DI-168 Design Idea
TOPSwitch®-GX

20 W Single Stage Flyback Power Supply With PFC for LED Ballasts

Application	Device	Power Output	Input Voltage	Output Voltage	Topology
LED Ballast	TOP247YN	20 W	85 – 277 VAC	12 V – 18 V, 1.67 A	PFC Flyback

Design Highlights

- Universal input range allows single design to be used worldwide
- Single stage PFC based CV/CC power supply
- Meets minimum PF requirement of 0.9 for commercial environment (ENERGY STAR SSL VER 1.0)
- Meets harmonic content limits as specified in IEC 61000-3-2 for Class C Equipment (see Figure 2)
- High efficiency (~80%) across entire input range
- Meets EN55015 B conducted EMI limits with >10 dBµV margin
- Auto-restart provides indefinite output short circuit withstand

Operation

The isolated flyback converter shown in Figure 1 is a single stage PFC-based LED ballast power supply. It can deliver an average output current of 1.67 A at 12 V, which makes it ideal for driving high current LED arrays. High power factor is achieved by operating a flyback converter in discontinuous conduction mode with minimal input capacitance. This results in a drain current envelope that follows the incoming AC voltage waveform. As discontinuous conduction mode results in higher primary RMS currents, a TOP247YN was selected to minimize the $R_{DS(ON)}$ of the MOSFET, reduce dissipation and improve overall efficiency.

Resistors R11, R12, R23, Q2, Q3, Q4 and their associated circuitry, together with the LED in U2, form a low-drop CC sense circuit and program the average load current to 1.67 A. At no-load, the output voltage is limited to about 18 V by R16 and VR2.

For high power factor and low harmonic content, U1 must operate at constant duty cycle over an AC input line frequency cycle. This is achieved by designing the loop gain crossover to be well below 100 Hz, the lowest rectified AC frequency. For this design, gain crossover occurs at ~30 Hz at low line and ~40 Hz at high line.

Capacitor C10 and R6 set the dominant pole at approximately 0.02 Hz, with R7 creating a zero at 200 Hz to improve phase margin at gain crossover. To isolate C10 from the CONTROL pin, where it would change the startup and auto-restart timing, Q1 is configured as an emitter follower driven by the output of U2B. Looking into the emitter, C10 appears to be larger ($C10 \times Q1_{hfe}$), and R6 appears to be smaller ($R6 / Q1_{hfe}$). This provides an equivalent capacitance value that is large enough to maintain a constant current into the CONTROL pin of U1 and therefore duty cycle over an AC line cycle.

The CONTROL pin bypass capacitor (C5) is just large enough to allow proper start-up as well as steady state operation. A larger value of C5 would increase start-up delay time.

An optional soft-start circuit is formed by D12, C15, C16, R18 to R21 and Q5. Prior to the output reaching regulation, Q5 is biased

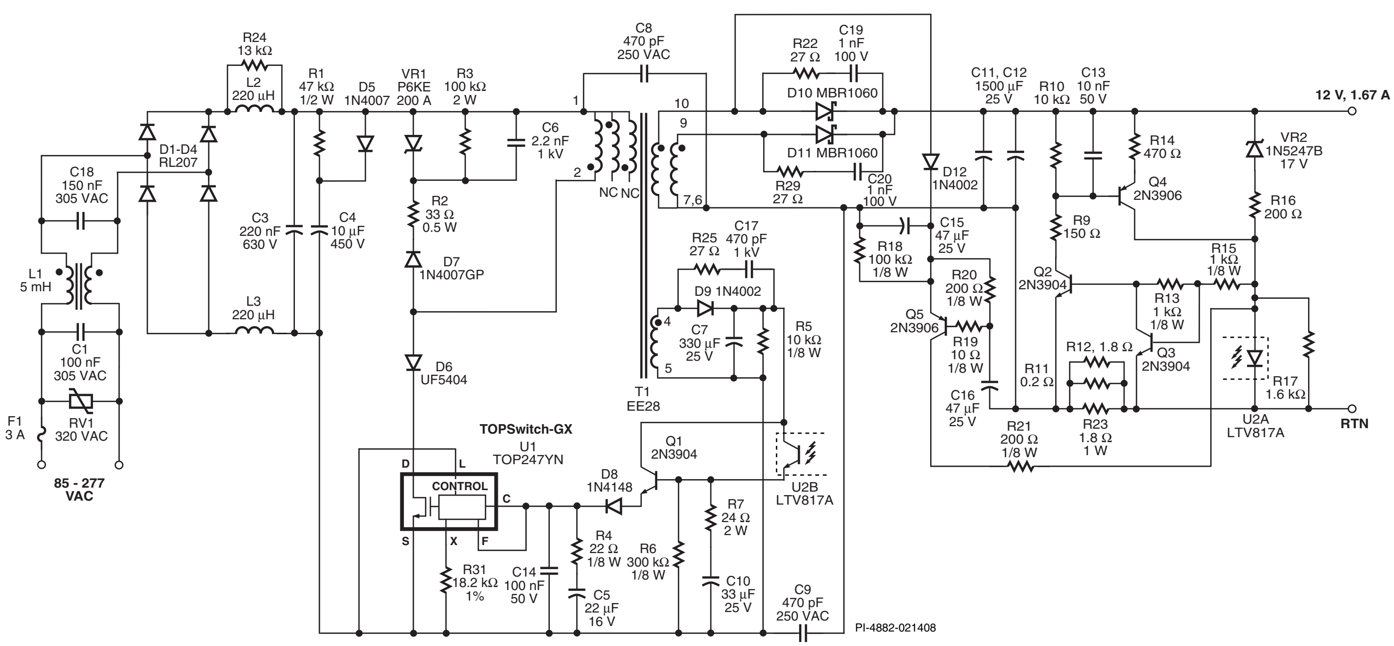

Figure 1. 20 W Single Stage Power Factor Corrected LED Driver Power Supply, Using a TOP247YN Device.

on while C16 charges to $V_{E(Q5)} - V_{BE(Q5)}$. Current is fed into the CONTROL pin of U1 via U2, which ensures that the output reaches regulation without glitching (due to entering auto-restart). At power down, C16 is reset by discharging via R18.

The two secondary windings of the transformer are rectified by D10 and D11, filtered by C11 and C12.

The primary clamp circuit is formed by D7, R2, R3, C6 and VR1. During normal operation, R3 and C6 set the clamping voltage, with VR1 defining the maximum clamp voltage during start-up and load transients. Slow glass passivated diode D7 has a reverse recovery time of 2 μs and helps recover some of the leakage energy thereby improving efficiency. Resistor R2 damps out high frequency ringing and helps reduce EMI.

Key Design Points

- On application of AC input, the inductance in the line causes a voltage spike. Startup capacitor C4 stabilizes the DC bus voltage as it charges through diode D5. Once in steady state, the capacitor is effectively decoupled from the circuit by D5. Resistor R1 is the bleeder to discharge C4 during power down. This arrangement also provides protection against differential mode voltage surges.
- Use PIXls spreadsheet to design the transformer. Enter the peak power (33 W), which corresponds to the average power of 20 W. Enter a minimum DC voltage equal to the peak of the minimum input AC voltage to determine the correct value of primary inductance.
- Set the value of KP to 1.0 to ensure critically discontinuous mode at the peak of minimum AC input voltage. Ensure that the converter operates in discontinuous mode (during steady state operation) at all times.
- Ensure that gain crossover occurs below 40 Hz. A higher bandwidth is undesirable as this degrades power factor by increasing the third harmonic content in the input current waveform.
- The size of the transformer should be based on thermal evaluation. Due to higher RMS currents in windings and core AC flux, a larger transformer is typically required than a standard DC fed flyback.
- Diode D6 must be an ultra-fast type. It prevents reverse currents from flowing through the TOPSwitch during its off time, the result of the small input capacitance.
- The secondary is split into 2 parallel windings and 2 separate diodes for improved efficiency.

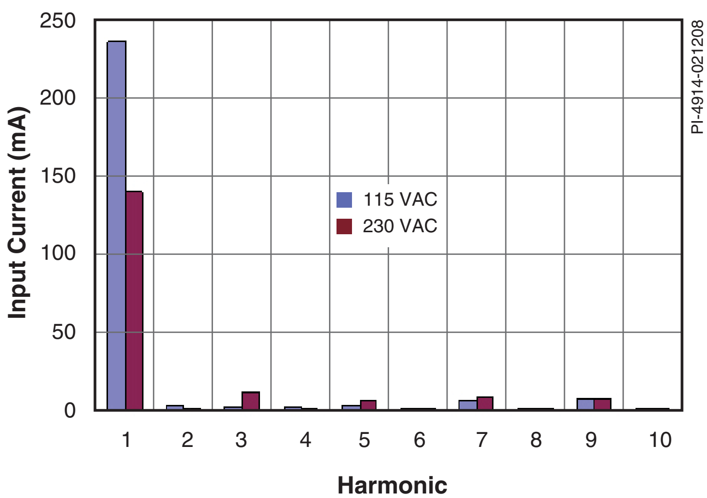

Figure 2. Harmonic Content Measured at 115 VAC and 230 VAC.

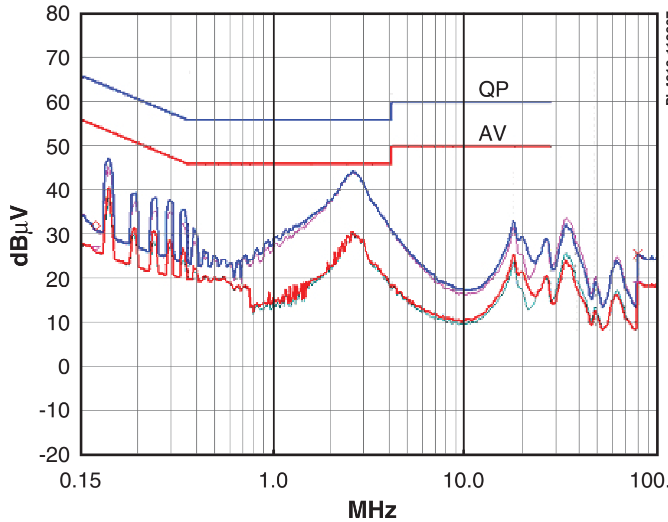

Figure 3. Worst Case Conducted EMI (230 VAC With Output Grounded) Measured Against EN55015 Limits.

Transformer Parameters

Core Material	EE28 NC-2H or equivalent, gapped for ALG of 452 nH/t²
Bobbin	EE28, 10 pin, Vertical
Winding Details	Shield: 20T × 2, AWG 33, tape Primary: 20T × 1, AWG 27, tape Shield: 4T × 4, AWG 25, tape Secondary: 4T × 2, AWG 23 T.I.W. Bias: 7T × 4, AWG 30, tape Primary: 20T × 1, AWG 27, tape
Winding Order	Shield (1–NC), Primary (2–3), Shield (NC–1), +12 V (9,10–6,7), Bias (4–5), Primary (3–1)
Primary Inductance	724 μH, ±10%
Primary Resonant Frequency	855 kHz (minimum)
Leakage Inductance	10 μH (maximum)

Table 1. Transformer Parameters. (NC = No Connection, T.I.W. = Triple Insulated Wire)

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