DI-157 Design Idea
LinkSwitch®-II

2.75 W USB Charger

Application	Device	Power Output	Input Voltage	Output Voltage	Topology
Low-cost USB Charger/Adapter	LNK613DG	2.75 W	85 – 265 VAC	5 V	Flyback

Design Highlights

- Revolutionary control concept enables very low cost, low part-count solution
  - Primary-side control eliminates secondary-side controller and optocoupler
  - Constant voltage (CV) accuracy: ±5%
  - Constant current (CC) accuracy: ±10%
  - Over-temperature protection with hysteretic recovery ensures safe PCB temperatures under all conditions
  - Auto-restart: output short circuit and open-loop protection
- Highly energy efficient
  - Average efficiency over load range: 74% (vs. the 64% Energy Star 2.0 requirement)
  - No-load input energy consumption: <40 mW at 230 VAC
- Easily meets the following specifications:
  - EN55022 and CISPR-22 Class B EMI (>10 dB margin)
  - IEC 61000-4-5 Class 3 AC line surge and ESD withstand
  - Meets <5 mA battery discharge requirement

Operation

The schematic in Figure 1 depicts the design for a 2.75 W universal input, constant voltage/constant current (CV/CC) charger power supply design based on Power Integrations' LinkSwitch family product LNK613DG. This design is useful for cell phone or similar USB charger applications. This includes battery chargers for cell phones, USB chargers, or any application requiring a CV/CC characteristic.

In this design diodes D1 through D4 rectify the AC input, and capacitors C1 and C2 filter the DC. The pi (π) filter formed by L1, C1, and C2 attenuates conducted differential-mode EMI. This, in combination with Power Integrations' transformer E-sheild™ technology, means EMI standard EN55022 class B compliance with strong margin, using no Y capacitor. Fusible, flameproof wire-wound resistor RF1 provides protection against catastrophic failure and limits inrush currents during start-up.

Figure 1 shows U1 biased from an optional bias supply, which reduces the no-load power consumption to less than 40 mW. The value of bypass capacitor C4 programs the amount of cable drop compensation. A value of 1 µF corresponds to compensation for a 0.3 Ω, 24 AWG USB output cable. (A 10 µF capacitor compensates 0.49 Ω, 26 AWG USB output cables.)

In the CV region, the output voltage is regulated by using on-off control. Output voltage is maintained by skipping switching cycles. Regulation is maintained by adjusting the ratio of enabled and disabled cycles. This also optimizes the efficiency of the converter over the entire load range. At light loads (trickle charge) the current limit is reduced to decrease the transformer flux density, which reduces audible noise and switching losses. As the load current increases, the current limit is increased and fewer and fewer cycles are skipped.

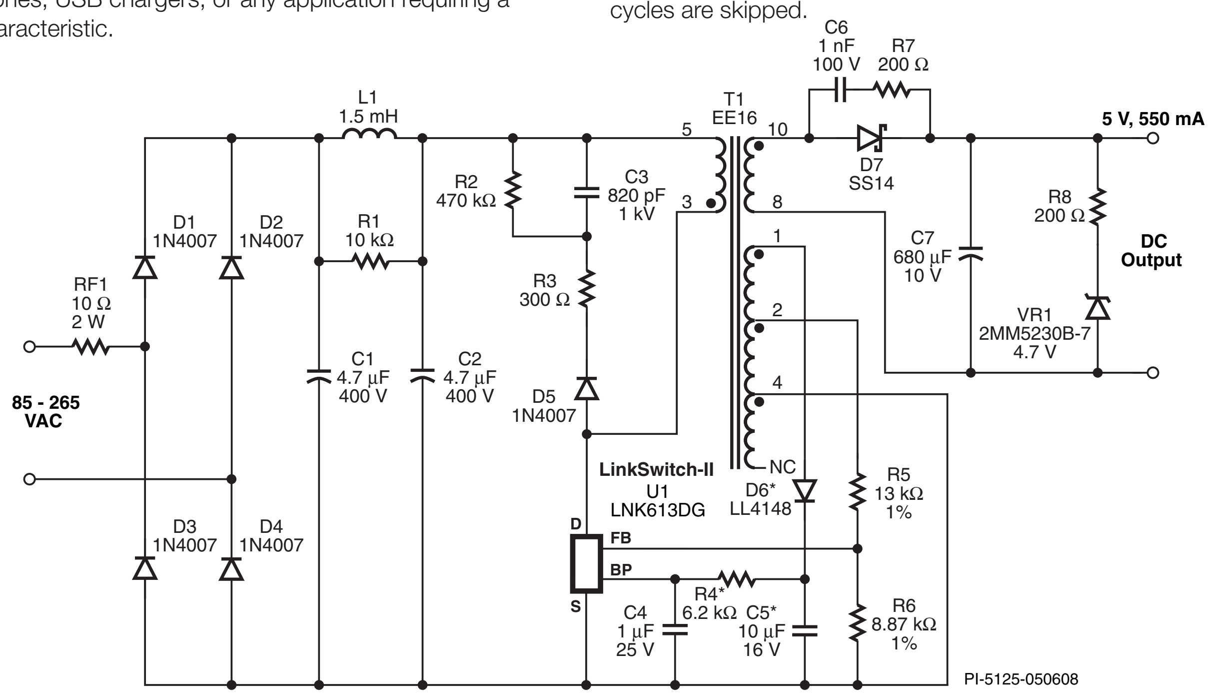

Figure 1: Schematic: 2.75 W CV/CC Universal Input Charger Power Supply.

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At the point where no switching cycles are skipped (maximum power point) the controller within the LinkSwitch-II transitions into CC mode. A further increase in the demand for load current causes the output voltage to drop. This drop in output voltage is reflected on the FB pin voltage. In response to the reduction of voltage at the FB pin, the switching frequency is linearly reduced to achieve constant output current.

The RCD-R clamp formed by D5, R2, R3, and C3 limits leakage inductance drain voltage spikes. Resistor R3 has a relatively large value to prevent ringing on the drain voltage waveform caused by the leakage inductance, which prevents excessive ringing during a turn off event, thereby reducing conducted EMI.

Diode D7 rectifies the secondary and C7 filters it. The combination of C6 and R7 limits transient voltage spikes across D7 and reduces conducted as well as radiated EMI. Resistor R8 and Zener diode VR1 form an output preload to ensure the output voltage at no-load is within acceptable limits and to also ensure that the battery does not fully discharge if the charger is unplugged from AC mains. Feedback resistors R5 and R6 set both the maximum operating frequency, and the output voltage in the CV region.

Key Design Points

- Capacitor C7 was chosen as a low ESR type capacitor to meet the output voltage ripple requirement without LC post filtering.
- If lower average efficiency is acceptable (a 3% to 4% drop), replace D7 with a PN-junction diode to lower cost. Then readjust R5 and R6 as needed to ensure the output voltage stays centered.
- Place the BYPASS pin capacitor (C4) physically close to U1 on the PCB.
- Minimize clamp and output diode loop areas to reduce EMI
- Space the AC input away from switching nodes to minimize noise coupling that may bypass input filtering.
- The extended creepage distance on U1 between the high and low voltage pins prevents arcing and improves reliability, especially important in very humid conditions.
- Use 1% tolerance resistors for R5 and R6 for better voltage and current regulation.

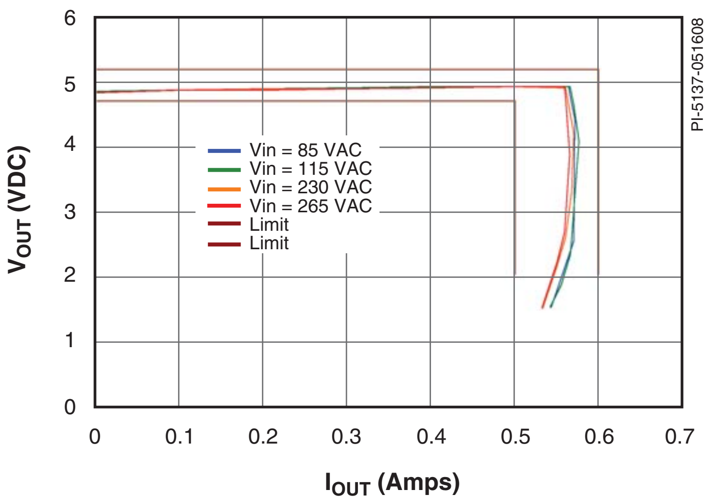

Figure 2. Typical CC/CV Characteristic Over Line at 25 °C.

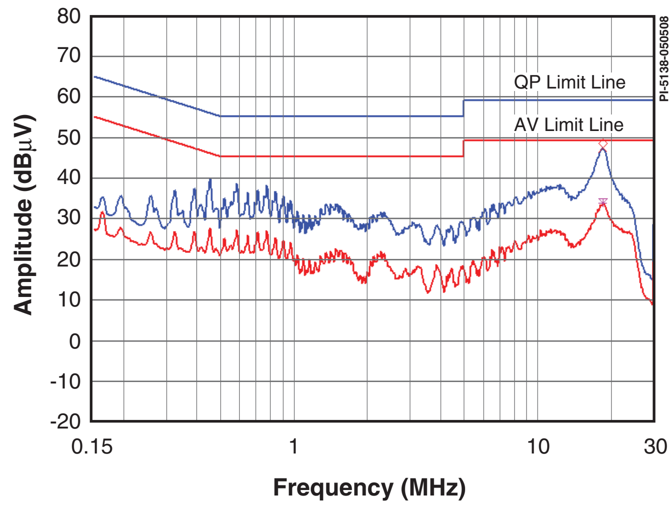

Figure 3. Conducted EMI, EN55022 B Limits: Measurements Made at 230 VAC with Output RTN Connected to Earth Ground .

Transformer Parameters	
Core Material	EE16, NC-2H or equivalent, gapped for ALG of 143 nH/t²
Bobbin	EE16, Horizontal, 10 pins, (5/5)
Winding Details	Shield: 23 T, 29 AWG Primary: 128 T, 36 AWG Feedback: 6T x 4, 30 AWG Bias: 6T x 4, 30 AWG 5 V: 7T, 22 TIW
Winding Order	Shield (4–NC) Insulation, Primary (3–5) Insulation, Feedback (2–1) Insulation, Bias (4–2) Insulation, 5 V (10–8) Insulation
Primary Inductance	2.58 mH, ±10%
Primary Resonant Frequency	500 kHz (minimum)
Leakage Inductance	130 µH (maximum)

Table 1. Transformer Parameters. (AWG = American Wire Gauge, TIW = Triple Insulated Wire, NC = No Connection)

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