

LED Driver ICs

EVAL-LED-ICL8001G-Bulb02

Quasi-Resonant Flyback Converter for Phase Cut Dimming with High Power Factor

ICL8001G

Application Note

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ICL8001G**Revision History: 2010-05-05, Revision 2.0****Previous Version: Version 1.0**

| Page | Subjects (major changes since last revision) |
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1 Content

The EVAL-LED-ICL8001G-Bulb02 demonstrates the single-stage flyback and PFC controller ICL8001G in an LED Bulb application. Its quasiresonant operation mode, primary side control, integrated PFC and phase-cut dimming control makes it the best in class system solution for dimmable LED bulbs.

2 Evaluation Board

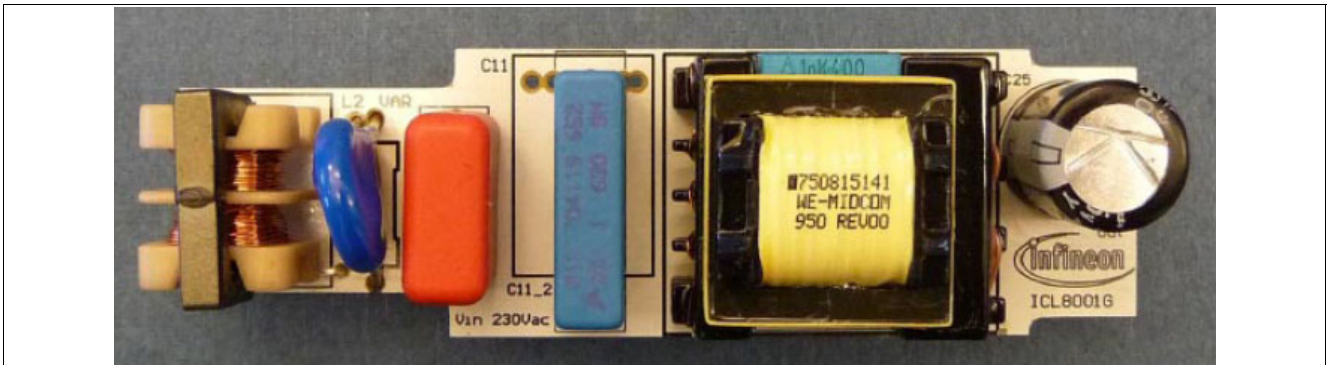


Figure 1 EVAL-LED-ICL8001G-Bulb02 Top Side

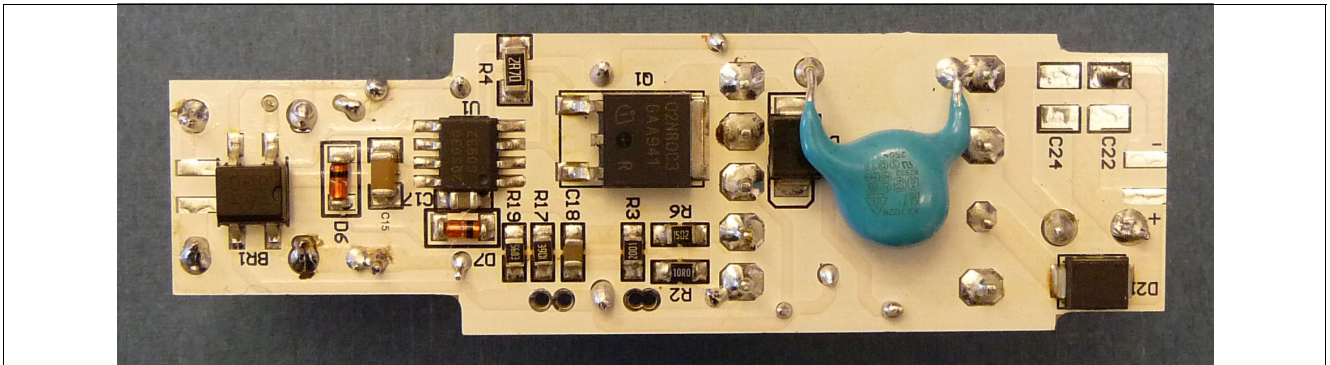


Figure 2 EVAL-LED-ICL8001G-Bulb02 Bottom Side

3 List of Features

- High, stable efficiency over wide operating range through quasiresonant operation mode
- Primary side side flyback control with integrated PFC and phase-cut dimming
- Energy efficient phase cut dimming
- Power cell for VCC pre-charging with constant current
- Built-in digital soft-start
- Foldback correction and cycle-by-cycle peak current limitation
- VCC over- and under-voltage lockout
- Auto restart mode for short circuit protection
- Adjustable latch-off mode for output overvoltage protection
- Best in class system BOM for dimmable bulbs

4 Technical Specification

Table 1 provides a summary of the EVAL-LED-ICL8001G-Bulb02 performance specification. The Input Voltage indications refer to the RMS voltage without modification by means of phase cut dimmer. Output parameter indicated refer to output voltage variation at fixed nominal input voltage.

Table 1 Performance Specification

| Specification | Min | Typ | Max | Unit |
|----------------|-----|-----|-----|------|
| Input Voltage | 207 | 230 | 253 | AC V |
| Output Voltage | 23 | 26 | 29 | V |
| Output Current | 380 | 350 | 320 | mA |
| Output Power | 9.0 | 9.1 | 9.2 | W |

5 Setup and Results

5.1 Input / Output sliding contact description

5.1.1 Vin

Input sliding contact for AC supply. Please see **Table 1** for the maximum input voltage.

5.1.2 Vout

Output sliding contact for output DC voltage with polarity indication. This output is isolated from the AC input supply. If you connect an additional load via this connector please make sure not to exceed the maximum output voltage- and power ratings as stated in **Table 1**.

5.2 Setup

For non-dimming operation of the board it is sufficient to connect the sliding contact for Vin directly to the input AC voltage (see **Table 1** for input voltage range). For dimming operation the phase cut dimmer shall be connected to the Vin contacts according the dimmer switch instructions of the dimmer manufacturer.

Attention:

Please be aware that high voltages of approximately 800 V will be accessible on the board.

5.3 Power Up

The ICL8001G integrates a start-up cell. This allows for short start-up times of the system without sacrificing the efficiency. **Figure 3** demonstrates a startup time from mains voltage switch on to light out of about 120ms for a VCC capacitance of C15 = 10uF.

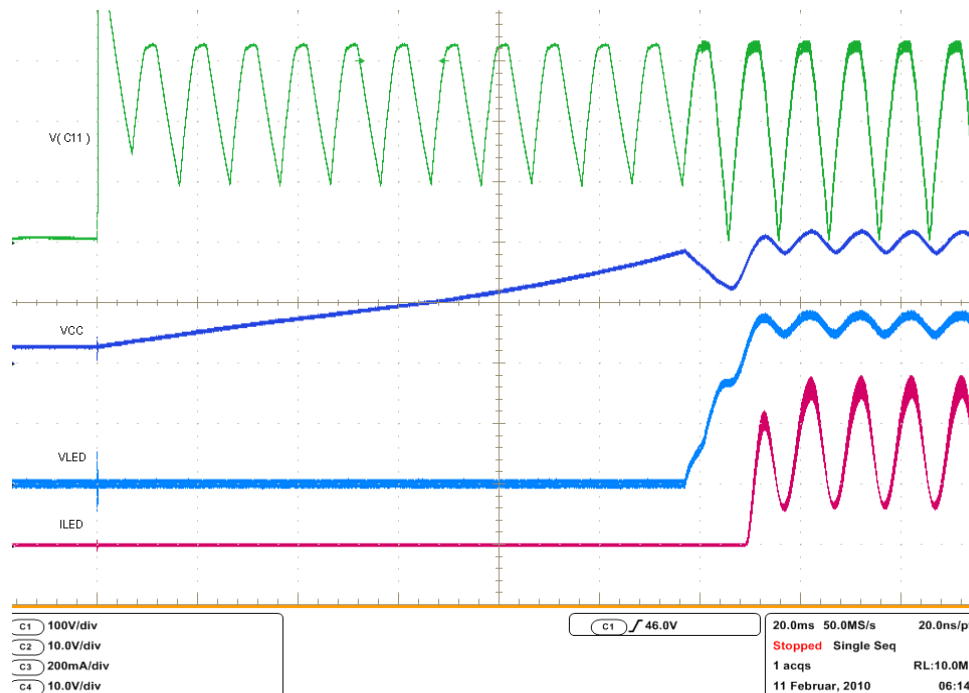


Figure 3 Startup: Rectified mains input voltage (green), Controller VCC (dark blue), output voltage (blue), and output current (red)

5.4 Operation

The ICL8001G is a quasiresonant flyback controller. **Figure 4** shows typical switching waveforms at the MOSFET Q1 on the primary side.

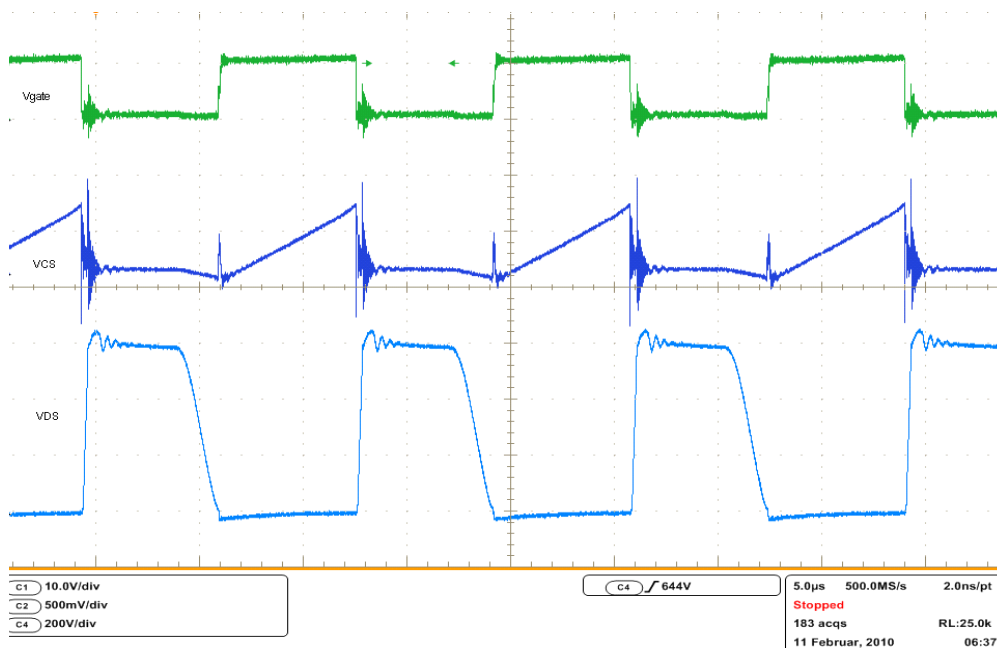


Figure 4 Typical switching waveforms at 230 Vac mains voltage: Gate Drive voltage V_{gs} , shunt signal VCS and Drain Source Voltage VDS showing quasi resonant on-switching at the first valley approaching zero-voltage

5.5 Constant Output Power Control

The ICL8001G allows for regulation of the approximate constant output power at fixed phase cut dimming position or fixed input AC voltage. See [Figure 5](#) for the measured output regulation characteristic at output voltage variation. At LED forward voltage decrease the driver power is lowered.

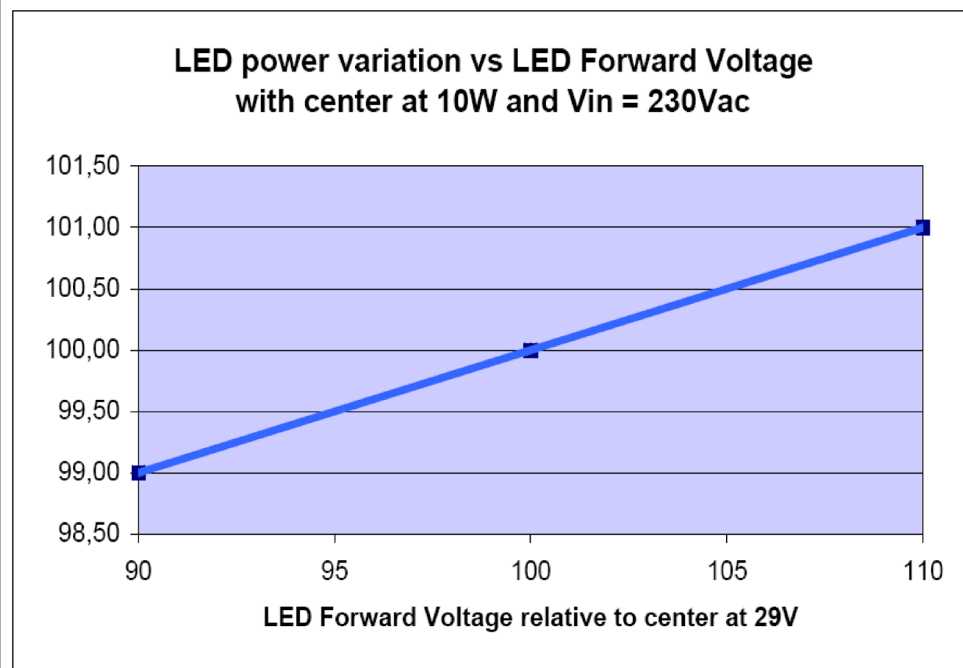


Figure 5 Approximate constant output power characteristics

5.6 Output Current Ripple

The output capacitor (C25 = 220uF) is sized for an output current ripple which exhibits no visible light modulation. If a smaller LED current ripple is required, a larger capacitance (C25) up to 470uF can be placed on the board.

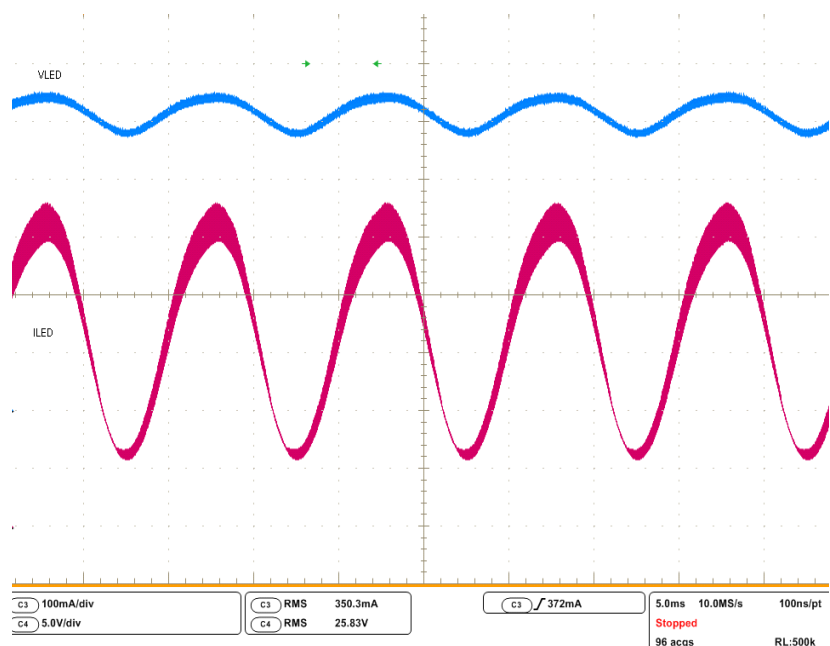


Figure 6 Typical Waveforms: Output voltage (blue) and output current (red)

5.7 Input Current Harmonics

The input current harmonics amplitudes fulfill the requirements of EN 61000-3-2 standard for input power range $P_{in} < 25W$ as well as $P_{in} > 25W$. The power factor can be adjusted to $PF > 99\%$ but the optimization for phase cut dimming especially leading edge dimmer switches may lead to lower values.

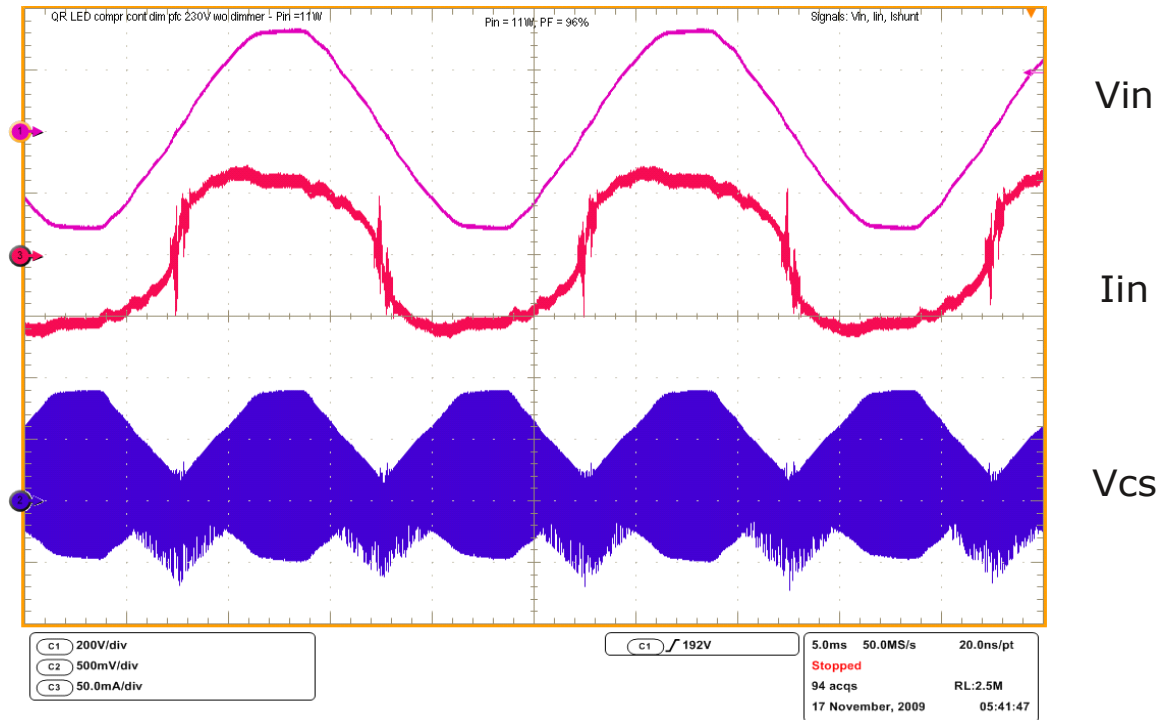


Figure 7 Input voltage V_{in} , Input current I_{in} and shunt voltage V_{cs}

5.8 Driver Efficiency

The driver efficiency curve exhibits high efficiency also for low dimming levels.

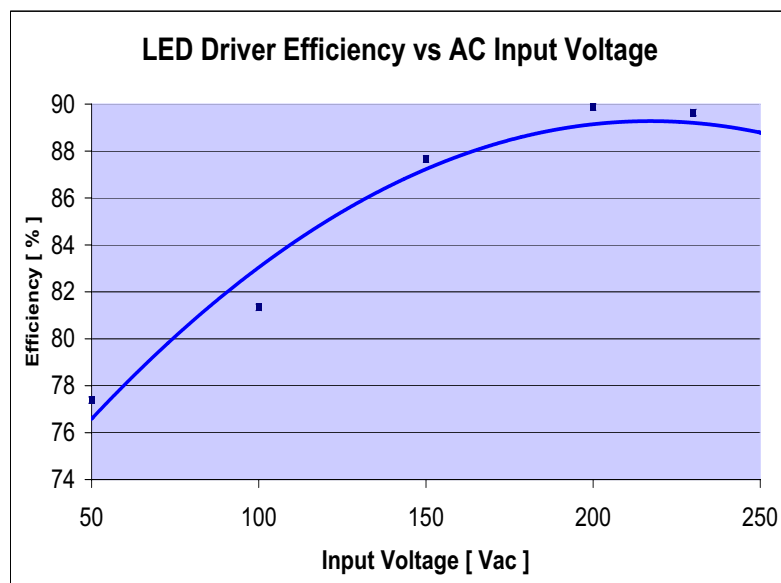


Figure 8 LED Driver efficiency at variable input voltage

5.9 Protection

The ICL8001G provides a full set of protection features as detailed in [Table 2](#).

Table 2 Protection Features

| | |
|----------------------|--------------|
| VCC Overvoltage | Auto Restart |
| VCC Undervoltage | Auto Restart |
| Over Temperature | Auto Restart |
| Output Overvoltage | Latch Off |
| Output Short Circuit | Latch Off |

6 Board Layout

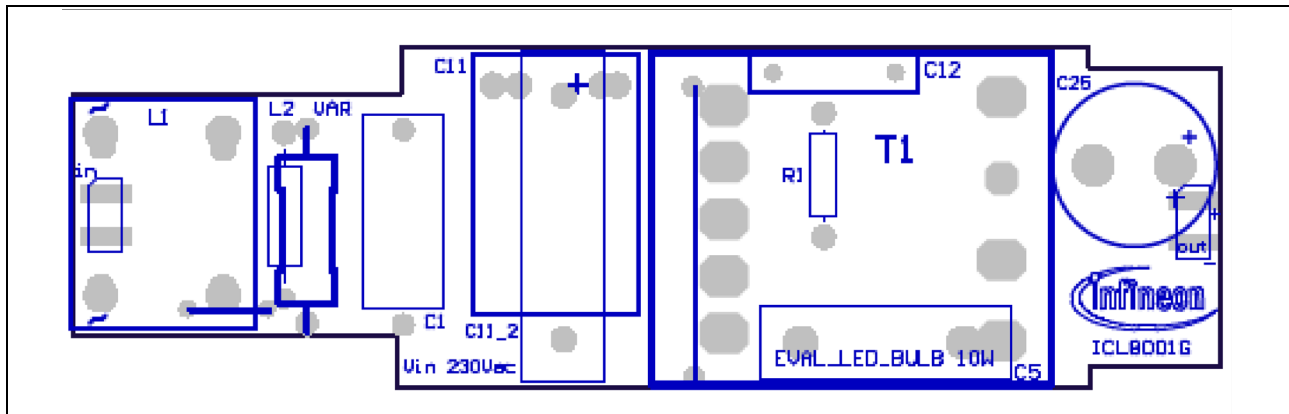


Figure 9 EVAL-LED-ICL8001G-Bulb02 - Top Layer

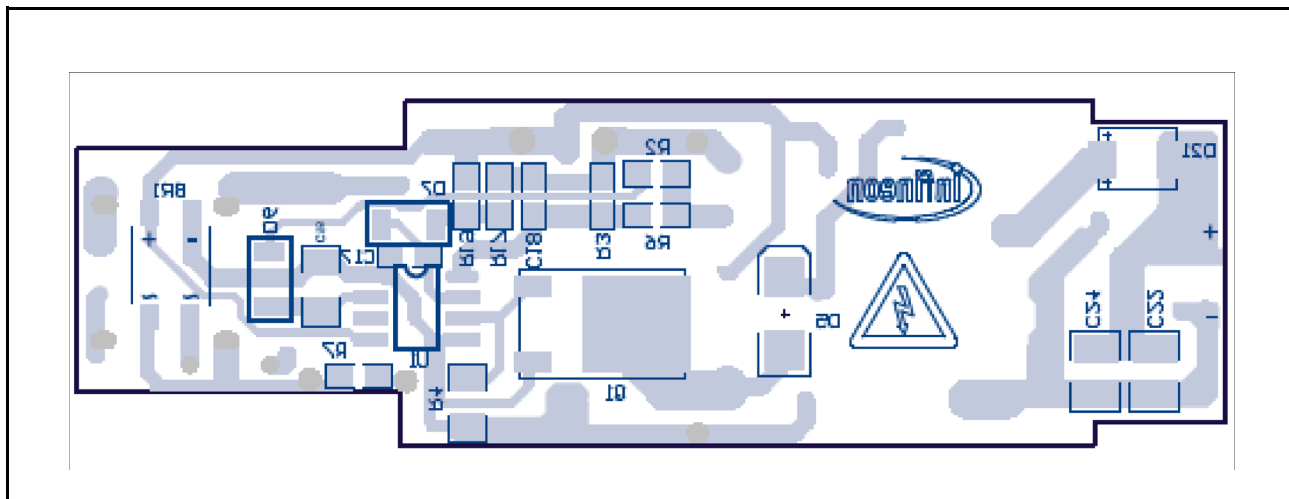


Figure 10 EVAL-LED-ICL8001G-Bulb02 - Bottom Layer

7 Schematic and BOM

7.1 Schematic

LED Bulb QR Flyback Driver with ICL8001G for Phase Cut Dimming & PFC using Primary Control

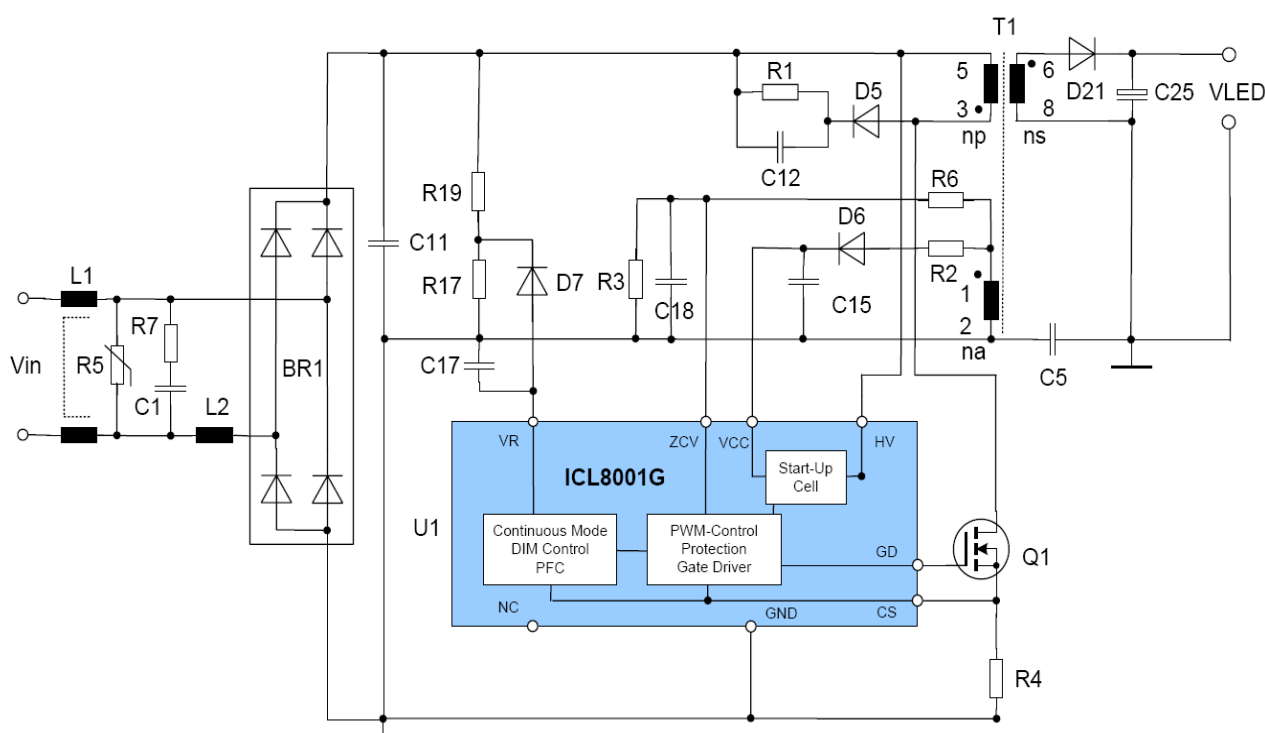


Figure 11 EVAL-LED-ICL8001G-Bulb02 Schematic

7.2 Bill of Material

|  Dimmable QR LED Driver Board BOM for ICL8001G – Primary Control Vin 230V / Pin 10.5W @ Vout 26V | | |
|--|-----------------------------|------------------------------------|
| Component | Value | Package |
| U1 | ICL8001G | P-DSO-8 |
| BR1 | RMB6S | SMD |
| D5 | not assembled | MURS 160 / 600V 1.0A |
| D6 | LL4148 | Mini-MELF |
| D7 | LL4148 | Mini-MELF |
| D21 | 60V, 2A, Schottky Diode | SMB |
| Q1 | SPD02N80C3 | D-PAK |
| C1 | 68nF/250VAC MKP-X2 | RM10 |
| C5 | 1n/250VAC-Y1 | RM10 |
| C11 | 33nF / 630V | RM15 EPCOS B32529/520/521/522 |
| C12 | 1nF / 400V | RM7.5 |
| C15 | 22uF / 25V | 1210 |
| C17 | 2.2nF / 25V | 0805 |
| C18 | 470pF / 25V | 0805 |
| C22, C24 | not assembled | 1206 |
| C25 | 220uF / 35V / Elko | RM 5, diameter 10, height 12 |
| L1 | 2x15mH / 0.4A | B82730 U3401A 020 |
| L2 | 1mH / 130mA | axial / EPCOS B78108S1105J |
| T1 | EF16/9 - L35 = 6.3mH | Würth 750815141 |
| | L68 = 39.2uH / L12 = 20.0uH | np=N35=190 / ns=N68=14 / na=N12=10 |
| R1 | 1M | axial |
| R2 | 10R0 | 0805 |
| R3 | 2k0 | 0805 |
| R4 | 2R7 | 1206 |
| R5 | Varistor / 275Vac | RM10 EPCOS S10K275 |
| R6 | 15k | 0805 |
| R7 | 0R0 | 1206 |
| R17 | 3k9 | 0805 |
| R19 | 560k | 0805 |
| J1 | Jumper | below L1 |
| J2 | Jumper | below T1 |

Figure 12 Bill Of Material

7.3 Transformer

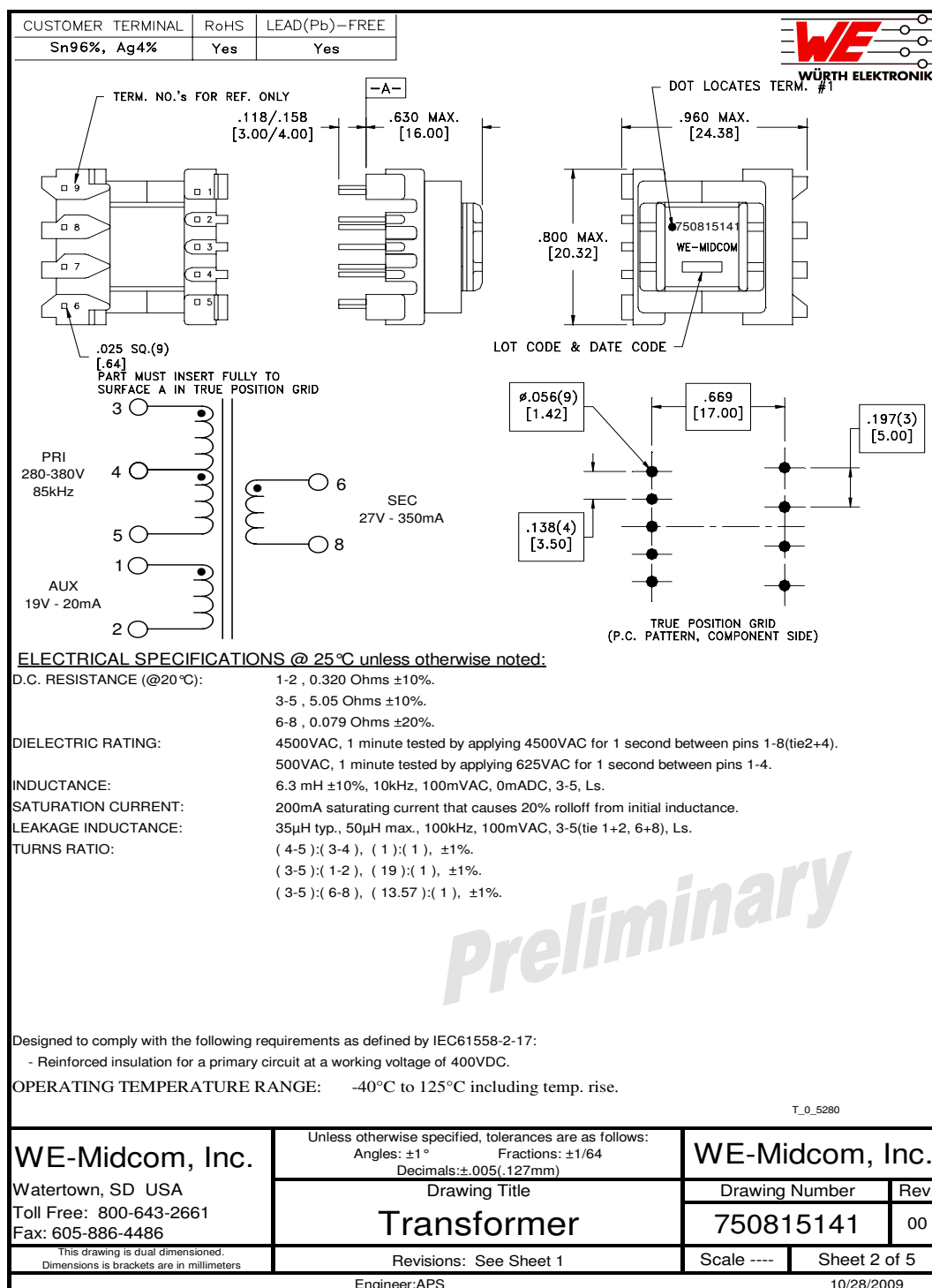


Figure 13 EVAL-LED-ICL8001G-Bulb02 Trafo Design

7.4 Related Documentation From Infineon

ICL8001G Datasheet at www.infineon.com

Quasi-Resonant Controller Application Note at www.infineon.com

Quasi-Resonant Controller Design Tips at www.infineon.com

www.infineon.com