NCL30083FLYGEVB, NCL30083BB1GEVB

10 W Passive PFC Flyback and Buck-Boost Dimmable LED Driver Evaluation Board User’s Manual

Introduction

This documentation package covers two NCL30083 LED driver implementations illustrating their use in an E26/E27 based A, PAR and BR LED lamps form factor. The Electronic Circuit Assembly (ECA) is designed to support either an isolated flyback or non-isolated buck-boost configuration. The nominal total power is 10 W for either application. The selection is controlled through selective component population of the ECA.

Figure 1. NCL30083FLYGEVB – Flyback

Figure 2. NCL30083BB1GEVB – Buck-Boost

Table 1. DESIGN PARAMETER

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Flyback (NCL30083FLYGEVB)</th>
<th>Buck Boost (NCL30083BB1GEVB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage</td>
<td>100 – 265 V ac</td>
<td></td>
</tr>
<tr>
<td>Line Frequency</td>
<td>50 Hz/60 Hz</td>
<td></td>
</tr>
<tr>
<td>Power Factor</td>
<td>&gt; 0.7</td>
<td></td>
</tr>
<tr>
<td>Safety (Designed to Meet)</td>
<td>IEC61347-2-13 EU</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UL8750 US</td>
<td></td>
</tr>
<tr>
<td>Optimized Output Voltage Range</td>
<td>9.6 – 22.1 V dc</td>
<td>30 – 60 V dc</td>
</tr>
<tr>
<td>Output Current</td>
<td>500 mA dc</td>
<td>195 mA dc</td>
</tr>
<tr>
<td></td>
<td>±2 %</td>
<td></td>
</tr>
<tr>
<td>Output Ripple</td>
<td>200 mA P-P</td>
<td>50 mA P-P</td>
</tr>
<tr>
<td>Efficiency</td>
<td>85%</td>
<td>90%</td>
</tr>
<tr>
<td>Start Up Time</td>
<td>&lt; 500 msec</td>
<td></td>
</tr>
</tbody>
</table>
Demo Board Modifications
The board as shipped contains the NCL30083 to demonstrate the line step dimming function which allows the LEDs to be dimmed in 5 discrete steps by toggling the AC line (Vin) off momentarily. Cvccbulk holds up VCC while Vin toggles low switching to the next lower dim level. Since the timing is user controlled by switching on/off the light switch the timing window is very wide. Toggling the AC input in one second is typical. It may take more than 20 seconds of AC off to reset the IC, at which time when turned on again it return to the 100% state. By removing the Cvccbulk the step dimming function is effectively disabled so the performance of the current control is just like the NCL300082. It is also possible with this board to replace the NCL30083 with an NCL30082 to evaluate the analog/dimming control.

The value of Rsense sets the final output current value in conjunction with Rtrim which is for fine adjustment. The nature of the primary side loop control makes the current adjustment somewhat iterative because several circuit parameters affect the output current setting. It is relatively easy by changing Rsense to increase the output of the evaluation board as long as the output power limit is considered.

Since the NCL30082/3 has a wide VCC range this allows one transformer/inductor design to a > 2:1 change in LED string forward voltage. If it is desired to reduce the output current, the output power is no longer the limit, but simply the level of the reflected voltage from the auxiliary winding which is monitored by the built in overvoltage protection of the VCC pin. If a higher output voltage at lower current is required, the auxiliary winding turns ratio would have to be modified.

The input capacitor network uses a valley fill PFC to achieve a power factor of > 0.8 to easily meet ENERGY STAR® input power factor requirements. If compliance with EN61000-3-2 Class C is required, the input capacitor network can be easily modified and simplified to one capacitor, this is discussed in the appendix.

Constant Current Control Architecture Introduction
Figure 4 portrays the primary and secondary current of a fly-back converter in discontinuous conduction mode (DCM). Figure 3 shows the basic circuit of a fly-back converter.

During the on-time of the MOSFET, the bulk voltage Vbulk is applied to the magnetizing and leakage inductors Lp and Lleak. The current ramps up.

When the MOSFET is turned-off, the inductor current first charges Cclump. The output diode is off until the voltage across Lp reverses and reaches:

\[ \frac{Nsp}{C_{clump}} \frac{V_{out}}{C_{loop}} \sqrt{\frac{V_f}{C_{loop}}} \]

The output diode current increase is limited by the leakage inductor. As a consequence, the secondary peak current is reduced:
The diode current reaches its peak when the leakage inductor is reset. Thus, in order to accurately regulate the output current, we need to take into account the leakage inductor current. This is accomplished by sensing the clamping network current. Practically, a node of the clamp capacitor is connected to $R_{\text{sense}}$ instead of the bulk voltage $V_{\text{bulk}}$. Then, by monitoring the voltage on the CS pin, we have an image of the primary current (red curve in Figure 4).

When the diode conducts, the secondary current decreases linearly from $I_{D,pk}$ to zero. When the diode current has turned off, the drain voltage begins to oscillate because of the resonating network formed by the inductors ($L_p + L_{\text{leak}}$) and the lump capacitor. This voltage is reflected on the auxiliary winding wired in fly-back mode. Thus, by looking at the auxiliary winding voltage, we can detect the end of the conduction time of secondary diode. The constant current control block picks up the leakage inductor current, the end of conduction of the output rectifier and controls the drain current to maintain the output current constant. We have:

\[
I_{\text{out}} = \frac{V_{\text{REF}}}{2N_{\text{sp}} R_{\text{sense}}} \quad \text{(eq. 1)}
\]

The output current value is set by choosing the sense resistor:

\[
R_{\text{sense}} = \frac{V_{\text{ref}}}{2N_{\text{sp}} I_{\text{out}}} \quad \text{(eq. 2)}
\]

From (eq. 1), the first key point is that the output current is independent of the inductor value. Moreover, the leakage inductance does not influence the output current value as the reset time is taken into account by the controller.

At this point the Excel® spreadsheet based design guide will help with many of the calculations.

A trim resistor allows for making fine adjustments to the current limit to set the output current precisely. The LFF circuit will create some error on the Cs pin which is adjusted out by proper choice of $R_{\text{trim}}$. So we will choose $R_{\text{sense}} = 1.8 \, \Omega$ and use $R_{\text{trim}}$ for the fine adjustments. After setting $R_4$ to $1.1 \, k\Omega$, $R_{\text{trim}}$ is $22 \, \Omega$. 

![Figure 4. Flyback Currents and Auxiliary Winding Voltage in DCM](http://onsemi.com)
NCL30083FLYGEVB, NCL30083BB1GEVB

SCHEMATIC

Figure 5. Input Circuit

Figure 6. Main Schematic

NOTE: Components labeled FB are only populated for the flyback version and components labeled BB are only required for the Buck-boost configuration
<table>
<thead>
<tr>
<th>Qty</th>
<th>Designator</th>
<th>Board Version</th>
<th>Part</th>
<th>Manufacturer</th>
<th>Mfr Part Number</th>
<th>Sub</th>
<th>Pb-Free</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CVccbulk</td>
<td>x* x*</td>
<td>27 μF</td>
<td>Panasonic</td>
<td>EEU-FC1E270</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>CVcc</td>
<td>x x</td>
<td>4.7 μF</td>
<td>Taiyo Yuden</td>
<td>EMK107AB475KA-T</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>Cleak</td>
<td>x x</td>
<td>4.7 μF</td>
<td>Rubycon</td>
<td>1001XJ9R75MX11</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>1</td>
<td>Cout</td>
<td>x</td>
<td>22 μF 16 V</td>
<td>Taiyo Yuden</td>
<td>EMK316BJ226ML-T</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>2</td>
<td>C2, C4</td>
<td>x x</td>
<td>18 pF 200 V</td>
<td>Rubycon</td>
<td>200LLE18MEFC10X12.5</td>
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<td>Yes</td>
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<td>2</td>
<td>C3, C5</td>
<td>x x</td>
<td>120 nF 400 V</td>
<td>Epcos</td>
<td>B32559C06124-***</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>1</td>
<td>C13</td>
<td>x</td>
<td>1000 pF 630 V</td>
<td>Kemet</td>
<td>C0402C102G9ACTU</td>
<td>Yes</td>
<td>Yes</td>
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<td>2</td>
<td>C14, C15</td>
<td>x x</td>
<td>470 pF 250 VAC Y2</td>
<td>Johanson Dielectric</td>
<td>502R29W471KV3E-****-SC</td>
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<td>Yes</td>
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<tr>
<td>2</td>
<td>Cleak</td>
<td>x</td>
<td>1000 pF 630 V</td>
<td>Kemet</td>
<td>C0805C102KBRACTU</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>1</td>
<td>C13</td>
<td>x</td>
<td>1000 pF 630 V</td>
<td>Kemet</td>
<td>C0805C102KBRACTU</td>
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<td>Yes</td>
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<td>1</td>
<td>CVcc</td>
<td>x</td>
<td>3.01 MΩ</td>
<td>Yageo</td>
<td>RC0805FR-073M01L</td>
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<td>Yes</td>
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<td>1</td>
<td>RLamp</td>
<td>x</td>
<td>47 kΩ</td>
<td>Yageo</td>
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<td>1</td>
<td>Rdamp</td>
<td>x x</td>
<td>180 Ω</td>
<td>Yageo</td>
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<td>Yes</td>
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<td>1</td>
<td>Rdamp</td>
<td>x x</td>
<td>10 Ω</td>
<td>Yageo</td>
<td>RC0603FR-07010RL</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>1</td>
<td>Rjump1</td>
<td>x* x*</td>
<td>0 Ω</td>
<td>Yageo</td>
<td>RC0402FR-070RL</td>
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<td>Yes</td>
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<td>Rtco , trim</td>
<td>x</td>
<td>10 kΩ</td>
<td>Yageo</td>
<td>RC0402FR-070KL</td>
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<td>Yes</td>
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<td>1</td>
<td>R8</td>
<td>x</td>
<td>10 kΩ</td>
<td>Yageo</td>
<td>RC0402FR-0710KL</td>
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<td>Yes</td>
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<td>0</td>
<td>Rjump2</td>
<td>* ...</td>
<td>10 Ω</td>
<td>Yageo</td>
<td>RC0402FR-0710KL</td>
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<td>Yes</td>
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<td>1</td>
<td>Riff</td>
<td>x x</td>
<td>620 Ω</td>
<td>Yageo</td>
<td>RC0402FR-07620RL</td>
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<td>Yes</td>
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<td>1</td>
<td>Rsens</td>
<td>x</td>
<td>0.68 Ω</td>
<td>Yageo</td>
<td>RL063FR-070R68L</td>
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<td>Yes</td>
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<td>0</td>
<td>Rsens</td>
<td>x</td>
<td>0.78 Ω</td>
<td>Yageo</td>
<td>RL063FR-070R68L</td>
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<td>Yes</td>
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<tr>
<td>2</td>
<td>Restart1, Restart</td>
<td>x x</td>
<td>1.0 MΩ</td>
<td>Yageo</td>
<td>RC0805FR-0710ML</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>1</td>
<td>Rrco</td>
<td>x x</td>
<td>100 kΩ NTC</td>
<td>Epcos</td>
<td>B57331V2104J60</td>
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<td>Yes</td>
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<tr>
<td>1</td>
<td>Rtrim</td>
<td>x</td>
<td>7.15 Ω</td>
<td>Vishay/Dale</td>
<td>CRCW0603FR75FKEA</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>1</td>
<td>Rzcd</td>
<td>x x</td>
<td>56 kΩ</td>
<td>Stackpole</td>
<td>RMCF90305TN10</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>1</td>
<td>R5</td>
<td>x x</td>
<td>51.1 kΩ</td>
<td>Yageo</td>
<td>RC0402FR-0751K1L</td>
<td>Yes</td>
<td>Yes</td>
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<td>1</td>
<td>R9</td>
<td>x x</td>
<td>4.7 Ω</td>
<td>Yageo</td>
<td>RC0805FR-07497L</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>1</td>
<td>R9</td>
<td>x x</td>
<td>100 Ω</td>
<td>Yageo</td>
<td>RC0805FR-07100RL</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>1</td>
<td>T1</td>
<td>x</td>
<td>XFRM_LINEAR</td>
<td>Wurth</td>
<td>750313435</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>1</td>
<td>U1</td>
<td>x* x*</td>
<td>NCL30083</td>
<td>ON Semiconductor</td>
<td>NCL300838BRM2R2G</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Wire , Input, White</td>
<td>x x</td>
<td>UL1430</td>
<td>Alpha Wire</td>
<td>#24 AWG, Stranded, 6&quot;</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>Wire, Output, Red</td>
<td>x x</td>
<td>UL1430</td>
<td>Alpha Wire</td>
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<td>Wire, Output, Black</td>
<td>x x</td>
<td>UL1430</td>
<td>Alpha Wire</td>
<td>#24 AWG, Stranded, 6&quot;</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*To convert the board to NCL30082, the identified components are changed, see NCL30082 configuration table.
Table 3. NCL30082 CONFIGURATION TABLE

<table>
<thead>
<tr>
<th>Topology</th>
<th>Dimming</th>
<th>Controller</th>
<th>Cvccbulk</th>
<th>Rjump1</th>
<th>Rjump2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flyback (FB)</td>
<td>Step Dimming</td>
<td>NCL30083</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No DIM Pin Access</td>
<td>NCL30082</td>
<td>Remove</td>
<td>Remove</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Access Dimming Pin</td>
<td>NCL30082</td>
<td>Replace with Connector*</td>
<td>Remove</td>
<td>X</td>
</tr>
<tr>
<td>Buck Boost (BB)</td>
<td>Step Dimming</td>
<td>NCL30083</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No DIM Pin Access</td>
<td>NCL30082</td>
<td>Remove</td>
<td>Remove</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Access Dimming Pin</td>
<td>NCL30082</td>
<td>Replace with Connector*</td>
<td>Remove</td>
<td>X</td>
</tr>
</tbody>
</table>

Notes:
- Connector Assembly
  - * Board Connector: Molex, Part Number 22035025
  - Mating Connector: Molex, Part Number 50375023
  - Connector Terminal: Molex, Part Number 8701039

GERBER VIEWS

Figure 7. Top Side PCB

Figure 8. Bottom Side PCB
CIRCUIT BOARD FABRICATION NOTES

1. Fabricate per IPC−6011 and IPC6012. Inspect to IPA−A−600 Class 2 or updated standard.
2. Printed Circuit Board is defined by files listed in fileset.
3. Modification to copper within the PCB outline is not allowed without permission, except where noted otherwise. The manufacturer may make adjustments to compensate for manufacturing process, but the final PCB is required to reflect the associated gerber file design ±0.001 in. for etched features within the PCB outline.
4. Material in accordance with IPC−4101/21, FR4, Tg 125°C min.
5. Layer to layer registration shall not exceed ±0.004 in.
6. External finished copper conductor thickness shall be 0.0013 in. min.
7. Copper plating thickness for through holes shall be 0.0007 in. min.
8. All holes sizes are finished hole size.
9. Finished PCB thickness 0.031 in.
10. All un-dimensioned holes to be drilled using the NC drill data.
11. Size tolerance of plated holes: ±0.003 in.
   non-plated holes ±0.002 in.
12. All holes shall be ±0.003 in. of their true position U.D.S.
13. Construction to be SMOBC, using liquid photo image (LPI) solder mask in accordance with IPC−SM−B40C, Type B, Class 2, and be green in color.
14. Solder mask mis-registration ±0.004 in. max.
15. Silkscreen shall be permanent non-conductive white ink.
16. The fabrication process shall be UL approved and the PCB shall have a flammability rating of UL94V0 to be marked on the solder side in silkscreen with date, manufactures approved logo, and type designation.
17. Warp and twist of the PCB shall not exceed 0.0075 in. per in.
18. 100% electrical verification required.
19. Surface finish: electroless nickel immersion gold (ENIG)
20. RoHS compliance required.
**FLYBACK TRANSFORMER SPECIFICATION**

<table>
<thead>
<tr>
<th>CUSTOMER TERMINAL</th>
<th>RoHS</th>
<th>LEAD(Pb)-FREE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn 96%, Ag 4%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Cryptic Notes:**

- **PART MUST INSERT FULLY TO SURFACE A IN RECOMMENDED GRID**
- **DOT LOCATES TERM. #1**
- **TERM. NO.’S FOR REF. ONLY**
- **DOT LOCATES TERM. #1**
- **LOT CODE & DATE CODE**
- **RECOMMENDED P.C. PATTERN, COMPONENT SIDE**

**ELECTRICAL SPECIFICATIONS @ 25°C unless otherwise noted:**

- **D.C. RESISTANCE (@ 20°C):**
  - 1−2 1.25 Ω ±10%
  - 3−4 0.695 Ω ±10%
  - FL1−FL2 0.090 Ω ±20%

- **DIELECTRIC RATING:**
  - 3,000 VAC, 1 minute tested by applying 3,750 VAC for 1 second between pins 4−FL1 (tie 2+3).
  - 500 VAC, 1 minute tested by applying 625 VAC for 1 second between pins 1−4.

- **INDUCTANCE:**
  - 700 μH ±10%, 10 kHz, 100 mVAC, 0 mADC, 3−4, Ls.

- **SATURATION CURRENT:**
  - 1 A saturating current that causes 20% rolloff from initial inductance.

- **LEAKAGE INDUCTION:**
  - 5 μH max, 100 kHz, 100 mVAC, 1−2 (tie FL1+FL2), Ls.
  - 15 μH max, 100 kHz, 100 mVAC, 3−4 (tie FL1+FL2), Ls.

- **TURNS RATIO:**
  - (4−3):(1−2), (2.5):(1.00), ±1%
  - (4−3):(FL1−FL2), (3):(1.00), ±1%

**OPERATING TEMPERATURE RANGE:**

- −40°C TO 125°C including temp. rise.

Unless otherwise specified, tolerances are as follows:

- Angles: ±1°
- Fractions: ±1/64
- Decimals: ±0.005 (.127 mm)

This drawing is dual dimensioned. Dimensions in brackets are in millimeters.
## BUCK BOOST INDUCTOR SPECIFICATION

<table>
<thead>
<tr>
<th>CUSTOMER TERMINAL</th>
<th>RoHS</th>
<th>LEAD(Pb)-FREE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn 96%, Ag 4%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**ELECTRICAL SPECIFICATIONS @ 25°C unless otherwise noted:**

- **D.C. RESISTANCE (@ 20°C):**
  - 1–2: 0.450 Ω ±10%.
  - 3–4: 0.965 Ω ±10%.

- **DIELECTRIC RATING:**
  - 1,000 VAC, 1 minute tested by applying 1,250 VAC for 1 second between pins 1–4.

- **INDUCTANCE:**
  - 950 μH ±10%, 10 kHz, 100 mVAC, 0 mADC, 3–4, Ls.

- **SATURATION CURRENT:**
  - 1 A saturating current that causes 20% rolloff from initial inductance.

- **LEAKAGE INDUCTANCE:**
  - 25.0 μH max, 100 kHz, 100 mVAC, 3–4 (tie 1+2), Ls.

- **TURNS RATIO:**
  - (4–3):(1–2), (3):(1.00), ±1%.

**OPERATING TEMPERATURE RANGE:**

- −40°C TO 125°C including temp. rise.

Unless otherwise specified, tolerances are as follows:
- Angles: ±1°
- Fractions: ±1/64
- Decimals: ±0.005 (.127 mm)

This drawing is dual dimensioned. Dimensions in brackets are in millimeters.
Figure 11. Flyback Top View

Figure 12. Flyback Bottom View
Figure 13. Buck Boost Top View

Figure 14. Buck Boost Bottom View
Figure 15. Flyback Lead Breakout

Mark the Appropriate Configuration

Note location of transformer Flying Leads trim as short as possible.

Figure 16. Buck Boost Lead Breakout
NCL30083FLYGEVB, NCL30083BB1GEVB

TEST PROCEDURE

Equipment Needed
• AC Source – 100 to 265 V ac 50/60 Hz Minimum 1 A ac capabilities
• AC Wattmeter – 30 W Minimum, True RMS Input Voltage and Current, Power Factor 0.2% accuracy or better
• DC Voltmeter – 100 V dc minimum 0.1% accuracy or better
• DC Ammeter – 1 A dc minimum 0.1% accuracy or better
• LED Load

lesai

Flyback – 14–17 V dc – 5 LED Load @ 500 mA
Buck Boost – 50–55 V dc – 15 LED Load @ 200 mA

Test Connections
1. Connect the Unit Under Test (UUT) per the test set up in Figure 17.
2. Set the AC source to 120 ±1 V ac RMS 60 Hz or 230 ±2 V ac RMS 50 Hz.

NOTE: Unless otherwise specified, all voltage measurements are taken at the terminals of the UUT.

Figure 17. Test Set Up

Functional Test Procedure

Table 4. FLYBACK VERSION (NCL30083FLYGEVB)

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Test Variable</th>
<th>Test Limits</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vin = 100 V ac</td>
<td>Output Current</td>
<td>490 mA – 510 mA</td>
<td></td>
</tr>
<tr>
<td>Vin = 120 V ac</td>
<td>Output Current</td>
<td>490 mA – 510 mA</td>
<td></td>
</tr>
<tr>
<td>Vin = 265 V ac</td>
<td>Output Current</td>
<td>490 mA – 510 mA</td>
<td></td>
</tr>
<tr>
<td>Vin = 265 V ac</td>
<td>Power Factor</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>Vin = 120 V ac</td>
<td>Efficiency (Use Actual Measured Data)</td>
<td>82%</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. BUCK BOOST VERSION (NCL30083BB1GEVB)

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Test Variable</th>
<th>Test Limits</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vin = 100 V ac</td>
<td>Output Current</td>
<td>190 mA – 200 mA</td>
<td></td>
</tr>
<tr>
<td>Vin = 120 V ac</td>
<td>Output Current</td>
<td>190 mA – 200 mA</td>
<td></td>
</tr>
<tr>
<td>Vin = 265 V ac</td>
<td>Output Current</td>
<td>190 mA – 200 mA</td>
<td></td>
</tr>
<tr>
<td>Vin = 265 V ac</td>
<td>Power Factor</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>Vin = 120 V ac</td>
<td>Efficiency (Use Actual Measured Data)</td>
<td>87%</td>
<td></td>
</tr>
</tbody>
</table>

Efficiency = ((VOUT × IOUT) / Pin) × 100%

Step Dimming Test Procedure
NCL30083BB1GEVB/NCL30083FLYGEVB
1. Connect the UUT to the LED load.
2. Apply 120 V ac power.
3. Verify that the output current is within the regulation limits as specified in the functional test procedure.
4. Interrupting the AC input for 1–2 s will step the output current down.
5. There 6 discrete current levels. After the lowest level, the current will return to maximum output.
6. Cycle the input power 6 times validating that the current steps down at each cycle and returns to maximum.
Figure 18. Flyback Line & Load Regulation

Figure 19. Flyback Relative Line Regulation
Figure 20. Flyback Line & Load Efficiency

Figure 21. Flyback Line & Load Power Factor
Figure 22. Flyback Output Ripple 120 V ac 60 Hz

Figure 23. Flyback Output Ripple 230 V ac 50 Hz
Figure 24. Buck Boost Line & Load Regulation

Figure 25. Buck Boost Efficiency over Line (V₁ = 55 V, I_out = 195 mA)
Figure 26. Buck Boost Power Factor over Line ($V_1 = 55 \text{ V/}I_{\text{out}} = 195 \text{ mA}$)

Figure 27. Buck Boost Output Ripple 120 V ac 60 Hz
Figure 28. Buck Boost Output Ripple 230 V ac 50 Hz

Figure 29. Conducted EMI Pre-compliance 150 kHz−2 MHz
IEC61000–3–2 Class C Compliance

Compliance to IEC61000–3–2 Class C (under 25 W) is not possible with the valley fill front end architecture since input current does not comply with Class D requirements or the waveform definition requirements as stated in this excerpt.

Active Input Power ≤ 25 W:
Discharge lighting equipment having an active input power smaller than or equal to 25 W shall comply with one of the following two sets of requirements:

- The harmonic currents shall not exceed the power-related limits of Table 6, column 2, or:
- The third harmonic current, expressed as a percentage of the fundamental current, shall not exceed 86% and the fifth shall not exceed 61%; moreover, the waveform of the input current shall be such that it begins to flow before or at 60°, has its last peak (if there are several peaks per half period) before or at 65° and does not stop flowing before 90°, where the zero crossing of the fundamental supply voltage is assumed to be at 0°.

If the discharge lighting equipment has a built-in dimming device, measurement is made only in the full load condition. It is possible to comply with the special waveform and harmonic requirements of the third paragraph with a standard peak charge front end if the bulk capacitance is properly sized. The bulk capacitor must be in the range of 200–300 nF/W for a 230 V ac line for Europe. Japan has a similar requirement; however, the bulk capacitance must be 800–1,200 nF/W because the nominal main is 100 V ac rather than 230 V ac. The recommended capacitance values are line specific. So there is no universal mains solution with a peak charge front end. It is possible to convert the Evaluation Board from a valley fill to peak charge front end by deleting, changing, and shorting selected components.
To illustrate Class C performance, an NCL30083FLYGEVB was modified and the input valley fill configuration was modified and the input bulk capacitor was changed to 2.2 μF, this is the typical performance data. Typical harmonic content is illustrated in Figure 34. For applications with 4 LEDs or less, the input capacitor value should be reduced to meet Class C harmonic content requirements.
Figure 33. 230 V ac, Class C – Flyback Line & Load Efficiency

<table>
<thead>
<tr>
<th></th>
<th>Power Factor</th>
<th>3\textsuperscript{rd} Harmonic</th>
<th>5\textsuperscript{th} Harmonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 LED</td>
<td>0.575</td>
<td>81%</td>
<td>52.4%</td>
</tr>
<tr>
<td>6 LED</td>
<td>0.587</td>
<td>78%</td>
<td>47.0%</td>
</tr>
<tr>
<td>7 LED</td>
<td>0.59</td>
<td>74.6%</td>
<td>40.6%</td>
</tr>
<tr>
<td>Class C Limit</td>
<td>–</td>
<td>86%</td>
<td>61%</td>
</tr>
</tbody>
</table>

Figure 34. Class C – Measured Harmonic Content. $V_{in} = 230$ V ac, 50 Hz
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