 | 564.000 | 18.850 | 86.12 |
| 230 | 50 | 229.85 | 104.54 | 21.898 | 0.911 | 17.31 | 33.1700 | 564.000 | 18.840 | 86.04 |
| 240 | 50 | 239.89 | 101.58 | 21.922 | 0.900 | 17.27 | 33.1400 | 565.000 | 18.830 | 85.90 |
| 265 | 50 | 264.93 | 95.77 | 21.991 | 0.867 | 17.11 | 33.1200 | 564.000 | 18.790 | 85.44 |

**Table 2 –** Test Result Summary for this Design.

### *11.1 工作模式效率*

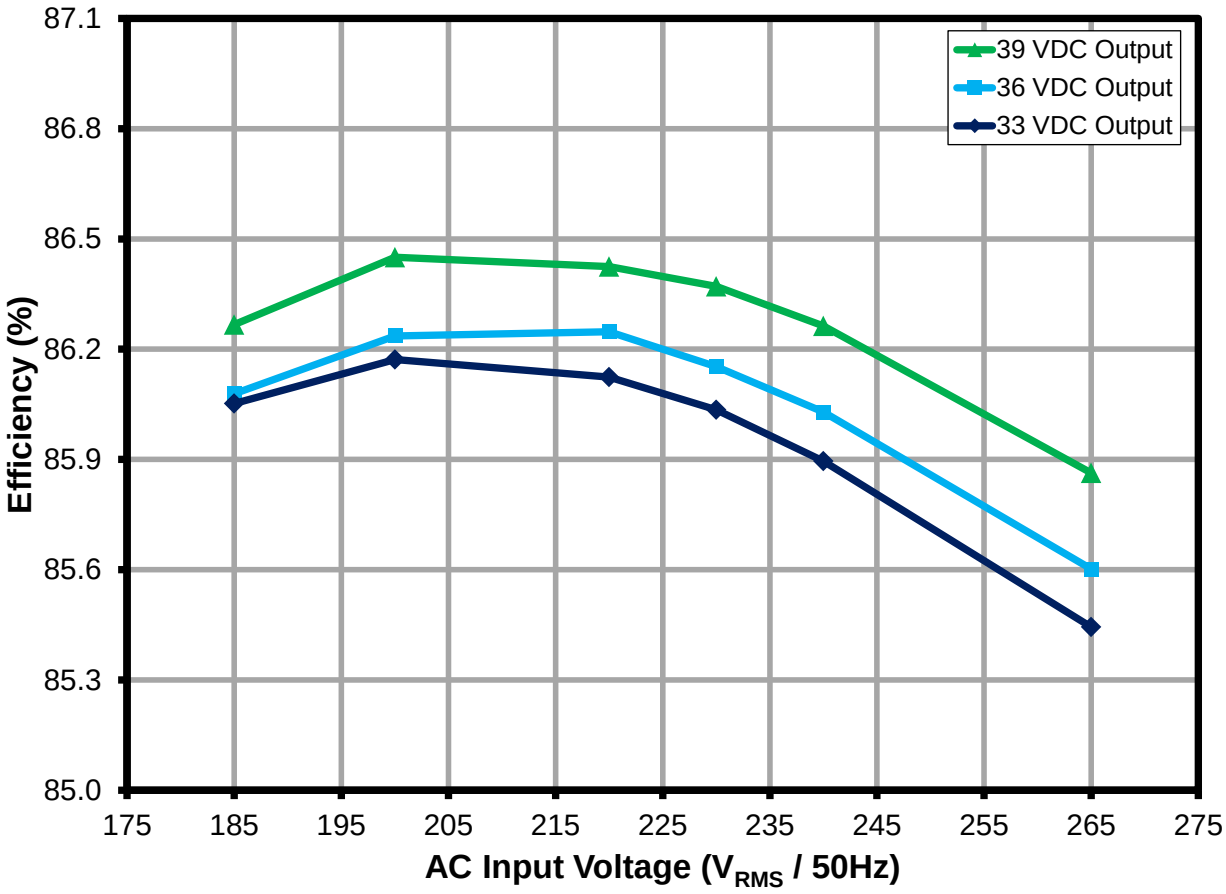


**Figure 15 –** Efficiency with Respect to AC Input Voltage.


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### *11.2 線電壓調節*

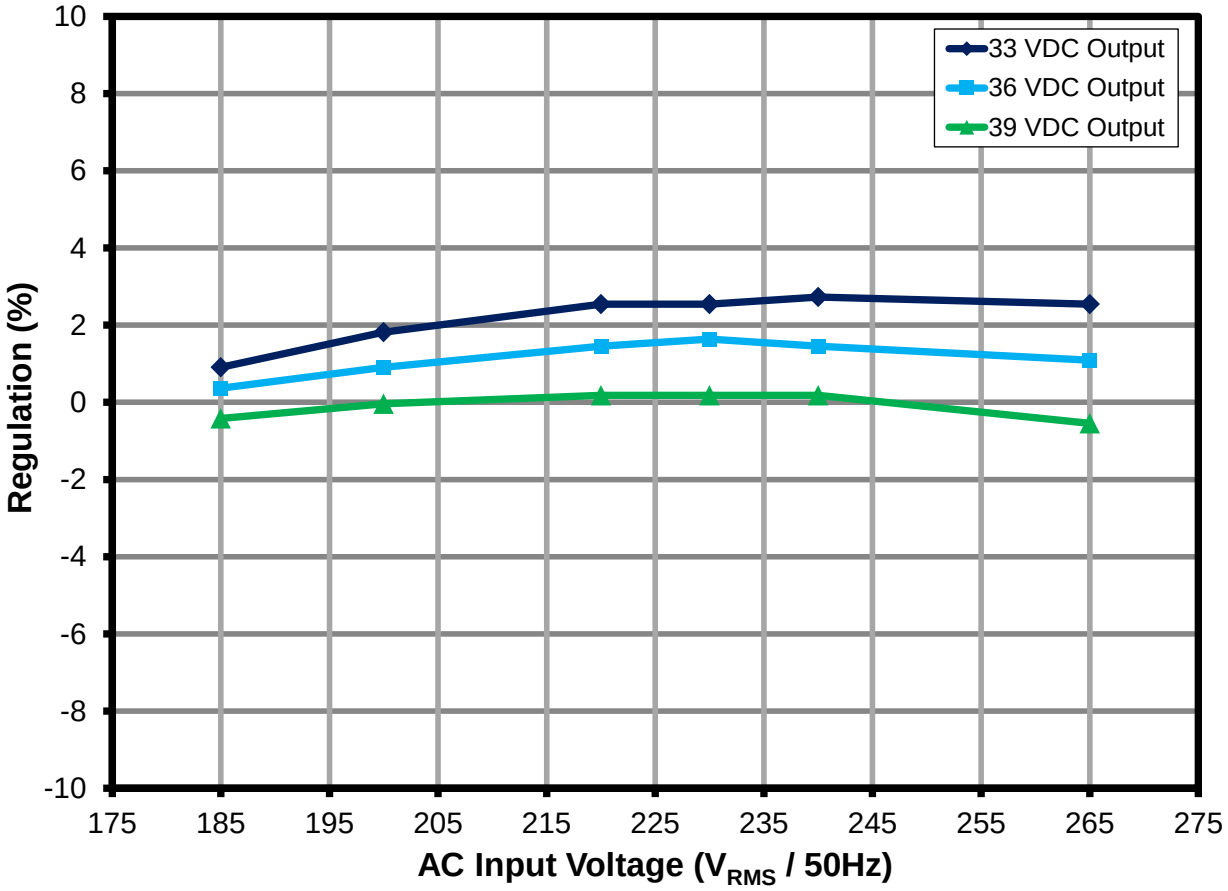


**Figure 16 –** Line Regulation, Room Temperature.

### *11.3 功率因數 (PF)*

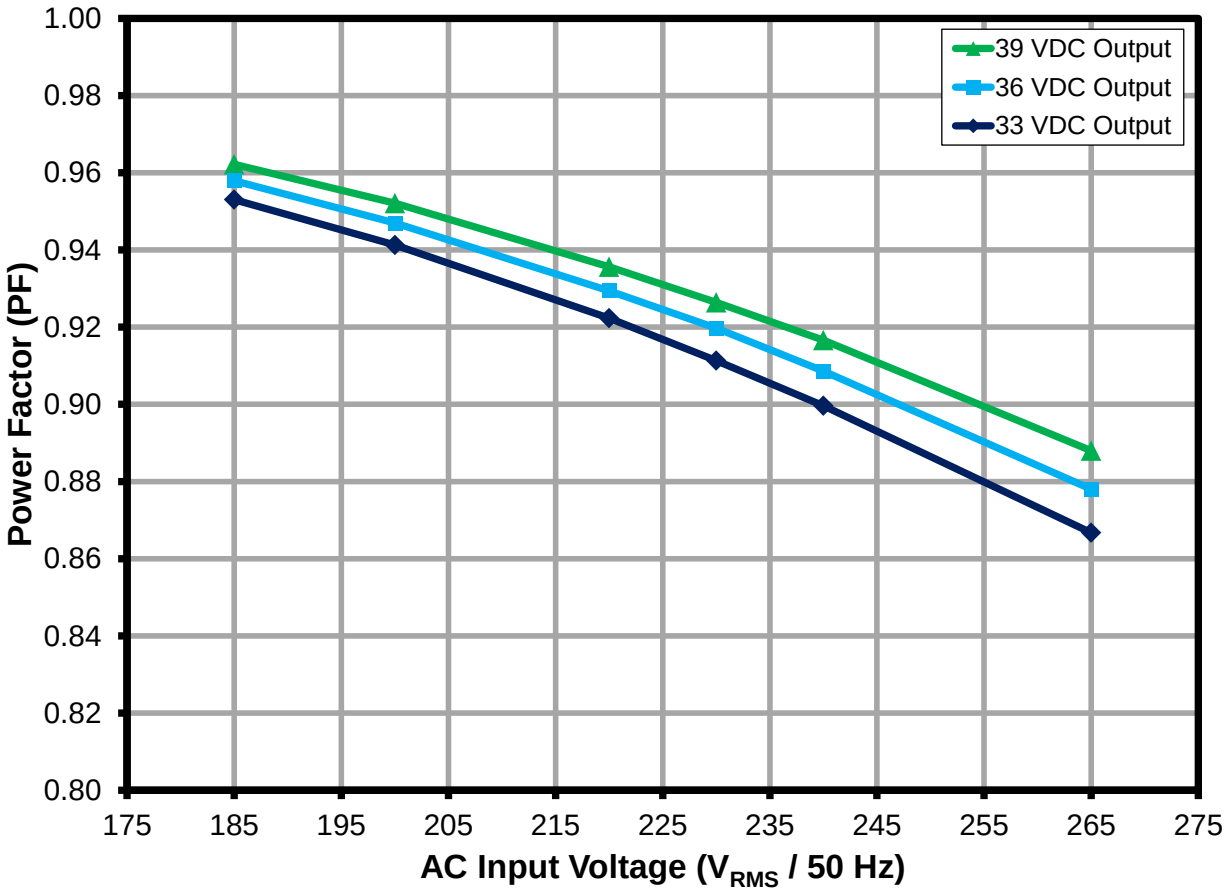


**Figure 17 –** High Power Factor within the Operating Range.


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### *11.4 總諧波失真 (THD) 百分比*

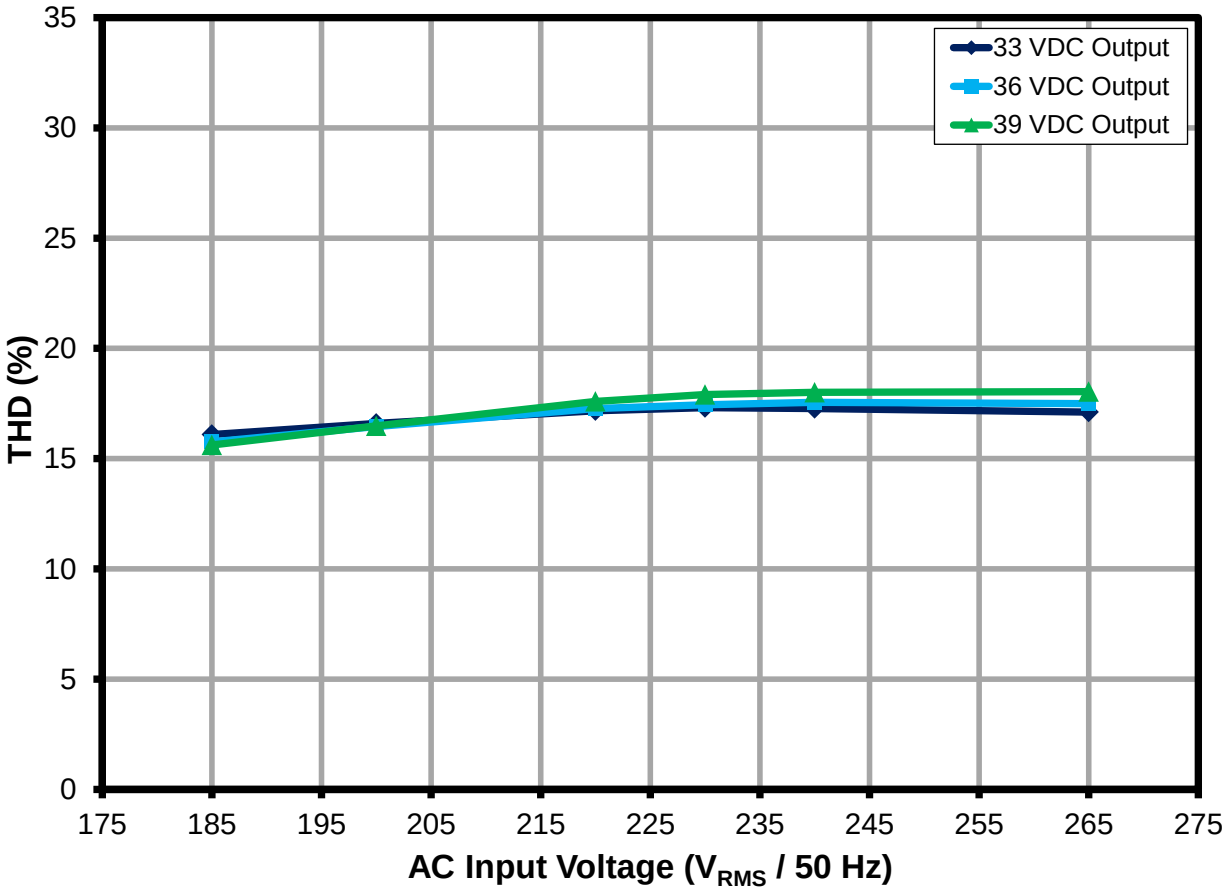


**Figure 18 –** Very Low %ATHD.

### *11.5 諧波含量*

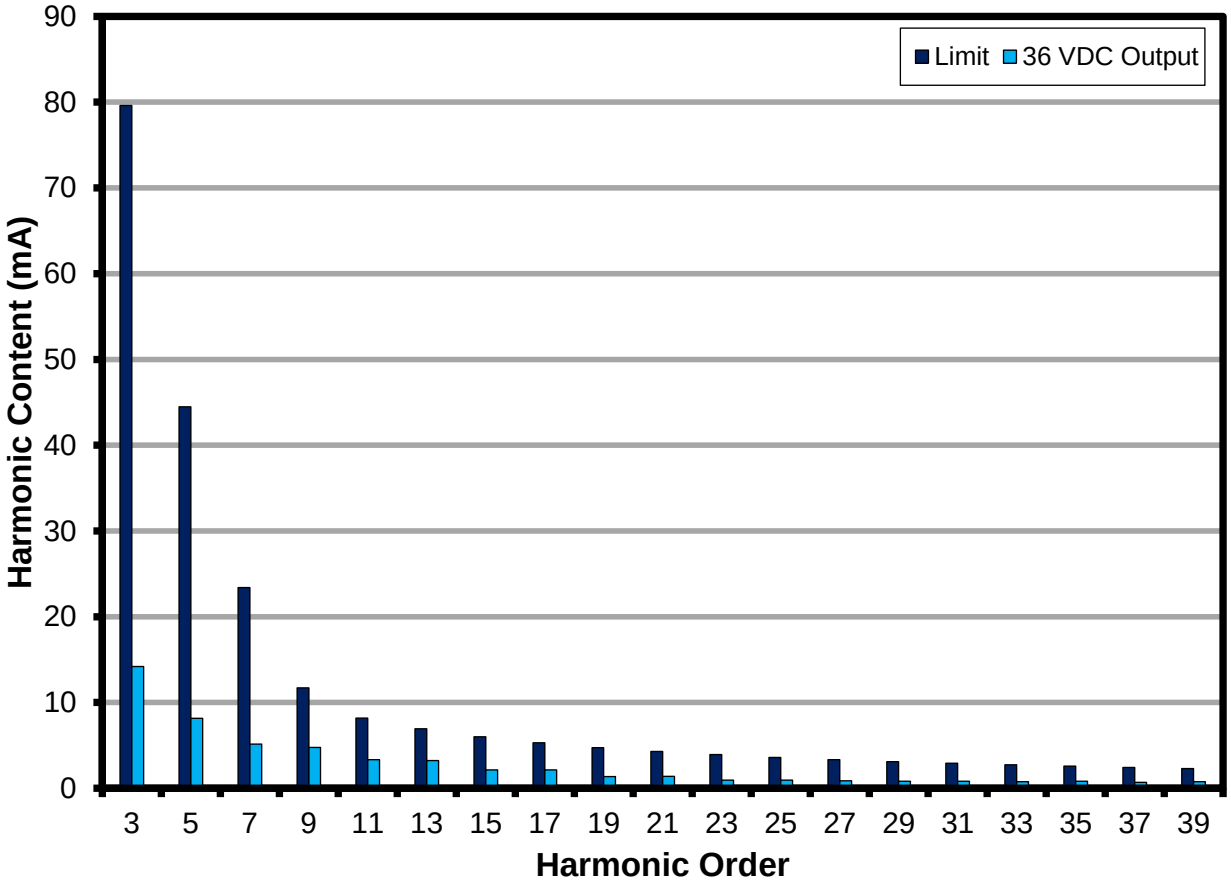


**Figure 19 –** Meets EN61000-3-2 Harmonics Contents Standards for <25 W Rating for 36 V LED Output.


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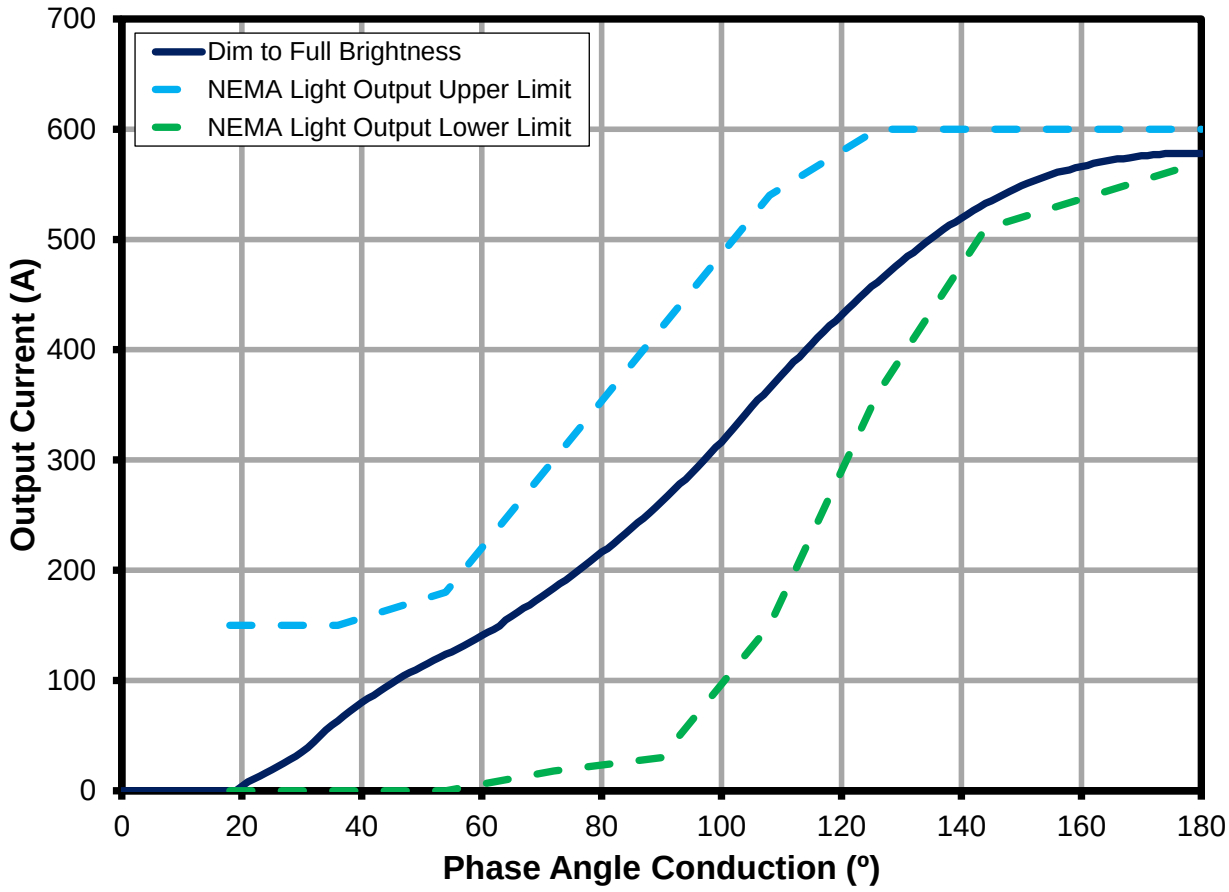
### *11.6 諧波測量*

| VAC ($V_{RMS}$) | Freq (Hz) | I (mA) | P | 功率因數 (PF) |
|---|---|---|---|---|
| 230 | 50.00 | 110.76 | 23.4120 | 0.9197 |
| **nth Order** | **mA Content** | **% Content** | **Limit (mA) <25 W** | **Remarks** |
| **1** | 109.04 | | | |
| **2** | 0.02 | 0.02% | | |
| **3** | 14.21 | 13.03% | 79.6008 | 27.59% |
| **5** | 8.15 | 7.47% | 44.4828 | 10.00% |
| **7** | 5.16 | 4.73% | 23.4120 | 7.00% |
| **9** | 4.75 | 4.36% | 11.7060 | 5.00% |
| **11** | 3.34 | 3.06% | 8.1942 | 3.00% |
| **13** | 3.24 | 2.97% | 6.9336 | 3.00% |
| **15** | 2.14 | 1.96% | 6.0091 | 3.00% |
| **17** | 2.15 | 1.97% | 5.3021 | 3.00% |
| **19** | 1.36 | 1.25% | 4.7440 | 3.00% |
| **21** | 1.39 | 1.27% | 4.2922 | 3.00% |
| **23** | 0.96 | 0.88% | 3.9190 | 3.00% |
| **25** | 0.96 | 0.88% | 3.6054 | 3.00% |
| **27** | 0.87 | 0.80% | 3.3384 | 3.00% |
| **29** | 0.81 | 0.74% | 3.1081 | 3.00% |
| **31** | 0.83 | 0.76% | 2.9076 | 3.00% |
| **33** | 0.76 | 0.70% | 2.7314 | 3.00% |
| **35** | 0.83 | 0.76% | 2.5753 | 3.00% |
| **37** | 0.70 | 0.64% | 2.4361 | 3.00% |
| **39** | 0.78 | 0.72% | 2.3112 | 3.00% |
| **41** | 0.59 | 0.54% | | |
| **43** | 0.68 | 0.62% | | |
| **45** | 0.50 | 0.46% | | |
| **47** | 0.64 | 0.59% | | |
| **49** | 0.44 | 0.40% | | |

**Table 3 –** 230 VAC Input Current Harmonic Measurement for 36 V LED.

### *11.7 調光特性*

The dimming characteristic was taken from a controlled AC supply to emulate the TRIAC conduction pattern.The reference design meets the dimming requirement as set by National Electrical Manufacturers Association (NEMA) Standards Publication SSL 1-2010 (Electronic Drivers for LED Devices, Arrays or Systems) and SSL 6-2010(Solid Light Lighting for Incandescent Replacement-Dimming).





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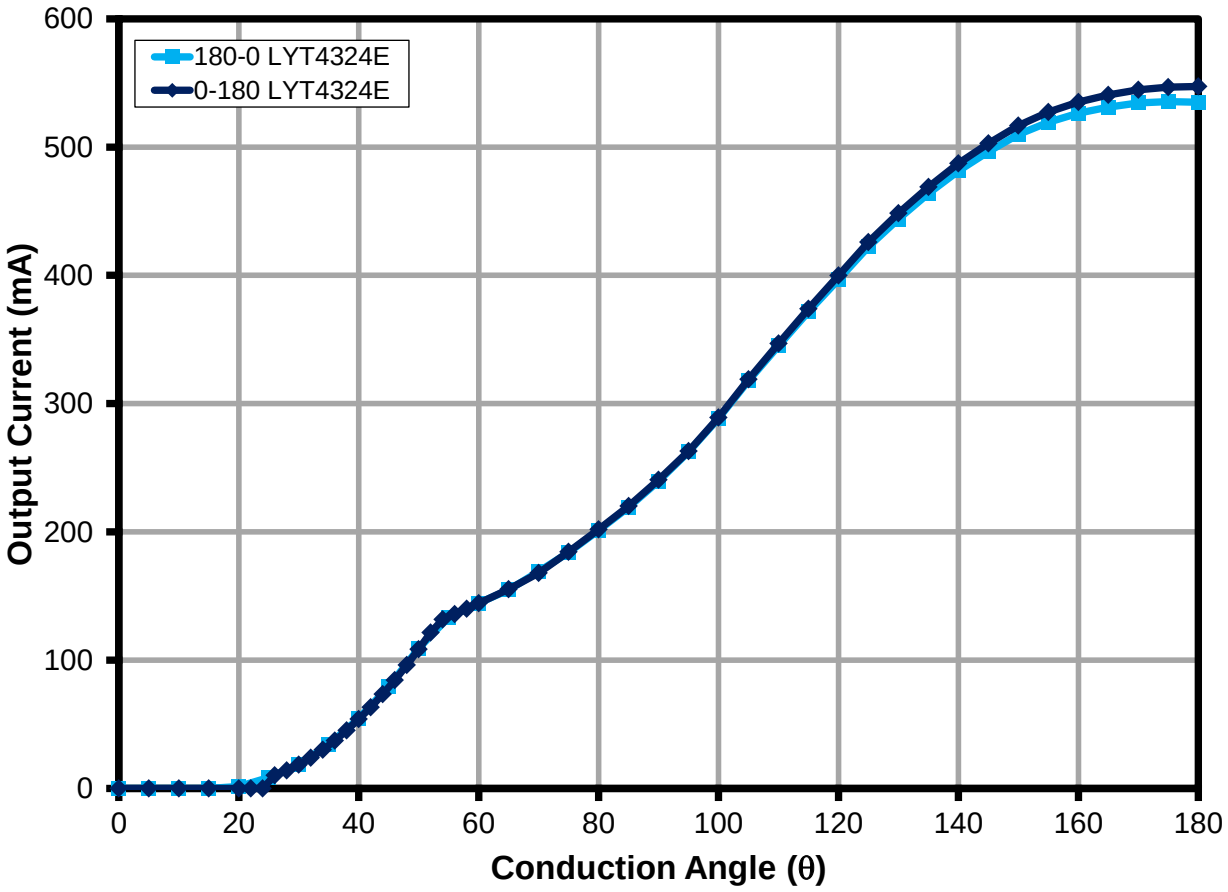


**Figure 20 –** Dimming Curve Characteristic From Full Dim to Full Brightness.Meets NEMA SSL 6-2010.

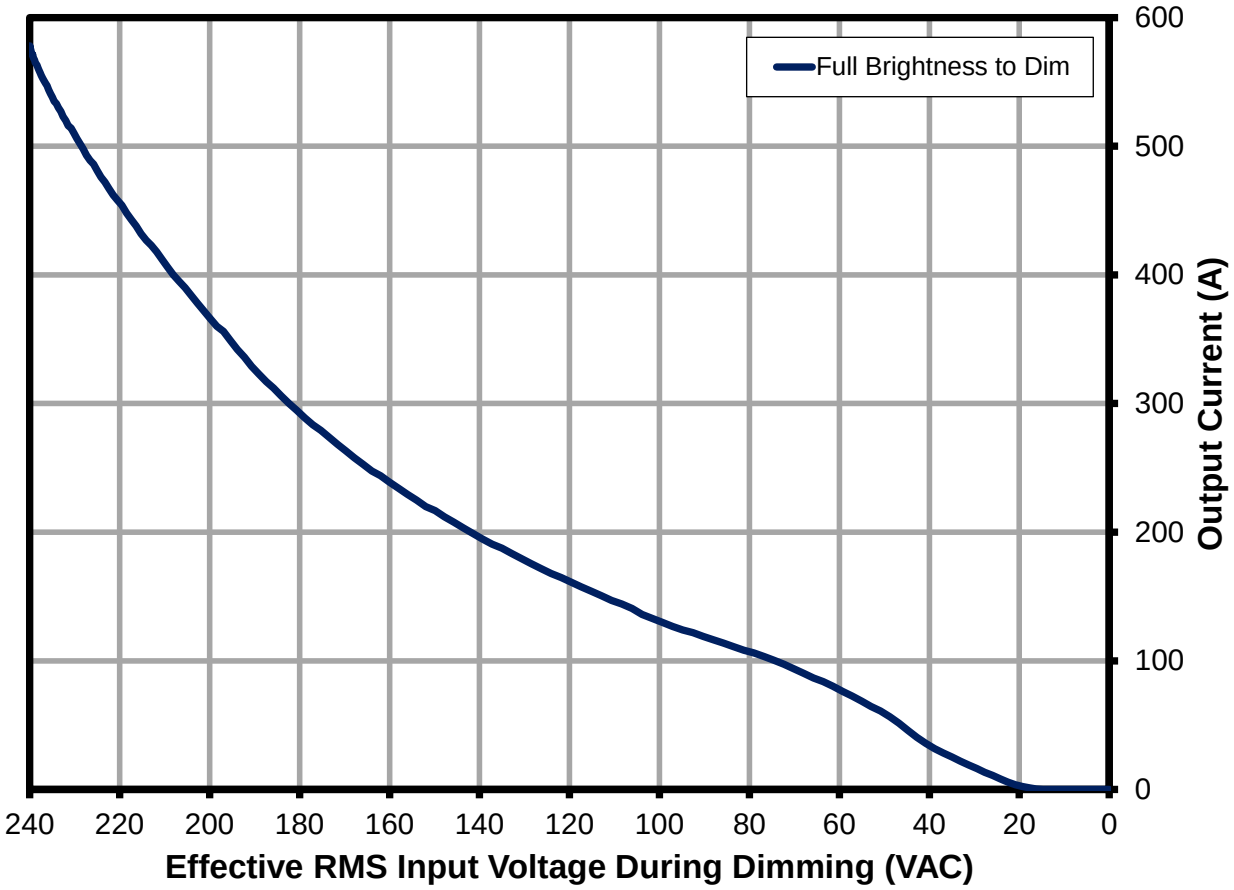


**Figure 21 –** Dimming Characteristic with Respect to RMS Input Voltage During Dimming.


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### *11.8 設備與調光器之間的相容性*

These are the list of dimmers verified for this reference design.Users are not limited on the following list.Make sure to test the dimmers according to its recommended operating line input frequency to avoid flicker.

| Dimmer Origin | 零件編號 | $I_{MIN}$ (mA) | $I_{MAX}$ (mA) | Dim Ratio |
|---|---|---|---|---|
| China | TCL 630 W | 147.4 | 556.0 | 4 |
| China | Sen Bo Lang | 189.4 | 555.0 | 3 |
| China | Eba Huang | 35.9 | 556.0 | 15 |
| China | SB elect 600 W | 1.3 | 545.5 | 420 |
| China | Myongbo | 191.4 | 558.0 | 3 |
| China | KBE 650 W | 0.6 | 555.5 | 926 |
| China | Clipmei | 147.2 | 556.0 | 4 |
| China | Mank 200 W | 202.8 | 557.0 | 3 |
| 韓國 | Anam 500 W | 191.0 | 551.0 | 3 |
| 韓國 | Shin Sung | 177.6 | 552.0 | 3 |
| 韓國 | Fantasia 500 W | 185.0 | 549.4 | 3 |
| 韓國 | Shin Sung 2 | 158.2 | 552.0 | 3 |
| 德國 | Rev 300 W | 0.1 | 537.6 | 5376 |
| 德國 | Busch 2250 600 W | 107.1 | 542.4 | 5 |
| 德國 | PEHA 400 W | 1.5 | 505.2 | 337 |
| 德國 | Merten 572499 400 W | 77.5 | 550.0 | 7 |
| 德國 | Busch 6513 420 W | 109.7 | 546.5 | 5 |
| 德國 | Berker 2875 600 W | 123.5 | 532.9 | 4 |
| 德國 | Ove | 113.4 | 503.9 | 4 |
| 德國 | Busch 691 U-101 | 106.4 | 529.2 | 5 |
| 德國 | Busch 6513 U-102 | 107.8 | 546.0 | 5 |
| 德國 | Peha 433AB | 174.1 | 534.5 | 3 |

## 12 散熱效能

The scan is conducted at ambient temperature of 25 ºC open frame, 185 VAC / 50 Hz input.


**Figure 22 –** Open Frame Thermal Scan

Legend:

Sp1 – Output Capacitor C14
Sp2 – Output Capacitor C15
Sp3 – Common Mode Inductor L2
Sp4 – Damper MOSFET Q3
Sp5 – Transformer T1.
Sp6 – Output Diode D8
Sp7 – Differential Inductor L1

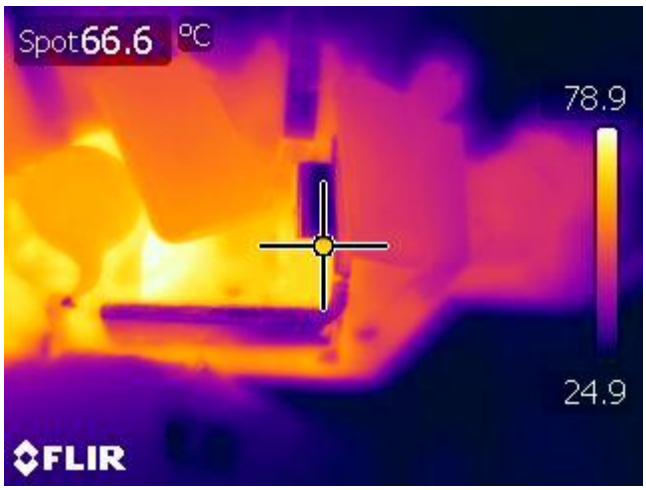


**Figure 23 –** U1 LNK4314E Device Temperature.


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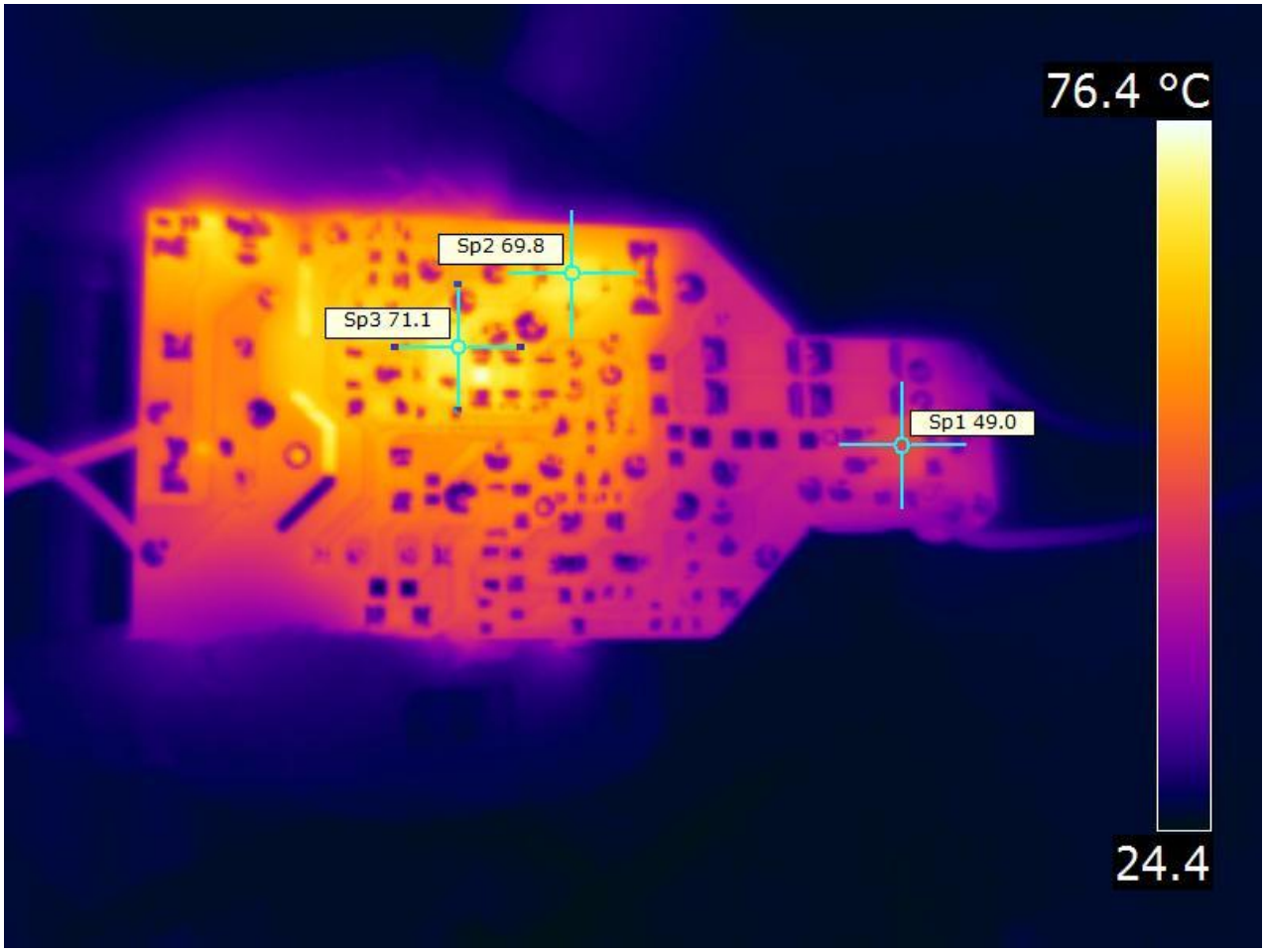


**Figure 24 –** Bottom Side Board Temperature at Open Frame.

Legend:

Sp1 – Bridge Rectifier BR1
Sp2 – Blocking Diode D4
Sp3 – Snubber Diode D3

# 13 波形

## *13.1 正常運作下的汲極電壓和電流*

No saturation in the inductor and designed guaranteed to work in continuous mode within the operating input voltage.

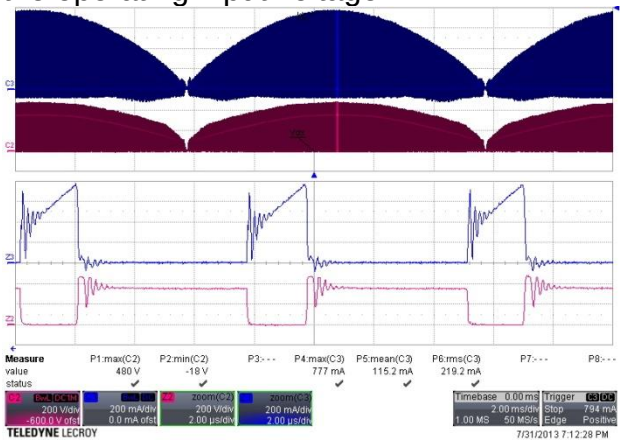


**Figure 25 –** 185 VAC / 50 Hz, 36 V LED String.
Ch2:$V_{DRAIN}$, 200 V / div.
Ch3:$I_{DRAIN}$, 0.2 A / div.
Time Scale:2 ms / div.
Zoom Time Scale:2 μs / div.

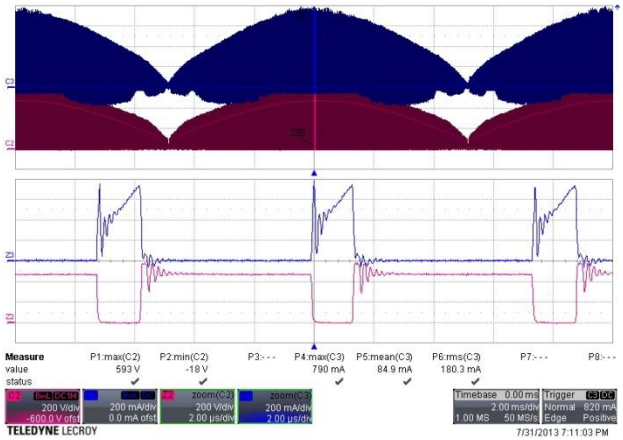


**Figure 26 –** 265 VAC / 50 Hz, 36 V LED String.
Ch2:$V_{DRAIN}$, 200 V / div.
Ch3:$I_{DRAIN}$, 0.2 A / div.
Time Scale:2 ms / div.
Zoom Time Scale:2 μs / div.

## *13.2 汲極電壓和電流啓動分析*

Device has a built in soft start thereby reducing the stress in the device, transformer and output diode .

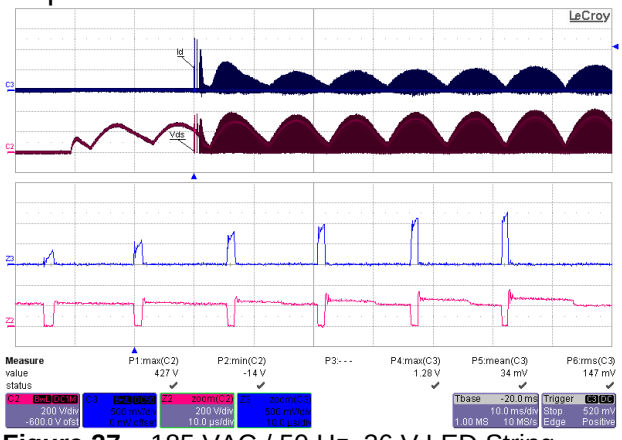


**Figure 27 –** 185 VAC / 50 Hz, 36 V LED String.
Ch2:$V_{DRAIN}$, 200 V / div.
Ch4:$I_{DRAIN}$, 0.2 A / div.
Time Scale:10 ms / div.
Zoom Time Scale:10 μs / div.

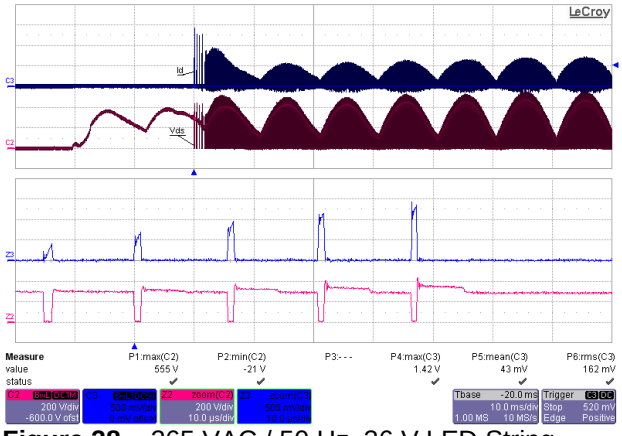


**Figure 28 –** 265 VAC / 50 Hz, 36 V LED String.
Ch2:$V_{DRAIN}$, 200 V / div.
Ch4:$I_{DRAIN}$, 0.2 A / div.
Time Scale:10 ms / div.
Zoom Time Scale:10 μs / div.


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### *13.3 輸出電壓啓動分析*

Start-up time <250 ms; the reference design will emit light within 250 ms at non-dimming operation.

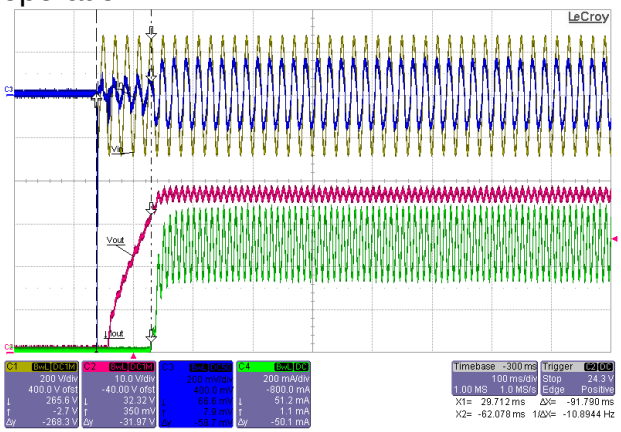


**Figure 29 –** 185 VAC / 50 Hz, 36 V LED
Ch1:$V_{IN}$, 200 V / div.
Ch2:$V_{OUT}$, 10 V / div.
Ch3:$I_{IN}$, 200 mA / div.
Ch4:$I_{OUT}$, 200 mA / div., 100 ms / div.

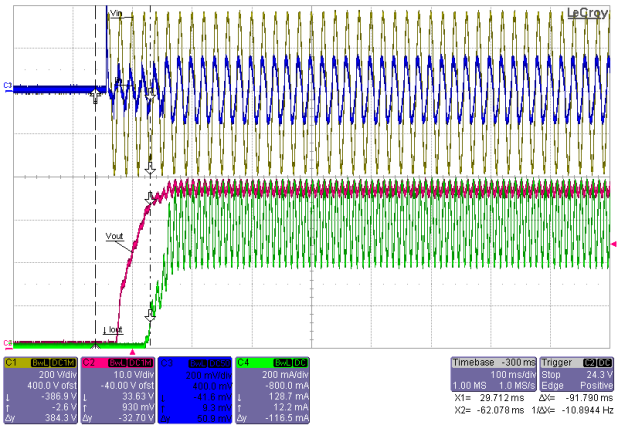


**Figure 30 –** 265 VAC / 50 Hz, 36 V LED
Ch1:$V_{IN}$, 200 V / div.
Ch2:$V_{OUT}$, 10 V / div.
Ch3:$I_{IN}$, 200 mA / div.
Ch4:$I_{OUT}$, 200 mA / div., 100 ms / div.

### *13.4 輸入和輸出電壓與電流分析*

Output current ripple is inversely proportional to the impedance of the LED.Verify the actual current ripple on the actual LED to be used in the system.Increase output capacitance for lesser output current ripple is intended.

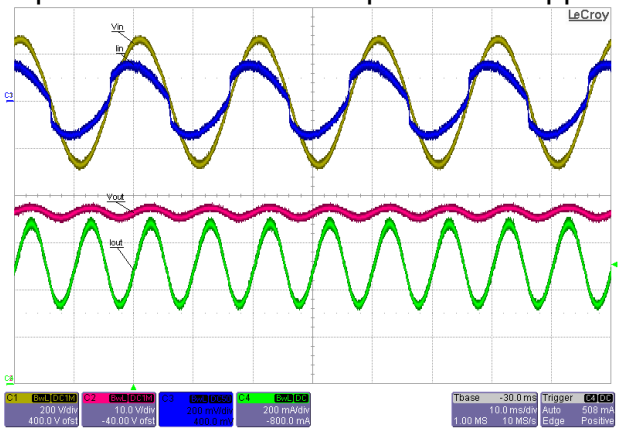


**Figure 31 –** 185 VAC / 50 Hz, 36 V LED String.
Ch1:$V_{IN}$, 200 V / div.
Ch2:$V_{OUT}$, 10 V / div.
Ch3:$I_{IN}$, 200 mA / div.
Ch4:$I_{OUT}$, 200 mA / div., 10 ms / div.

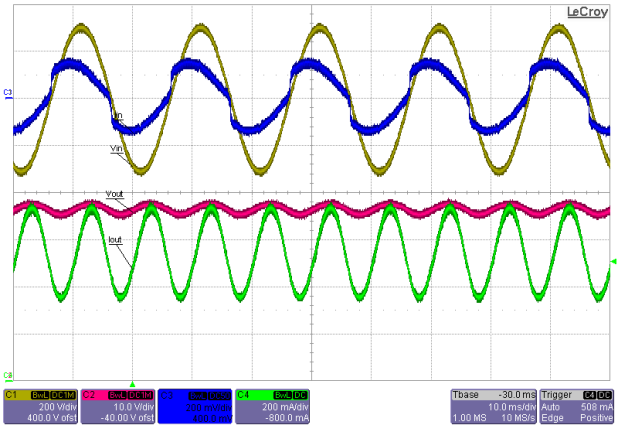


**Figure 32 –** 220 VAC / 50 Hz, 36 V LED String.Ch1:$V_{IN}$, 200 V / div.
Ch2:$V_{OUT}$, 10 V / div.
Ch3:$I_{IN}$, 200 mA / div.
Ch4:$I_{OUT}$, 200 mA / div., 10 ms / div.

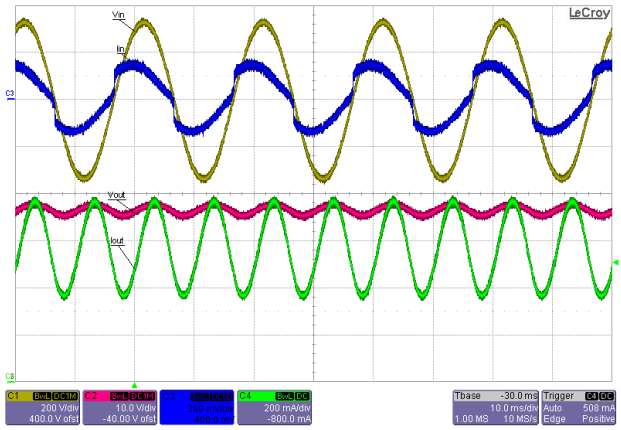


**Figure 33 –** 240 VAC / 50 Hz, 36 V LED String.
Ch1:$V_{IN}$, 200 V / div.
Ch2:$V_{OUT}$, 10 V / div.
Ch3:$I_{IN}$, 200 mA / div.
Ch4:$I_{OUT}$, 200 mA / div., 10 ms / div.

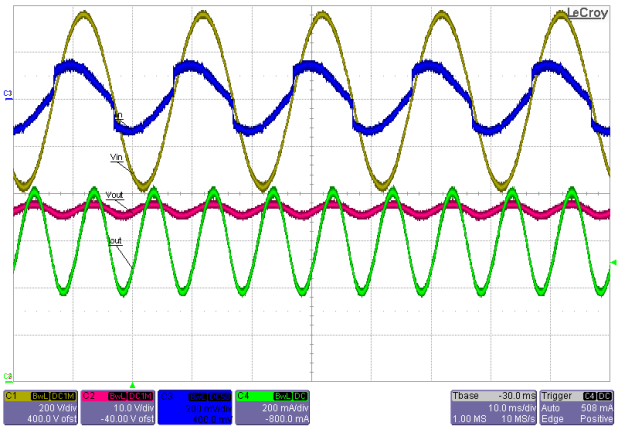


**Figure 34 –** 265 VAC / 50 Hz, 36 V LED String.
Ch1:$V_{IN}$, 200 V / div.
Ch2:$V_{OUT}$, 10 V / div.
Ch3:$I_{IN}$, 200 mA / div.
Ch4:$I_{OUT}$, 200 mA / div., 10 ms / div.

## *13.5 汲極電壓和電流分析：正常運作到輸出短路*

No saturation in the inductor during short-circuit, inductor current is limited by the $I_{LIM}$.

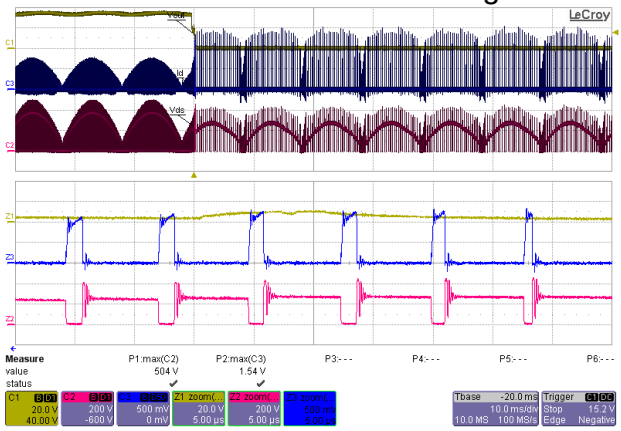


**Figure 35 –** 185 VAC / 50 Hz, Normal Operation then Output Short.
Ch1:$V_{OUT}$, 20 V / div.
Ch2:$V_{DS}$, 200 V / div.
Ch4:$I_{DRAIN}$, 0.5 A / div., 10 ms / div.
Z3:$I_{DRAIN}$, 0.2 A / div., 5 µs / div.

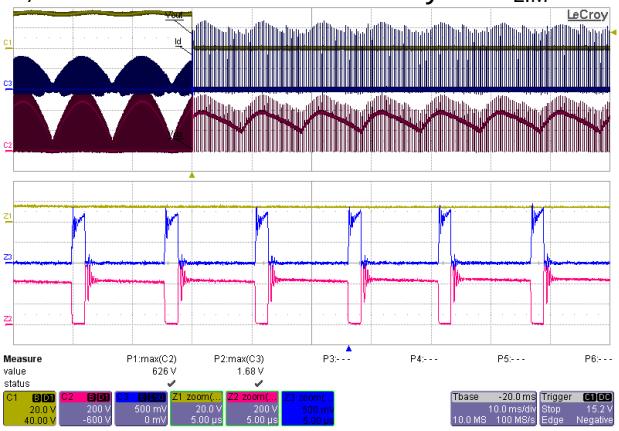


**Figure 36 –** 265 VAC / 50 Hz, Normal Operation then Output Short.
Ch1:$V_{OUT}$, 20 V / div.
Ch2:$V_{DS}$, 200 V / div.
Ch4:$I_{DRAIN}$, 0.5 A / div., 10 ms / div.
Z3:$I_{DRAIN}$, 0.2 A / div., 5 µs / div.


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## *13.6 汲極電壓和電流分析：啓動但發生輸出短路*

No saturation in the inductor during start-up short-circuit due to the built-in soft-start.

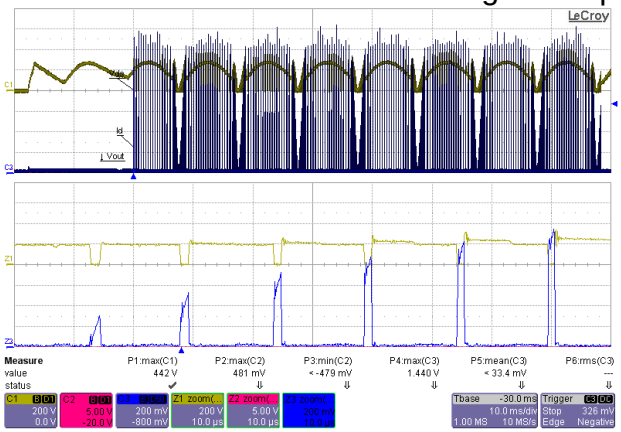


**Figure 37 –** 185 VAC / 50 Hz, Output Shorted.
Ch1:$V_{DS}$, 20 V / div.
Ch3:$I_{DRAIN}$, 0.2 A / div., 10 ms / div.
Z3:$I_{DRAIN}$, 0.2 A / div., 10 µs / div.

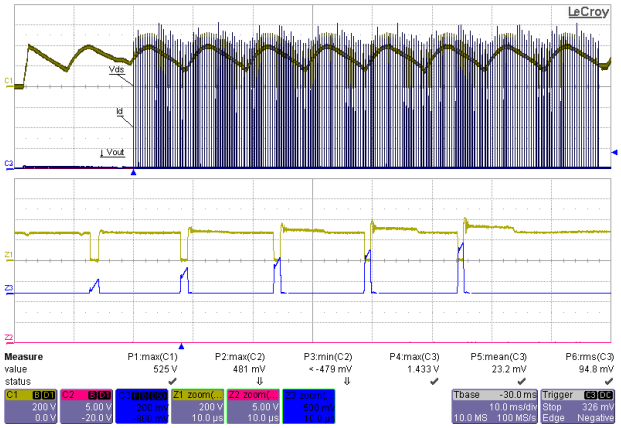


**Figure 38 –** 265 VAC / 50 Hz, Output Shorted.
Ch1:$V_{DS}$, 20 V / div.
Ch3:$I_{DRAIN}$, 0.2 A / div., 10 ms / div.
Z3:$I_{DRAIN}$, 0.2 A / div., 10 µs / div..

## *13.7 無負載運作*

The driver is protected during no-load operation, U1 operating is cycle skipping mode.

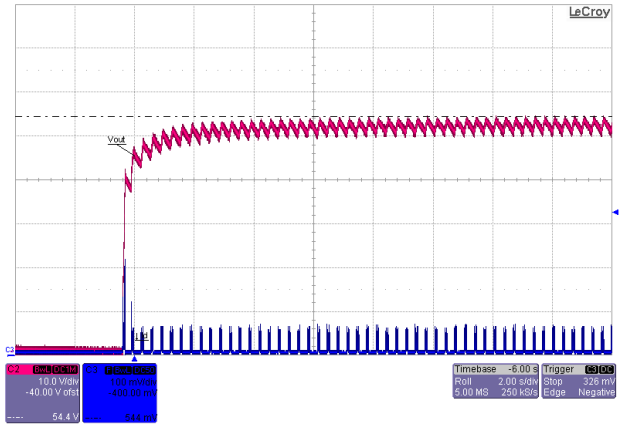


**Figure 39 –** 185 VAC / 50 Hz, Start-up No-load.
Ch2:$V_{OUT}$, 10 V / div.
Ch3:$I_{DS}$, 0.1 A / div.
Time Scale:2 s / div.

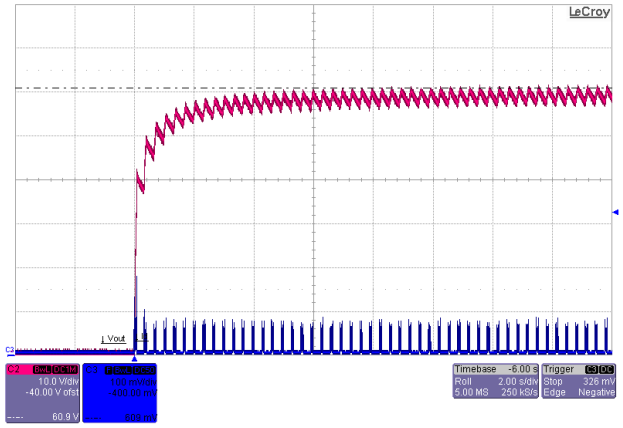


**Figure 40 –** 265 VAC / 50 Hz, Start-up No-load.
Ch2:$V_{OUT}$, 10 V / div.
Ch3:$I_{DS}$, 0.1 A / div.
Time Scale:2 s / div.

### *13.8 AC 週期*

The reference design has no perceptible delay.

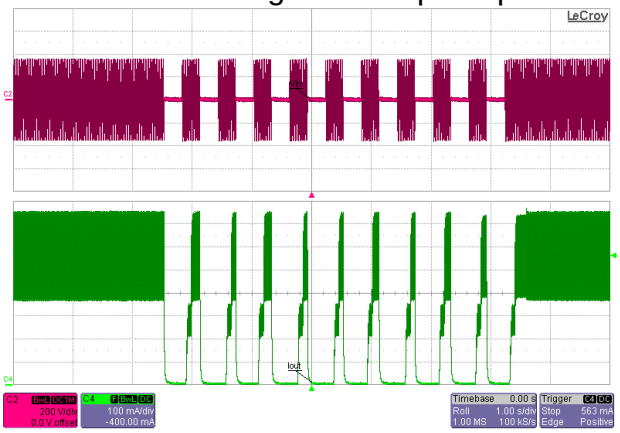


**Figure 41 –** 240 VAC / 50 Hz,
300 ms On – 300 ms Off.
Load:36 V LED String.
Ch1:$V_{IN}$, 200 V / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:1 s / div.

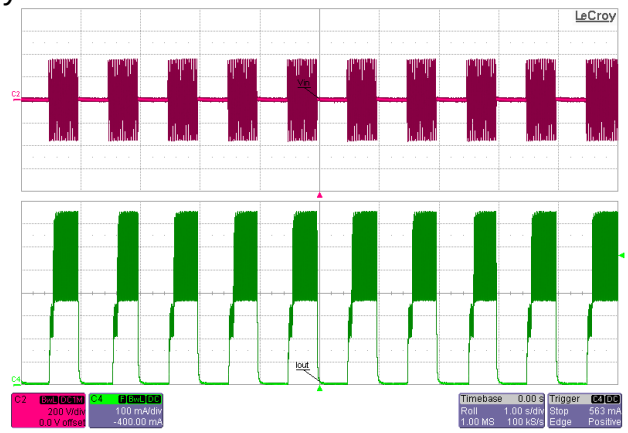


**Figure 42 –** 240 VAC / 50 Hz,
500 ms On – 500 ms Off.
Load:36 V LED String.
Ch1:$V_{IN}$, 200 V / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:1 s / div.

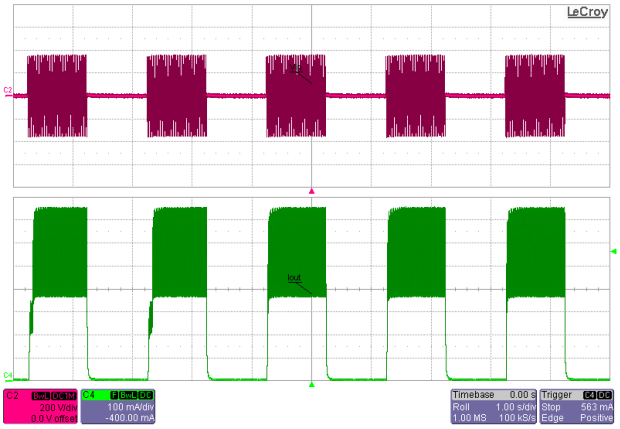


**Figure 43 –** 240 VAC / 50 Hz,
1s On – 1s Off.
Load:36 V LED String.
Ch1:$V_{IN}$, 200 V / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:1 s / div.

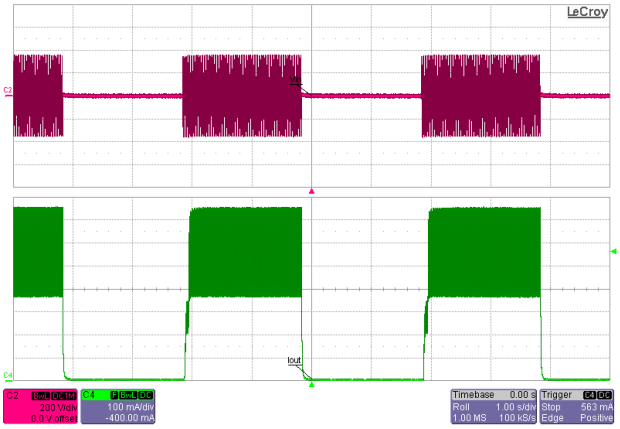


**Figure 44 –** 240 VAC / 50 Hz,
2s On – 2s Off.
Load:36 V LED String.
Ch1:$V_{IN}$, 200 V / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:1 s / div.


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## *13.9 調光波形*

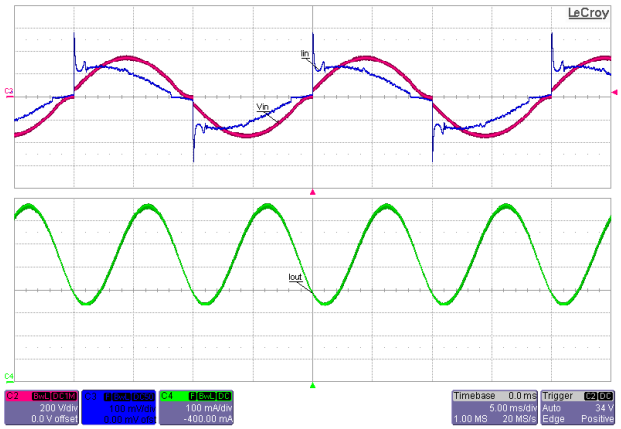


**Figure 45 –** 240 VAC / 50 Hz, (China) TCL 630 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

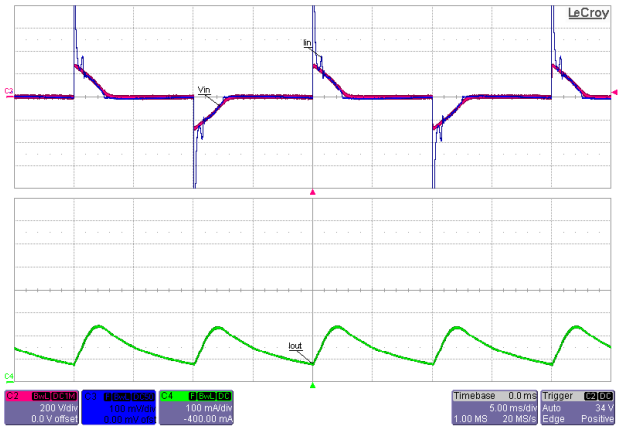


**Figure 46 –** 240 VAC / 50 Hz, (China) TCL 630 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

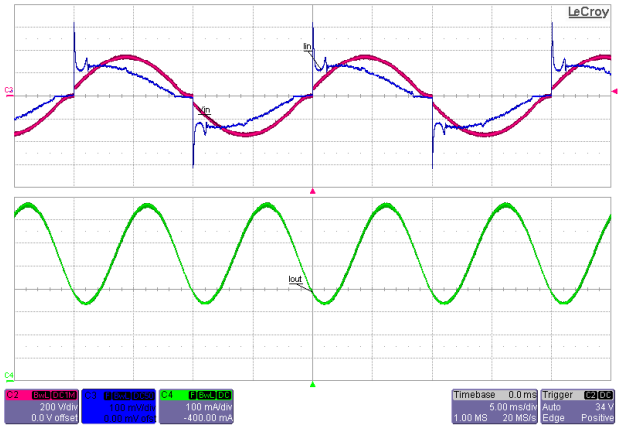


**Figure 47 –** 240 VAC / 50 Hz, (China) Sen Bo Lang 300 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

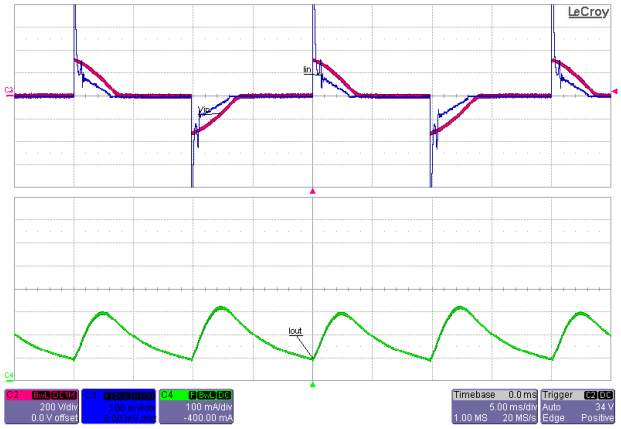


**Figure 48 –** 240 VAC / 50 Hz, (China) Sen Bo Lang 300 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

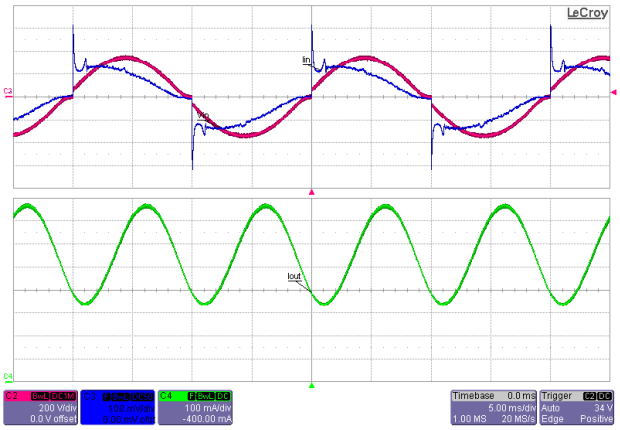


**Figure 49 –** 240 VAC / 50 Hz, (China) Eba Huang Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

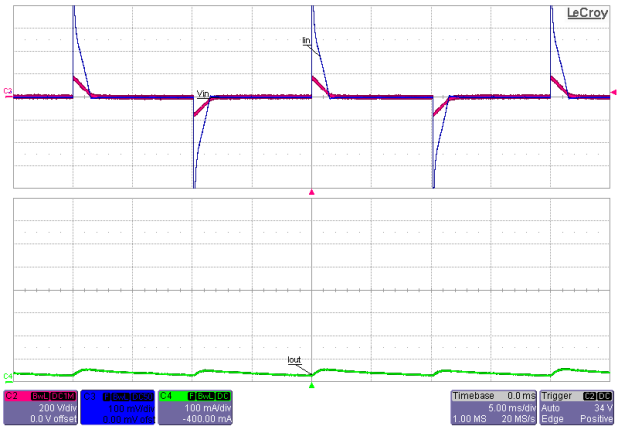


**Figure 50 –** 240 VAC / 50 Hz, (China) Eba Huang Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

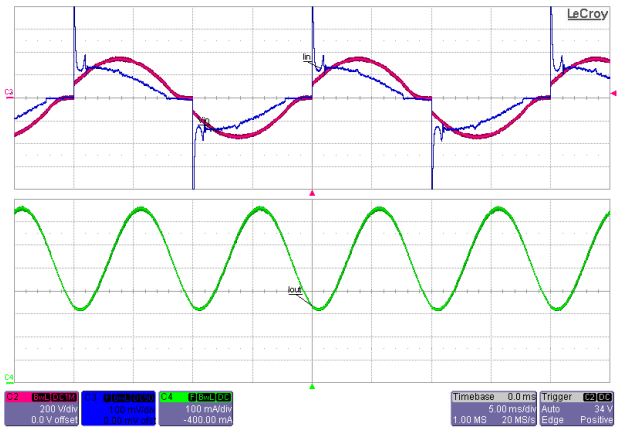


**Figure 51 –** 240 VAC / 50 Hz, (China) SB elect 600 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

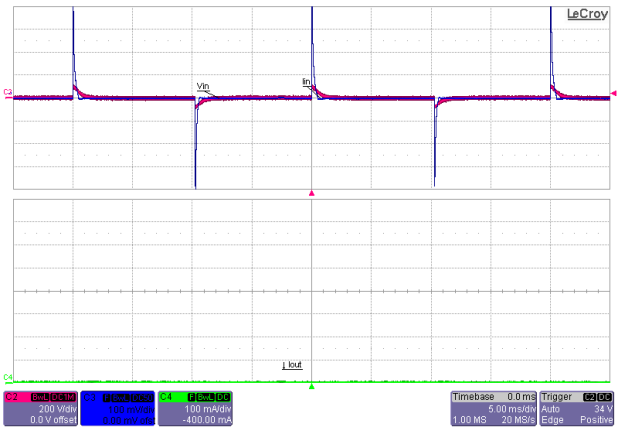


**Figure 52 –** 240 VAC / 50 Hz, (China) SB elect 600 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.


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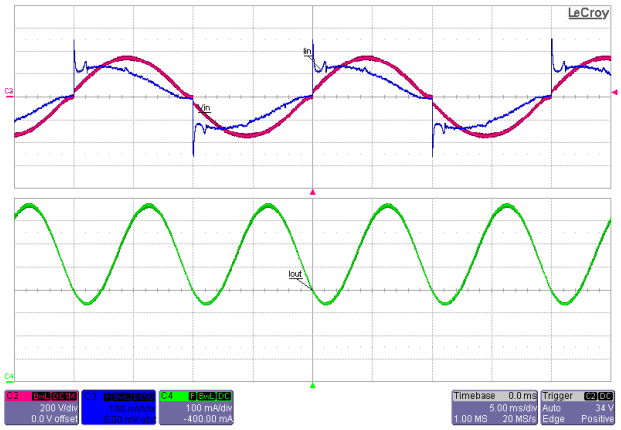


**Figure 53 –** 240 VAC / 50 Hz, (China) Myongbo Dimmer at Full TRIAC conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

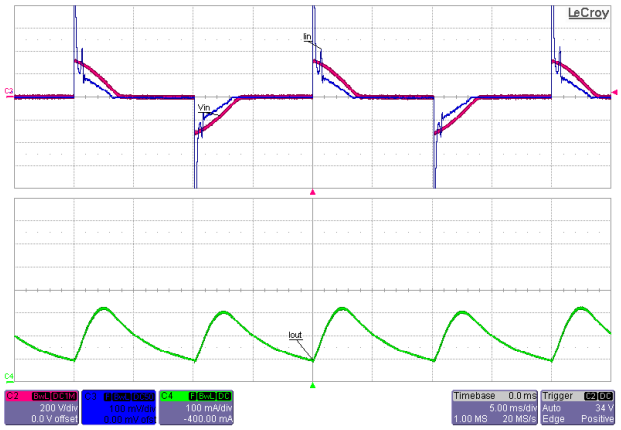


**Figure 54 –** 240 VAC / 50 Hz, (China) Myongbo Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

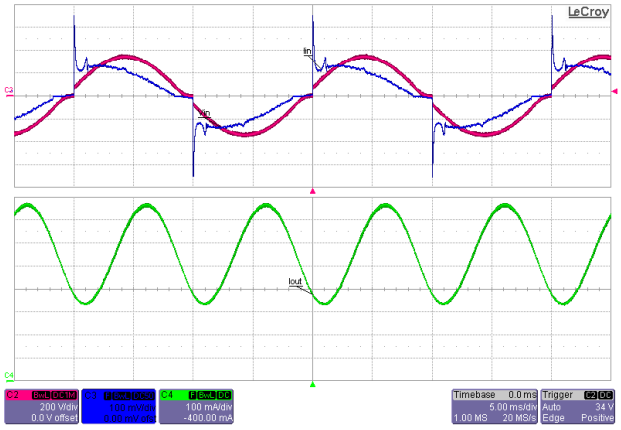


**Figure 55 –** 240 VAC / 50 Hz, (China) KBE, 650 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

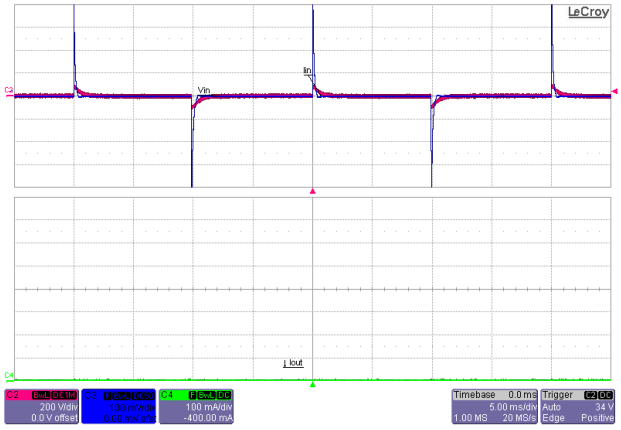


**Figure 56 –** 240 VAC / 50 Hz, (China) KBE, 650 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

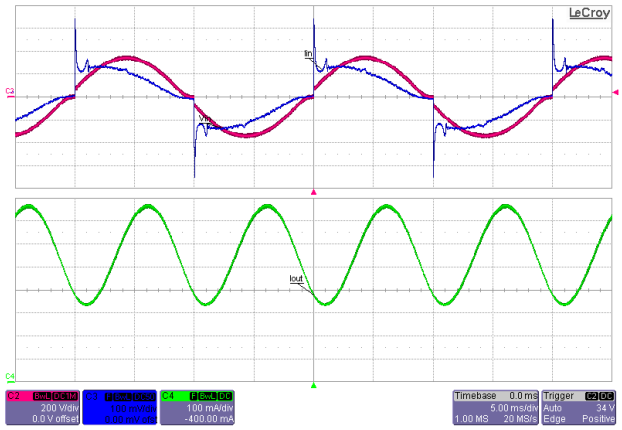


**Figure 57 –** 240 VAC / 50 Hz, (China) Clipmei Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

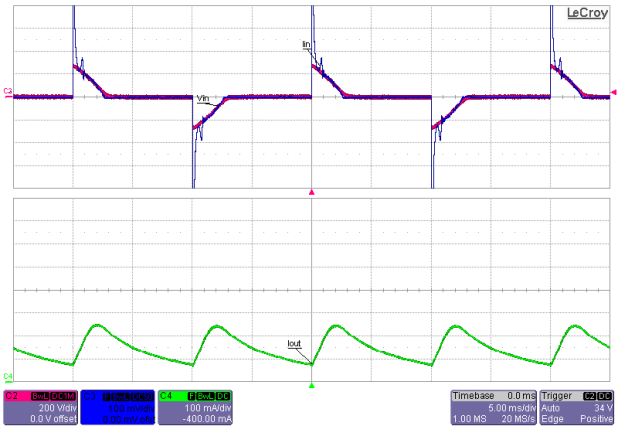


**Figure 58 –** 240 VAC / 50 Hz, (China) Clipmei Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

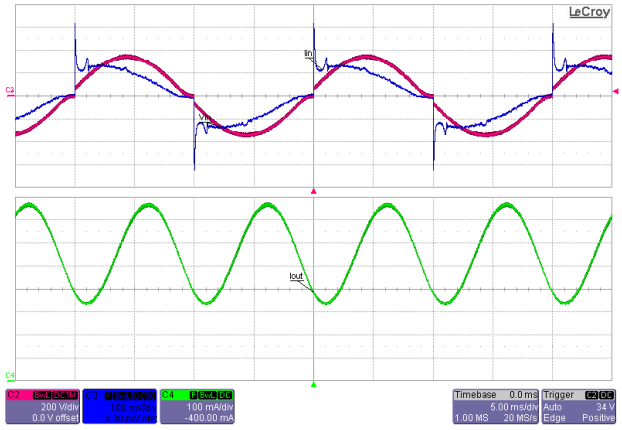


**Figure 59 –** 240 VAC / 50 Hz, (China) Mank 200 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

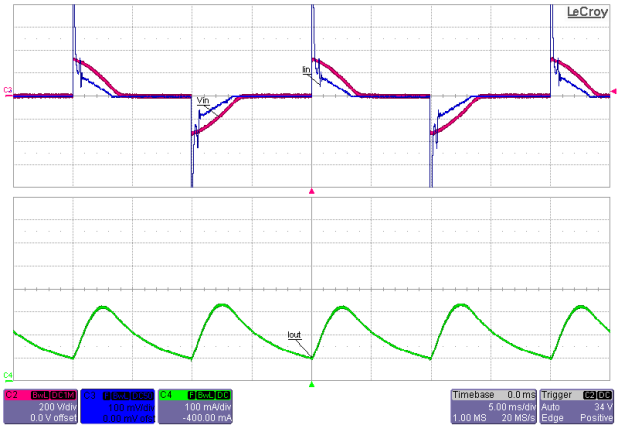


**Figure 60 –** 240 VAC / 50 Hz, (China) Mank 200 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.


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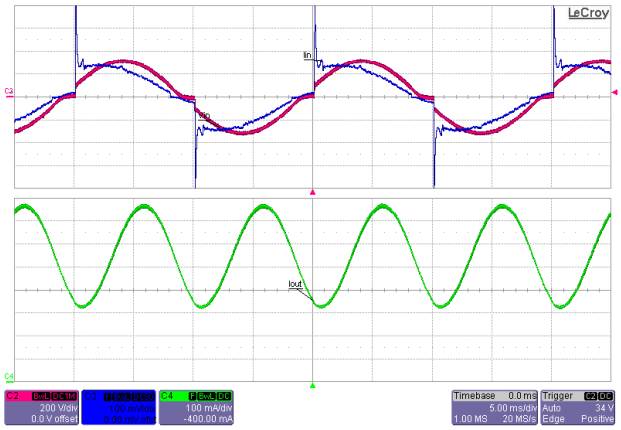


**Figure 61 –** 240 VAC / 50 Hz, (Korea) Anam, 500 W Dimmer at full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

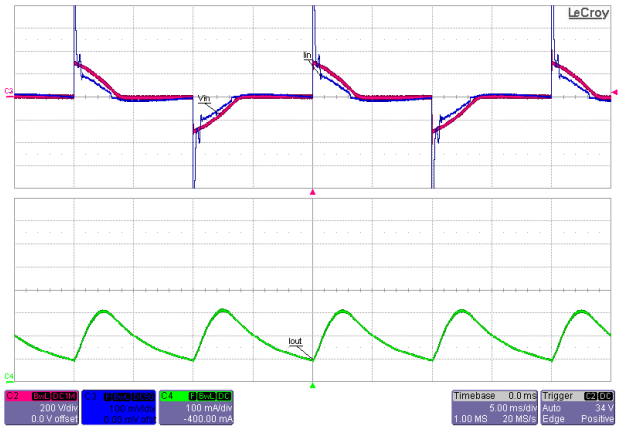


**Figure 62 –** 240 VAC / 50 Hz, (Korea) Anam, 500 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

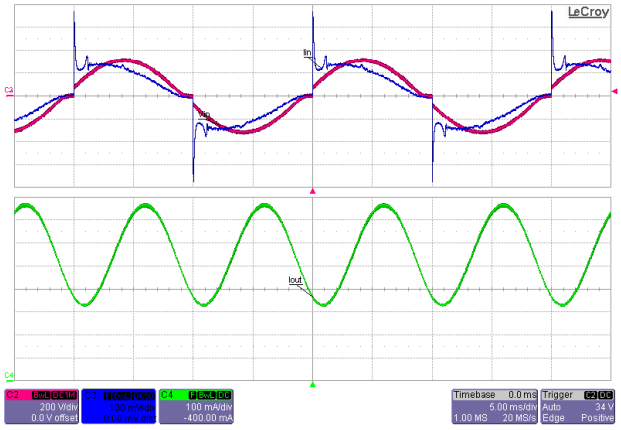


**Figure 63 –** 240 VAC / 50 Hz, (Korea) Shin Sung Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

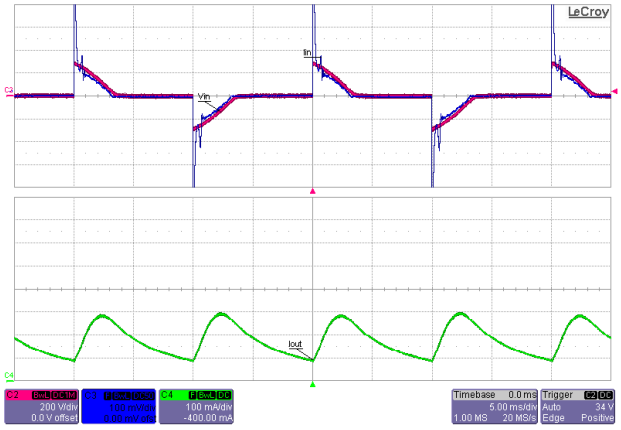


**Figure 64 –** 240 VAC / 50 Hz, (Korea) Shin Sung Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

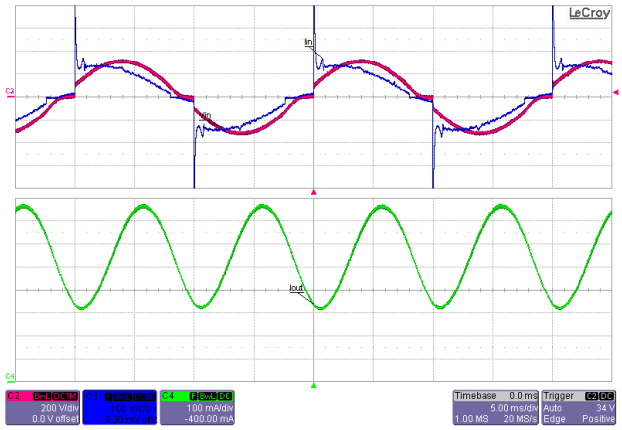


**Figure 65 –** 240 VAC / 50 Hz, (Korea) Fantasia 500 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

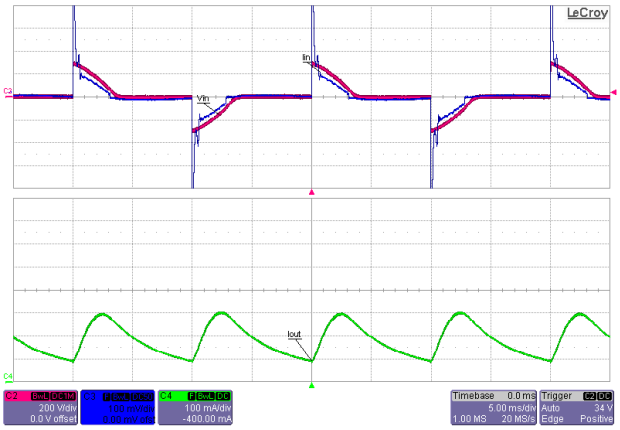


**Figure 66 –** 240 VAC / 50 Hz, (Korea) Fantasia 500 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

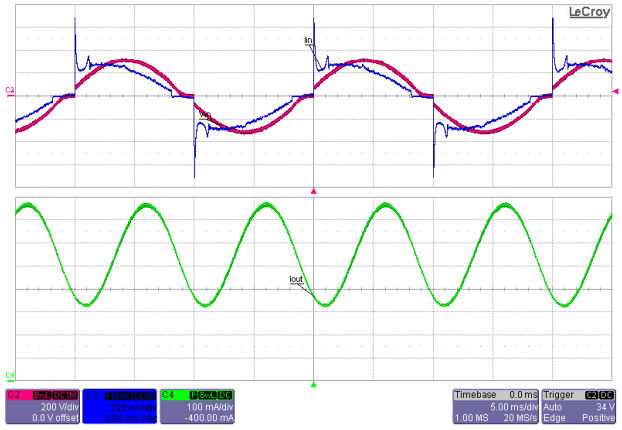


**Figure 67 –** 240 VAC / 50 Hz, (Korea) Shin Sung 2 Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

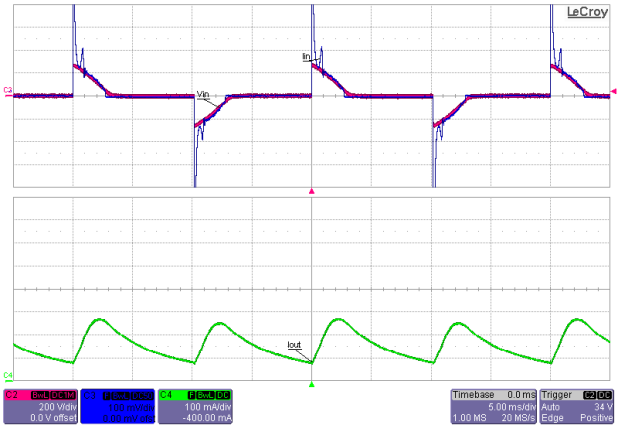


**Figure 68 –** 240 VAC / 50 Hz, (Korea) Shin Sung 2 Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.


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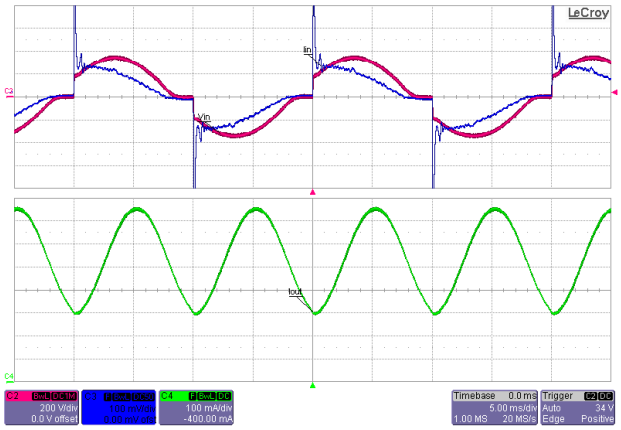


**Figure 69 –** 240 VAC / 50 Hz, (Germany) Rev 300 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

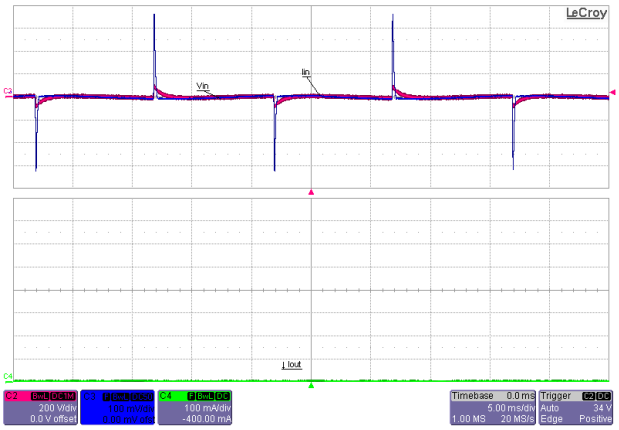


**Figure 70 –** 240 VAC / 50 Hz, (Germany) Rev 300 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

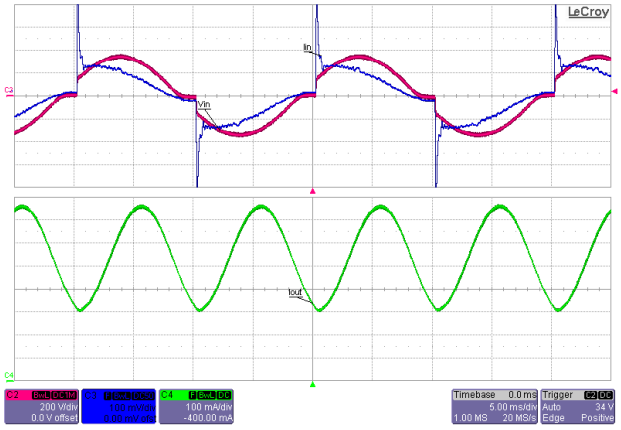


**Figure 71 –** 240 VAC / 50 Hz, (Germany) Busch 2250 600 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

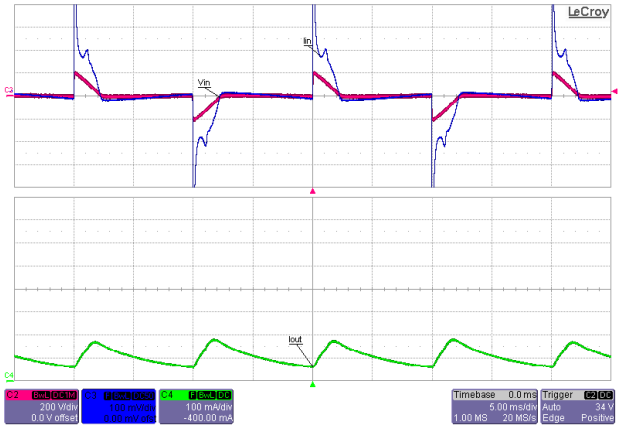


**Figure 72 –** 240 VAC / 50 Hz, (Germany) Busch 2250 600 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

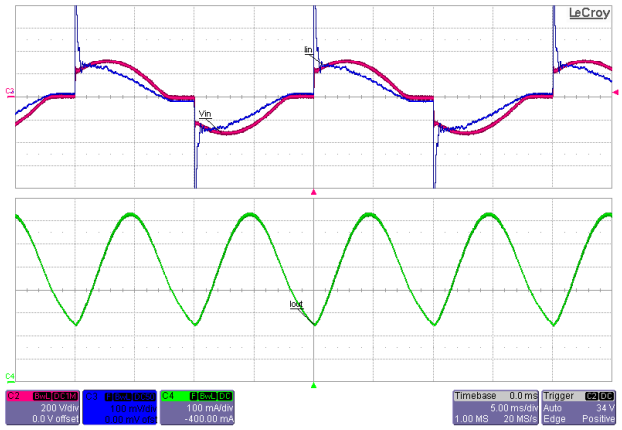


**Figure 73 –** 240 VAC / 50 Hz, (Germany) PEHA 400 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

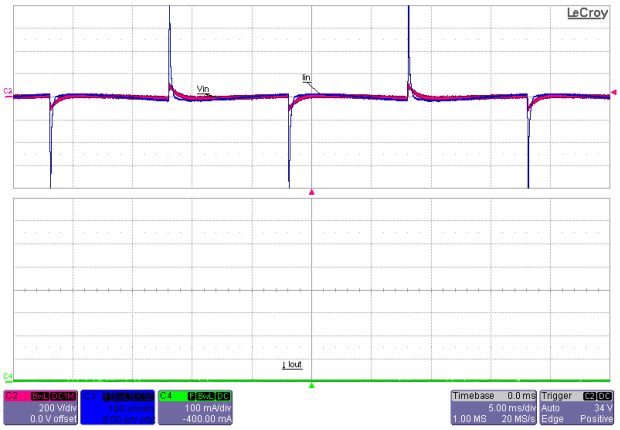


**Figure 74 –** 240 VAC / 50 Hz, (Germany) PEHA 400 W Dimmer at Minimum TRIAC conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

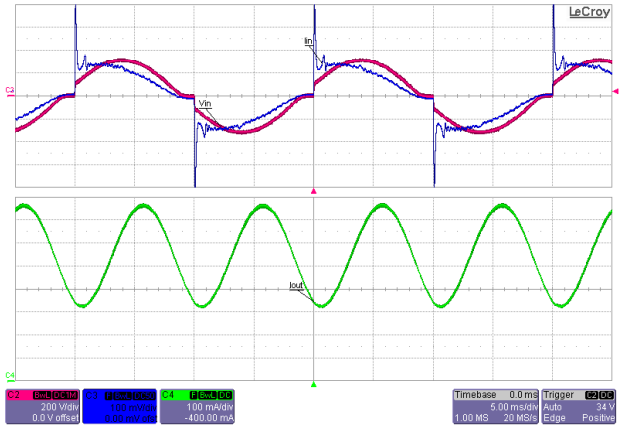


**Figure 75 –** 240 VAC / 50 Hz, (Germany) Merten 572499, 400 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

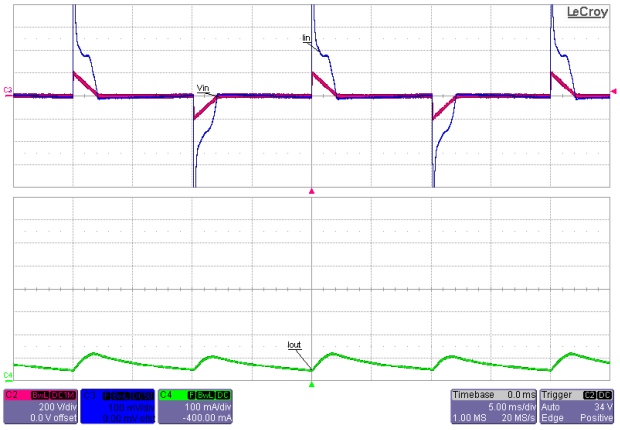


**Figure 76 –** 240 VAC / 50 Hz, (Germany) Merten 572499, 400 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.


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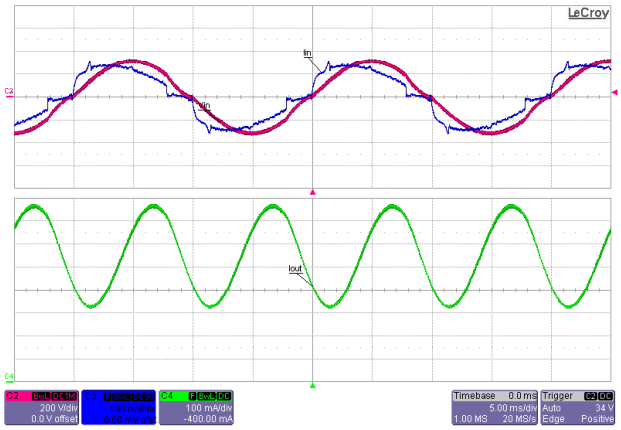


**Figure 77 –** 240 VAC / 50 Hz, (Germany) Busch 6513, 420 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

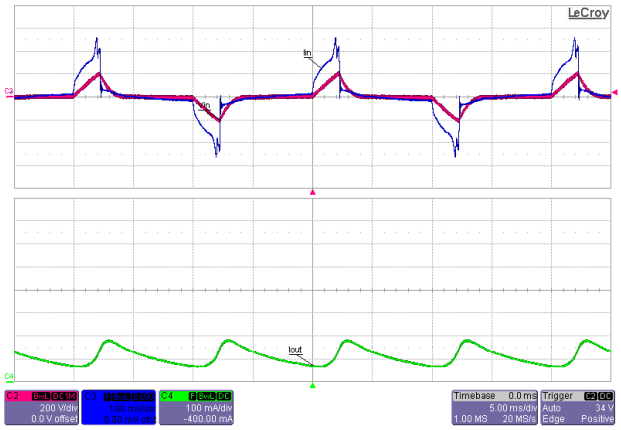


**Figure 78 –** 240 VAC / 50 Hz, (Germany) Busch 6513, 420 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

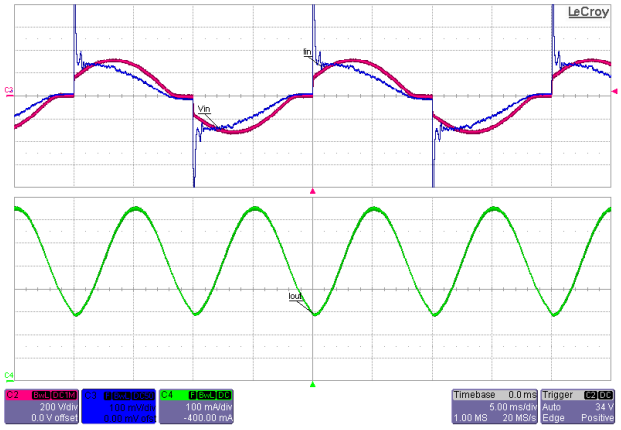


**Figure 79 –** 240 VAC / 50 Hz, (Germany) Berker 2875, 600 W Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

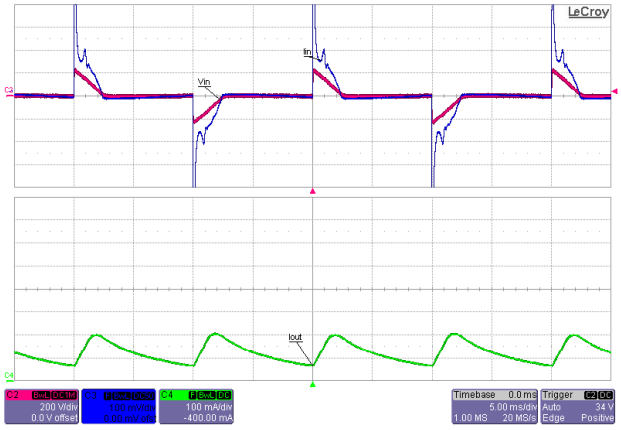


**Figure 80 –** 240 VAC / 50 Hz, (Germany) Berker 2875, 600 W Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

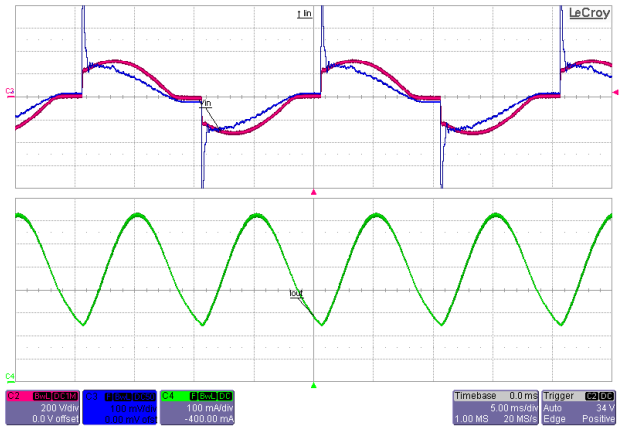


**Figure 81 –** 240 VAC / 50 Hz, (Germany) Ove Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

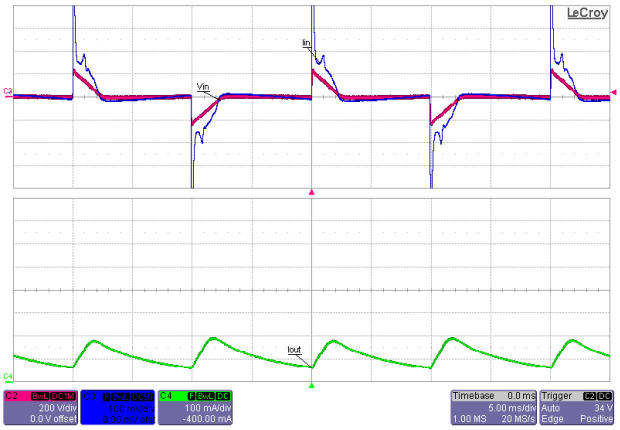


**Figure 82 –** 240 VAC / 50 Hz, (Germany) Ove Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

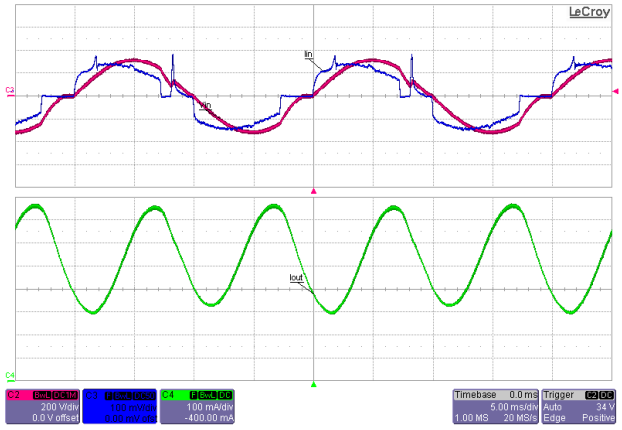


**Figure 83 –** 240 VAC / 50 Hz, (Germany) Busch 691 U-101 Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

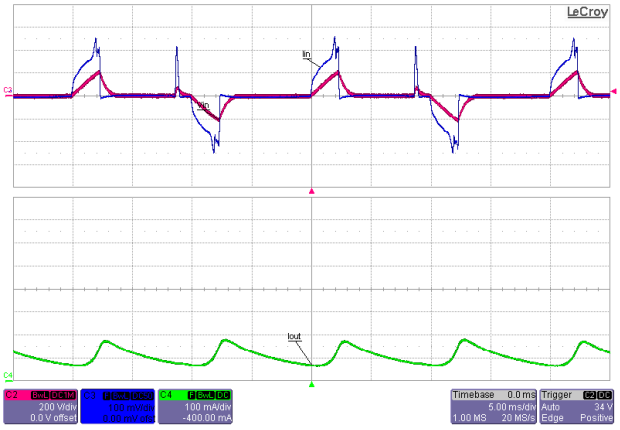


**Figure 84 –** 240 VAC / 50 Hz, (Germany) Busch 691 U-101 Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.


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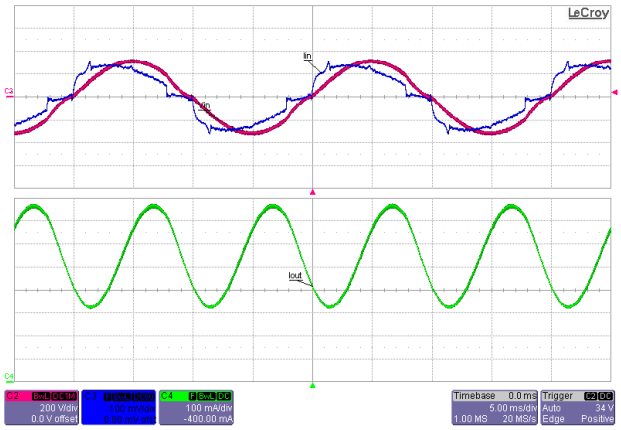


**Figure 85 –** 240 VAC / 50 Hz, (Germany) Busch 6513 U102 Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

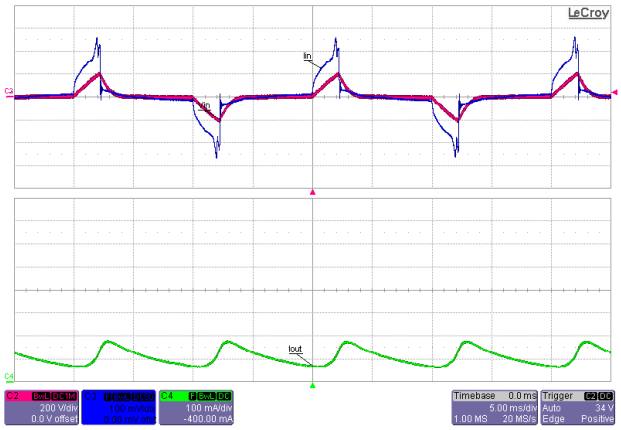


**Figure 86 –** 240 VAC / 50 Hz, (Germany) Busch 6513 U102 Dimmer at minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

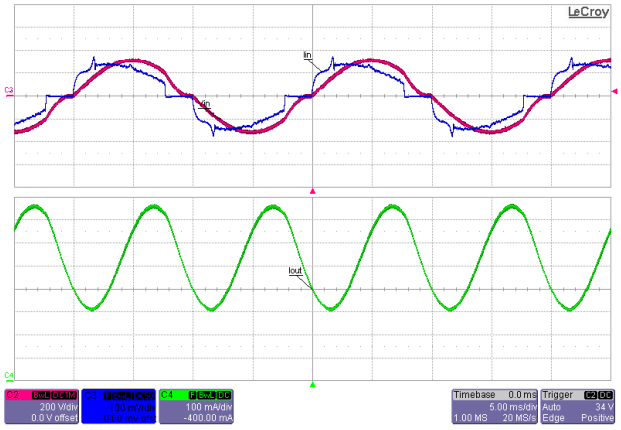


**Figure 87 –** 240 VAC / 50 Hz, (Germany) PEHA 433AB Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

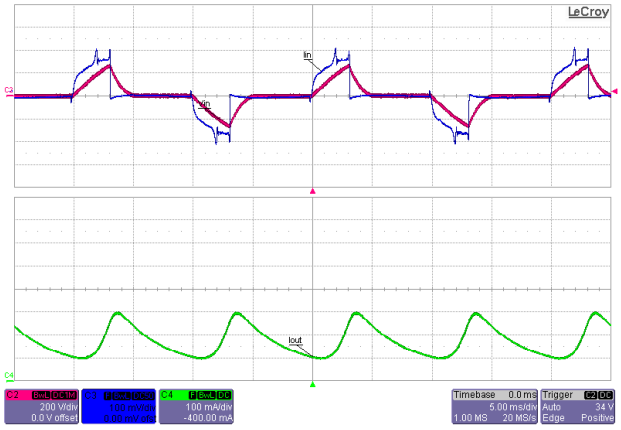


**Figure 88 –** 240 VAC / 50 Hz, (Germany) PEHA 433AB Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

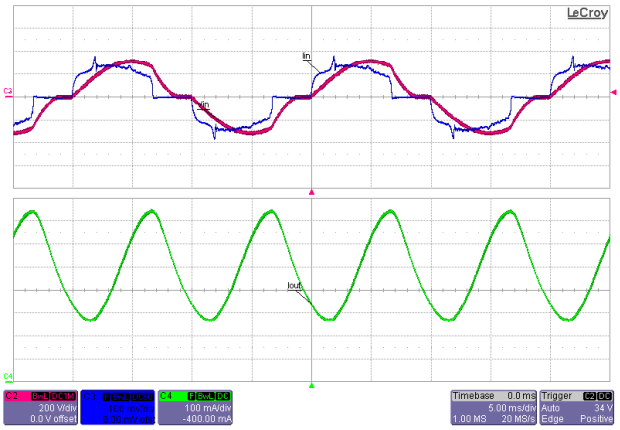


**Figure 89 –** 240 VAC / 50 Hz, (Germany) PEHA 433AB oA Dimmer at Full TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.

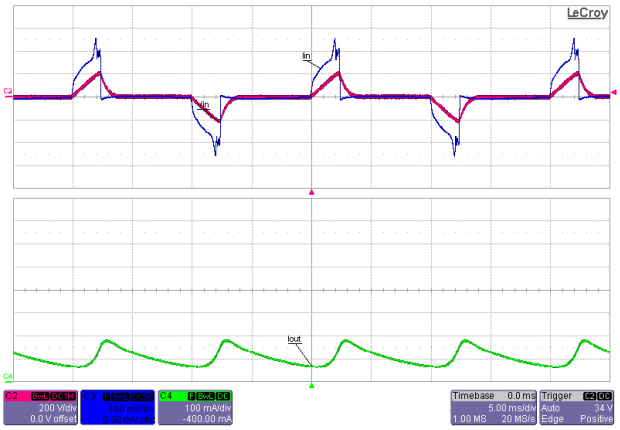


**Figure 90 –** 240 VAC / 50 Hz, (Germany) PEHA 433AB oA Dimmer at Minimum TRIAC Conduction.
Load:36 V LED String.
Ch2:$V_{IN}$, 200 V / div.
Ch3:$I_{IN}$, 100 mA / div.
Ch4:$I_{OUT}$, 100 mA / div.
Time Scale:5 ms / div.


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## *13.10 線電壓突波波形*

### 13.10.1 線差動電壓突波

**Figure 91 –** 265 VAC / 60 Hz, 36 V Load,
$V_{DS}$ = 591 $V_{PK}$
(+) 500 V Diff. Line Surge at 90º.
Ch1:$V_{DS}$, 200 V / div.
Ch2:$I_{IN}$, 500 mA / div.
Time Scale:1 µs / div.

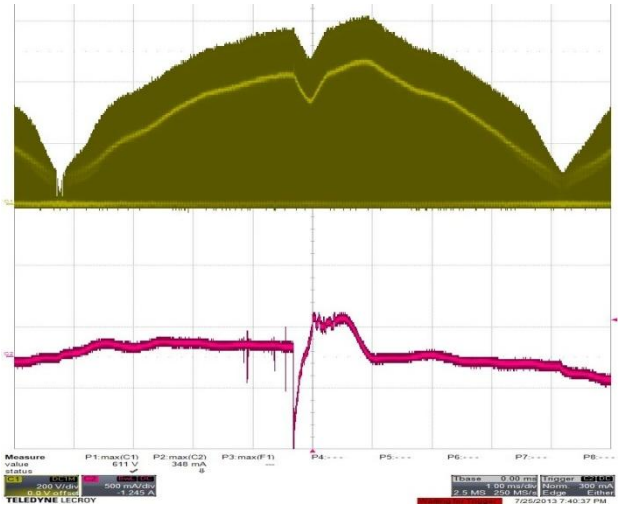

**Figure 92 –** 265 VAC / 50 Hz, 36 V Load,
$V_{DS}$ = 611 $V_{PK}$
(+) 500 V Diff. Line Surge at 270º.
Ch1:$V_{BULK}$, 100 V / div.
Ch2:$V_{DS}$, 200 V / div.
Time Scale:200 µs / div.
Zoom Time Scale:20 µs / div.

### 13.10.2 差動振盪突波

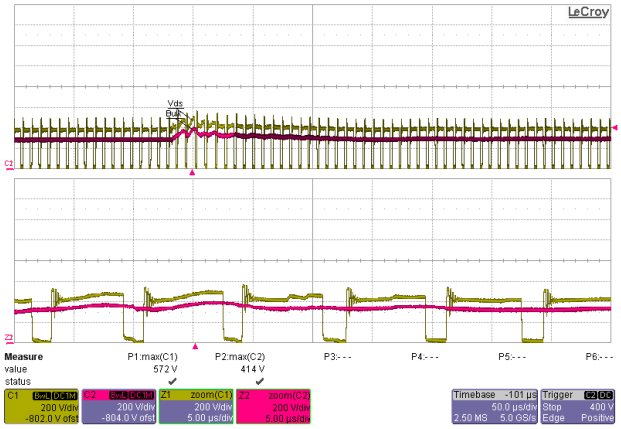

**Figure 93 –** 230 VAC / 60 Hz, 36 V Load,
$V_{DS}$ = 572 $V_{PK}$
(+) 500 V Differential Ring Surge at 90º.
Ch1:$V_{DS}$, 200 V / div.
Ch2:$V_{BULK}$, 200 V / div.
Zoom Time Scale:5 µs / div.

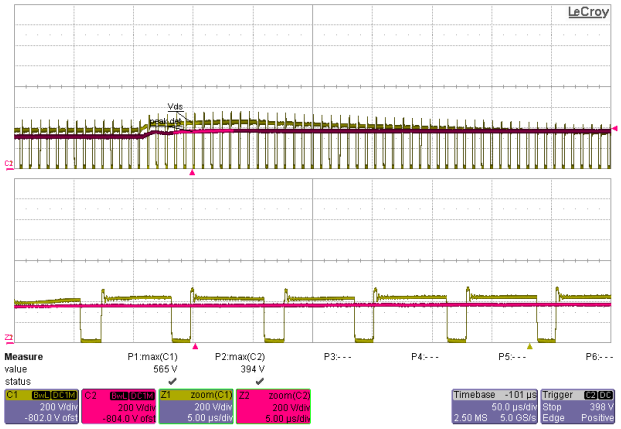

**Figure 94 –** 230 VAC / 60 Hz, 36 V Load,
$V_{DS}$ = 565 $V_{PK}$
(+) 500 V Differential Ring Surge at 0º.
Ch1:$V_{DS}$, 200 V / div.
Ch2:$V_{BULK}$, 200 V / div.
Zoom Time Scale:5 µs / div.

## 14 線電壓突波

Input voltage was set at 230 VAC / 60 Hz.Output was loaded with 36 V LED string and operation was verified following each surge event.Two units were verified in the following conditions.

Differential input line 1.2 / 50 μs surge testing was completed on one test unit to IEC61000-4-5.

| Surge Level (V) | Input Voltage (VAC) | Injection Location | Injection Phase (°) | Test Result (Pass/Fail) |
|---|---|---|---|---|
| +500 | 120 | L to N | 0 | Pass |
| -500 | 120 | L to N | 270 | Pass |
| +500 | 120 | L to N | 90 | Pass |
| -500 | 120 | L to N | 180 | Pass |

Differential input line ring surge testing was completed on one test unit to IEC61000-4-5.

| Surge Level (V) | Input Voltage (VAC) | Injection Location | Injection Phase (°) | Test Result (Pass/Fail) |
|---|---|---|---|---|
| +2500 | 120 | L to N | 0 | Pass |
| -2500 | 120 | L to N | 270 | Pass |
| +2500 | 120 | L to N | 90 | Pass |
| -2500 | 120 | L to N | 180 | Pass |

Unit passes under all test conditions.


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# 15 傳導性 EMI

## *15.1 設備*

Receiver:

Rohde & Schwartz
ESPI - Test Receiver (9 kHz – 3 GHz)
Model No:ESPI3

LISN:

Rohde & Schwartz
Two-Line-V-Network
Model No:ENV216

## *15.2 EMI 測試裝置*

Usually LED driver is placed in a conical metal housing (for self-ballasted lamps; CISPR15 Edition 7.2) but since lamp housing is not available during the UUT was tested then it was evaluated as shown in the figure below.

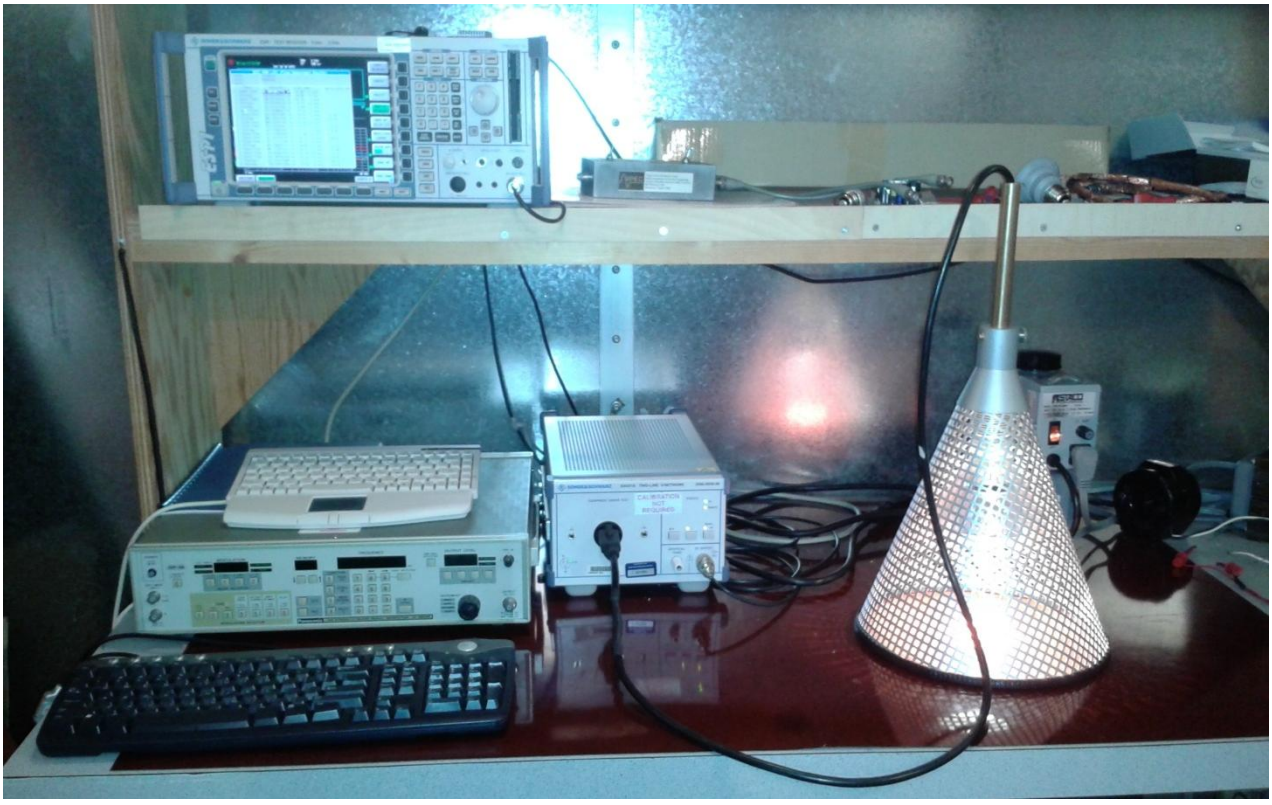

**Figure 95 –** Conducted Emissions Measurement Set-up.

## *15.3 EMI 測試結果*

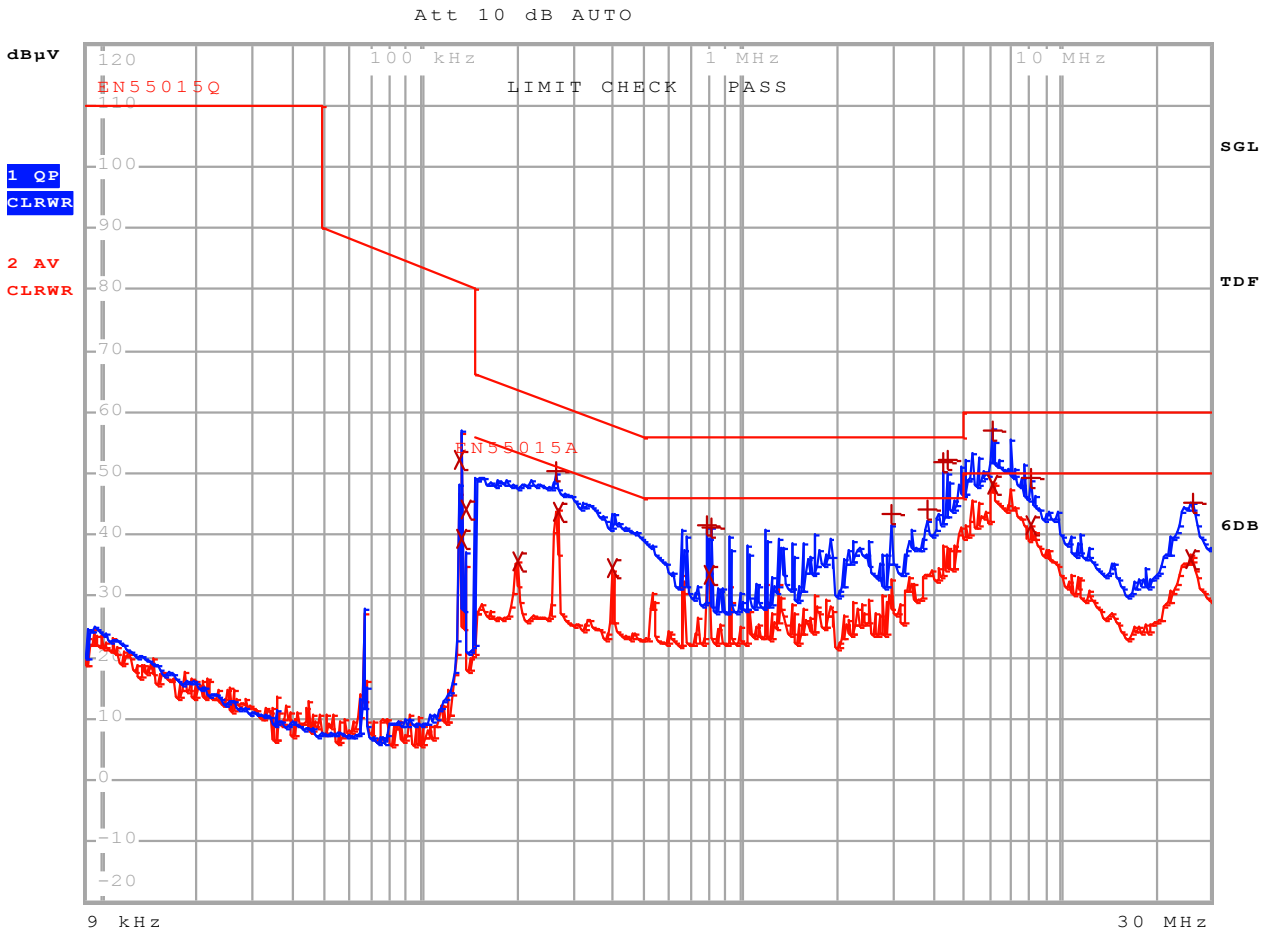


**Figure 96 –** Conducted EMI, 36 V output / 550 mA Steady-State Load, 230 VAC, 60 Hz, and EN55015 Limits.


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EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

| | TRACE | FREQUENCY | LEVEL dBµV | | | DELTA LIMIT dB |
|---|---|---|---|---|---|---|
| 2 | Average | 130.825395691 kHz | 38.20 | L1 | gnd | |
| 1 | Quasi Peak | 133.454986145 kHz | 64.55 | L1 | gnd | -16.50 |
| 2 | Average | 133.454986145 kHz | 64.29 | N | gnd | |
| 2 | Average | 136.137431366 kHz | 24.88 | L1 | gnd | |
| 1 | Quasi Peak | 174.145343305 kHz | 52.73 | L1 | gnd | -12.02 |
| 2 | Average | 200.175581485 kHz | 35.00 | N | gnd | -18.60 |
| 1 | Quasi Peak | 208.303512797 kHz | 50.42 | L1 | gnd | -12.85 |
| 1 | Quasi Peak | 227.818484195 kHz | 50.65 | N | gnd | -11.87 |
| 1 | Quasi Peak | 246.694773277 kHz | 50.50 | L1 | gnd | -11.36 |
| 1 | Quasi Peak | 254.169871602 kHz | 51.18 | N | gnd | -10.43 |
| 2 | Average | 267.135089486 kHz | 44.12 | N | gnd | -7.07 |
| 2 | Average | 401.705024172 kHz | 36.36 | N | gnd | -11.45 |
| 1 | Quasi Peak | 434.988979109 kHz | 45.29 | L1 | gnd | -11.86 |
| 2 | Average | 667.263434405 kHz | 34.06 | N | gnd | -11.93 |
| 2 | Average | 798.145472681 kHz | 35.73 | N | gnd | -10.26 |
| 1 | Quasi Peak | 3.76891518811 MHz | 42.16 | L1 | gnd | -13.83 |
| 2 | Average | 3.76891518811 MHz | 33.46 | L1 | gnd | -12.53 |
| 1 | Quasi Peak | 4.16322710559 MHz | 45.25 | L1 | gnd | -10.74 |
| 2 | Average | 5.28619370567 MHz | 41.89 | N | gnd | -8.10 |
| 1 | Quasi Peak | 5.555842711143 MHz | 46.93 | N | gnd | -13.06 |

**Figure 97 –** Conducted EMI, 36 V / 550 mA Steady-State Load Steady-State Load, 230 VAC, 60 Hz, and EN55015 Limits / Line and Neutral Scan Design Margin Measurement.

## 16 修訂記錄

| Date | Author | Revision | Description and Changes | Reviewed |
|---|---|---|---|---|
| 25-Sep-13 | ME | 1.0 | Initial Release | Apps & Mktg |
| | | | | |
| | | | | |
| | | | | |
| | | | | |



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