Title | Reference Design Kit for a Low Standby Current Non-Isolated Flyback Power Supply Using LinkSwitch™-TN2 LNK3202D
---|---
 Specification | 85 VAC – 277 VAC Input; 3.8 V / 20 mA and 12 V / 20 mA Outputs
 Application | Home and Building Automation
 Author | Applications Engineering Department
 Document Number | RDR-623
 Date | May 24, 2018
 Revision | 1.4

**Summary and Features**
- Highly integrated solution with LNK3202D
- Low component count with integrated 725 V MOSFET, current sensing and protection
- Wide range AC input
- <65 μA standby input current across AC line
- Two outputs, 3.8 V (±5%) and 12 V (±10%)
- <7 mW no-load input power at 115 VAC
- <12 mW no-load input power at 230 VAC
- Load short-circuit protection
- EN55022B conducted EMI compliant

**PATENT INFORMATION**
The products and applications illustrated herein (including transformer construction and circuits external to the products) 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 <http://www.powerint.com>. Power Integrations grants its customers a license under certain patent rights as set forth at <http://www.powerint.com/ip.htm>.
Table of Contents

1 Introduction ............................................................................................................ 4
2 Power Supply Specification ...................................................................................... 5
3 Schematic ............................................................................................................... 6
4 Circuit Description ................................................................................................. 7
   4.1 Input Rectifier, Protection and EMI Filtering ....................................................... 7
   4.2 LinkSwitch-TN2 Primary Side and Main Output Circuit Operation ................. 7
   4.3 Regulation of Slave Output ................................................................................ 7
   4.4 Output Side and Feedback Loop ........................................................................ 7
5 PCB Layout ............................................................................................................. 9
6 Bill of Materials ..................................................................................................... 10
7 Transformer Specification ...................................................................................... 11
   7.1 Electrical Diagram ........................................................................................... 11
   7.2 Electrical Specifications ................................................................................... 11
   7.3 Material List ................................................................................................... 11
   7.4 Transformer Build Diagram ............................................................................. 12
   7.5 Transformer Instructions ................................................................................ 12
   7.6 Transformer Winding Illustrations .................................................................... 13
8 Transformer Design Spreadsheet ........................................................................... 17
9 Performance Data ................................................................................................. 20
   9.1 Full Load Efficiency vs. Input Line Voltage ...................................................... 20
   9.1.1 Efficiency vs. Line Voltage, 0.3 W (20 mA on 12 V, 20 mA on 3.8 V) ....... 20
   9.2 No-Load Input Power ..................................................................................... 21
   9.3 Various Load Current vs. Input Line Voltage ................................................... 22
   9.4 Input Current at Standby vs. Input Line Voltage ............................................ 23
   9.5 Line and Load Regulation ............................................................................... 24
      9.5.1 12 V Line Regulation at 0.3 W (20 mA on 12 V, 20 mA on 5 V) ............ 24
      9.5.2 3.8 V Line Regulation at 0.3 W (20 mA on 12 V, 20 mA on 3.8 V) ....... 25
      9.5.3 3.8 V Regulation with Varying Load (12 V Unloaded) .......................... 26
10 Thermal Performance ............................................................................................ 27
   10.1 Open Case ..................................................................................................... 27
   10.2 85 VAC at Room Temperature ...................................................................... 27
   10.3 265 VAC at Room Temperature ...................................................................... 29
11 Waveforms ......................................................................................................... 31
   11.1 3.8 V Output Load Transient Response ............................................................ 31
   11.2 12 V Output Load Transient Response ............................................................ 31
   11.3 Switching Waveforms ..................................................................................... 32
      11.3.1 Drain to Source Voltage and Current during Normal Operation .......... 32
      11.3.2 Drain to Source Voltage and Current Waveforms during Start-up ........ 33
      11.3.3 Input and Output Voltages Waveforms during Start-up ......................... 34
      11.3.4 Output Short Auto-Restart ................................................................... 36
   11.4 Output Ripple Measurements ........................................................................... 37
      11.4.1 Ripple Measurement Technique ............................................................. 37
11.4.2 Measurement Results .................................................................................................................. 38
12 Conducted EMI .................................................................................................................................. 40
  12.1 Test Set-up Equipment .................................................................................................................. 40
    12.1.1 Equipment and Load Used .................................................................................................... 40
  12.2 Floating Output (QP / AV) ............................................................................................................. 41
    12.2.1 Line 115 VAC (0.3 W, 12 V and 3.8 V Full Load) ................................................................. 41
    12.2.2 Line 230 VAC (0.3 W, 12 V and 3.8 V Full Load) ................................................................. 42
13 Lightning Surge Test ............................................................................................................................ 43
  13.1 Differential Mode Surge Test ......................................................................................................... 43
  13.2 Ring Wave Surge Test .................................................................................................................... 44
14 Revision History .................................................................................................................................... 46

**Important Note:**
Although this board is designed to satisfy safety isolation requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.
1 Introduction

This document is an engineering report describing a dual output 12 V, 20 mA and 3.8 V, 20 mA non-isolated power supply utilizing a device from the LinkSwitch-TN2 family of ICs. This design shows the simplicity and efficiency that is possible due to the high level of integration while still providing exceptional performance.

This document contains the power supply specification, schematic, bill of materials, transformer documentation, printed circuit layout, and performance data.

![Figure 1 – Populated Circuit Board Photograph, Top.](image1)

![Figure 2 – Populated Circuit Board Photograph, Bottom.](image2)
### 2 Power Supply Specification

The table below represents the minimum acceptable performance of the design. Actual performance is listed in the results section.

<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>277</td>
<td>VAC</td>
<td>2 Wire – No P.E.</td>
</tr>
<tr>
<td>Frequency</td>
<td>$f_{LINE}$</td>
<td>47</td>
<td>50/60</td>
<td>64</td>
<td>Hz</td>
<td></td>
</tr>
<tr>
<td>No-load Input Power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></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 1</td>
<td>$V_{OUT1}$</td>
<td>10.8</td>
<td>12</td>
<td>13.2</td>
<td>V</td>
<td>±10%</td>
</tr>
<tr>
<td>Output Current 1</td>
<td>$I_{OUT1}$</td>
<td>0</td>
<td>20</td>
<td>190</td>
<td>mA</td>
<td>20 MHz Bandwidth.</td>
</tr>
<tr>
<td>Output Voltage Ripple 1</td>
<td>$V_{RIPPLE1}$</td>
<td>3.61</td>
<td>3.8</td>
<td>3.99</td>
<td>V</td>
<td>±5%</td>
</tr>
<tr>
<td>Output Voltage 2</td>
<td>$V_{OUT2}$</td>
<td>4</td>
<td>20</td>
<td>150</td>
<td>mV</td>
<td>20 MHz Bandwidth.</td>
</tr>
<tr>
<td>Output Current 2</td>
<td>$I_{OUT2}$</td>
<td>4</td>
<td>20</td>
<td>150</td>
<td>mA</td>
<td>See Figure 14</td>
</tr>
<tr>
<td>Output Voltage Ripple 2</td>
<td>$V_{RIPPLE2}$</td>
<td>347</td>
<td></td>
<td></td>
<td>mV</td>
<td>20 MHz Bandwidth.</td>
</tr>
<tr>
<td>Peak Power Output</td>
<td>$P_{OUT_PEAK}$</td>
<td>347</td>
<td></td>
<td></td>
<td>mW</td>
<td></td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conducted EMI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CISPR22B / EN55022B Floating</td>
<td>Resistive Load, 6 dB Margin.</td>
</tr>
<tr>
<td><strong>Line Surge</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V</td>
<td>1.2 µs / 50 µs Surge Mode, 2 Ω.</td>
</tr>
<tr>
<td>Differential Mode</td>
<td>$T_{AMB}$</td>
<td>0</td>
<td>24</td>
<td></td>
<td>°C</td>
<td>Free Convection, Sea Level in Sealed Enclosure.</td>
</tr>
</tbody>
</table>

---

24-May-18 RDR-623 LinkSwitch-TN2 Low Standby Current Power Supply

Power Integrations
Tel: +1 408 414 9200  Fax: +1 408 414 9201  www.power.com
3 Schematic

Figure 3 – Schematic.
4 Circuit Description

4.1 Input Rectifier, Protection and EMI Filtering
Bridge Rectifier BR1 rectifies the AC line voltage providing a full wave rectified DC to either pass across R1 or VR1; R1 for a lower standby current at no-load conditions and for VR1 during normal operations. EMI filter consists of inductor L1 and capacitor C1. EMI is further reduced by the integrated frequency jitter feature of the LinkSwitch-TN2 family of devices. Fusible resistor RF1 protects by safely opening the circuit in case of catastrophic failure of any of the components in the circuit. Together with RV1 and C1, they aid in surge protection of the circuit. Varistor RV1 clamps input voltage while RF1 is for inrush current protection. Capacitor C1 is rated at 1 µF 400 V to pass the ±500 differential surge, but a 4.7 µF can be used if unit needs to pass ±1 kV.

4.2 LinkSwitch-TN2 Primary Side and Main Output Circuit Operation
The LNK3202D is from the LinkSwitch™-TN2 family of ICs. These ICs incorporate a high power MOSFET, oscillator, On/Off control for highest efficiency, a high-voltage switched current source for self-biasing, frequency jittering, and other protection circuitry all in one device. The LNK3202D IC was used for a non-isolated flyback with dual output (12 V and 3.8 V) both delivering up to 20 mA.

Primary-side of the circuit is connected to the IC through the DRAIN (D) pin. The D pin provides the internal operating current for both the start-up and steady-state operations. During turn on time, current ramps up in the primary winding storing energy in the core of the transformer. The IC senses the current in the power MOSFET and when current threshold (ILIMIT) is exceeded, the power MOSFET in U1 is turned off and will remain off for the remainder of that cycle. On/Off control compares the output voltage to a reference. The result is then used to enable or disable the power MOSFET. Through this, regulation of the output is maintained by skipping cycles and without using an error amplifier and ramp generator.

4.3 Regulation of Slave Output
An additional winding is obtained for the 12 V output. Since the output voltage is higher than VBP(SHUNT) (5.2 V), R5 is connected from this winding into the BP pin. This was done to achieve the lowest possible no-load consumption.

On the winding for 12 V, 2 turns were added to meet 10% output regulation in full load.

4.4 Output Side and Feedback Loop
The 3.8 V output is rectified by D3 and C6. Diode D3 is a Schottky barrier rectifier. Since 3.8 V is the main output, a Schottky was used on its output for better efficiency since it reduces rectification loss. Capacitor C7 can be added in parallel with C6 in case ripple
voltages must be lessened. As for the 12 V output, D2 and C5 are used. Diode D2 is a fast switching diode. Both D2 and D3 have a maximum $t_{RR} = 50$ ns.

Output voltage of 3.8 V is sensed through resistor divider R6 and R4 and fed back to U1. Voltage on FB pin must be maintained at 2 V so resistors are in 1% tolerance. A low cost general purpose capacitor C4 was used in parallel with R4, to prevent pulse bunching.
5 PCB Layout

**Figure 4** – Printed Circuit Layout, Top.

**Figure 5** – Printed Circuit 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>1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC</td>
<td>B105-G</td>
<td>Comchip</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>C1</td>
<td>1 μF, 400 V, Electrolytic, (6.3 x 11)</td>
<td>EKMG401ELL1R0MF11D</td>
<td>United Chemi-Con</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>C3 C4</td>
<td>100 nF, 25 V, Ceramic, X7R, 0805</td>
<td>08053C04KAT2A</td>
<td>AVX</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>C5</td>
<td>56 μF, 16 V, Electrolytic, Very Low ESR, 22 mΩ, (10 x 25)</td>
<td>EKZE160ELL560ME11N</td>
<td>Nippon Chemi-Con</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>C6</td>
<td>220 μF, 10 V, Electrolytic, Very Low ESR, 130 mΩ, (6.3 x 11)</td>
<td>EKZE100ELL221MF11D</td>
<td>Nippon Chemi-Con</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>C7</td>
<td>10 μF, 10 V, Ceramic, X7R, 0805</td>
<td>L912X7R1A106M</td>
<td>TDK</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>D2</td>
<td>200 V, 1 A, MINI2</td>
<td>DA22F2100LCT-ND</td>
<td>Panasonic</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>D3</td>
<td>60 V, 1 A, DIODE SCHOTTKY, PWRDI 123</td>
<td>DFLS160-7</td>
<td>Diodes, Inc.</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>L1</td>
<td>2.2 mH, 0.046 A, 20%</td>
<td>RL-5480-1-2200</td>
<td>Rencon</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>R1</td>
<td>RES, 30 kΩ, 5%, 1/4 W, Thick Film, 1206</td>
<td>ERJ-6G/EYJ3003V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>R4</td>
<td>RES, 22.6 kΩ, 1%, 1/16 W, Thick Film, 0603</td>
<td>ERJ-3EKF2262V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>R5</td>
<td>RES, 71.5 kΩ, 1%, 1/4 W, Thick Film, 1206</td>
<td>ERJ-8ENF7152V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>R6</td>
<td>RES, 13 kΩ, 1%, 1/4 W, Metal Film</td>
<td>MFR-25FBF-13K0</td>
<td>Yageo</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>RF1</td>
<td>RES, 8.2 Ω, 2 W, Fusible/Flame Proof Wire Wound</td>
<td>CRF253-4 8R2</td>
<td>Vitrohm</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>RV1</td>
<td>275 VAC, 23 J, 7 mm, RADIAL</td>
<td>V27SL4A4P</td>
<td>Littlefuse</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>T1</td>
<td>Bobbin, EE8.3, Vertical, 6 pins (8.2 mm W x 8.2 mm L x 6.9 mm H) Transformer</td>
<td>EE-0802</td>
<td>Zhenhui</td>
</tr>
<tr>
<td>17</td>
<td>1</td>
<td>TP1</td>
<td>Test Point, WHT, Miniature THRU-HOLE MOUNT</td>
<td>5002</td>
<td>Keystone</td>
</tr>
<tr>
<td>18</td>
<td>3</td>
<td>TP2 TP4 TP6</td>
<td>Test Point, BLK, Miniature THRU-HOLE MOUNT</td>
<td>5001</td>
<td>Keystone</td>
</tr>
<tr>
<td>19</td>
<td>1</td>
<td>TP3</td>
<td>Test Point, BLUE, Miniature THRU-HOLE MOUNT</td>
<td>5117</td>
<td>Keystone</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>TP5</td>
<td>Test Point, RED, Miniature THRU-HOLE MOUNT</td>
<td>5000</td>
<td>Keystone</td>
</tr>
<tr>
<td>21</td>
<td>1</td>
<td>UI</td>
<td>LinkSwitch-TN2, SO-8C</td>
<td>LNK3202D</td>
<td>Power Integrations</td>
</tr>
<tr>
<td>22</td>
<td>1</td>
<td>VR1</td>
<td>Diode, Zener, 43 V, ±7%, 1 W, PMDS, DO-214AC, SMA</td>
<td>PTZTE2543A</td>
<td>Rohm Semi</td>
</tr>
</tbody>
</table>
7 Transformer Specification

7.1 Electrical Diagram

![Transformer Electrical Diagram](image)

**Figure 6** – Transformer Electrical Diagram.

7.2 Electrical Specifications

<table>
<thead>
<tr>
<th>Main Inductance</th>
<th>Pin 1 and pin 3 together, measured at 110 kHz, 0.4 V_{RMS}</th>
<th>796 \mu H \pm 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Strength</td>
<td>1 second, 60 Hz, from primary to secondary.</td>
<td>N/A</td>
</tr>
</tbody>
</table>

7.3 Material List

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[5]</td>
<td>Tape, 3M 1298 Polyester Film, 2.0 Mils Thick, 4.5 mm Wide.</td>
</tr>
</tbody>
</table>
### 7.4 Transformer Build Diagram

![Transformer Build Diagram](image)

**Figure 7** – Transformer Build Diagram.

### 7.5 Transformer Instructions

<table>
<thead>
<tr>
<th>General Note</th>
<th>For the purpose of these instructions, bobbin is oriented on winder such that pin side is on the left side (see illustration). Winding direction as shown is clockwise.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tape</strong></td>
<td>Use 1 layer of tape Item [5] for insulation.</td>
</tr>
<tr>
<td><strong>Tape</strong></td>
<td>Spread last layer evenly across bobbin.</td>
</tr>
<tr>
<td><strong>Tape</strong></td>
<td>Spread last layer evenly across bobbin.</td>
</tr>
<tr>
<td><strong>Assembly</strong></td>
<td>Use 2 layers of tape Item [4] for insulation.</td>
</tr>
<tr>
<td></td>
<td>Grind core halves for specified primary inductance, insert bobbin, and secure core halves.</td>
</tr>
</tbody>
</table>
### 7.6 Transformer Winding Illustrations

**General Note**

For the purpose of these instructions, bobbin is oriented on winder such that pin side is on the left side (see illustration). Winding direction as shown is clockwise.

**WD 1**


**Tape**

Finish at pin 1.
**WD 2**


**Tape**

Finish at pin 5.

Use 1 layer of tape Item [5] for insulation.

Apply one layer of tape Item [5] for insulation.
WD 3

Starting at pin 6, wind 22 turns of wire Item [4] in 1 layer

Tape

Finish at Pin 4.
Apply two layers of tape in (Item [5]) for insulation.
Grind core halves for specified primary inductance, insert bobbin, and secure core halves.
# Transformer Design Spreadsheet

*Note:* Since the spreadsheet input is limited to a single value for voltage and current and this is a dual output design, the current specification was changed to 27 mA to account for the total combined power of both the 12 V and 3.8 V outputs.

<table>
<thead>
<tr>
<th>ACDC_LinkSwitchTN2_Flyback_021417; Rev.1.1; Copyright Power Integrations 2017</th>
<th>INPUT</th>
<th>INFO</th>
<th>OUTPUT</th>
<th>UNIT</th>
<th>ACDC_LinkSwitchTN2 Flyback Design Spreadsheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENTER APPLICATION VARIABLES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LINE VOLTAGE RANGE</td>
<td>Universal</td>
<td></td>
<td>AC line voltage range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VACMIN</td>
<td>85.00</td>
<td>Volts</td>
<td>Minimum AC line voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VACTYP</td>
<td>115.00</td>
<td>Volts</td>
<td>Typical AC line voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VACMAX</td>
<td>265.00</td>
<td>Volts</td>
<td>Maximum AC line voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fL</td>
<td>50</td>
<td>Hertz</td>
<td>AC mains frequency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIME_BRIDGE_CONDUCTION</td>
<td>2.52</td>
<td>milliseconds</td>
<td>Input bridge rectifier diode conduction time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LINE RECTIFICATION</td>
<td>F</td>
<td>F</td>
<td>Select 'F'ull wave rectification or 'H'alf wave rectification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOUT</td>
<td>12.00</td>
<td>Volts</td>
<td>Output voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IOUT</td>
<td>0.027</td>
<td>Amperes</td>
<td>Average output current specification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC THRESHOLD VOLTAGE</td>
<td>0.00</td>
<td>Volts</td>
<td>Voltage drop across the sense resistor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OUTPUT CABLE RESISTANCE</td>
<td>0.00</td>
<td>Ohms</td>
<td>Enter the resistance of the output cable (if used)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EFFICIENCY</td>
<td>0.85</td>
<td>Efficiency Estimate at output terminals. Under 0.8 if no better data available</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOSS ALLOCATION FACTOR</td>
<td>0.50</td>
<td></td>
<td>The ratio of power losses during the MOSFET off-state to the total system losses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>POUT</td>
<td>0.32</td>
<td>Watts</td>
<td>Continuous Output Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIN</td>
<td>1.00</td>
<td>uFarads</td>
<td>Input capacitor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VMIN</td>
<td>93.52</td>
<td>Volts</td>
<td>Valley of the rectified VACMIN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VMAX</td>
<td>374.77</td>
<td>Volts</td>
<td>Peak of the VACMAX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEEDBACK</td>
<td>BIAS</td>
<td>BIAS</td>
<td>Select the type of feedback required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIAS WINDING</td>
<td>NO</td>
<td>NO</td>
<td>Select whether a bias winding is required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LINKSWITCH-TN2 VARIABLES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CURRENT LIMIT MODE</td>
<td>STD</td>
<td>STD</td>
<td>Pick between RED(Reduced) or STD(Standard) current limit mode of operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PACKAGE</td>
<td>SO-8C</td>
<td>SO-8C</td>
<td>Device package</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GENERIC DEVICE</td>
<td>Auto</td>
<td>LNK3202</td>
<td>Device series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEVICE CODE</td>
<td>LNK3202P</td>
<td>Device code</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOR</td>
<td>50</td>
<td>Volts</td>
<td>Voltage reflected to the primary winding when the MOSFET is off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VDSON</td>
<td>10.0</td>
<td>Volts</td>
<td>MOSFET on-time drain to source voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VDSOFF</td>
<td>499.8</td>
<td>Volts</td>
<td>MOSFET off-time drain to source voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ILIMITMIN</td>
<td>0.126</td>
<td>Amperes</td>
<td>Minimum current limit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ILIMITTYP</td>
<td>0.136</td>
<td>Amperes</td>
<td>Typical current limit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ILIMITMAX</td>
<td>0.146</td>
<td>Amperes</td>
<td>Maximum current limit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSMIN</td>
<td>62000</td>
<td>Hertz</td>
<td>Minimum switching frequency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSMAX</td>
<td>66000</td>
<td>Hertz</td>
<td>Typical switching frequency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDSON</td>
<td>88.40</td>
<td>Ohms</td>
<td>MOSFET drain to source resistance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRIMARY WAVEFORM PARAMETERS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MODE OF OPERATION</td>
<td>DCM</td>
<td>Mode of operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KRP/KDP</td>
<td>7.665</td>
<td>Measure of continuous/discontinuous mode of operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KP_TRANSIENT</td>
<td>2.656</td>
<td>KP under conditions of a transient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMAX</td>
<td>0.072</td>
<td>Maximum duty cycle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Unit/Description</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------</td>
<td>----------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIME_ON</td>
<td>1.168</td>
<td>useconds MOSFET conduction time at the minimum line voltage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIME_ON_MIN</td>
<td>0.346</td>
<td>useconds MOSFET conduction time at the maximum line voltage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IAVG_PRIMARY</td>
<td>0.005</td>
<td>Amperes Average input current</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRMS_PRIMARY</td>
<td>0.020</td>
<td>Amperes Root mean squared value of the primary current</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPRIMARY_MIN</td>
<td>716</td>
<td>uH Minimum primary inductance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPRIMARY_TYP</td>
<td>796</td>
<td>uH Typical primary inductance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPRIMARY_MAX</td>
<td>876</td>
<td>uH Maximum primary inductance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPRIMARY_TOL</td>
<td>10</td>
<td>Primary inductance tolerance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPEAK_SECONDARY</td>
<td>0.579</td>
<td>Amperes Peak secondary current</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRMS_SECONDARY</td>
<td>0.116</td>
<td>Amperes Root mean squared value of the secondary current</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIV_SECONDARY</td>
<td>106.45</td>
<td>Volts Peak inverse voltage on the secondary diode, not including the leakage spike</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VF_SECONDARY</td>
<td>0.70</td>
<td>Volts Secondary diode forward voltage drop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRANSFORMER CONSTRUCTION PARAMETERS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core selection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CORE</td>
<td>EE8</td>
<td>EE8 Select the transformer core</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOBBIN</td>
<td>B-EE8-H</td>
<td>Select the bobbin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AE</td>
<td>7.00</td>
<td>mm^2 Cross sectional area of the core</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LE</td>
<td>19.20</td>
<td>mm Effective magnetic path length of the core</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AL</td>
<td>610.0</td>
<td>nH/(turns^2) Ungapped effective inductance of the core</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VE</td>
<td>0.0</td>
<td>mm^3 Volume of the core</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AW</td>
<td>0.00</td>
<td>mm^2 Window area of the bobbin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW</td>
<td>4.78</td>
<td>mm Width of the bobbin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLT</td>
<td>0.00</td>
<td>mm Mean length per turn of the bobbin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MARGIN</td>
<td>0.00</td>
<td>mm Safety margin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary winding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPRIMARY</td>
<td>123</td>
<td>Primary number of turns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMAX_TARGET</td>
<td>1500</td>
<td>Gauss Target value of the magnetic flux density</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMAX_ACTUAL</td>
<td>1350</td>
<td>Gauss Actual value of the magnetic flux density</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BAC</td>
<td>675</td>
<td>Gauss AC flux density</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALG</td>
<td>53</td>
<td>nH/T^2 Gapped core effective inductance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LG</td>
<td>0.153</td>
<td>mm Core gap length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAYERS_PRIMARY</td>
<td>2</td>
<td>Number of primary layers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AWG_PRIMARY</td>
<td>40</td>
<td>Primary winding wire AWG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OD_PRIMARY_INSULATED</td>
<td>0.098</td>
<td>mm Primary winding wire outer diameter with insulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OD_PRIMARY_BARE</td>
<td>0.080</td>
<td>mm Primary winding wire outer diameter without insulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMA_PRIMARY</td>
<td>505</td>
<td>mil^2/Amperes The primary winding wire CMA is higher than 500 mil^2/Amperes: Decrease the primary layers or wire thickness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary winding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSECONDARY</td>
<td>31</td>
<td>Secondary turns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AWG_SECONDARY</td>
<td>36</td>
<td>Secondary winding wire AWG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OD_SECONDARY_INSULATED</td>
<td>0.432</td>
<td>mm Secondary winding wire outer diameter with insulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OD_SECONDARY_BARE</td>
<td>0.127</td>
<td>mm Secondary winding wire outer diameter without insulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMA_SECONDARY</td>
<td>215</td>
<td>mil^2/Amperes Secondary winding CMA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bias winding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NBIAS</td>
<td>N/A</td>
<td>Bias turns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VF_BIAS</td>
<td>N/A</td>
<td>Volts Bias diode forward voltage drop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VBIAS</td>
<td>N/A</td>
<td>Volts Bias winding voltage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIVB</td>
<td>N/A</td>
<td>Volts Peak inverse voltage on the bias diode</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBP</td>
<td>0.1</td>
<td>uF BP pin capacitor</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FEEDBACK PARAMETERS**
### MULTIPLE OUTPUT PARAMETERS

<table>
<thead>
<tr>
<th>Output 1</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VOUT1</td>
<td>12.00</td>
<td>Volts</td>
<td>Output Voltage 1</td>
</tr>
<tr>
<td>IOUT1</td>
<td>0.020</td>
<td>Amperes</td>
<td>Output Current 1</td>
</tr>
<tr>
<td>POUT1</td>
<td>0.24</td>
<td>Watts</td>
<td>Output Power 1</td>
</tr>
<tr>
<td>VD1</td>
<td>0.70</td>
<td>Volts</td>
<td>Secondary diode forward voltage drop for output 1</td>
</tr>
<tr>
<td>NS1</td>
<td>31</td>
<td></td>
<td>Number of turns for output 1</td>
</tr>
<tr>
<td>ISRMS1</td>
<td>0.086</td>
<td>Amperes</td>
<td>Root mean square value of the secondary current for output 1</td>
</tr>
<tr>
<td>IRIPPLE1</td>
<td>0.084</td>
<td>Amperes</td>
<td>Current ripple on the secondary waveform for output 1</td>
</tr>
<tr>
<td>PIV1</td>
<td>106.45</td>
<td>Volts</td>
<td>Peak inverse voltage on the secondary diode for output 1</td>
</tr>
<tr>
<td>DIODE1_RECOMMEND</td>
<td>MUR120</td>
<td></td>
<td>Recommended diode for output 1</td>
</tr>
<tr>
<td>PRELOAD</td>
<td>4.02</td>
<td>kohms</td>
<td>Preload resistor to ensure a load of at least 3mA on the first output</td>
</tr>
<tr>
<td>CMS1</td>
<td>17.2</td>
<td>Cmils</td>
<td>Bare conductor effective area in circular mils for output 1</td>
</tr>
<tr>
<td>AWGS1</td>
<td>37</td>
<td>AWG</td>
<td>Wire size for output 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Output 2</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VOUT2</td>
<td>3.80</td>
<td>Volts</td>
<td>Output Voltage 2</td>
</tr>
<tr>
<td>IOUT2</td>
<td>0.020</td>
<td>Amperes</td>
<td>Output Current 2</td>
</tr>
<tr>
<td>POUT2</td>
<td>0.08</td>
<td>Watts</td>
<td>Output Power 2</td>
</tr>
<tr>
<td>VD2</td>
<td>0.70</td>
<td>Volts</td>
<td>Secondary diode forward voltage drop for output 2</td>
</tr>
<tr>
<td>NS2</td>
<td>11</td>
<td></td>
<td>Number of turns for output 2</td>
</tr>
<tr>
<td>ISRMS2</td>
<td>0.086</td>
<td>Amperes</td>
<td>Root mean square value of the secondary current for output 2</td>
</tr>
<tr>
<td>IRIPPLE2</td>
<td>0.084</td>
<td>Amperes</td>
<td>Current ripple on the secondary waveform for output 2</td>
</tr>
<tr>
<td>PIV2</td>
<td>37.32</td>
<td>Volts</td>
<td>Peak inverse voltage on the secondary diode for output 2</td>
</tr>
<tr>
<td>DIODE2_RECOMMEND</td>
<td>SB160</td>
<td></td>
<td>Recommended diode for output 2</td>
</tr>
<tr>
<td>CMS2</td>
<td>17.2</td>
<td>Cmils</td>
<td>Bare conductor effective area in circular mils for output 2</td>
</tr>
<tr>
<td>AWGS2</td>
<td>37</td>
<td>AWG</td>
<td>Wire size for output 2</td>
</tr>
</tbody>
</table>
9 Performance Data

9.1 Full Load Efficiency vs. Input Line Voltage

9.1.1 Efficiency vs. Line Voltage, 0.3 W (20 mA on 12 V, 20 mA on 3.8 V)

![Graph showing efficiency vs. line voltage](image)

**Figure 8** – Efficiency vs. Line Voltage, Room Temperature.
9.2 *No-Load Input Power*

![Graph showing No-Load Input Power vs. Input Line Voltage, Room Temperature.](image)

*Figure 9 – No-Load Input Power vs. Input Line Voltage, Room Temperature.*
9.3 Various Load Current vs. Input Line Voltage

Note: 0-100% load applied on 3.8 V with 12 V unloaded.

![Graph showing various load currents vs. input line voltage.](image)

**Figure 10** – Various Load Current vs Input Line Voltage, Room Temperature.
9.4 *Input Current at Standby vs. Input Line Voltage*

![Graph showing input current at standby vs. input line voltage.](image)

**Figure 11** – Input Current at Standby vs. Input Line Voltage, Room Temperature.
### 9.5 Line and Load Regulation

9.5.1 12 V Line Regulation at 0.3 W (20 mA on 12 V, 20 mA on 5 V)

![Graph showing 12 V Output Voltage vs. Input Line Voltage, Room Temperature.](image)

**Figure 12** – 12 V Output Voltage vs. Input Line Voltage, Room Temperature.
9.5.2 3.8 V Line Regulation at 0.3 W (20 mA on 12 V, 20 mA on 3.8 V)

Figure 13 — 3.8 V Output Voltage vs. Input Line Voltage, Room Temperature.
Figure 14 – 3.8 V Output Voltage with Varying Load.
10 Thermal Performance

10.1 Open Case
For thermal measurement, soak the power supply first for 1 hour. It is recommended that the power supply be placed in an enclosure box to ensure that the ambient temperature is within the room temperature. Add a thermocouple to monitor ambient temperature.

10.2 85 VAC at Room Temperature

Figure 15 – Measured Temperature at 0.3 W, Ambient Temperature = 24 °C.
D2 – 12 V Output Diode.
Spot Temperature = 34 °C.

Figure 16 – Measured Temperature at 0.3 W, Ambient Temperature = 24 °C.
L1 – Inductor.
Spot Temperature = 35.3 °C.

Figure 17 – Measured Temperature at 0.3 W, Ambient Temperature = 24 °C.
VR1 – Zener Diode.
Spot Temperature = 54.8 °C

Figure 18 – Measured Temperature at 0.3 W, Ambient Temperature = 24 °C.
T1 – Transformer.
Spot Temperature = 55.1 °C.
Figure 19 – Measured Temperature at 0.3 W,
Ambient Temperature = 24 °C.
D3 – 3.8 V Output Diode.
Spot Temperature = 32.2 °C.
10.3 265 VAC at Room Temperature

**Figure 20** – Measured Temperature at 0.3 mW, Ambient Temperature = 24 °C.
D2 – 12 V Output Diode.
Spot Temperature = 30.3 °C.

**Figure 21** – Measured Temperature at 0.3 mW, Ambient Temperature = 24 °C.
L1 – Inductor
Spot Temperature = 28.9 °C.

**Figure 22** – Measured Temperature at 0.3 mW, Ambient Temperature = 24 °C
VR1 – Zener Diode.
Spot Temperature = 31 °C.

**Figure 23** – Measured Temperature at 0.3 mW, Ambient Temperature = 24 °C.
T1 – Transformer.
Spot Temperature = 30.9 °C.
Figure 24 – Measured Temperature at 0.3 mW, Ambient Temperature = 24 °C
D3 – 3.8 V Output Diode.
Spot Temperature = 32.2 °C.
11 Waveforms

11.1 3.8 V Output Load Transient Response
Results were taken at the output terminal which is the typical specified measurement condition. The 3.8 V output is loaded with 20 mA (full load).

Figure 25 – 85 VAC, 0-100% Load Step.
\[ V_{\text{MAX}}: 3.9526 \text{ V} \]
\[ V_{\text{MIN}}: 3.5573 \text{ V} \]
Upper: \( V_{\text{OUT}} \), 1 V / div.
Lower: \( I_{\text{LOAD}} \), 10 mA / div., 5 ms / div.

Figure 26 – 265 VAC, 0-100% Load Step.
\[ V_{\text{MAX}}: 3.9526 \text{ V} \]
\[ V_{\text{MIN}}: 3.5573 \text{ V} \]
Upper: \( V_{\text{OUT}} \), 1 V / div.
Lower: \( I_{\text{LOAD}} \), 10 mA / div., 5 ms / div.

11.2 12 V Output Load Transient Response
Results were taken at the output terminal of 12 V loaded with 20mA. 3.8 V Output was loaded with 5 mA.

Figure 27 – 85 VAC, 0-100% Load Step.
\[ V_{\text{MAX}}: 12.343 \text{ V} \]
\[ V_{\text{MIN}}: 11.078 \text{ V} \]
Upper: \( V_{\text{OUT}} \), 4 V / div.
Lower: \( I_{\text{LOAD}} \), 10 mA / div., 40 ms / div.

Figure 28 – 265 VAC, 0-100% Load Step.
\[ V_{\text{MAX}}: 12.343 \text{ V} \]
\[ V_{\text{MIN}}: 11.078 \text{ V} \]
Upper: \( V_{\text{OUT}} \), 4 V / div.
Lower: \( I_{\text{LOAD}} \), 10 mA / div., 40 ms / div.
11.3 Switching Waveforms

11.3.1 Drain to Source Voltage and Current during Normal Operation

**Figure 29** – 85 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 0 A.
Upper: $I_{\text{DRAIN}}$, 50 mA / div.
Lower: $V_{\text{DRAIN}}$, 50 V / div., 10 $\mu$s / div.

**Figure 30** – 265 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 0 A.
Upper: $I_{\text{DRAIN}}$, 50 mA / div.
Lower: $V_{\text{DRAIN}}$, 100 V / div., 5 $\mu$s / div.

**Figure 31** – 85 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 20 mA.
Upper: $I_{\text{DRAIN}}$, 50 mA / div.
Lower: $V_{\text{DRAIN}}$, 50 V / div., 10 $\mu$s / div.

**Figure 32** – 265 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 20 mA.
Upper: $I_{\text{DRAIN}}$, 50 mA / div.
Lower: $V_{\text{DRAIN}}$, 100 V / div., 5 $\mu$s / div.
11.3.2 Drain to Source Voltage and Current Waveforms during Start-up

**Figure 33** – 85 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 0 A.
Upper: $V_{DRAIN}$, 50 V, 5 ms / div.
Lower: $I_{DRAIN}$, 100 mA / div.

**Figure 34** – 265 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 0 A.
Upper: $V_{DRAIN}$, 100 V, 5 ms / div.
Lower: $I_{DRAIN}$, 100 mA / div.

**Figure 35** – 85 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 20 mA.
Upper: $V_{DRAIN}$, 50 V, 5 ms / div.
Lower: $I_{DRAIN}$, 100 mA / div.

**Figure 36** – 265 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 20 mA.
Upper: $V_{DRAIN}$, 100 V, 5 ms / div.
Lower: $I_{DRAIN}$, 100 mA / div.
11.3.3 Input and Output Voltages Waveforms during Start-up

Figure 37 – 85 VAC Input.
Condition: 12 V – 0 A, 3.8 V – 0 A.
Upper: $V_{\text{IN}}$, 100 V, 20 ms / div.
Middle: $V_{\text{OUT1}}$, 1 V / div.
Lower: $V_{\text{OUT2}}$, 5 V / div.

Figure 38 – 265 VAC Input.
Condition: 12 V – 0 A, 3.8 V – 0 A.
Upper: $V_{\text{IN}}$, 100 V, 20 ms / div.
Middle: $V_{\text{OUT1}}$, 1 V / div.
Lower: $V_{\text{OUT2}}$, 5 V / div.

Figure 39 – 85 VAC Input.
Condition: 12 V – 0 A, 3.8 V – 20 mA.
Upper: $V_{\text{IN}}$, 100 V, 20 ms / div.
Middle: $V_{\text{OUT1}}$, 1 V / div.
Lower: $V_{\text{OUT2}}$, 5 V / div.

Figure 40 – 265 VAC Input.
Condition: 12 V – 0 A, 3.8 V – 20 mA.
Upper: $V_{\text{IN}}$, 100 V, 20 ms / div.
Middle: $V_{\text{OUT1}}$, 1 V / div.
Lower: $V_{\text{OUT2}}$, 5 V / div.
Figure 41 – 85 VAC Input.
Condition: 12 V – 0 A, 3.8 V – 20 mA.
Upper: \( V_{\text{IN}} \), 100 V, 20 ms / div.
Middle: \( V_{\text{OUT1}} \), 1 V / div.
Lower: \( V_{\text{OUT2}} \), 5 V / div.

Figure 42 – 265 VAC Input.
Condition: 12 V – 0 A, 3.8 V – 20 mA.
Upper: \( V_{\text{IN}} \), 100 V, 20 ms / div.
Middle: \( V_{\text{OUT1}} \), 1 V / div.
Lower: \( V_{\text{OUT2}} \), 5 V / div.
11.3.4 Output Short Auto-Restart
Short the main output (3.8 V) and monitor $V_{DS}$, $I_{DS}$, output voltage and output current.

Figure 43 – 85 VAC Input.
Condition: 3.8 V – Shorted, 12 V – 0 mA.
Auto-Restart: 91 ms.
Upper: $V_{DS}$, 100 V / div., 1 s / div.
Upper Middle: $I_{DS}$, 100 mA / div.
Lower Middle: $V_{OUT3.8}$, 1 V / div.
Lower: $I_{OUT3.8}$, 10 mA / div.

Figure 44 – 265 VAC Input.
Condition: 3.8 V – Shorted, 12 V – 0 mA.
Auto-Restart: 91 ms.
Upper: $V_{DS}$, 200 V / div., 1 s / div.
Upper Middle: $I_{DS}$, 100 mA / div.
Lower Middle: $V_{OUT3.8}$, 1 V / div.
Lower: $I_{OUT3.8}$, 10 mA / div.

<table>
<thead>
<tr>
<th>Input Voltage (VAC)</th>
<th>Input Power (mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>85</td>
<td>60</td>
</tr>
<tr>
<td>265</td>
<td>117</td>
</tr>
</tbody>
</table>
11.4 Output Ripple Measurements

11.4.1 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. Details of the probe modification are provided in the Figures below.

The 4987BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 µF/50 V ceramic type and one (1) 47 µF/16 V aluminum electrolytic. The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).

![Probe Ground](image1)

**Figure 45** – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

![Probe Tip](image2)

**Figure 46** – Oscilloscope Probe with Probe Master ([www.probemaster.com](http://www.probemaster.com)) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)
11.4.2 Measurement Results

11.4.2.1 Output Ripple Voltage Waveforms for 3.8 V Output

Figure 47 – 85 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 0 A.
\( V_{\text{RIPPLE}} \), 20 mV / div., 20 ms, 400 \( \mu s / \text{div.} \).

Figure 48 – 265 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 0 A.
\( V_{\text{RIPPLE}} \), 20 mV / div., 20 ms, 660 \( \mu s / \text{div.} \).

Figure 49 – 85 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 20 mA.
\( V_{\text{RIPPLE}} \), 10 mV / div., 20 ms, 400 \( \mu s / \text{div.} \).

Figure 50 – 265 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 20 mA.
\( V_{\text{RIPPLE}} \), 20 mV / div., 20 ms, 660 \( \mu s / \text{div.} \).
11.4.2.2 Output Ripple Voltage Waveforms for 12 V Output

**Figure 51** – 85 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 0 A.
V\(_{\text{RIPPLE}}\), 20 mV / div., 5 ms, 140 \(\mu\)s / div.

**Figure 52** – 265 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 0 A.
V\(_{\text{RIPPLE}}\), 20 mV / div., 20 ms, 660 \(\mu\)s / div.

**Figure 53** – 85 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 20 mA.
V\(_{\text{RIPPLE}}\), 20 mV / div., 5 ms, 140 \(\mu\)s / div.

**Figure 54** – 265 VAC Input.
Condition: 3.8 V – 20 mA, 12 V – 20 mA.
V\(_{\text{RIPPLE}}\), 20 mV / div., 5 ms, 400 \(\mu\)s / div.
12 Conducted EMI

12.1 Test Set-up Equipment

12.1.1 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 meter Hi-tester.
4. Chroma measurement test fixture.

Figure 55 – EMI Test Set-up.
12.2 Floating Output (QP / AV)

12.2.1 Line 115 VAC (0.3 W, 12 V and 3.8 V Full Load)

Figure 56 – Floating Negative Output at 115 VAC.
12.2.2 Line 230 VAC (0.3 W, 12 V and 3.8 V Full Load)

Figure 57 – Floating Negative Output at 230 VAC.
13  Lightning Surge Test

The unit was subjected to ±500 V, differential surge using 10 strikes at each condition. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

13.1 Differential Mode Surge Test

The unit passed ±500 V (L1/L2) on full load, 20 mA on each output.

![Figure 58 – Differential Mode Surge Test at 500 V.](image-url)
13.2 Ring Wave Surge Test
The unit passed ±2.5 kV on full load, 20 mA on each output.

Figure 59 – Ring Wave Surge Test at 2.5 kV.
<table>
<thead>
<tr>
<th>Ring Wave Voltage (kV)</th>
<th>Phase Angle (°)</th>
<th>Generator Impedance (Ω)</th>
<th>Number of Strikes</th>
<th>Test Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>0</td>
<td>5</td>
<td>10</td>
<td>PASS</td>
</tr>
<tr>
<td>2.5</td>
<td>90</td>
<td>5</td>
<td>10</td>
<td>PASS</td>
</tr>
<tr>
<td>2.5</td>
<td>180</td>
<td>5</td>
<td>10</td>
<td>PASS</td>
</tr>
<tr>
<td>2.5</td>
<td>270</td>
<td>5</td>
<td>10</td>
<td>PASS</td>
</tr>
<tr>
<td>-2.5</td>
<td>0</td>
<td>5</td>
<td>10</td>
<td>PASS</td>
</tr>
<tr>
<td>-2.5</td>
<td>90</td>
<td>5</td>
<td>10</td>
<td>PASS</td>
</tr>
<tr>
<td>-2.5</td>
<td>180</td>
<td>5</td>
<td>10</td>
<td>PASS</td>
</tr>
<tr>
<td>-2.5</td>
<td>270</td>
<td>5</td>
<td>10</td>
<td>PASS</td>
</tr>
</tbody>
</table>
14 Revision History

<table>
<thead>
<tr>
<th>Date</th>
<th>Author</th>
<th>Revision</th>
<th>Description &amp; Changes</th>
<th>Reviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>02-Oct-17</td>
<td>DL</td>
<td>1.0</td>
<td>Initial Release.</td>
<td>Mktg &amp; Apps</td>
</tr>
<tr>
<td>10-Oct-17</td>
<td>KM</td>
<td>1.1</td>
<td>Updated Figure 10.</td>
<td></td>
</tr>
<tr>
<td>27-Oct-17</td>
<td>KM</td>
<td>1.2</td>
<td>Fixed Schematic Errors.</td>
<td></td>
</tr>
<tr>
<td>02-May-18</td>
<td>KM</td>
<td>1.3</td>
<td>Added Transformer Supplier for T1.</td>
<td></td>
</tr>
<tr>
<td>24-May-18</td>
<td>KM</td>
<td>1.4</td>
<td>Converted DER-623 to RDR-623</td>
<td></td>
</tr>
</tbody>
</table>
For the latest updates, visit our website: www.power.com

Reference Designs are technical proposals concerning how to use Power Integrations’ gate drivers in particular applications and/or with certain power modules. These proposals are “as is” and are not subject to any qualification process. The suitability, implementation and qualification are the sole responsibility of the end user. The statements, technical information and recommendations contained herein are believed to be accurate as of the date hereof. All parameters, numbers, values and other technical data included in the technical information were calculated and determined to our best knowledge in accordance with the relevant technical norms (if any). They may base on assumptions or operational conditions that do not necessarily apply in general. We exclude any representation or warranty, express or implied, in relation to the accuracy or completeness of the statements, technical information and recommendations contained herein. No responsibility is accepted for the accuracy or sufficiency of any of the statements, technical information, recommendations or opinions communicated and any liability for any direct, indirect or consequential loss or damage suffered by any person arising therefrom is expressly disclaimed.

Power Integrations reserves the right to make changes to its products at any time to improve reliability or manufacturability. Power Integrations does not assume any liability arising from the use of any device or circuit described herein. POWER INTEGRATIONS MAKES NO WARRANTY HEREIN AND SPECIFICALLY DISCLAIMS ALL WARRANTIES INCLUDING, WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF THIRD PARTY RIGHTS.

Patent Information

The products and applications illustrated herein (including transformer construction and circuits’ external to the products) 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. Power Integrations grants its customers a license under certain patent rights as set forth at http://www.power.com/ip.htm.

The PI Logo, TOPSwitch, TinySwitch, LinkSwitch, LYTSwitch, Innoswitch, DPA-Switch, PeakSwitch, CAPZero, SENZer, LinkZero, HiperPFS, HiperTFs, HiperLCs, Qspeed, EcoSmart, Clampless, E-Shield, Filterfuse, FluxLink, StackFET, PI Expert and PI FACTS are trademarks of Power Integrations, Inc. Other trademarks are property of their respective companies. ©Copyright 2015 Power Integrations, Inc.

Power Integrations Worldwide Sales Support Locations

WORLD HEADQUARTERS
5245 Hellyer Avenue
San Jose, CA 95136, USA.
Main: +1-408-414-9200
Customer Service:
Phone: +1-408-414-9665
Fax: +1-408-414-9765
e-mail: uasales@power.com

GERMANY
(IGBT Driver Sales)
HellewegForum 1
59469 Ense, Germany
Tel: +49-2938-64-39990
Email: igbt-driver.sales@power.com

KOREA
RM 602, 6FL
Korea City Air Terminal B/D, 159-6
Samsung-Dong, Kangnam-Gu, Seoul, 135-728 Korea
Phone: +82-2-2016-6610
Fax: +82-2-2016-6630
e-mail: koreasales@power.com

CHINA (SHANGHAI)
2410, Charity Plaza, No. 8B,
North Caixi Road,
Shanghai, PRC 200030
Phone: +86-21-6354-0323
Fax: +86-21-6354-0325
e-mail: chinasales@power.com

CHINA (SHENZHEN)
17/F, Hivic Building, No. 2, Keji Nan 8th Road, Nanshan District,
Shenzhen, China, 518057
Phone: +86-755-8872-8869
Fax: +86-755-8672-8690
e-mail: chinasales@power.com

INDIA
#1, 14th Main Road
Vasanthanagar
Bangalore-560052
India
Phone: +91-80-4113-8020
Fax: +91-80-4113-8023
e-mail: indiasales@power.com

ITALY
Via Milano 20, 3rd, Fl.
20099 Sesto San Giovanni (MI)
Italy
Phone: +39-024-550-8701
Fax: +39-028-928-6009
e-mail: eurosales@power.com

TAIWAN
5F, No. 318, Nei Hu Rd.,
Sec. 1 Nei Hu District
Taipei 11493, Taiwan R.O.C.
Phone: +886-2-2659-4570
Fax: +886-2-2659-4550
e-mail: tawansales@power.com

UK
Cambridge Semiconductor,
a Power Integrations company
Westbrook Centre, Block 5, 2nd Floor
Milton Road
Cambridge CB4 1YG
Phone: +44 (0) 1223-446483
e-mail: eurosales@power.com

For the latest updates, visit our website: www.power.com

Reference Designs are technical proposals concerning how to use Power Integrations’ gate drivers in particular applications and/or with certain power modules. These proposals are “as is” and are not subject to any qualification process. The suitability, implementation and qualification are the sole responsibility of the end user. The statements, technical information and recommendations contained herein are believed to be accurate as of the date hereof. All parameters, numbers, values and other technical data included in the technical information were calculated and determined to our best knowledge in accordance with the relevant technical norms (if any). They may base on assumptions or operational conditions that do not necessarily apply in general. We exclude any representation or warranty, express or implied, in relation to the accuracy or completeness of the statements, technical information and recommendations contained herein. No responsibility is accepted for the accuracy or sufficiency of any of the statements, technical information, recommendations or opinions communicated and any liability for any direct, indirect or consequential loss or damage suffered by any person arising therefrom is expressly disclaimed.

Power Integrations reserves the right to make changes to its products at any time to improve reliability or manufacturability. Power Integrations does not assume any liability arising from the use of any device or circuit described herein. POWER INTEGRATIONS MAKES NO WARRANTY HEREIN AND SPECIFICALLY DISCLAIMS ALL WARRANTIES INCLUDING, WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF THIRD PARTY RIGHTS.

Patent Information

The products and applications illustrated herein (including transformer construction and circuits’ external to the products) 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. Power Integrations grants its customers a license under certain patent rights as set forth at http://www.power.com/ip.htm.

The PI Logo, TOPSwitch, TinySwitch, LinkSwitch, LYTSwitch, Innoswitch, DPA-Switch, PeakSwitch, CAPZero, SENZer, LinkZero, HiperPFS, HiperTFs, HiperLCs, Qspeed, EcoSmart, Clampless, E-Shield, Filterfuse, FluxLink, StackFET, PI Expert and PI FACTS are trademarks of Power Integrations, Inc. Other trademarks are property of their respective companies. ©Copyright 2015 Power Integrations, Inc.

Power Integrations Worldwide Sales Support Locations

WORLD HEADQUARTERS
5245 Hellyer Avenue
San Jose, CA 95136, USA.
Main: +1-408-414-9200
Customer Service:
Phone: +1-408-414-9665
Fax: +1-408-414-9765
e-mail: uasales@power.com

GERMANY
(IGBT Driver Sales)
HellewegForum 1
59469 Ense, Germany
Tel: +49-2938-64-39990
Email: igbt-driver.sales@power.com

KOREA
RM 602, 6FL
Korea City Air Terminal B/D, 159-6
Samsung-Dong, Kangnam-Gu, Seoul, 135-728 Korea
Phone: +82-2-2016-6610
Fax: +82-2-2016-6630
e-mail: koreasales@power.com

CHINA (SHANGHAI)
2410, Charity Plaza, No. 8B,
North Caixi Road,
Shanghai, PRC 200030
Phone: +86-21-6354-0323
Fax: +86-21-6354-0325
e-mail: chinasales@power.com

CHINA (SHENZHEN)
17/F, Hivic Building, No. 2, Keji Nan 8th Road, Nanshan District,
Shenzhen, China, 518057
Phone: +86-755-8872-8869
Fax: +86-755-8672-8690
e-mail: chinasales@power.com

INDIA
#1, 14th Main Road
Vasanthanagar
Bangalore-560052
India
Phone: +91-80-4113-8020
Fax: +91-80-4113-8023
e-mail: indiasales@power.com

ITALY
Via Milano 20, 3rd, Fl.
20099 Sesto San Giovanni (MI)
Italy
Phone: +39-024-550-8701
Fax: +39-028-928-6009
e-mail: eurosales@power.com

TAIWAN
5F, No. 318, Nei Hu Rd.,
Sec. 1 Nei Hu District
Taipei 11493, Taiwan R.O.C.
Phone: +886-2-2659-4570
Fax: +886-2-2659-4550
e-mail: tawansales@power.com

UK
Cambridge Semiconductor,
a Power Integrations company
Westbrook Centre, Block 5, 2nd Floor
Milton Road
Cambridge CB4 1YG
Phone: +44 (0) 1223-446483
e-mail: eurosales@power.com