

## 設計範例報告

|      |                                                          |
|------|----------------------------------------------------------|
| 標題   | 使用 <i>LinkSwitch™-II LNK604DG</i> 的低成本、3 W 輸出隔離式 LED 驅動器 |
| 規格   | 90 VAC – 265 VAC 輸入；<br>9 V <sub>TYP</sub> ，330 mA 輸出    |
| 應用   | GU10 LED 燈泡                                              |
| 作者   | 應用工程部門                                                   |
| 文件編號 | DER-351                                                  |
| 日期   | 2012 年 11 月 14 日                                         |
| 修訂   | 2.1                                                      |

### 摘要與功能

- 精準 (一次側控制) 定電流 (CC)
  - 精準定電流、負載和線電壓低於  $\pm 5\%$  差異
- 低零件數解決方案 (17 種電氣元件)
- 過溫保護，具有磁滯恢復能力
- 輸出短路和開迴路保護，具有自動重新啟動能力
  - 265 VAC 條件下，無負載功耗低於 200 mW
  - 輕鬆符合 EN55015 和 CISPR-22 B 級 EMI 標準

### 專利資訊

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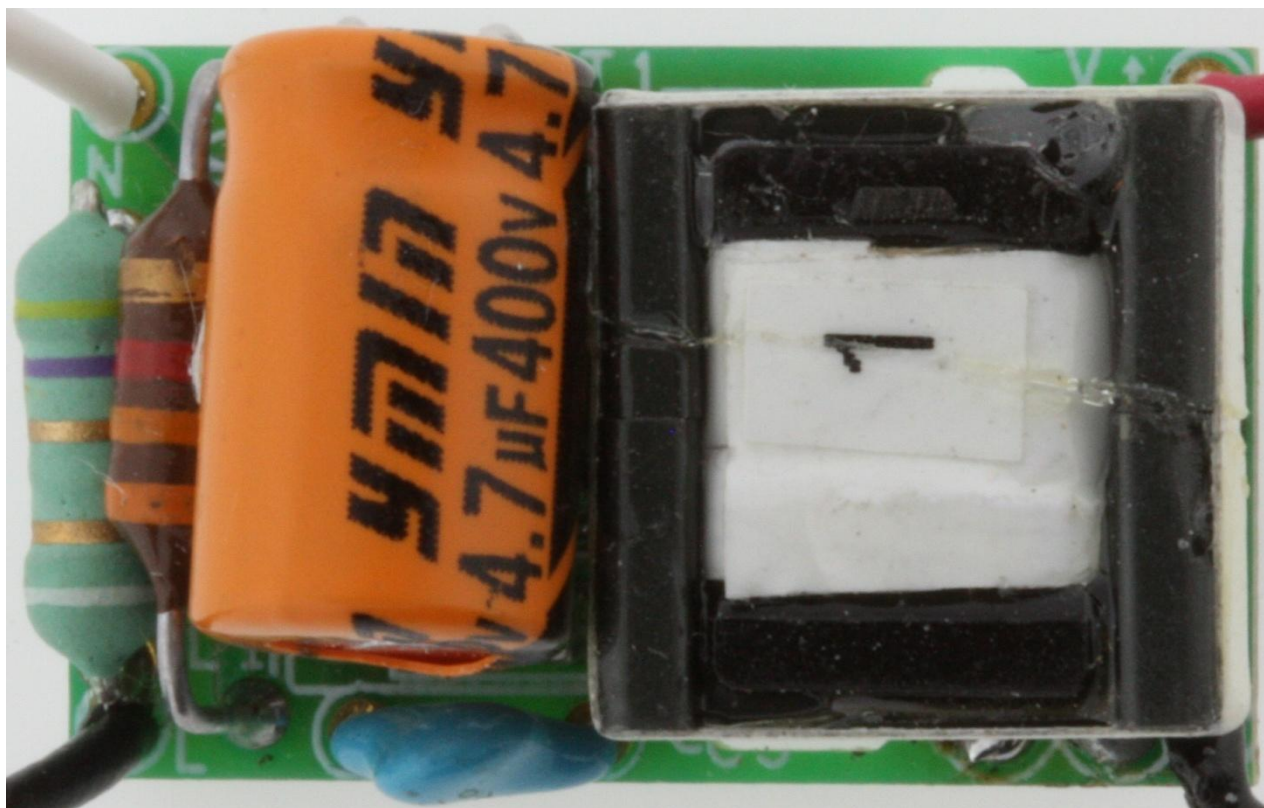
**重要事項：**雖然此電路板的設計滿足安全隔離需求，但其工程原型未經相關機構核准。因此，執行所有測試應使用隔離變壓器才能提供 AC 輸入給原型板。



## 1 簡介

本工程報告說明全電壓輸入、9 V、330 mA LED 驅動器設計。這類電源供應器使用 Power Integrations LinkSwitch-II 系列的 LNK604DG 裝置。

本文件包含電源供應器和變壓器規格、電路圖、物料清單，以及本電源供應器相關的典型效能特性。



**Figure 1** – Populated Circuit Board, Top (1.02" [26 mm] x .63" [16 mm]).



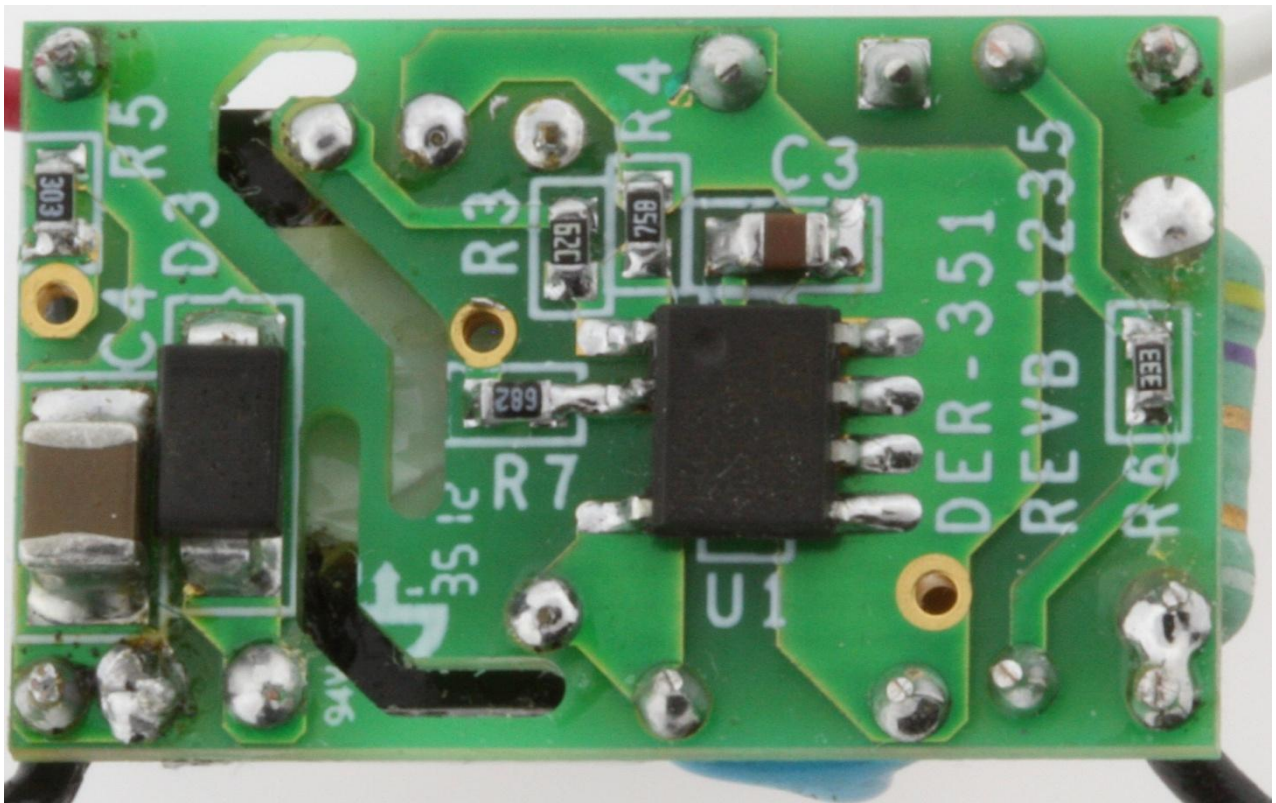


Figure 2 – Populated Circuit Board, Bottom.

## 2 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                                  | 類型            | 最大值 | 單位           | 註解                   |
|------------------------------------------|-------------------------------------|--------------------------------------|---------------|-----|--------------|----------------------|
| 輸入<br>電壓<br>頻率                           | $V_{IN}$<br>$f_{LINE}$              | 90                                   | 50/60         | 265 | VAC<br>Hz    | 雙線 – 無 P.E.          |
| 輸出<br>輸出電壓<br>輸出電流<br>總輸出功率<br>連續輸出功率    | $V_{OUT}$<br>$I_{OUT}$<br>$P_{OUT}$ | 7                                    | 9<br>330<br>3 | 11  | V<br>mA<br>W |                      |
| 效率<br>滿載                                 | $\eta$                              | 75                                   |               |     | %            | 以 115 / 230 VAC 輸入測得 |
| 環境<br>傳導性 EMI<br>差動突波 (1.2 / 50 $\mu$ s) |                                     | CISPR 15B / EN55015B<br>500 V / 1 kV |               |     |              |                      |
| 環境溫度                                     | $T_{AMB}$                           |                                      | 40            |     | $^{\circ}$ C |                      |



### 3 電路圖

#### 3.1 電路圖 - 無箝位電路

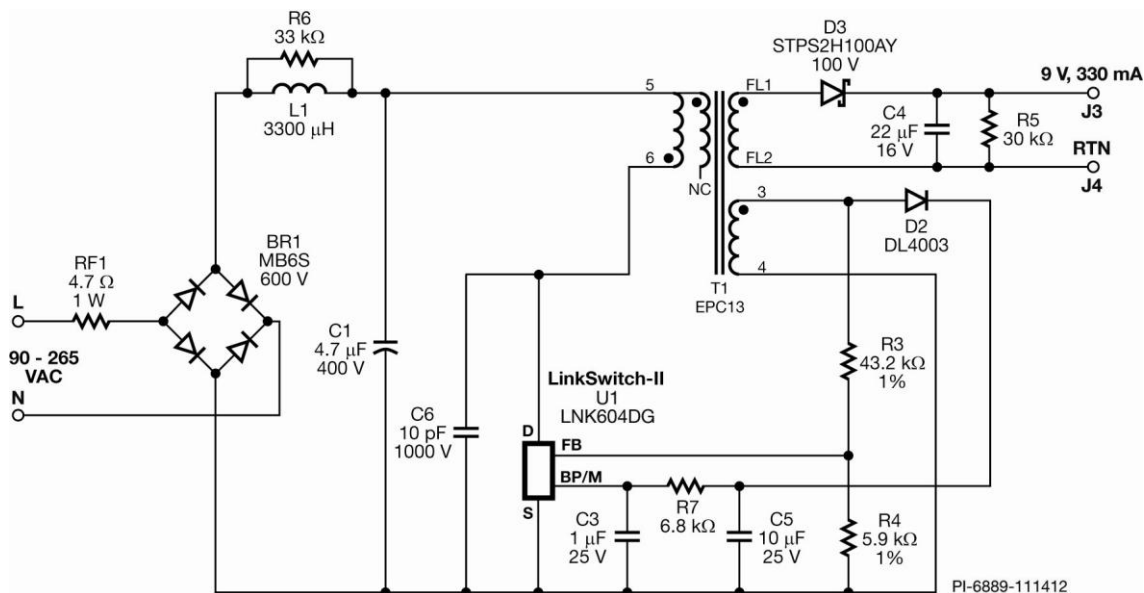


Figure 3A – Schematic (No Clamp Circuit).

#### 3.2 電路圖 - 箝位電路

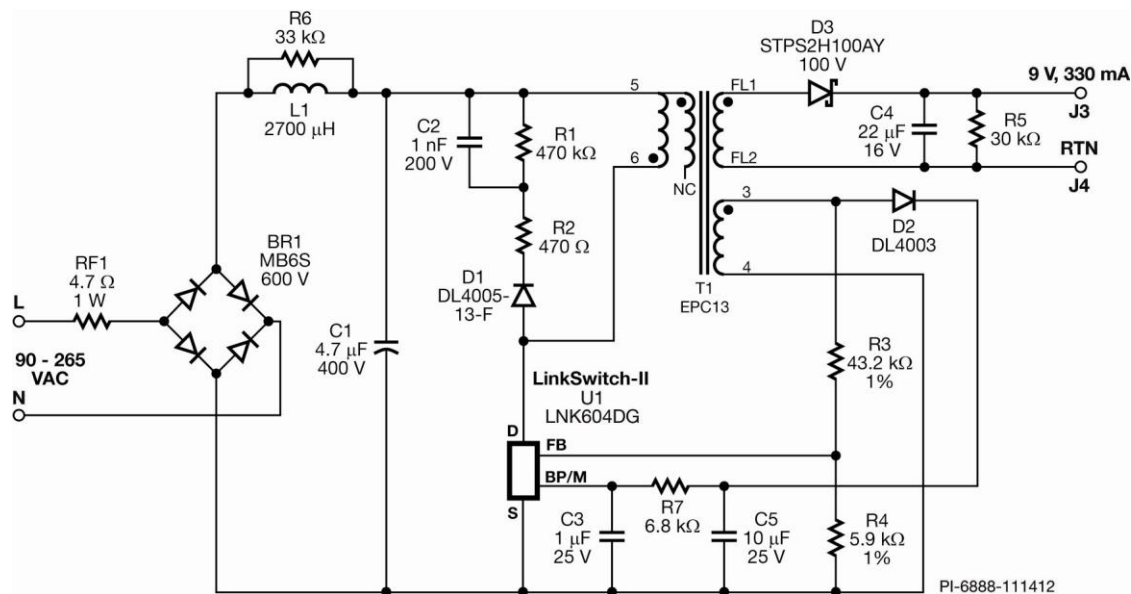


Figure 3B – Schematic (With Optional Clamp Circuit, for 1 kV Surge).

## 4 電路說明

### 4.1 輸入濾波器

橋式整流器 BR1 能對 AC 輸入進行整流。整流後的 DC 會以大電容器 C1 進行濾波。電感器 L1 搭配電容器 C1 可削減差模 EMI 雜訊。此配置加上 Power Integrations 的變壓器 E-shield™ 技術，可讓這個設計符合 EN55015 B 級 EMI 標準。電阻器 R6 會減弱過大振盪，並減少 EMI。當第一次施加 AC 時，可熔防火電阻器 RF1 會限制突波電流，這個電阻器還兼具保險絲的功能。

### 4.1 一次側電源電路

經過整流和濾波的輸入電壓會套用到 T1 一次側繞組的一端。變壓器的一次側繞組另外一端則會由 U1 驅動。來源電阻器 C6 的少量汲極電流會限制因變壓器漏電感造成的汲極電壓突波。外部偏壓供電器 D2、R7 和 C5 可改善功率效率。選擇慢速恢復二極體用於 D2，以改善 EMI。電容器 C3 會為 U1 的 BYPASS (BP) 接腳 (內部控制器的供電接腳) 提供本機去耦合。

圖 3B 中的箝位電路 C2、R1、R2、D1 可使最大汲極電壓施加 1 kV 快速差動突波時低於 700 V。

### 4.1 輸出整流和調節

變壓器的二次側輸出會由 D3 (一種蕭特基屏障二極體，選擇能提供高效率者) 進行整流，並由 C4 進行濾波。LNK604DG 調節輸出的方式是，使用開/關控制以進行 CV 調節，使用頻率控制進行定電流 (CC) 調節。回授電阻器 R3 和 R4 擁有 1% 公差值，可精準確定輸出電流的中心。輸出電壓設為高於最大 LED 電壓，會在斷開負載情況下限制過壓。



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## 5 PCB 佈局

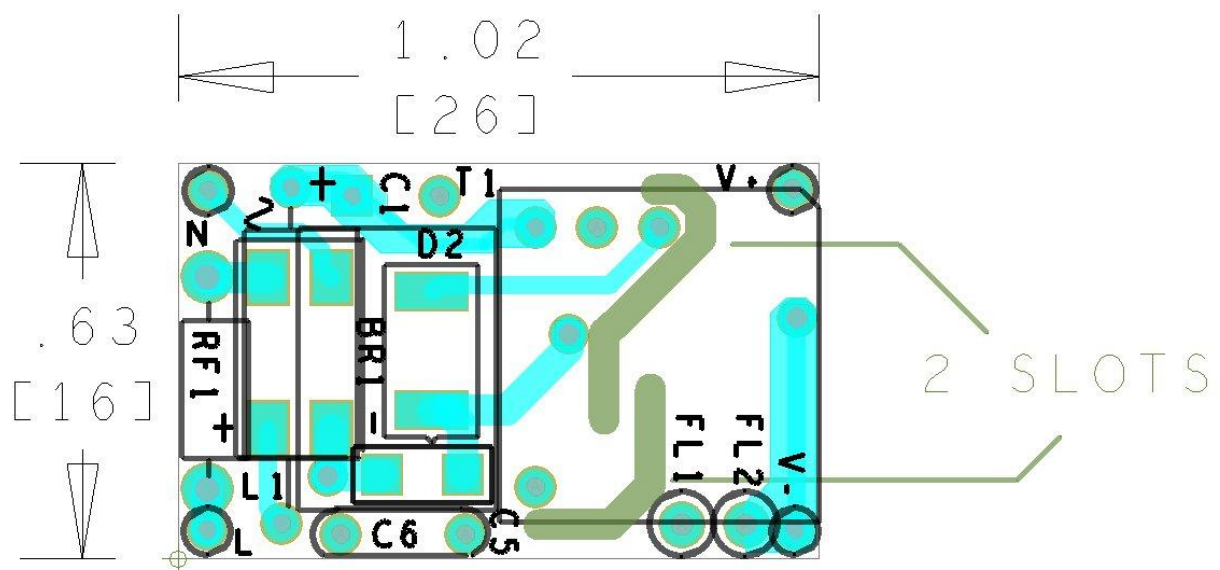


Figure 4 – Top Side.

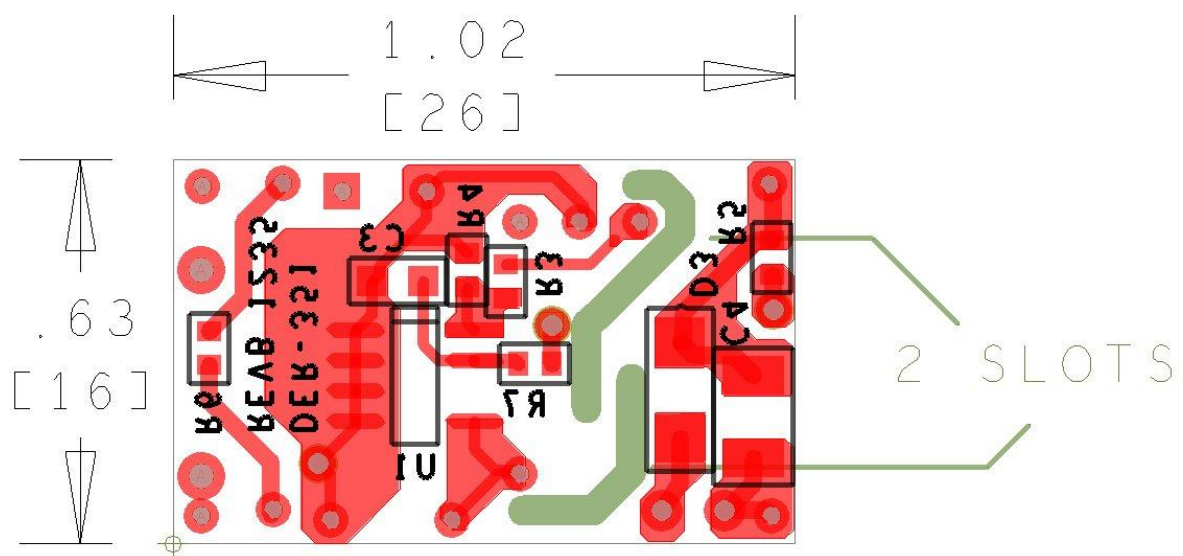


Figure 5 – Bottom Side.

## 6 物料清單

### 6.1 無一次側箝位設計物料清單 (圖 3A)

| Item | Qty | Ref Des | Description                                                 | Mfg Part Number    | Mfg                |
|------|-----|---------|-------------------------------------------------------------|--------------------|--------------------|
| 1    | 1   | BR1     | 600 V, 0.5 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC          | MB6S-TP            | Micro Commercial   |
| 2    | 1   | C1      | 4.7 $\mu$ F, 400 V, Electrolytic, (8 x 11.5)                | TAQ2G4R7MK0811MLL3 | Taicon             |
| 3    | 1   | C3      | 1 $\mu$ F, 25 V, Ceramic, X5R, 0805                         | C2012X5R1E105K     | TDK                |
| 4    | 1   | C4      | 22 $\mu$ F, 16 V, Ceramic, X5R, 1210                        | GRM32ER61C226ME20L | Murata             |
| 5    | 1   | C5      | 10 $\mu$ F, 25 V, Ceramic, X5R, 1206                        | C3216X7R1E106K     | TDK                |
| 6    | 1   | C6      | 10 pF, 1 kV, Ceramic, SL, 0.2" L.S.                         | DEA1X3A100JC1B     | Murata             |
| 7    | 1   | D2      | 200 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF)    | DL4003-13-F        | Diodes, Inc.       |
| 8    | 1   | D3      | 100 V, 2 A, Schottky, SMA                                   | STPS2H100AY        | ST Micro           |
| 9    | 1   | L1      | 3300 $\mu$ H, 62 mA, 59.5 $\Omega$ , Axial Ferrite Inductor | B78108S1335J       | Epcos              |
| 10   | 1   | R3      | 43.2 k $\Omega$ , 1%, 1/16 W, Thick Film, 0603              | ERJ-3EKF4322V      | Panasonic          |
| 11   | 1   | R4      | 5.9 k $\Omega$ , 1%, 1/16 W, Thick Film, 0603               | ERJ-3EKF5901V      | Panasonic          |
| 12   | 1   | R5      | 30 k $\Omega$ , 5%, 1/10 W, Thick Film, 0603                | ERJ-3GEYJ303V      | Panasonic          |
| 13   | 1   | R6      | 33 k $\Omega$ , 5%, 1/10 W, Thick Film, 0603                | ERJ-3GEYJ333V      | Panasonic          |
| 14   | 1   | R7      | 6.8 k $\Omega$ , 5%, 1/10 W, Thick Film, 0603               | ERJ-3GEYJ682V      | Panasonic          |
| 15   | 1   | RF1     | 4.7 $\Omega$ , 1 W, Fusible/Flame Proof Wire Wound          | FKN1WSJR-52-4R7    | Yago               |
| 16   | 1   | T1      | Bobbin, EPC13, Horizontal, 10 pins                          | BEPC-13-1110CPH    | TDK                |
| 17   | 1   | U1      | LinkSwitch-II, CV/CC, SO-8C                                 | LNK604DG           | Power Integrations |

### 6.2 箝位設計物料清單 (圖 3B)

| Item | Qty | Ref Des | Description                                              | Mfg Part Number    | Mfg                |
|------|-----|---------|----------------------------------------------------------|--------------------|--------------------|
| 1    | 1   | BR1     | 600 V, 0.5 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC       | MB6S-TP            | Micro Commercial   |
| 2    | 1   | C1      | 4.7 $\mu$ F, 400 V, Electrolytic, (8 x 11.5)             | TAQ2G4R7MK0811MLL3 | Taicon             |
| 3    | 1   | C2      | 1 nF, 200 V, Ceramic, X7R, 0805                          | 08052C102KAT2A     | AVX                |
| 4    | 1   | C3      | 1 $\mu$ F, 25 V, Ceramic, X5R, 0805                      | C2012X5R1E105K     | TDK                |
| 5    | 1   | C4      | 22 $\mu$ F, 16 V, Ceramic, X5R, 1210                     | GRM32ER61C226ME20L | Murata             |
| 6    | 1   | C5      | 10 $\mu$ F, 25 V, Ceramic, X5R, 1206                     | C3216X7R1E106K     | TDK                |
| 7    | 1   | D1      | 600 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF) | DL4005-13-F        | Diodes, Inc.       |
| 8    | 1   | D2      | 200 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF) | DL4003-13-F        | Diodes, Inc.       |
| 9    | 1   | D3      | 100 V, 2 A, Schottky, SMA                                | STPS2H100AY        | ST Micro           |
| 10   | 1   | L1      | 2700 $\mu$ H, 75 mA, 40 Ohm, Axial Ferrite Inductor      | B78148S1275J       | Epcos              |
| 11   | 1   | R1      | 470 k $\Omega$ , 5%, 1/4 W, Thick Film, 1206             | ERJ-8GEYJ474V      | Panasonic          |
| 12   | 1   | R2      | 470 $\Omega$ , 5%, 1/8 W, Thick Film, 0805               | ERJ-6GEYJ471V      | Panasonic          |
| 13   | 1   | R3      | 43.2 k $\Omega$ , 1%, 1/16 W, Thick Film, 0603           | ERJ-3EKF4322V      | Panasonic          |
| 14   | 1   | R4      | 5.9 k $\Omega$ , 1%, 1/16 W, Thick Film, 0603            | ERJ-3EKF5901V      | Panasonic          |
| 15   | 1   | R5      | 30 k $\Omega$ , 5%, 1/10 W, Thick Film, 0603             | ERJ-3GEYJ303V      | Panasonic          |
| 16   | 1   | R6      | 33 k $\Omega$ , 5%, 1/10 W, Thick Film, 0603             | ERJ-3GEYJ333V      | Panasonic          |
| 17   | 1   | R7      | 6.8 k $\Omega$ , 5%, 1/10 W, Thick Film, 0603            | ERJ-3GEYJ682V      | Panasonic          |
| 18   | 1   | RF1     | 4.7 $\Omega$ , 1 W, Fusible/Flame Proof Wire Wound       | FKN1WSJR-52-4R7    | Yago               |
| 19   | 1   | T1      | Bobbin, EPC13, Horizontal, 10 pins                       | BEPC-13-1110CPH    | TDK                |
| 20   | 1   | U1      | LinkSwitch-II, CV/CC, SO-8C                              | LNK604DG           | Power Integrations |



## 7 PIXIs 設計試算表

| ACDC_LinkSwitch-II_091611; Rev.1.13;<br>Copyright Power Integrations 2011 | INPUT  | INFO | OUTPUT | UNIT  | ACDC_LinkSwitch-II_091611_Rev1-13;<br>LinkSwitch-II Discontinuous Flyback<br>Transformer Design Spreadsheet           |
|---------------------------------------------------------------------------|--------|------|--------|-------|-----------------------------------------------------------------------------------------------------------------------|
| <b>ENTER APPLICATION VARIABLES</b>                                        |        |      |        |       |                                                                                                                       |
| VACMIN                                                                    |        |      | 85.00  | V     | Minimum AC Input Voltage                                                                                              |
| VACMAX                                                                    |        |      | 265.00 | V     | Maximum AC Input Voltage                                                                                              |
| fL                                                                        |        |      | 50.00  | Hz    | AC Mains Frequency                                                                                                    |
| VO                                                                        | 9.00   |      | 9.00   | V     | Output Voltage (at continuous power)                                                                                  |
| IO                                                                        | 0.33   |      | 0.33   | A     | Power Supply Output Current (corresponding to peak power)                                                             |
| Power                                                                     |        |      | 2.97   | W     | Continuous Output Power                                                                                               |
| n                                                                         | 0.75   |      | 0.75   |       | 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                                                                             |
| Add Bias Winding                                                          | YES    |      | YES    |       | Choose Yes to add a Bias winding to power the LinkSwitch-II.                                                          |
| CIN                                                                       | 4.70   |      | 4.70   | uF    | Input Capacitance                                                                                                     |
| <b>ENTER LinkSwitch-II VARIABLES</b>                                      |        |      |        |       |                                                                                                                       |
| Chosen Device                                                             | LNK604 |      | LNK604 |       | Chosen LinkSwitch-II device                                                                                           |
| Package                                                                   | DG     |      | DG     |       | Select package (PG, GG or DG)                                                                                         |
| ILIMITMIN                                                                 |        |      | 0.24   | A     | Minimum Current Limit                                                                                                 |
| ILIMITTYP                                                                 |        |      | 0.25   | A     | Typical Current Limit                                                                                                 |
| ILIMITMAX                                                                 |        |      | 0.28   | A     | Maximum Current Limit                                                                                                 |
| FS                                                                        |        |      | 66.00  | kHz   | Typical Device Switching Frequency at maximum power                                                                   |
| VOR                                                                       |        |      | 80.16  | V     | Reflected Output Voltage (VOR < 135 V Recommended)                                                                    |
| VDS                                                                       |        |      | 10.00  | V     | LinkSwitch-II on-state Drain to Source Voltage                                                                        |
| VD                                                                        |        |      | 0.50   | V     | Output Winding Diode Forward Voltage Drop                                                                             |
| KP                                                                        |        |      | 1.83   |       | Ensure KDP > 1.3 for discontinuous mode operation                                                                     |
| <b>FEEDBACK WINDING PARAMETERS</b>                                        |        |      |        |       |                                                                                                                       |
| NFB                                                                       |        |      | 15.00  |       | Feedback winding turns                                                                                                |
| VFLY                                                                      |        |      | 8.91   | V     | Flyback Voltage - Voltage on Feedback Winding during switch off time                                                  |
| VFOR                                                                      |        |      | 5.72   | V     | Forward voltage - Voltage on Feedback Winding during switch on time                                                   |
| <b>BIAS WINDING PARAMETERS</b>                                            |        |      |        |       |                                                                                                                       |
| VB                                                                        |        |      | 10.00  | V     | Bias Winding Voltage. Ensure that VB > VFLY. Bias winding is assumed to be AC-STACKED on top of Feedback winding      |
| NB                                                                        |        |      | 3.00   |       | Bias Winding number of turns                                                                                          |
| REXT                                                                      |        |      | 8.30   | k-ohm | Suggested value of BYPASS pin resistor (use standard 5% resistor)                                                     |
| <b>DESIGN PARAMETERS</b>                                                  |        |      |        |       |                                                                                                                       |
| DCON                                                                      |        |      | 4.50   | us    | Output diode conduction time                                                                                          |
| TON                                                                       |        |      | 6.97   | us    | LinkSwitch-II On-time (calculated at minimum inductance)                                                              |
| RUPPER                                                                    |        |      | 23.19  | k-ohm | Upper resistor in Feedback resistor divider                                                                           |
| RLOWER                                                                    |        |      | 6.04   | k-ohm | Lower resistor in resistor divider                                                                                    |
| <b>ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES</b>                      |        |      |        |       |                                                                                                                       |
| <b>Core Type</b>                                                          |        |      |        |       |                                                                                                                       |



|                                                |       |         |              |           |                                                                                                                                               |
|------------------------------------------------|-------|---------|--------------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Core                                           | EPC13 |         | EPC13        |           | Enter Transformer Core. Based on the output power the recommended core sizes are EE13 or EE16                                                 |
| Bobbin                                         |       |         | EPC13_BOBBIN |           | Generic EPC13_BOBBIN                                                                                                                          |
| AE                                             |       |         | 12.50        | mm^2      | Core Effective Cross Sectional Area                                                                                                           |
| LE                                             |       |         | 30.60        | mm        | Core Effective Path Length                                                                                                                    |
| AL                                             |       |         | 870.00       | nH/turn^2 | Ungapped Core Effective Inductance                                                                                                            |
| BW                                             |       |         | 6.88         | mm        | Bobbin Physical Winding Width                                                                                                                 |
| M                                              |       |         | 0.00         | mm        | Safety Margin Width (Half the Primary to Secondary Creepage Distance)                                                                         |
| L                                              |       |         | 3.00         |           | Number of Primary Layers                                                                                                                      |
| NS                                             |       |         | 16.00        |           | Number of Secondary Turns. To adjust Secondary number of turns change DCON                                                                    |
| <b>DC INPUT VOLTAGE PARAMETERS</b>             |       |         |              |           |                                                                                                                                               |
| VMIN                                           |       |         | 51.52        | V         | Minimum DC bus voltage                                                                                                                        |
| VMAX                                           |       |         | 374.77       | V         | Maximum DC bus voltage                                                                                                                        |
| <b>CURRENT WAVEFORM SHAPE PARAMETERS</b>       |       |         |              |           |                                                                                                                                               |
| DMAX                                           |       |         | 0.46         |           | Maximum duty cycle measured at VMIN                                                                                                           |
| IAVG                                           |       |         | 0.10         | A         | Input Average current                                                                                                                         |
| IP                                             |       |         | 0.24         | A         | Peak primary current                                                                                                                          |
| IR                                             |       |         | 0.24         | A         | Primary ripple current                                                                                                                        |
| IRMS                                           |       |         | 0.11         | A         | Primary RMS current                                                                                                                           |
| <b>TRANSFORMER PRIMARY DESIGN PARAMETERS</b>   |       |         |              |           |                                                                                                                                               |
| LPMIN                                          |       |         | 1512.00      | uH        | Minimum Primary Inductance                                                                                                                    |
| LPTYP                                          |       |         | 1680.00      | uH        | Typical Primary inductance                                                                                                                    |
| LP_TOLERANCE                                   |       |         | 10.00        | %         | Tolerance in primary inductance                                                                                                               |
| NP                                             |       |         | 135.00       |           | Primary number of turns. To adjust Primary number of turns change BM_TARGET                                                                   |
| ALG                                            |       |         | 92.18        | nH/turn^2 | Gapped Core Effective Inductance                                                                                                              |
| BM_TARGET                                      |       |         | 2500.00      | Gauss     | Target Flux Density                                                                                                                           |
| BM                                             |       |         | 2488.89      | Gauss     | Maximum Operating Flux Density (calculated at nominal inductance), BM < 2500 is recommended                                                   |
| BP                                             |       | Warning | 3011.56      | Gauss     | !!! Warning. Peak Flux density exceeds 3000 Gauss and is not recommended. Reduce BP by increasing NS                                          |
| BAC                                            |       |         | 1244.44      | Gauss     | AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)                                                                                     |
| ur                                             |       |         | 169.48       |           | Relative Permeability of Ungapped Core                                                                                                        |
| LG                                             |       |         | 0.17         | mm        | Gap Length (LG > 0.1 mm)                                                                                                                      |
| BWE                                            |       |         | 20.64        | mm        | Effective Bobbin Width                                                                                                                        |
| OD                                             |       |         | 0.15         | mm        | Maximum Primary Wire Diameter including insulation                                                                                            |
| INS                                            |       |         | 0.03         |           | Estimated Total Insulation Thickness (= 2 * film thickness)                                                                                   |
| DIA                                            |       |         | 0.12         | mm        | Bare conductor diameter                                                                                                                       |
| AWG                                            |       |         | 37.00        |           | Primary Wire Gauge (Rounded to next smaller standard AWG value)                                                                               |
| CM                                             |       |         | 20.16        | Cmils     | Bare conductor effective area in circular mils                                                                                                |
| CMA                                            |       | Warning | 187.20       | Cmils/A   | !!! Warning. CMA is less than 200 and may cause overheating of the primary winding. Increase primary winding layers or use larger transformer |
| <b>TRANSFORMER SECONDARY DESIGN PARAMETERS</b> |       |         |              |           |                                                                                                                                               |
| <b>Lumped parameters</b>                       |       |         |              |           |                                                                                                                                               |
| ISP                                            |       |         | 2.00         | A         | Peak Secondary Current                                                                                                                        |
| ISRMS                                          |       |         | 0.73         | A         | Secondary RMS Current                                                                                                                         |
| IRIPPLE                                        |       |         | 0.65         | A         | Output Capacitor RMS Ripple Current                                                                                                           |
| CMS                                            |       |         | 145.69       | Cmils     | Secondary Bare Conductor minimum circular                                                                                                     |



|                                        |  |  |        |       |                                                                                                                     |
|----------------------------------------|--|--|--------|-------|---------------------------------------------------------------------------------------------------------------------|
|                                        |  |  |        |       | mils                                                                                                                |
| AWGS                                   |  |  | 28.00  |       | Secondary Wire Gauge (Rounded up to next larger standard AWG value)                                                 |
| <b>VOLTAGE STRESS PARAMETERS</b>       |  |  |        |       |                                                                                                                     |
| VDRAIN                                 |  |  | 563.09 | V     | Maximum Drain Voltage Estimate (Assumes 20% clamping voltage tolerance and an additional 10% temperature tolerance) |
| PIVS                                   |  |  | 53.42  | V     | Output Rectifier Maximum Peak Inverse Voltage                                                                       |
| <b>FINE TUNING</b>                     |  |  |        |       |                                                                                                                     |
| RUPPER_ACTUAL                          |  |  | 23.19  | k-ohm | Actual Value of upper resistor (RUPPER) used on PCB                                                                 |
| RLOWER_ACTUAL                          |  |  | 6.04   | k-ohm | Actual Value of lower resistor (RLOWER) used on PCB                                                                 |
| Actual (Measured) Output Voltage (VDC) |  |  | 9.00   | V     | Measured Output voltage from first prototype                                                                        |
| Actual (Measured) Output Current (ADC) |  |  | 0.33   | Amps  | Measured Output current from first prototype                                                                        |
| RUPPER_FINE                            |  |  | 23.19  | k-ohm | New value of Upper resistor (RUPPER) in Feedback resistor divider. Nearest standard value is 23.2 k-ohms            |
| RLOWER_FINE                            |  |  | 6.04   | k-ohm | New value of Lower resistor (RLOWER) in Feedback resistor divider. Nearest standard value is 6.04 k-ohms            |

**Note:**

- 1) BP = 3011 gauss is accepted with no saturation observed in drain current waveform.
- 2) CMA = 187 Cmil/A : Used #36 AWG for primary winding.



## 8 變壓器規格

### 8.1 電氣圖

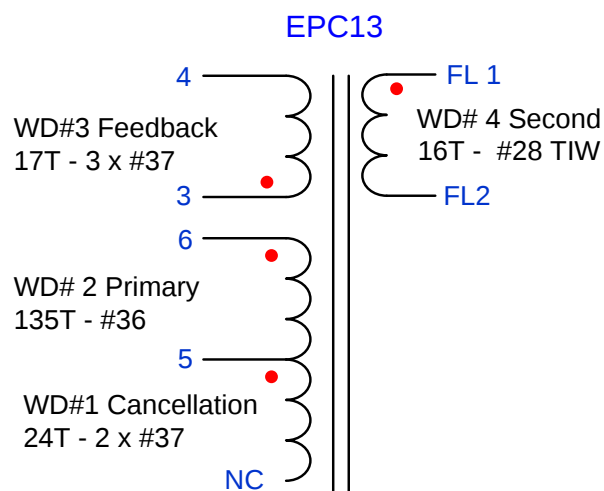


Figure 6 – Transformer Electrical Diagram.

### 8.2 電氣規格

|                            |                                                                          |              |
|----------------------------|--------------------------------------------------------------------------|--------------|
| Electrical Strength        | 1 second, 60 Hz, from primary to secondary.                              | 3000 VAC     |
| Primary Inductance         | Pin 5-6, other windings open, measured at 100 kHz, 1 V <sub>RMS</sub> .  | 1.68 mH, ±7% |
| Resonant Frequency         | Pin 5-6, other windings open.                                            | 500 kHz      |
| Primary Leakage Inductance | Pin 5-6, with FL1-FL2 shorted, measured at 100 kHz, 1 V <sub>RMS</sub> . | 60 μH        |

### 8.3 材料

| Item | Description                                                    |
|------|----------------------------------------------------------------|
| [1]  | Core: EPC13, PC44, gapped for ALG of 84.69 nH/T <sup>2</sup> . |
| [2]  | Bobbin: EPC13, Horizontal, 10 pins, (5/5).                     |
| [3]  | Magnet Wire: #36 AWG.                                          |
| [4]  | Magnet Wire: #37 AWG.                                          |
| [5]  | Magnet Wire: #28 AWG, TIW.                                     |
| [6]  | Tape: 3M 1298 Polyester film, 2.0 mils thick, 7.0 mm wide.     |
| [7]  | Varnish: Dolph BC-359, or equivalent.                          |



## 8.4 變壓器建構圖

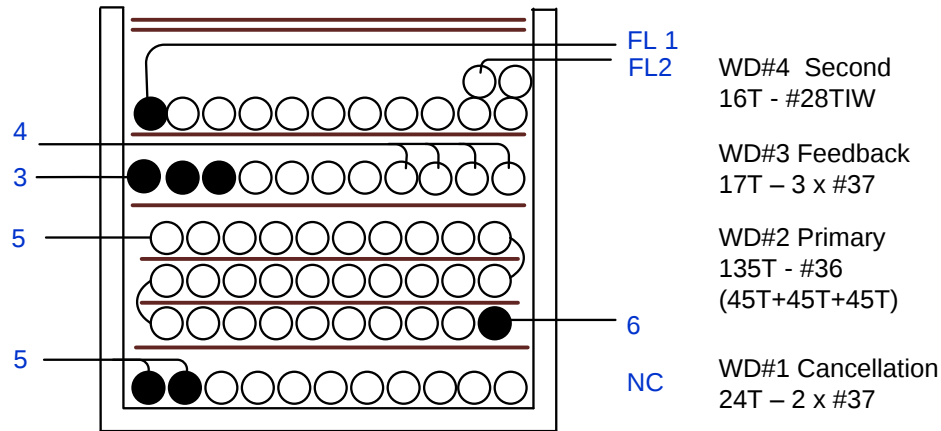


Figure 7 – Transformer Build Diagram.

## 8.5 變壓器結構

|                                          |                                                                                                                                                                                                                                                                                                                        |
|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>WD#1<br/>Cancellation<br/>Winding</b> | Pin 1 - pin 5 side of the bobbin oriented to left hand side.<br>Start at pin 5, wind 24 bifilar turns of item [4] in one layer. Wind with tight tension across bobbin evenly. Cut the end of the wire.                                                                                                                 |
| <b>Insulation</b>                        | 1 layer of tape item [6] for basic insulation.                                                                                                                                                                                                                                                                         |
| <b>WD#2<br/>Primary Winding</b>          | Start at pin 6, wind 45 turns of item [3] from right to left. Apply one layer of tape [5]. Then wind another 45 turns on the next layer from left to right. Apply one layer of tape [5]. Wind the last 45 turns from right to left. Terminate on pin 5. Wind with tight tension and spread turns across bobbin evenly. |
| <b>Insulation</b>                        | 1 layer of tape item [6] for basic insulation.                                                                                                                                                                                                                                                                         |
| <b>WD#3<br/>Feedback<br/>Winding</b>     | Start at pin 3, wind 17 trifilar turns of item [4] from left to right uniformly. Spread the winding across bobbin evenly and terminate at pin 4.                                                                                                                                                                       |
| <b>Insulation</b>                        | 1 layer of tape item [6] for basic insulation.                                                                                                                                                                                                                                                                         |
| <b>WD#4<br/>Secondary<br/>Winding</b>    | Start at pin 2 <b>temporarily</b> , wind 16 turns of item [5] from left to right in 1 layer and 3 turns on 2 <sup>nd</sup> layer, leave the end lead floating at the right hand side, and mark it as FL2. Bring the start end of the wire across the bobbin to the right side and fly out, mark it as FL1.             |
| <b>Insulation</b>                        | 2 layers of tape item [6] for basic insulation.                                                                                                                                                                                                                                                                        |
| <b>Core Assemble</b>                     | Gap core and assemble. Secure core halves with tape.                                                                                                                                                                                                                                                                   |
| <b>Varnish</b>                           | Dip varnish assembly with item [7].                                                                                                                                                                                                                                                                                    |

## 9 效能資料

All measurements were taken at room temperature using an LED load. The following data were measured using 3 sets of loads for a load range of 7 V to 11 V. Refer to the table on Section 9.3 for the complete set of test data values.

### 9.1 效率

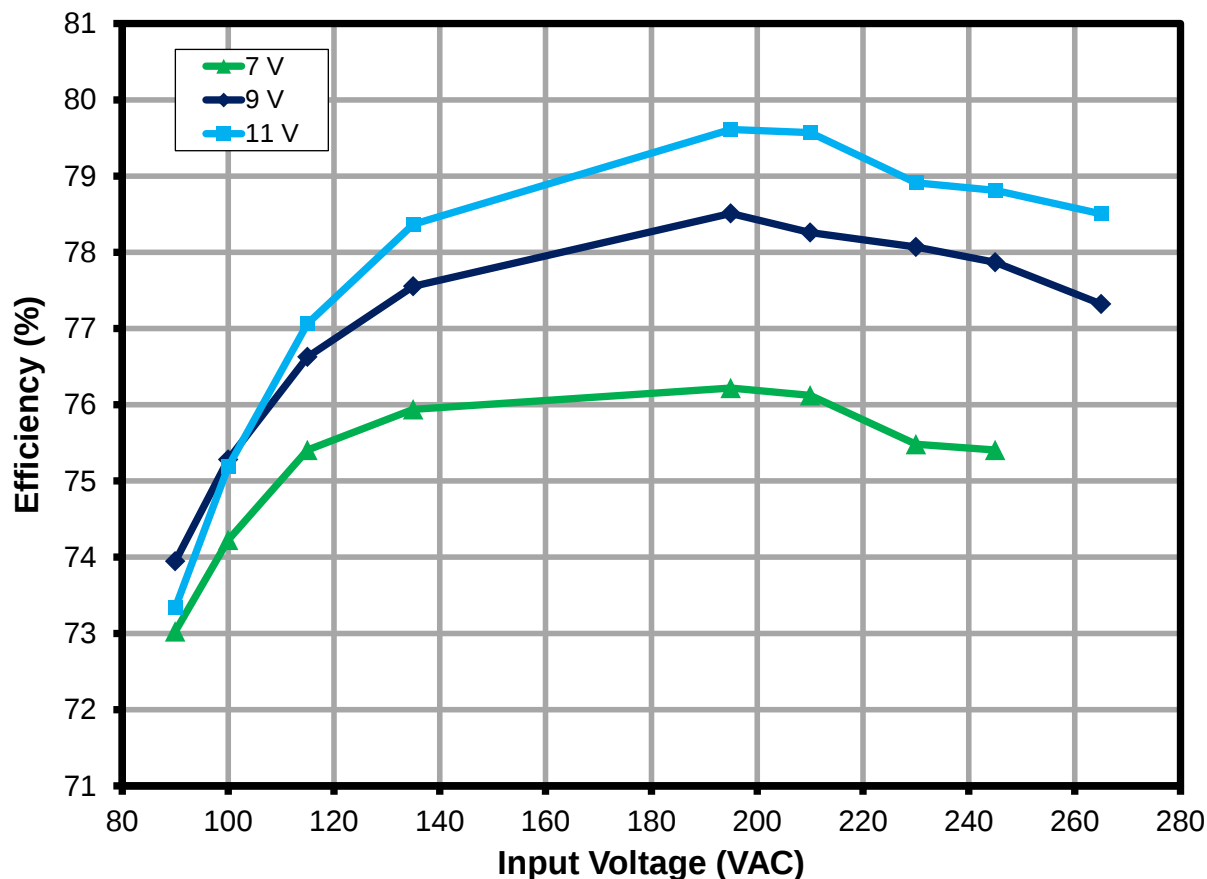


Figure 8 – Efficiency vs. Line and Load.



## 9.2 線電壓與負載穩定度關係圖

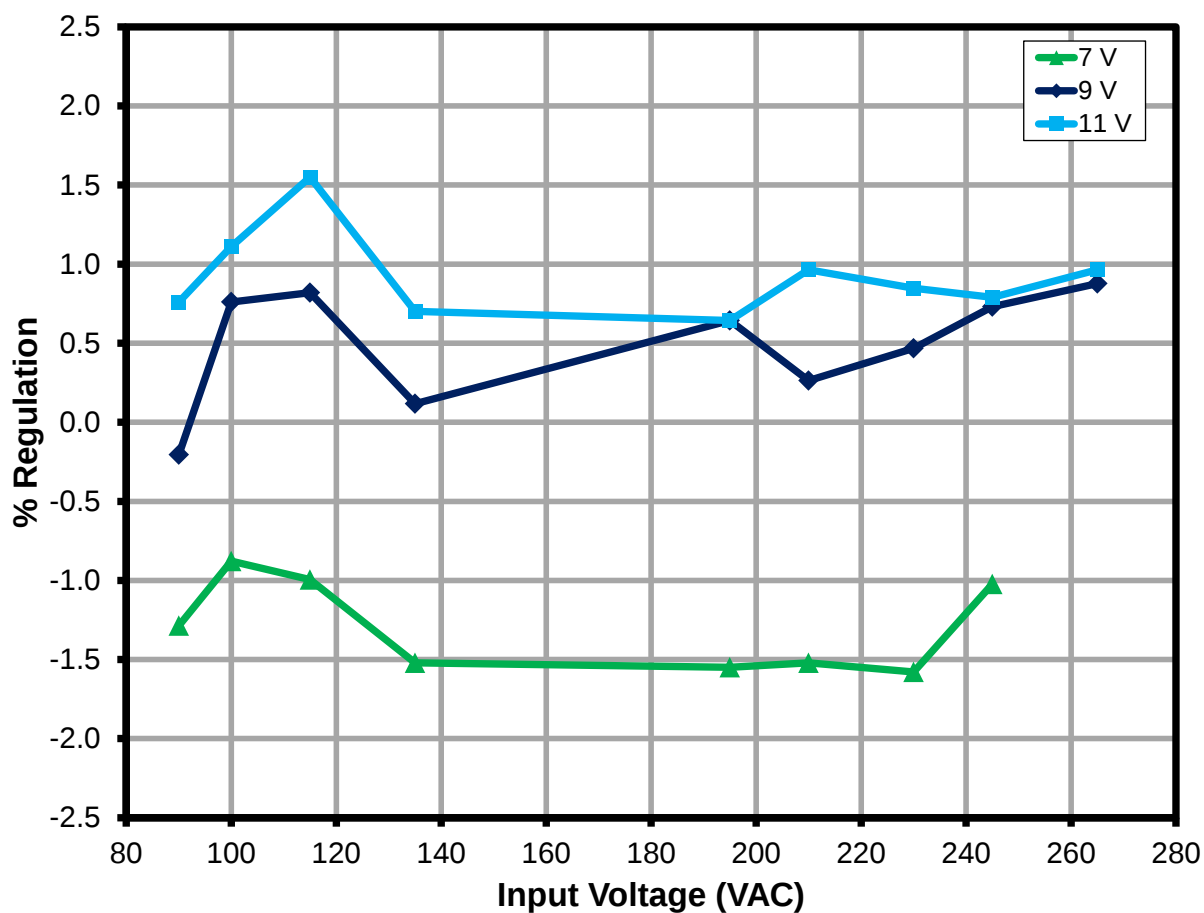


Figure 9 – Regulation vs. Line and Load.



### 9.3 測試資料

All measurements were taken with the board at open frame, 25 °C ambient.

#### 9.3.1 測試資料，7 V 輸出

| Input                      |              | Input Measurement                      |                                         |                        | Load Measurement                       |                                         |                         | Calculation             |                   |             |
|----------------------------|--------------|----------------------------------------|-----------------------------------------|------------------------|----------------------------------------|-----------------------------------------|-------------------------|-------------------------|-------------------|-------------|
| VAC<br>(V <sub>RMS</sub> ) | Freq<br>(Hz) | V <sub>IN</sub><br>(V <sub>RMS</sub> ) | I <sub>IN</sub><br>(mA <sub>RMS</sub> ) | P <sub>IN</sub><br>(W) | V <sub>OUT</sub><br>(V <sub>DC</sub> ) | I <sub>OUT</sub><br>(mA <sub>DC</sub> ) | P <sub>OUT</sub><br>(W) | P <sub>CAL</sub><br>(W) | Efficiency<br>(%) | Loss<br>(W) |
| 90                         | 60           | 89.93                                  | 55.59                                   | 3.11                   | 6.68                                   | 337.60                                  | 2.27                    | 2.26                    | 73.03             | 0.84        |
| 100                        | 60           | 99.97                                  | 50.99                                   | 3.07                   | 6.68                                   | 339.00                                  | 2.28                    | 2.26                    | 74.23             | 0.79        |
| 115                        | 60           | 114.98                                 | 45.71                                   | 3.02                   | 6.67                                   | 338.60                                  | 2.28                    | 2.26                    | 75.41             | 0.74        |
| 135                        | 60           | 134.97                                 | 40.77                                   | 2.98                   | 6.67                                   | 336.80                                  | 2.27                    | 2.25                    | 75.94             | 0.72        |
| 195                        | 50           | 194.99                                 | 31.67                                   | 2.97                   | 6.67                                   | 336.70                                  | 2.27                    | 2.25                    | 76.22             | 0.71        |
| 210                        | 50           | 209.94                                 | 30.32                                   | 2.98                   | 6.68                                   | 336.80                                  | 2.27                    | 2.25                    | 76.12             | 0.71        |
| 230                        | 50           | 230.02                                 | 28.79                                   | 3.00                   | 6.67                                   | 336.60                                  | 2.27                    | 2.25                    | 75.48             | 0.74        |
| 245                        | 50           | 244.95                                 | 27.85                                   | 3.03                   | 6.67                                   | 338.50                                  | 2.28                    | 2.26                    | 75.40             | 0.74        |
| 265                        | 50           | 265.03                                 | 26.73                                   | 3.06                   | 6.68                                   | 337.10                                  | 2.28                    | 2.25                    | 74.42             | 0.78        |

#### 9.3.2 測試資料，9 V 輸出

| Input                      |              | Input Measurement                      |                                         |                        | Load Measurement                       |                                         |                         | Calculation             |                   |             |
|----------------------------|--------------|----------------------------------------|-----------------------------------------|------------------------|----------------------------------------|-----------------------------------------|-------------------------|-------------------------|-------------------|-------------|
| VAC<br>(V <sub>RMS</sub> ) | Freq<br>(Hz) | V <sub>IN</sub><br>(V <sub>RMS</sub> ) | I <sub>IN</sub><br>(mA <sub>RMS</sub> ) | P <sub>IN</sub><br>(W) | V <sub>OUT</sub><br>(V <sub>DC</sub> ) | I <sub>OUT</sub><br>(mA <sub>DC</sub> ) | P <sub>OUT</sub><br>(W) | P <sub>CAL</sub><br>(W) | Efficiency<br>(%) | Loss<br>(W) |
| 90                         | 60           | 89.93                                  | 69.89                                   | 4.05                   | 8.74                                   | 341.30                                  | 3.00                    | 2.98                    | 73.95             | 1.06        |
| 100                        | 60           | 99.96                                  | 63.95                                   | 4.02                   | 8.74                                   | 344.60                                  | 3.02                    | 3.01                    | 75.28             | 0.99        |
| 115                        | 60           | 114.98                                 | 57.10                                   | 3.95                   | 8.73                                   | 344.80                                  | 3.03                    | 3.01                    | 76.63             | 0.92        |
| 135                        | 60           | 134.97                                 | 50.49                                   | 3.88                   | 8.74                                   | 342.40                                  | 3.01                    | 2.99                    | 77.55             | 0.87        |
| 195                        | 50           | 194.99                                 | 39.02                                   | 3.85                   | 8.73                                   | 344.20                                  | 3.02                    | 3.00                    | 78.51             | 0.83        |
| 210                        | 50           | 209.94                                 | 37.27                                   | 3.85                   | 8.72                                   | 342.90                                  | 3.01                    | 2.99                    | 78.26             | 0.84        |
| 230                        | 50           | 230.02                                 | 35.31                                   | 3.86                   | 8.72                                   | 343.60                                  | 3.02                    | 3.00                    | 78.07             | 0.85        |
| 245                        | 50           | 244.95                                 | 34.13                                   | 3.89                   | 8.73                                   | 344.50                                  | 3.03                    | 3.01                    | 77.87             | 0.86        |
| 265                        | 50           | 265.04                                 | 32.71                                   | 3.92                   | 8.73                                   | 345.00                                  | 3.03                    | 3.01                    | 77.32             | 0.89        |

#### 9.3.3 測試資料，11 V 輸出

| Input                      |              | Input Measurement                      |                                         |                        | Load Measurement                       |                                         |                         | Calculation             |                   |             |
|----------------------------|--------------|----------------------------------------|-----------------------------------------|------------------------|----------------------------------------|-----------------------------------------|-------------------------|-------------------------|-------------------|-------------|
| VAC<br>(V <sub>RMS</sub> ) | Freq<br>(Hz) | V <sub>IN</sub><br>(V <sub>RMS</sub> ) | I <sub>IN</sub><br>(mA <sub>RMS</sub> ) | P <sub>IN</sub><br>(W) | V <sub>OUT</sub><br>(V <sub>DC</sub> ) | I <sub>OUT</sub><br>(mA <sub>DC</sub> ) | P <sub>OUT</sub><br>(W) | P <sub>CAL</sub><br>(W) | Efficiency<br>(%) | Loss<br>(W) |
| 90                         | 60           | 89.93                                  | 89.18                                   | 5.28                   | 11.21                                  | 344.60                                  | 3.87                    | 3.86                    | 73.34             | 1.41        |
| 100                        | 60           | 99.97                                  | 79.75                                   | 5.17                   | 11.20                                  | 345.80                                  | 3.89                    | 3.87                    | 75.19             | 1.28        |
| 115                        | 60           | 114.98                                 | 70.44                                   | 5.06                   | 11.20                                  | 347.30                                  | 3.90                    | 3.89                    | 77.06             | 1.16        |
| 135                        | 60           | 134.97                                 | 61.67                                   | 4.93                   | 11.19                                  | 344.40                                  | 3.87                    | 3.85                    | 78.37             | 1.07        |
| 195                        | 50           | 194.99                                 | 47.10                                   | 4.85                   | 11.18                                  | 344.20                                  | 3.86                    | 3.85                    | 79.61             | 0.99        |
| 210                        | 50           | 209.94                                 | 45.17                                   | 4.87                   | 11.18                                  | 345.30                                  | 3.88                    | 3.86                    | 79.57             | 1.00        |
| 230                        | 50           | 230.02                                 | 42.90                                   | 4.90                   | 11.18                                  | 344.90                                  | 3.87                    | 3.86                    | 78.91             | 1.03        |
| 245                        | 50           | 244.95                                 | 41.28                                   | 4.90                   | 11.17                                  | 344.70                                  | 3.87                    | 3.85                    | 78.81             | 1.04        |
| 265                        | 50           | 265.04                                 | 39.43                                   | 4.93                   | 11.17                                  | 345.30                                  | 3.87                    | 3.86                    | 78.50             | 1.06        |



## 10 散熱效能

Images captured after running for >30 minutes at room temperature (25 °C), no airflow, open frame

### 10.1 $V_{IN} = 115 \text{ VAC}$

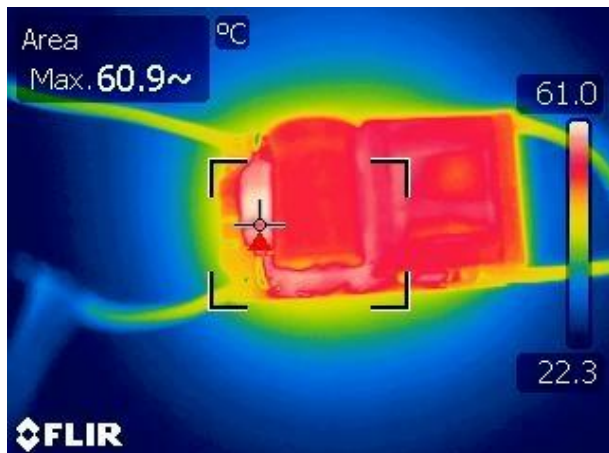


Figure 10 – EMI filter inductor: 60.9 °C.

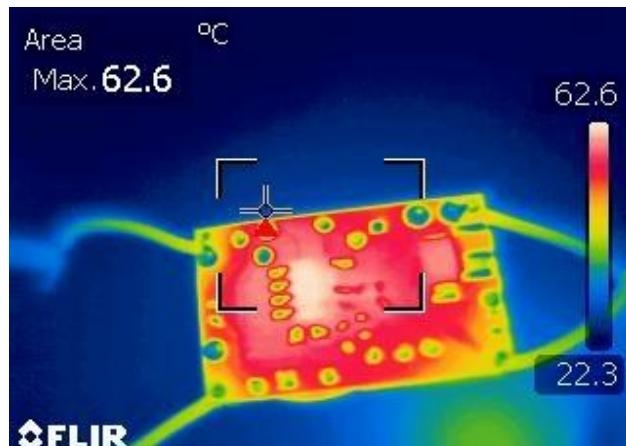


Figure 11 – LNK604DG: 62.6 °C.

### 10.2 $V_{IN} = 230 \text{ VAC}$

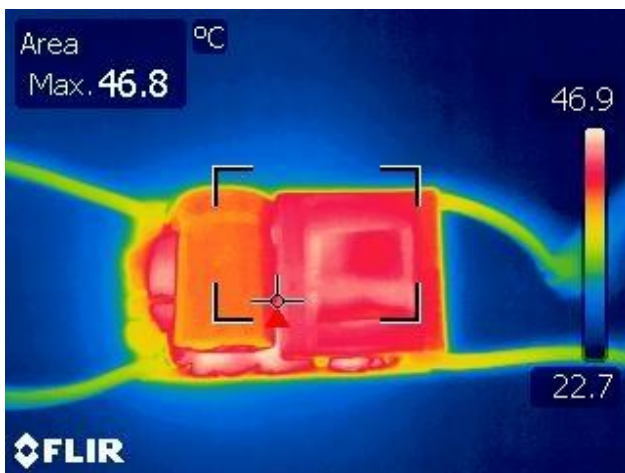


Figure 12 – Transformer: 46.8 °C.

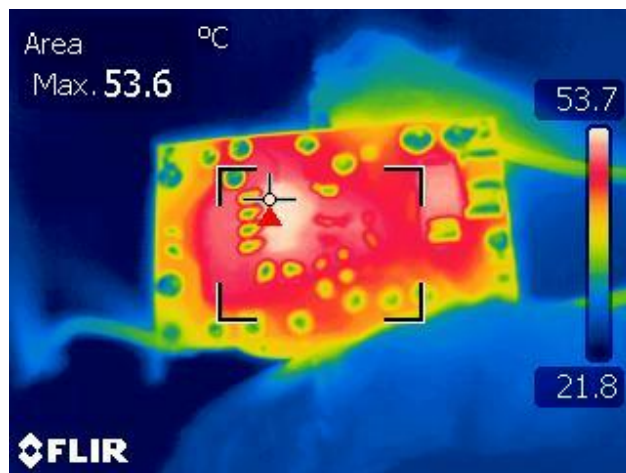
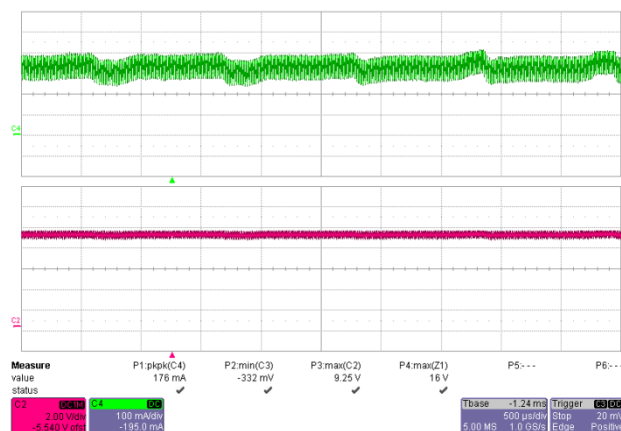


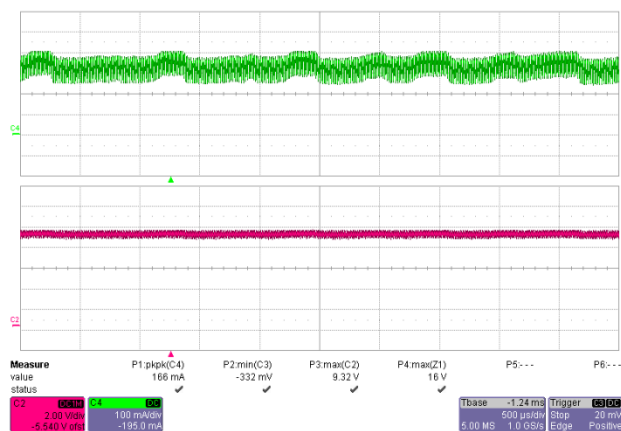
Figure 13 – LNK604DG 53.6 °C.



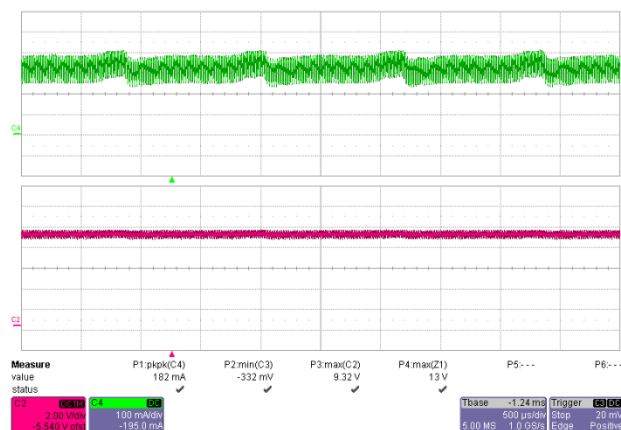
## 11.2 正常運作下的輸出電流和輸出電壓



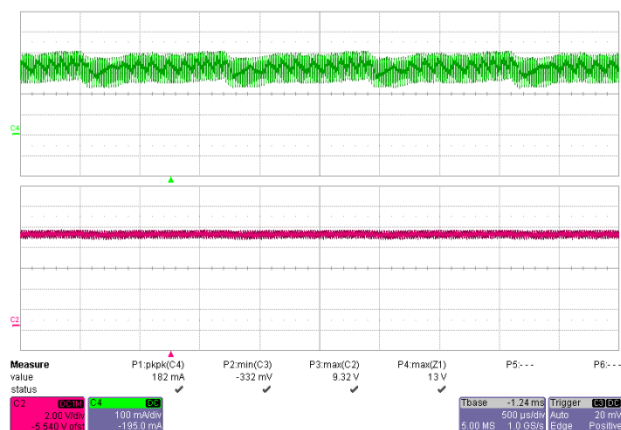
**Figure 18 – 90 VAC, 60 Hz Full Load.**  
Upper:  $I_{OUT}$ , 100 mA / div.  
Lower:  $V_{OUT}$ , 20 V, 500  $\mu$ s / div.



**Figure 19 – 115 VAC, 60 Hz Full Load.**  
Upper:  $I_{OUT}$ , 100 mA / div.  
Lower:  $V_{OUT}$ , 20 V, 500  $\mu$ s / div.



**Figure 20 – 230 VAC, 50 Hz Full Load.**  
Upper:  $I_{OUT}$ , 100 mA / div.  
Lower:  $V_{OUT}$ , 20 V, 500  $\mu$ s / div.



**Figure 21 – 265 VAC, 50 Hz Full Load.**  
Upper:  $I_{OUT}$ , 100 mA / div.  
Lower:  $V_{OUT}$ , 20 V, 500  $\mu$ s / div.

### 11.3 輸出電流/電壓上升及下降

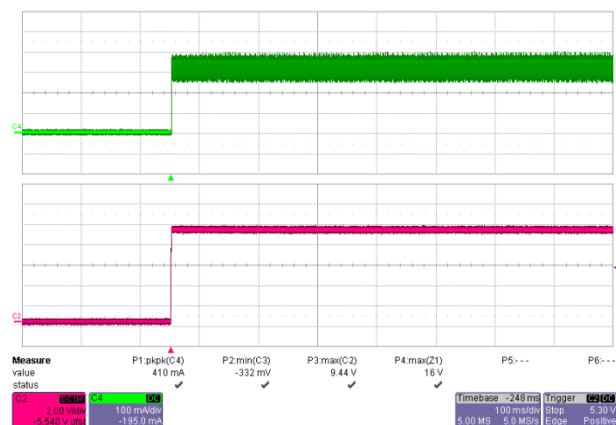


Figure 22 – 90 VAC, 60 Hz Output Rise.

Upper:  $I_{OUT}$ , 100 mA / div.

Lower:  $V_{OUT}$ , 20 V, 100 ms / div.

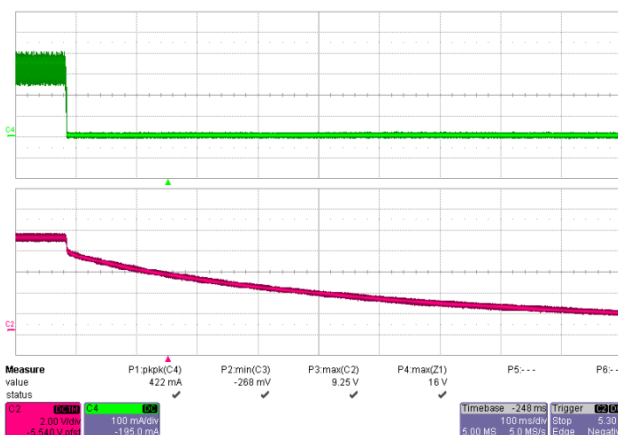


Figure 23 – 90 VAC, 60 Hz Output Fall.

Upper:  $I_{OUT}$ , 100 mA / div.

Lower:  $V_{OUT}$ , 20 V, 100 ms / div.

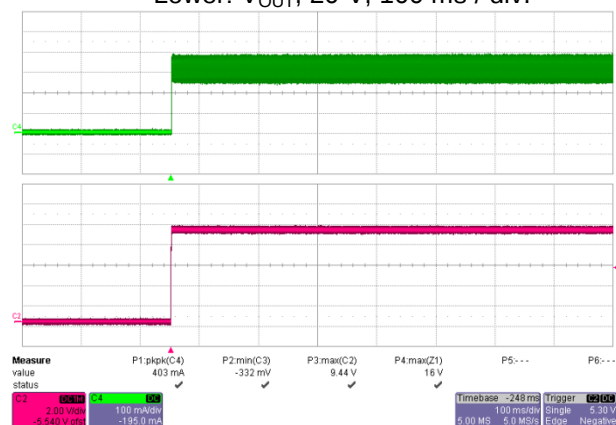


Figure 24 – 265 VAC, 50 Hz Output Rise.

Upper:  $I_{OUT}$ , 100 mA / div.

Lower:  $V_{OUT}$ , 20 V, 100 ms / div.

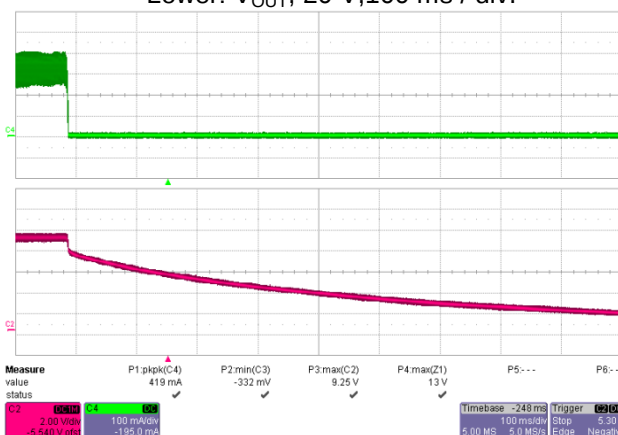


Figure 25 – 265 VAC, 50 Hz Output Fall.

Upper:  $I_{OUT}$ , 100 mA / div.

Lower:  $V_{OUT}$ , 20 V, 100 ms / div.

### 11.4 啟動時的輸入電壓和輸出電流波形

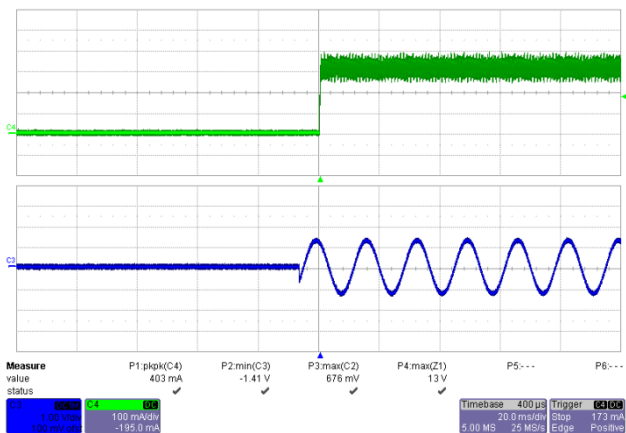


Figure 26 – 90 VAC, 60 Hz.

Upper:  $I_{OUT}$ , 100 mA / div.  
Lower:  $V_{IN}$ , 100 V, 20 ms / div.

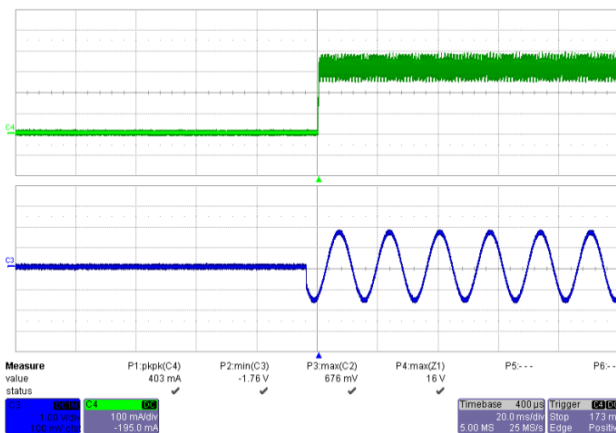


Figure 27 – 115 VAC, 60 Hz.

Upper:  $I_{OUT}$ , 100 mA / div.  
Lower:  $V_{IN}$ , 100 V, 20 ms / div.

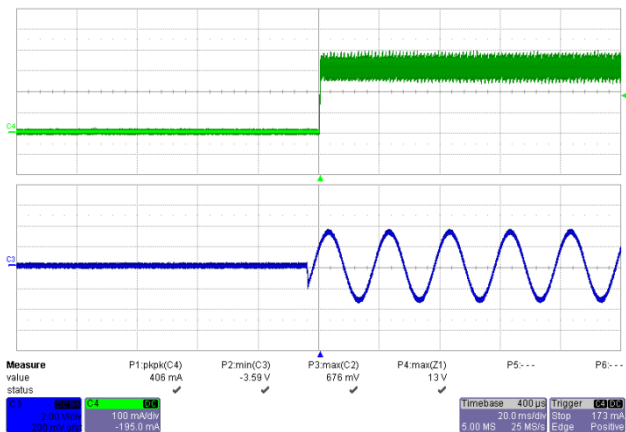


Figure 28 – 230 VAC, 50 Hz.

Upper:  $I_{OUT}$ , 100 mA / div.  
Lower:  $V_{IN}$ , 200 V, 20 ms / div.

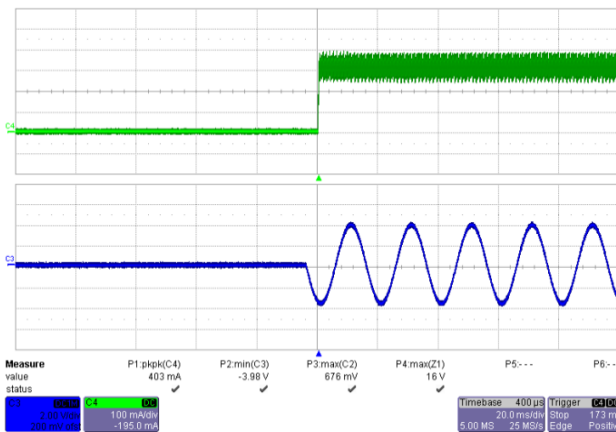


Figure 29 – 265 VAC, 50 Hz.

Upper:  $I_{OUT}$ , 100 mA / div.  
Lower:  $V_{IN}$ , 200 V, 20 ms / div.

## 11.5 正常操作下的汲極波形

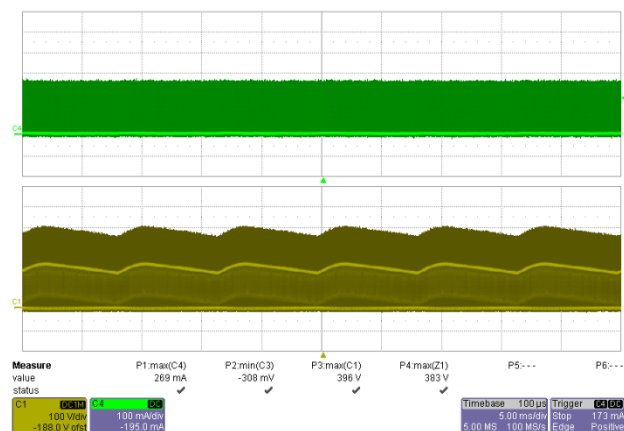


Figure 30 – 90 VAC, 60 Hz.

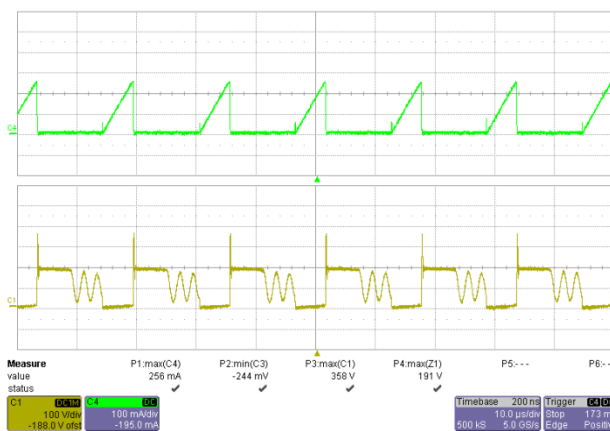
Upper:  $I_{DRAIN}$ , 100 mA / div.Lower:  $V_{DRAIN}$ , 100 V, 5 ms / div.

Figure 31 – 90 VAC, 60 Hz.

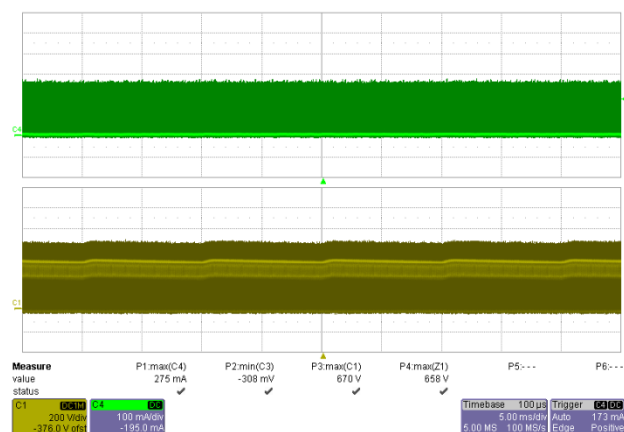
Upper:  $I_{DRAIN}$ , 100 mA / div.Lower:  $V_{DRAIN}$ , 100 V, 10  $\mu$ s / div.

Figure 32 – 265 VAC, 50 Hz.

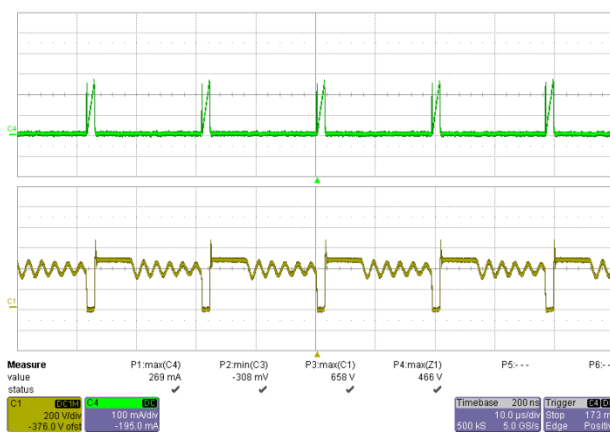
Upper:  $I_{DRAIN}$ , 100 A / div.Lower:  $V_{DRAIN}$ , 200 V, 5 ms / div.

Figure 33 – 265 VAC, 50 Hz.

Upper:  $I_{DRAIN}$ , 100 A / div.Lower:  $V_{DRAIN}$ , 200 V, 10  $\mu$ s / div.

### 11.6 正常操作下的輸出二極體波形

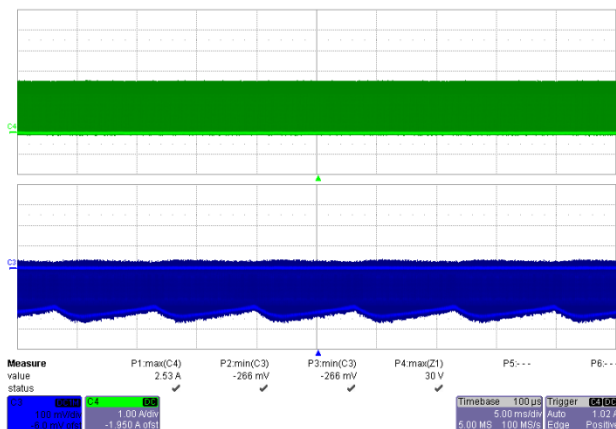


Figure 34 – 90 VAC, 60 Hz.

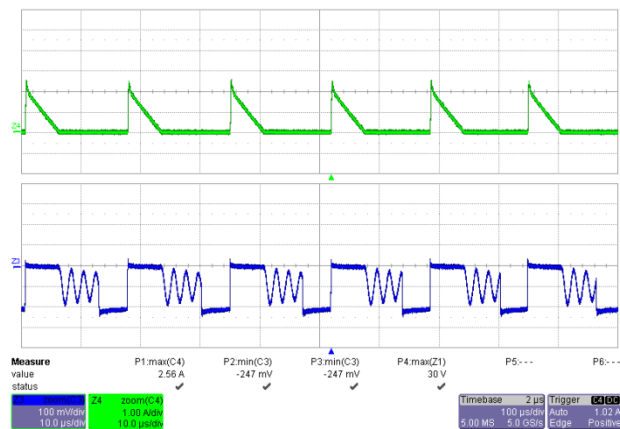
Upper:  $I_{DRAIN}$ , 1 A / div.Lower:  $V_{DRAIN}$ , 100 V, 5 ms / div.

Figure 35 – 90 VAC, 60 Hz.

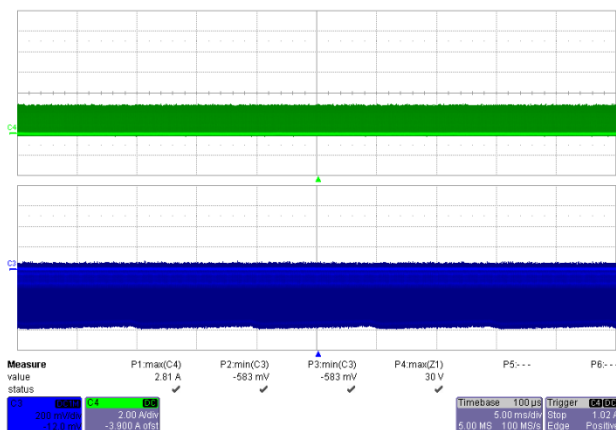
Upper:  $I_{DRAIN}$ , 1 A / div.Lower:  $V_{DRAIN}$ , 100 V, 10  $\mu$ s / div.

Figure 36 – 265 VAC, 50 Hz.

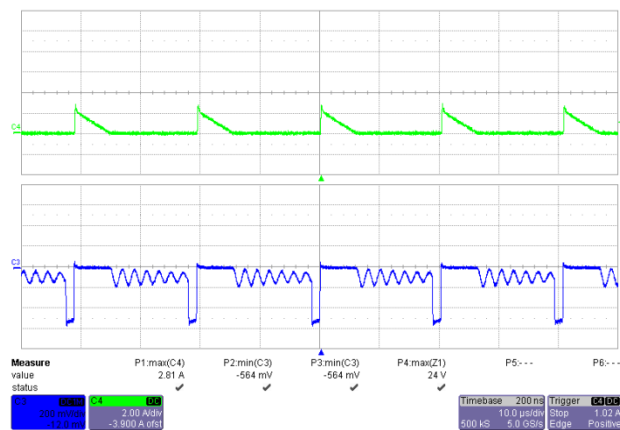
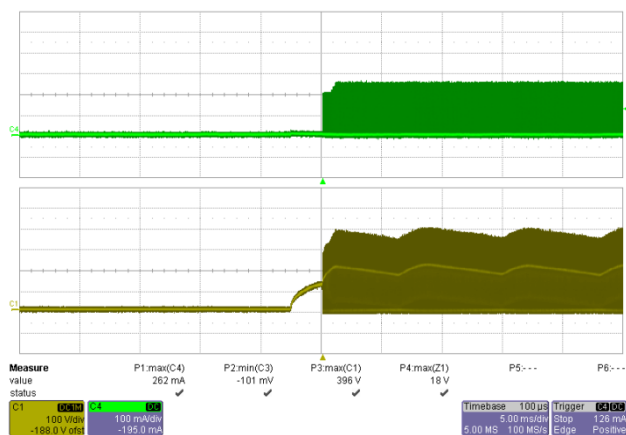
Upper:  $I_{DRAIN}$ , 2 A / div.Lower:  $V_{DRAIN}$ , 200 V, 5 ms / div.

Figure 37 – 265 VAC, 50 Hz.

Upper:  $I_{DRAIN}$ , 2 A / div.Lower:  $V_{DRAIN}$ , 200 V, 10  $\mu$ s / div.

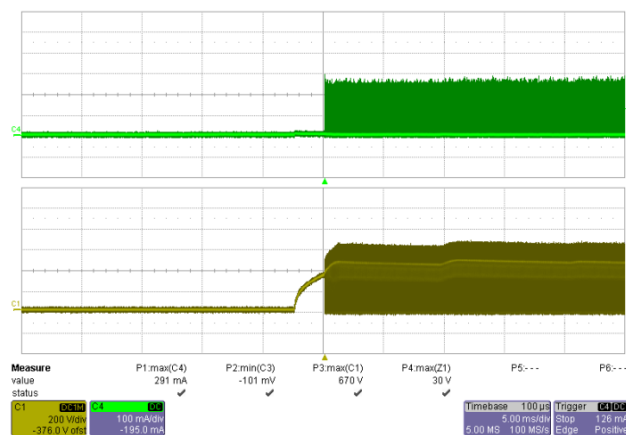
### 11.7 啓動及極電壓和電流



**Figure 38** – 90 VAC, 60 Hz.

Upper:  $I_{DRAIN}$ , 100 mA / div.

Lower:  $V_{DRAIN}$ , 100 V, 5 ms / div.



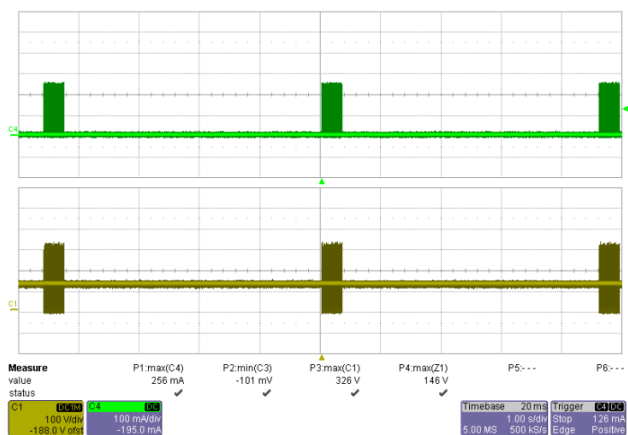
**Figure 39** – 265 VAC, 50 Hz.

Upper:  $I_{DRAIN}$ , 100 mA / div.

Lower:  $V_{DRAIN}$ , 200 V, 5 ms / div.



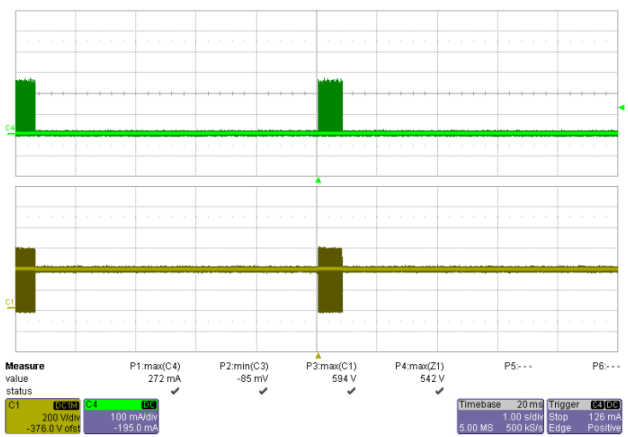
### 11.8 輸出短路時的汲極電流和汲極電壓



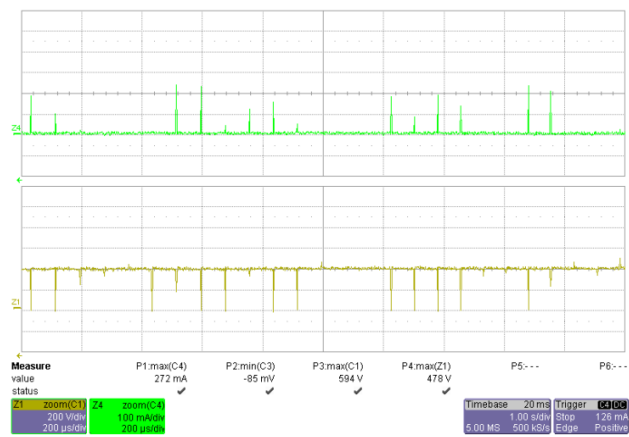
**Figure 40** – 90 VAC, 60 Hz Output Short Condition.  
Upper:  $I_{DRAIN}$ , 100 mA / div.  
Lower:  $V_{DRAIN}$ , 100 V, 1 s / div.



**Figure 41** – 90 VAC, 60 Hz Output Short Condition.  
Upper:  $I_{DRAIN}$ , 100 mA / div.  
Lower:  $V_{DRAIN}$ , 100 V, 10  $\mu$ s / div.



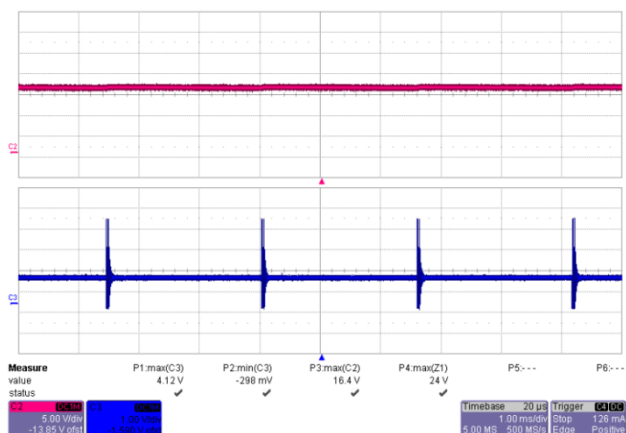
**Figure 42** – 265 VAC, 50 Hz Output Short Condition.  
Upper:  $I_{DRAIN}$ , 100 mA / div.  
Lower:  $V_{DRAIN}$ , 200 V, 1 s / div.



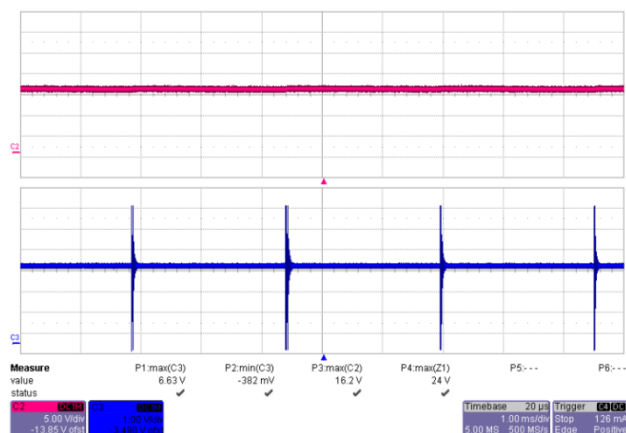
**Figure 43** – 265 VAC, 50 Hz Output Short Condition.  
Upper:  $I_{DRAIN}$ , 100 mA / div.  
Lower:  $V_{DRAIN}$ , 200 V, 50  $\mu$ s / div.



## 11.9 無負載輸出電壓



**Figure 44** – 90 VAC, 60 Hz No-Load Characteristic.  
Upper:  $V_{OUT}$ , 5 V / div.  
Lower:  $V_{DRAIN}$ , 100 V / div., 1 ms / div.



**Figure 45** – 265 VAC, 50 Hz No-Load Characteristic.  
Upper:  $V_{OUT}$ , 5 V / div.  
Lower:  $V_{DRAIN}$ , 100 V / div., 1 ms / div.



## 12 傳導性 EMI

The unit was tested using LED load (9 V) with input voltage of 115 VAC, 60 Hz at room temperature.

| EDIT PEAK LIST (Final Measurement Results) |                   |            |                |     |        |
|--------------------------------------------|-------------------|------------|----------------|-----|--------|
| Trace1:                                    | EN55015Q          |            |                |     |        |
| Trace2:                                    | EN55015A          |            |                |     |        |
| Trace3:                                    | ---               |            |                |     |        |
| TRACE                                      | FREQUENCY         | LEVEL dBμV | DELTA LIMIT dB |     |        |
| 2 Average                                  | 9.4590904509 kHz  | 23.49      | N              | gnd |        |
| 2 Average                                  | 116.100896051 kHz | 18.66      | L1             | gnd |        |
| 2 Average                                  | 126.977840157 kHz | 26.15      | N              | gnd |        |
| 1 Quasi Peak                               | 167.350252 kHz    | 57.92      | N              | gnd | -7.16  |
| 2 Average                                  | 170.713992065 kHz | 45.34      | N              | gnd | -9.57  |
| 1 Quasi Peak                               | 225.562855639 kHz | 53.90      | N              | gnd | -8.70  |
| 2 Average                                  | 227.818484195 kHz | 40.90      | N              | gnd | -11.62 |
| 1 Quasi Peak                               | 280.761663784 kHz | 48.87      | N              | gnd | -11.92 |
| 2 Average                                  | 283.569280422 kHz | 36.24      | L1             | gnd | -14.46 |
| 2 Average                                  | 500.008614528 kHz | 32.42      | N              | gnd | -13.57 |
| 1 Quasi Peak                               | 1.1883298484 MHz  | 40.38      | N              | gnd | -15.61 |
| 2 Average                                  | 1.87810643122 MHz | 28.98      | N              | gnd | -17.01 |
| 1 Quasi Peak                               | 3.1196815376 MHz  | 44.07      | N              | gnd | -11.92 |
| 2 Average                                  | 3.1196815376 MHz  | 31.28      | N              | gnd | -14.71 |
| 2 Average                                  | 30 MHz            | 14.73      | N              | gnd | -35.26 |



Figure 46 – Conducted EMI 9 V / 330 mA Load, 115 VAC, 60 Hz, and EN55015 Limits.



| EDIT PEAK LIST (Final Measurement Results) |                   |            |        |        |          |
|--------------------------------------------|-------------------|------------|--------|--------|----------|
| Trace1:                                    | EN55015Q          |            |        |        |          |
| Trace2:                                    | EN55015A          |            |        |        |          |
| Trace3:                                    | ---               |            |        |        |          |
| TRACE                                      | FREQUENCY         | LEVEL dBμV |        | DELTA  | LIMIT dB |
| 2 Average                                  | 9.272709 kHz      | 22.48      | L1 gnd |        |          |
| 2 Average                                  | 159.22802259 kHz  | 41.21      | N gnd  | -14.29 |          |
| 1 Quasi Peak                               | 162.428505844 kHz | 55.77      | L1 gnd | -9.56  |          |
| 1 Quasi Peak                               | 214.615317539 kHz | 53.17      | L1 gnd | -9.85  |          |
| 2 Average                                  | 214.615317539 kHz | 39.34      | N gnd  | -13.68 |          |
| 2 Average                                  | 267.135089486 kHz | 36.42      | N gnd  | -14.77 |          |
| 1 Quasi Peak                               | 269.806440381 kHz | 50.46      | L1 gnd | -10.65 |          |
| 1 Quasi Peak                               | 322.728292586 kHz | 46.70      | L1 gnd | -12.93 |          |
| 2 Average                                  | 322.728292586 kHz | 33.94      | N gnd  | -15.69 |          |
| 2 Average                                  | 378.424303998 kHz | 32.73      | N gnd  | -15.58 |          |
| 1 Quasi Peak                               | 485.30343514 kHz  | 47.29      | L1 gnd | -8.95  |          |
| 2 Average                                  | 485.30343514 kHz  | 35.30      | N gnd  | -10.94 |          |
| 1 Quasi Peak                               | 1.02356729084 MHz | 43.34      | N gnd  | -12.65 |          |
| 1 Quasi Peak                               | 1.6177059882 MHz  | 43.31      | N gnd  | -12.68 |          |
| 2 Average                                  | 1.66672409735 MHz | 31.94      | N gnd  | -14.05 |          |
| 1 Quasi Peak                               | 2.18042326152 MHz | 44.39      | L1 gnd | -11.60 |          |
| 2 Average                                  | 2.18042326152 MHz | 31.30      | N gnd  | -14.69 |          |
| 1 Quasi Peak                               | 2.82420699879 MHz | 46.15      | L1 gnd | -9.84  |          |
| 2 Average                                  | 3.44606925067 MHz | 32.96      | N gnd  | -13.03 |          |

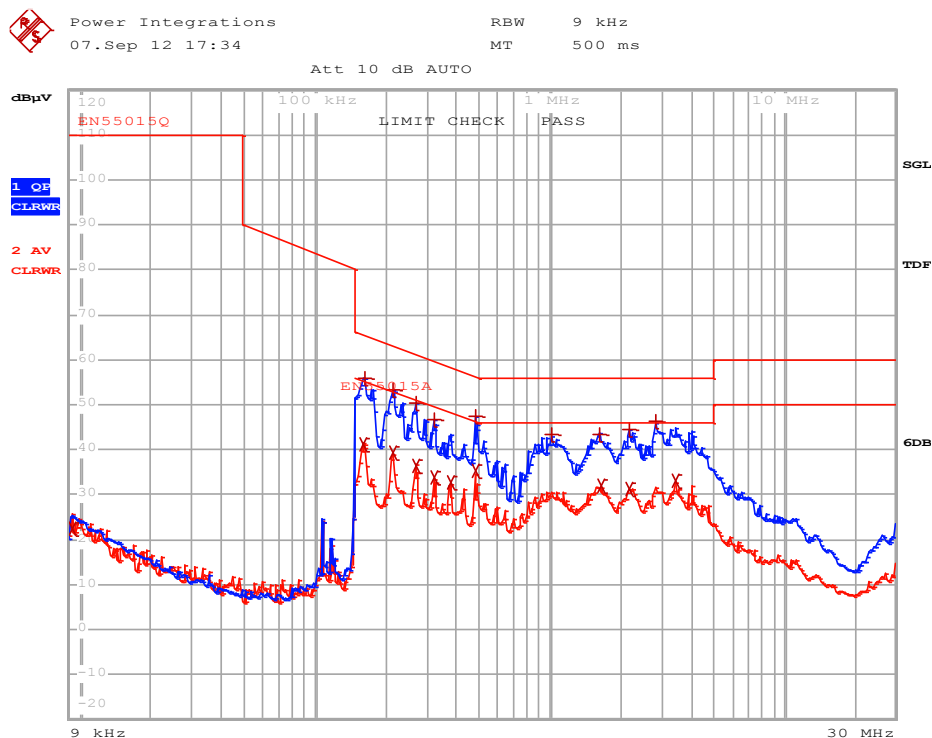


Figure 47 – Conducted EMI 9 V / 330 mA Load, 230 VAC, 60 Hz, and EN55015 Limits.



### 13 線電壓突波

Input voltage was set at 230 VAC / 60 Hz. Output was loaded with 9 V LED string.  
Differential input line 1.2 / 50 □s surge testing

#### 13.1 500 V 突波 (無箝位電路)

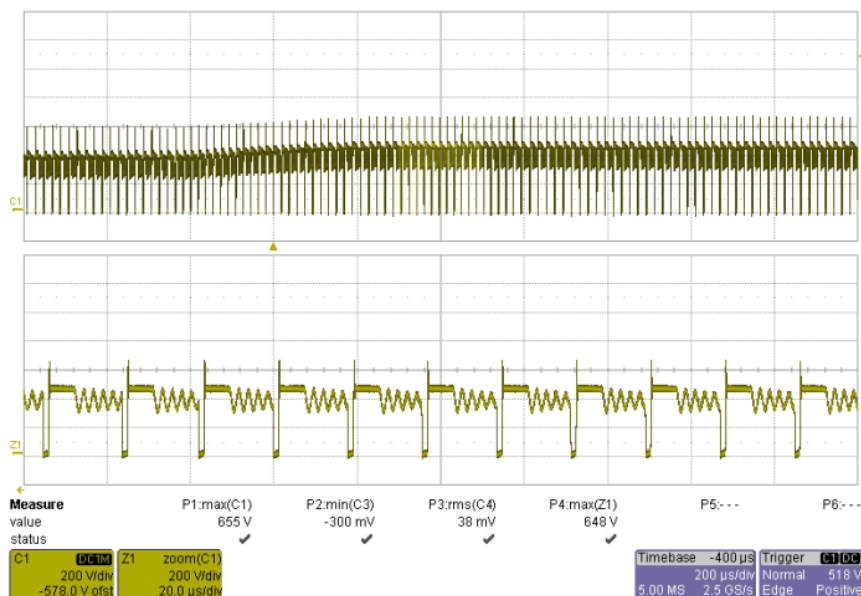


Figure 48 – Drain Voltage Waveform at 500 V Fast Surge.

#### 13.2 1 kV 突波 (有箝位電路)

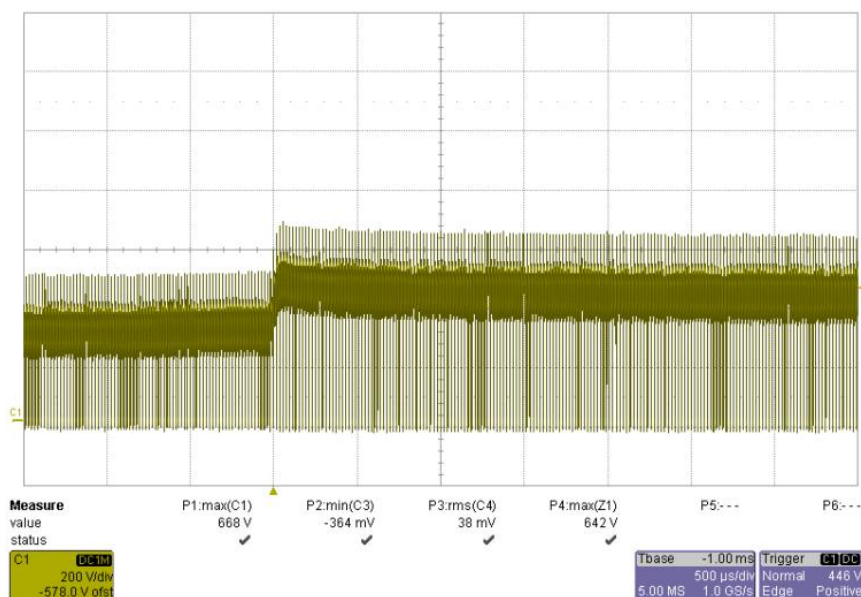


Figure 49 – Drain Voltage Waveform at 1 kV Fast Surge.





**14 修訂記錄**

| Date      | Author | Revision | Description and Changes      | Reviewed    |
|-----------|--------|----------|------------------------------|-------------|
| 22-Oct-12 | DK     | 2.0      | Initial Release              | Apps & Mktg |
| 14-Nov-12 | DK     | 2.1      | Updated Schematic 3A and BOM |             |
|           |        |          |                              |             |
|           |        |          |                              |             |



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