Design Example Report

<table>
<thead>
<tr>
<th>Title</th>
<th>5 W Adapter Using LinkSwitch™-CV LNK625DG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specification</td>
<td>Input: 85 VAC – 265 VAC; Output: 5 V / 1 A</td>
</tr>
<tr>
<td>Application</td>
<td>Adapter</td>
</tr>
<tr>
<td>Author</td>
<td>Applications Engineering Department</td>
</tr>
<tr>
<td>Document Number</td>
<td>DER-669</td>
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<tr>
<td>Date</td>
<td>April 8, 2019</td>
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<tr>
<td>Revision</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Summary and Features
- Low parts count solution
- Auto-restart output short-circuit, open-loop and over-temperature protection
- Primary side regulated
- Meets EN55022 EMI

The products and applications illustrated herein (including circuits external to the products and transformer construction) may be covered by one or more U.S. and foreign patents or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations’ patents may be found at [www.power.com](http://www.power.com).
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### 11.1 Test Set-up Equipment

#### 11.1.1 Equipment and Load Used

### 11.2 Test Set-up

### 11.3 Conductive EMI with Artificial Hand Output (QP / AV)

#### 11.3.1 115 VAC Line

#### 11.3.2 115 VAC Neutral

#### 11.3.3 230 VAC Line

#### 11.3.4 230 VAC Neutral

### 11.4 Conductive EMI with Floating Output (QP / AV)

#### 11.4.1 115 VAC Line

#### 11.4.2 115 VAC Neutral

#### 11.4.3 230 VAC Line

#### 11.4.4 230 VAC Neutral

## 12 Revision History
1 Introduction

This document is an engineering design report describing a 5 W / 5 V adapter power supply using LNK625DG. Input is 85 VAC to 265 VAC.

The document contains the power supply specification, schematic, transformer documentation, performance data and EMI scan.

Figure 1 – Populated Circuit Board.
## 2 Power Supply Specification

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage</td>
<td>$V_{IN}$</td>
<td>85</td>
<td>115/230</td>
<td>265</td>
<td>VAC</td>
<td>2 Wire</td>
</tr>
<tr>
<td>Frequency</td>
<td>$f_{LINE}$</td>
<td>50/60</td>
<td>50/60</td>
<td></td>
<td>Hz</td>
<td></td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Voltage</td>
<td>$V_{OUT}$</td>
<td>4.75</td>
<td>5.0</td>
<td>5.25</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Output Current</td>
<td>$I_{OUT}$</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Ripple</td>
<td></td>
<td></td>
<td></td>
<td>150</td>
<td>mV</td>
<td></td>
</tr>
<tr>
<td>Continuous Output Power</td>
<td>$P_{OUT}$</td>
<td>5</td>
<td>5</td>
<td></td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>Average Efficiency</td>
<td>$\eta$</td>
<td>74</td>
<td>74</td>
<td></td>
<td>%</td>
<td>At Nominal Lines.</td>
</tr>
<tr>
<td>EMI</td>
<td></td>
<td>EN55022</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>$T_{amb}$</td>
<td>0</td>
<td></td>
<td>40</td>
<td>ºC</td>
<td></td>
</tr>
</tbody>
</table>
3 Schematic

Figure 2 – Schematic.
4 Circuit Description

The schematic in Figure 2 shows an adapter design using the LNK625DG IC that provides constant voltage (CV) performance. The circuit is designed to operate from 85 VAC to 265 VAC input, with an output voltage of 5 V providing a maximum load current of 1 A. It consumes very little standby power and uses no Y capacitor but still meet stringent EMI requirements.

4.1 Input and EMI Filtering

Bridge rectifier BR1 is a full wave rectifier. The rectified DC is then filtered by capacitors C1 and C2. Inductor L1, L2 forms a pi filter with capacitors C1 and C2 which helps to reduce differential EMI noise. This filtering, together with the integrated switching frequency jitter provided in U1 and transformer E-Shield techniques, provide a generous EMI margin without the need for a Y capacitor across the primary and secondary windings of transformer T1.

4.2 LinkSwitch-CV Device

The LinkSwitch-CV family of devices has been developed to cost effectively replace all existing solutions in low power adapter applications. It is optimized for constant voltage (CV) adapter applications while using minimal external parts including the complete elimination of the optocoupler and shunt regulator.

The LNK625DG IC monolithically integrates the 700 V power MOSFET switch and controller, which consists of an oscillator, feedback (sense and logic) circuit, 6 V regulator, BYPASS (BP) pin programming functions, over-temperature protection, frequency jittering, current limit circuit and leading-edge blanking.

The LNK625DG IC also provides a sophisticated range of protection features including auto-restart for control loop component open/short-circuit faults and output short-circuit conditions. The use of a low auto-restart on time reduces the power delivered by more than 95% for output short-circuits and control loop faults. Accurate hysteretic thermal shutdown ensures safe average PCB temperatures under all conditions. Extended creepage distance between high and low voltage pins prevent arcing and helps meet safety requirements. The LinkSwitch-CV IC also can be used without a bias winding as it is completely self-biased.

4.3 Primary Circuit

During U1’s on time current flows through the primary winding of transformer T1 and stores energy in its magnetic field. During U1’s off time, the energy stored in the transformer is transferred to the secondary side, delivering current to both the output capacitors and the load.

The clamp circuit formed by resistors R1 and R2 along with blocking diode D1 and capacitor C3 ensures that the drain node voltage is well below the 700 V rating of the...
internal MOSFET of U1. The clamp circuit is also carefully designed to reduce and dampen any oscillation present in the voltage spike caused by the transformer’s leakage inductance.

### 4.4 Output Rectification

The secondary output is rectified by diode D3 which is placed in the return leg to help reduce EMI and simplify the transformer construction. An RC snubber circuit composed of resistor R7 and capacitor C7 is placed across the output diode to also reduce high frequency EMI. A stable output voltage is maintained by capacitor C8. Inductor L3 and capacitor C9 form an LC post filter which helps to attenuate switching noise and reduces output ripple. Resistor R8 is a preload resistor whose value has been empirically chosen to provide the best possible regulation at light loads without significantly affecting no-load input power or efficiency.

### 4.5 Feedback Winding

The LinkSwitch-CV IC eliminates the need for an optocoupler for tight output voltage regulation, as good as ±5%, through the use of a feedback winding. The FEEDBACK (FB) pin voltage, which is derived from the voltage divider formed by resistors R4 and R5, is sampled approximately 2.5 \( \mu \text{s} \) after U1’s internal power MOSFET turns off. Based upon this information the device regulates the output voltage.

The feedback winding was also designed with more turns than necessary so that it may act as a bias winding. The winding provides bias current to U1 through the BP pin and reduces the input power consumption during light loads and no-load conditions. Capacitor C4 provides a stable bias voltage while resistor R3 is chosen to supply the necessary BP pin current. Capacitor C5 is the BP pin capacitor and should be placed as close as possible to the BP pin and SOURCE (S) pins of the device.
5 PCB Layout

Figure 3 – PCB Layout, Top.

Figure 4 – PCB Layout, Bottom.
## 6 Bill of Materials

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Ref Des</th>
<th>Description</th>
<th>Mfg Part Number</th>
<th>Mfg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>BR1</td>
<td>600 V, 0.5 A, Bridge Rectifier, SMD, MBS-1, 4-501C</td>
<td>MB65-TP</td>
<td>Micro Commercial</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>C1</td>
<td>4.7 µF, 400 V, Electrolytic, (8 x 11.5)</td>
<td>TAQ2G4R7MK0811MLL3</td>
<td>Taicon</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>C2</td>
<td>4.7 µF, 400 V, Electrolytic, (8 x 11.5)</td>
<td>TAQ2G4R7MK0811MLL3</td>
<td>Taicon</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>C3</td>
<td>1 nF, 250 V, Ceramic, X7R, 0805</td>
<td>GRM21AR72E102KW01D</td>
<td>Murata</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>C4</td>
<td>10 µF, 25 V, Electrolytic, Gen. Purpose, (5 x 12)</td>
<td>ECA-1EM100</td>
<td>Panasonic</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>C5</td>
<td>1 µF, 50 V, Ceramic, X7R, 0805</td>
<td>C2012X7R1H055085AC</td>
<td>TDK</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>C6</td>
<td>330 pF, 50 V, Ceramic, X7R, 0603</td>
<td>CC0603KRX7R8331</td>
<td>Yageo</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>C7</td>
<td>1 nF, 50 V, Ceramic, X7R, 0805</td>
<td>08055C102KAT2A</td>
<td>AVX</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>C8</td>
<td>470 µF, 10 V, Electrolytic, Very Low ESR, 72 mΩ, (8 x 11.5)</td>
<td>EKZE100ELL471MHBD</td>
<td>Nippon Chemi-Con</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>C9</td>
<td>100 µF, 10 V, Electrolytic, Very Low ESR, 300 mΩ, (5 x 11)</td>
<td>EKZE100ELL101ME11D</td>
<td>Nippon Chemi-Con</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>D1</td>
<td>Diode, Standard, 1000V, 1A, Surface Mount, MINISMA, Mini SMA/SOD-123</td>
<td>CGRM4007-G</td>
<td>Comchip</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>D2</td>
<td>Diode, Standard, 1000V, 1A, Surface Mount, MINISMA, Mini SMA/SOD-123</td>
<td>CGRM4007-G</td>
<td>Comchip</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>D3</td>
<td>40 V, 2 A, Schottky, SMD, DO-214AA</td>
<td>SS24-3J5/2T</td>
<td>Vishay</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>L1</td>
<td>FIXED IND, 1.2 mH, ±10%, Imax=150 mA, 3.3 Ω max, TH, UNSHIELDED</td>
<td>AIUR-16-122K</td>
<td>Abracon</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>L2</td>
<td>4.7 µH, 600 mV SMD INDUCTOR, MULTILAYER</td>
<td>MLZ2012N4R7LT000</td>
<td>TDK</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>L3</td>
<td>Ferrite Bead, Z=70 Ω @ 100 MHz, Rd=0.100 Ω, 1.5 A, -55°C ~ 125°C, 1206 (3216 Metric)</td>
<td>CIB31P700NE</td>
<td>Samsung</td>
</tr>
<tr>
<td>17</td>
<td>1</td>
<td>R1</td>
<td>RES, 180 kΩ, 5%, 1/4 W, Thick Film, 1206</td>
<td>ERJ-8G3Y184V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>18</td>
<td>1</td>
<td>R2</td>
<td>RES, 221 kΩ, 1%, 1/4 W, Thick Film, 1206</td>
<td>P221FCT-ND</td>
<td>Panasonic</td>
</tr>
<tr>
<td>19</td>
<td>1</td>
<td>R3</td>
<td>RES, 3.92 kΩ, 1%, 1/8 W, Thick Film, 0805</td>
<td>ERJ-6ENF53921V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>R4</td>
<td>RES, 16.9 kΩ, 1%, 1/8 W, Thick Film, 0805</td>
<td>ERJ-6EYJ622V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>21</td>
<td>1</td>
<td>R5</td>
<td>RES, 5.23 kΩ, 1%, 1/8 W, Thick Film, 0805</td>
<td>ERJ-6ENF5231V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>22</td>
<td>1</td>
<td>R6</td>
<td>RES, 105 kΩ, 1%, 1/8 W, Thick Film, 0805</td>
<td>ERJ-6ENF1053V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>23</td>
<td>1</td>
<td>R7</td>
<td>RES, 18 Ω, 5%, 1/10 W, Thick Film, 0603</td>
<td>ERJ-3EYJ180V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>24</td>
<td>1</td>
<td>R8</td>
<td>RES, 909 Ω, 1%, 1/16 W, Thick Film, 0603</td>
<td>ERJ-3EKF9090V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>25</td>
<td>1</td>
<td>RF1</td>
<td>RES, 10 Ω, 5%, 2 W, Wirewound, Fusible</td>
<td>FW20A10R01A</td>
<td>Bourns</td>
</tr>
<tr>
<td>26</td>
<td>1</td>
<td>T1</td>
<td>Bobbin, EE13 (2+5) P V 1 SEC PM9820</td>
<td>WS-51319</td>
<td>Win Shine</td>
</tr>
<tr>
<td>27</td>
<td>1</td>
<td>U1</td>
<td>LinkSwitch-CV, SO-8C</td>
<td>LNK625DG</td>
<td>Power Integrations</td>
</tr>
<tr>
<td>28</td>
<td>1</td>
<td>+5V</td>
<td>Test Point, RED, Miniature THRU-HOLE MOUNT</td>
<td>5000K-ND</td>
<td>Keystone</td>
</tr>
<tr>
<td>29</td>
<td>1</td>
<td>RTV</td>
<td>Test Point, BLK, Miniature THRU-HOLE MOUNT</td>
<td>5001K-ND</td>
<td>Keystone</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>L</td>
<td>Test Point, WHT, Miniature THRU-HOLE MOUNT</td>
<td>5002K-ND</td>
<td>Keystone</td>
</tr>
<tr>
<td>31</td>
<td>1</td>
<td>N</td>
<td>Test Point, BLK, Miniature THRU-HOLE MOUNT</td>
<td>5001K-ND</td>
<td>Keystone</td>
</tr>
</tbody>
</table>
7 Transformer Specification

7.1 Electrical Diagram

![Electrical Diagram]

**Figure 5** – Transformer Electrical Diagram.

7.2 Mechanical Diagram

![Mechanical Diagram]

**Figure 6** – Transformer Mechanical Diagram.
### 7.3 Material List

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1]</td>
<td>Core: EE13, PC95, Gapped for ALG of 100 nH/T².</td>
</tr>
<tr>
<td>[3]</td>
<td>Barrier Tape: Polyester Film [1 mil (25 µm) base thickness], 8.50 mm Wide.</td>
</tr>
</tbody>
</table>

### 7.4 Electrical Test Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Strength, VAC</td>
<td>60 Hz 1 second, from pins 1, 2, 3, 4, 5 to pins 7, 8, 9, 10.</td>
<td>3000</td>
</tr>
<tr>
<td>Nominal Primary Inductance, μH</td>
<td>Measured at 1 V_{pk-pk}, typical switching frequency, between pin 1 to pin 3, with all other windings open.</td>
<td>1369</td>
</tr>
<tr>
<td>Tolerance, ±%</td>
<td>Tolerance of Primary Inductance</td>
<td>10.0</td>
</tr>
<tr>
<td>Maximum Primary Leakage, μH</td>
<td>Measured between pin 1 to pin 3, with all other windings shorted.</td>
<td>54.77</td>
</tr>
</tbody>
</table>

Although the design of the software considered safety guidelines, it is the user's responsibility to ensure that the user's power supply design meets all applicable safety requirements of user's product.

The products and applications illustrated herein (including circuits external to the products and transformer construction) may be covered by one or more U.S. and foreign patents or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations' patents may be found at www.powerint.com.
### 7.5 Transformer Winding Illustrations

<table>
<thead>
<tr>
<th>Winding Preparation</th>
<th>![Image]</th>
<th>For the purpose of these instructions, bobbin is oriented on winder such that pin side is on the left side. Winding direction is clockwise direction.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WD1:</strong> Feedback</td>
<td>![Image]</td>
<td>Start on pin(s) 2 and wind 14 turns (x4 AWG #38) in 1 layer from left to right. Terminate at pin 5.</td>
</tr>
<tr>
<td><strong>Insulation</strong></td>
<td>![Image]</td>
<td>Add 1 layer of tape, Item [3], for insulation.</td>
</tr>
<tr>
<td><strong>WD2:</strong> Primary</td>
<td>![Image]</td>
<td>Start on pin(s) 3 and wind 115 turns (x1 AWG #34) in 4 layers from left to right. Wind in same rotational direction as Feedback winding. At the last layer spread the winding evenly across entire bobbin. Terminate at pin 1 after finish.</td>
</tr>
<tr>
<td><strong>Insulation</strong></td>
<td>Add 2 layers of tape, Item [3], for insulation.</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td><strong>WD3: Shield</strong></td>
<td>Start on pin(s) 1 and wind 20 turns (x2 AWG #38). Wind in same rotational direction as primary winding. Form a 4 group of 5 turns with spaces in between each group. Leave this end of shield winding not connected.</td>
<td></td>
</tr>
<tr>
<td><strong>Insulation</strong></td>
<td>Add 2 layers of tape, Item [3], for insulation.</td>
<td></td>
</tr>
<tr>
<td><strong>WD4: Secondary</strong></td>
<td>Start on pin(s) 6 and wind 9 turns (x2 TIW #27) in 2 layers. Wind in clockwise direction. Finish this winding on pin(s) 7.</td>
<td></td>
</tr>
<tr>
<td><strong>Insulation</strong></td>
<td>Add 3 layers of tape, Item [3], for insulation.</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Finish</strong></td>
<td>Dip varnish uniformly in Item [4]. Do not vacuum impregnate.</td>
<td></td>
</tr>
</tbody>
</table>
8 Performance Data

Note: Data were taken at room temperature. Measurements were taken at the end of PCB.

8.1 Full Load Efficiency vs. Input Line Voltage (at PCB)

Figure 7 – Efficiency vs. Line Voltage, Room Temperature Measured at the End of the PCB.
8.2 Efficiency vs. Load (at PCB)

![Graph showing efficiency vs. load for different voltages](image)

**Figure 8** – Efficiency vs. Load, Room Temperature Measured at PCB.
### 8.3 Average Efficiency

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Minimum Average Efficiency (%)</th>
<th>Maximum Power in No-load Mode (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOE VI</td>
<td>$\geq 0.0834 \times \ln(P_{\text{OUT}}) - 0.0014 \times P_{\text{OUT}} + 0.609$</td>
<td>73.62% ≤0.100</td>
</tr>
</tbody>
</table>

#### 8.3.1 115 VAC / 60 Hz

<table>
<thead>
<tr>
<th>Load (A)</th>
<th>$V_{\text{IN}}$ (V RMS)</th>
<th>$I_{\text{IN}}$ (A RMS)</th>
<th>$P_{\text{IN}}$ (W)</th>
<th>$V_{\text{OUT}}$ at PCB (V DC)</th>
<th>$I_{\text{OUT}}$ (A DC)</th>
<th>$P_{\text{OUT}}$ (W)</th>
<th>Efficiency at PCB (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>114.95</td>
<td>0.10</td>
<td>6.64</td>
<td>4.98</td>
<td>1.00</td>
<td>4.99</td>
<td>75.08</td>
</tr>
<tr>
<td>75%</td>
<td>114.96</td>
<td>0.08</td>
<td>4.99</td>
<td>5.01</td>
<td>0.75</td>
<td>3.76</td>
<td>75.43</td>
</tr>
<tr>
<td>50%</td>
<td>114.97</td>
<td>0.06</td>
<td>3.29</td>
<td>5.03</td>
<td>0.50</td>
<td>2.52</td>
<td>76.60</td>
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<tr>
<td>25%</td>
<td>114.98</td>
<td>0.03</td>
<td>1.69</td>
<td>5.05</td>
<td>0.25</td>
<td>1.26</td>
<td>74.85</td>
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Average 75.49

#### 8.3.2 230 VAC / 50 Hz

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<th>Load (A)</th>
<th>$V_{\text{IN}}$ (V RMS)</th>
<th>$I_{\text{IN}}$ (A RMS)</th>
<th>$P_{\text{IN}}$ (W)</th>
<th>$V_{\text{OUT}}$ at PCB (V DC)</th>
<th>$I_{\text{OUT}}$ (A DC)</th>
<th>$P_{\text{OUT}}$ (W)</th>
<th>Efficiency at PCB (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>229.99</td>
<td>0.06</td>
<td>6.47</td>
<td>4.94</td>
<td>1.00</td>
<td>4.94</td>
<td>76.39</td>
</tr>
<tr>
<td>75%</td>
<td>229.99</td>
<td>0.05</td>
<td>4.91</td>
<td>4.99</td>
<td>0.75</td>
<td>3.74</td>
<td>76.27</td>
</tr>
<tr>
<td>50%</td>
<td>230.00</td>
<td>0.04</td>
<td>3.33</td>
<td>4.98</td>
<td>0.50</td>
<td>2.50</td>
<td>75.13</td>
</tr>
<tr>
<td>25%</td>
<td>230.00</td>
<td>0.02</td>
<td>1.71</td>
<td>4.99</td>
<td>0.25</td>
<td>1.25</td>
<td>73.08</td>
</tr>
</tbody>
</table>

Average 75.22
8.4 No-Load Input Power

No-load input power soak time: 15 mins.

![Graph showing no-load input power vs input voltage](image)

**Figure 9** — No-Load Input Power.
8.5 **Line and Load Regulation**

8.5.1 Line Regulation at Full Load (at PCB)

![Graph showing line regulation at full load](image)

*Figure 10 – Line Regulation at Full Load.*
8.5.2 Load Regulation (at PCB)

Figure 11 – Load Regulation.
9 Waveforms

9.1 Drain Voltage and Current, Normal Operation Full Load

**Figure 12** – 85 VAC Input, Full Load.
- Upper: $V_{DS}$, 100 V / div.
- Lower: $I_{DS}$, 200 mA / div., 10 μs / div.
- $V_{DS(\text{MAX})}$: 235.15 V.
- $I_{DS(\text{MAX})}$: 354.94 mA.

**Figure 13** – 115 VAC Input, Full Load.
- Upper: $V_{DS}$, 100 V / div.
- Lower: $I_{DS}$, 200 mA / div., 10 μs / div.
- $V_{DS(\text{MAX})}$: 274.68 V.
- $I_{DS(\text{MAX})}$: 354.94 mA.

**Figure 14** – 230 VAC Input, Full Load.
- Upper: $V_{DS}$, 100 V / div.
- Lower: $I_{DS}$, 200 mA / div., 10 μs / div.
- $V_{DS(\text{MAX})}$: 443.87 V.
- $I_{DS(\text{MAX})}$: 373.12 mA.

**Figure 15** – 265 VAC Input, Full Load.
- Upper: $V_{DS}$, 100 V / div.
- Lower: $I_{DS}$, 200 mA / div., 10 μs / div.
- $V_{DS(\text{MAX})}$: 499.21 V.
- $I_{DS(\text{MAX})}$: 381.03 mA.
9.2  Drain Voltage and Current Start-up Profile

Figure 16 – 85 VAC Input, Full Load.
Upper: $V_{DS}$, 100 V / div.
Lower: $I_{DS}$, 500 mA / div., 2 ms / div.
$V_{DS(\text{MAX})}$: 238.34 V.
$I_{DS(\text{MAX})}$: 314.23 mA.

Figure 17 – 115 VAC Input, Full Load.
Upper: $V_{DS}$, 100 V / div.
Lower: $I_{DS}$, 400 mA / div., 2 ms / div.
$V_{DS(\text{MAX})}$: 269.96 V.
$I_{DS(\text{MAX})}$: 314.23 mA.

Figure 18 – 230 VAC Input, Full Load.
Upper: $V_{DS}$, 100 V / div.
Lower: $I_{DS}$, 400 mA / div., 2 ms / div.
$V_{DS(\text{MAX})}$: 447.83 V.
$I_{DS(\text{MAX})}$: 413.04 mA.

Figure 19 – 265VAC Input, Full Load.
Upper: $V_{DS}$, 100 V / div.
Lower: $I_{DS}$, 400 mA / div., 2 ms / div.
$V_{DS(\text{MAX})}$: 507.11 V.
$I_{DS(\text{MAX})}$: 452.57 mA.
9.3 Output Diode Reverse Voltage

**Figure 20** – 85 VAC Input, Full Load.
Upper: $V_{\text{DIODE}}$, 10 V / div.
Lower: $I_{\text{DIODE}}$, 5 A / div., 10 μs / div.
$V_{\text{DIODE(MAX)}}$: 12.648 V.
$I_{\text{DIODE(MAX)}}$: 5.3162 A.

**Figure 21** – 115 VAC Input, Full Load.
Upper: $V_{\text{DIODE}}$, 10 V / div.
Lower: $I_{\text{DIODE}}$, 5 A / div., 10 μs / div.
$V_{\text{DIODE(MAX)}}$: 15.81 V.
$I_{\text{DIODE(MAX)}}$: 5.3162 A.

**Figure 22** – 230 VAC Input, Full Load.
Upper: $V_{\text{DIODE}}$, 10 V / div.
Lower: $I_{\text{DIODE}}$, 5 A / div., 10 μs / div.
$V_{\text{DIODE(MAX)}}$: 28.854 V.
$I_{\text{DIODE(MAX)}}$: 6.1067 A.

**Figure 23** – 265 VAC Input, Full Load.
Upper: $V_{\text{DIODE}}$, 10 V / div.
Lower: $I_{\text{DIODE}}$, 5 A / div., 10 μs / div.
$V_{\text{DIODE(MAX)}}$: 31.621 V.
$I_{\text{DIODE(MAX)}}$: 6.1067 A.
9.4 Output Rise Time

**Figure 24** – 85 VAC Input, Full Load. 
\[ V_{\text{OUT}}, 1 \text{ V / div.}, 20 \text{ ms / div.} \]

**Figure 25** – 115 VAC Input, Full Load. 
\[ V_{\text{OUT}}, 1 \text{ V / div.}, 20 \text{ ms / div.} \]

**Figure 26** – 230 VAC Input, Full Load. 
\[ V_{\text{OUT}}, 1 \text{ V / div.}, 20 \text{ ms / div.} \]

**Figure 27** – 265 VAC Input, Full Load. 
\[ V_{\text{OUT}}, 1 \text{ V / div.}, 20 \text{ ms / div.} \]
9.5 Turn On Delay

**Figure 28** – 85 VAC Input, Full Load.
Upper: $V_{OUT}$, 2 V / div.
Lower: $V_{IN}$, 200 V / div., 20 ms / div.
Turn On Delay: 3.6 ms.

**Figure 29** – 115 VAC Input, Full Load.
Upper: $V_{OUT}$, 2 V / div.
Lower: $V_{IN}$, 200 V / div., 20 ms / div.
Turn On Delay: 2.6 ms.

**Figure 30** – 230 VAC Input, Full Load.
Upper: $V_{OUT}$, 2 V / div.
Lower: $V_{IN}$, 200 V / div., 20 ms / div.
Turn On Delay: 2.4 ms.

**Figure 31** – 265 VAC Input, Full Load.
Upper: $V_{OUT}$, 2 V / div.
Lower: $V_{IN}$, 200 V / div., 20 ms / div.
Turn On Delay: 2.35 ms.
9.6 **Output Ripple Measurements**

9.6.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized in order to reduce spurious signals due to pick-up.

The 5125BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 μF/50 V ceramic type and one (1) 47.0 μF/16 V aluminum electrolytic. *The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).*

![Figure 32](image1.png) **Figure 32** – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

![Figure 33](image2.png) **Figure 33** – Oscilloscope Probe with Probe Master 5125BA BNC Adapter. (Modified with wires for probe ground for ripple measurement, and two parallel decoupling capacitors added)
9.6.2 Output Ripple Measurements

**Figure 34** – 85 VAC Input, Full Load.
Upper: \( V_{\text{OUT}} \), 40 mV / div., 400 ms / div.
Lower: \( V_{\text{OUTZOOM}} \), 40 mV / div., 30 μs / div.
Output Ripple PK-PK: 105.93 mV.

**Figure 35** – 115 VAC Input, Full Load.
Upper: \( V_{\text{OUT}} \), 40 mV / div., 400 ms / div.
Lower: \( V_{\text{OUTZOOM}} \), 40 mV / div., 30 μs / div.
Output Ripple PK-PK: 115.42 mV.

**Figure 36** – 230 VAC Input, Full Load.
Upper: \( V_{\text{OUT}} \), 40 mV / div., 400 ms / div.
Lower: \( V_{\text{OUTZOOM}} \), 40 mV / div., 30 μs / div.
Output Ripple PK-PK: 123.32 mV.

**Figure 37** – 265 VAC Input, Full Load.
Upper: \( V_{\text{OUT}} \), 40 mV / div., 400 ms / div.
Lower: \( V_{\text{OUTZOOM}} \), 40 mV / div., 30 μs / div.
Output Ripple PK-PK: 128.06 mV.
10 Temperature Measurements

All measurements were taken at room temperature, full load inside an acrylic box. Unit was heat soaked for 30 minutes prior to measurement.

<table>
<thead>
<tr>
<th></th>
<th>85 VAC</th>
<th>265 VAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNK625DG</td>
<td>91.2</td>
<td>75.8</td>
</tr>
<tr>
<td>Output Diode</td>
<td>71.4</td>
<td>74.5</td>
</tr>
<tr>
<td>Transformer</td>
<td>69.6</td>
<td>65</td>
</tr>
<tr>
<td>Ambient</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>

**Figure 38** – Thermal Setup.
10.1 Thermal Performance

10.1.1 Thermal Performance at 85 VAC
Ambient temperature is 28.5 ºC.

Figure 39 – U1 – LNK625DG Controller.
Spot: 91.2 ºC.

Figure 40 – D3 – Output Diode.
Spot: 71.4 ºC.

Figure 41 – D1 – Primary Snubber Diode.
Spot: 72.5 ºC.

Figure 42 – T1 – Transformer.
Spot: 69.6 ºC.
**Figure 43** – BR1 – Bridge Rectifier Diode. Spot: 60.2 °C.

**Figure 44** – C8 – Output Capacitor. Spot: 59.6 °C.
10.1.2 Thermal Performance at 265 VAC

Ambient temperature is 28.5 ºC.

**Figure 395** – U1 – LNK625DG Controller.
Spot: 75.8 ºC.

**Figure 46** – D3 – Output Diode.
Spot: 74.5 ºC.

**Figure 407** – D1 – Primary Snubber Diode.
Spot: 60.5 ºC.

**Figure 418** – T1 – Transformer.
Spot: 65 ºC.
**Figure 429** – BR1 – Bridge Rectifier Diode.  
Spot: 39.6 °C.

**Figure 50** – C8 – Output Capacitor.  
Spot: 60.4 °C.
10.1.3 Thermal Performance at 50 °C

Place the test unit inside a thermal chamber. Increase chamber temperature to 50 °C. Soak until stable. Monitor all components and ambient temperature.

![Thermal Performance Graph](image)

**Figure 431** – 115 VAC Input, Full Load at 50 °C Ambient.
<table>
<thead>
<tr>
<th>Amb</th>
<th>U1</th>
<th>C9</th>
<th>C8</th>
<th>L3</th>
<th>D3</th>
<th>Core</th>
<th>Winding</th>
<th>D1</th>
<th>R2</th>
<th>L1</th>
<th>C2</th>
<th>C1</th>
<th>BR1</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>52.2</td>
<td>95.2</td>
<td>72.3</td>
<td>78.8</td>
<td>77.9</td>
<td>97.1</td>
<td>78.4</td>
<td>82.3</td>
<td>82.8</td>
<td>84.7</td>
<td>63.2</td>
<td>68.2</td>
<td>64.2</td>
<td>69</td>
<td>73.5</td>
</tr>
</tbody>
</table>

![Graph showing temperature over time for various components](image-url)
10.1.4 Thermal Performance at 40 ºC

10.1.4.1 85 VAC

<table>
<thead>
<tr>
<th>Amb</th>
<th>U1</th>
<th>C9</th>
<th>C8</th>
<th>L3</th>
<th>D3</th>
<th>Core</th>
<th>Winding</th>
<th>D1</th>
<th>R2</th>
<th>L1</th>
<th>C2</th>
<th>C1</th>
<th>BR1</th>
<th>C4</th>
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</thead>
<tbody>
<tr>
<td>43.3</td>
<td>106.8</td>
<td>64.4</td>
<td>71.1</td>
<td>71.2</td>
<td>90.1</td>
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<td>58</td>
<td>64.2</td>
<td>60</td>
<td>68.2</td>
<td>72.6</td>
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10.1.4.2 265 VAC

<table>
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<tr>
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<th>C8</th>
<th>L3</th>
<th>D3</th>
<th>Core</th>
<th>Winding</th>
<th>D1</th>
<th>R2</th>
<th>L1</th>
<th>C2</th>
<th>C1</th>
<th>BR1</th>
<th>C4</th>
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<tbody>
<tr>
<td>43.2</td>
<td>84.3</td>
<td>64.4</td>
<td>71.3</td>
<td>69.8</td>
<td>90.7</td>
<td>70.9</td>
<td>74.9</td>
<td>73.4</td>
<td>75.1</td>
<td>51.2</td>
<td>56.8</td>
<td>52</td>
<td>54.6</td>
<td>62.6</td>
</tr>
</tbody>
</table>

10.2 Thermal Shutdown and Recovery

10.2.1 Shutdown and Recovery Temperature at 85 VAC, 50 ºC Ambient

![Graph showing temperature and time for different components during shutdown and recovery](image)

Figure 52 – 85 VAC Input.
Thermal Shutdown: U1 = 123.7 ºC.
Thermal Recovery: U1 = 76.8 ºC.
11 Conducted EMI

11.1 Test Set-up Equipment

11.1.1 Equipment and Load Used
   1. Rohde and Schwarz ENV216 two line V-network.
   2. Rohde and Schwarz ESRP EMI test receiver.
   3. Hioki 3322 power Hi-tester.
   4. Chroma measurement test fixture.
   5. 5Ω resistor load.
   6. Input voltage set at 115 VAC and 230 VAC.

11.2 Test Set-up

Figure 443 – EMI Set-up.
11.3 **Conductive EMI with Artificial Hand Output (QP / AV)**

11.3.1 115 VAC Line

![Conductive EMI with Artificial Hand Output (QP / AV) graph]

**Figure 54** – AH Connected to the Negative Output, Line.
11.3.2 115 VAC Neutral

**Figure 455** – AH Connected to the Negative Output, Neutral.
11.3.3 230 VAC Line

![Figure 56](image)

**Table:**

<table>
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<tr>
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<th>Frequency</th>
<th>Level dBuV</th>
<th>DeltaLimit</th>
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</thead>
<tbody>
<tr>
<td>1 Quasi Peak</td>
<td>753.0000 kHz</td>
<td>47.49 L1</td>
<td>-8.51 dB</td>
</tr>
<tr>
<td>2 Average</td>
<td>753.0000 kHz</td>
<td>37.83 L1</td>
<td>-8.67 dB</td>
</tr>
<tr>
<td>2 Average</td>
<td>1.3403 MHz</td>
<td>37.33 L1</td>
<td>-8.67 dB</td>
</tr>
<tr>
<td>2 Average</td>
<td>1.8960 MHz</td>
<td>36.97 L1</td>
<td>-9.03 dB</td>
</tr>
<tr>
<td>2 Average</td>
<td>2.4315 MHz</td>
<td>36.63 L1</td>
<td>-9.37 dB</td>
</tr>
</tbody>
</table>

*Figure 56 – AH Connected to the Negative Output, Line.*
11.3.4 230 VAC Neutral

**Figure 57** – AH Connected to the Negative Output, Neutral.

---

<table>
<thead>
<tr>
<th>Trace/Detector</th>
<th>Frequency</th>
<th>Level dBµV</th>
<th>DeltaLimit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Quasi Peak</td>
<td>755.2500 kHz</td>
<td>49.60 N</td>
<td>-6.40 dB</td>
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<tr>
<td>1 Quasi Peak</td>
<td>1.3515 MHz</td>
<td>47.96 N</td>
<td>-8.04 dB</td>
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<tr>
<td>2 Average</td>
<td>1.3425 MHz</td>
<td>37.59 N</td>
<td>-8.41 dB</td>
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<tr>
<td>2 Average</td>
<td>755.2500 kHz</td>
<td>37.49 N</td>
<td>-8.51 dB</td>
</tr>
<tr>
<td>1 Quasi Peak</td>
<td>663.0000 kHz</td>
<td>47.26 N</td>
<td>-8.74 dB</td>
</tr>
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</table>
11.4 Conductive EMI with Floating Output (QP / AV)

11.4.1 115 VAC Line

**Figure 58** – Floating Output, Line.
11.4.2 115 VAC Neutral

**Figure 59** – Floating Output, Neutral.
11.4.3  230 VAC Line

Figure 60 – Floating Output, Line.
### 11.4.4 230 VAC Neutral

**Figure 61** – Floating Output, Neutral.

<table>
<thead>
<tr>
<th>Trace/Detector</th>
<th>Frequency</th>
<th>Level dBμV</th>
<th>DeltaLimit</th>
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<tbody>
<tr>
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<td>43.84 N</td>
<td>-12.16 dB</td>
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<tr>
<td>2 Average</td>
<td>753.0000 kHz</td>
<td>33.19 N</td>
<td>-12.81 dB</td>
</tr>
<tr>
<td>2 Average</td>
<td>1.3380 MHz</td>
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<tr>
<td>2 Average</td>
<td>1.8938 MHz</td>
<td>32.49 N</td>
<td>-13.51 dB</td>
</tr>
<tr>
<td>2 Average</td>
<td>510.0000 kHz</td>
<td>32.10 N</td>
<td>-13.90 dB</td>
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# 12 Revision History

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<tr>
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<th>Author</th>
<th>Revision</th>
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<td>14-Feb-18</td>
<td>MAGM</td>
<td>1.2</td>
<td>Updated Waveforms</td>
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<td>08-Apr-19</td>
<td>KM</td>
<td>1.3</td>
<td>Updated Errors in Section 7.4 and 7.5.</td>
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