25 W @ 9 V SMPS Charger (USB-PD)

Overview

This project is a Switch-Mode Power Supply (SMPS) in flyback configuration, delivering 25 W output power at 9 V DC.
It features USB Power Delivery (PD) communication for fast charging via a USB Type-C port and uses the UCC28750 flyback controller for high-efficiency operation with isolated feedback.
The design follows modern compact-charger topologies, combining power, feedback, and communication circuits on a single 2-layer PCB (GND plane on the bottom).

Key Specifications

Parameter	Value
Input Voltage	220 – 240 VAC
Output Voltage	5 V / 9 V (USB-PD)
Output Current	up to 2.8 A
Output Power	25 W max
Topology	Isolated Flyback
Switching Controller	TI UCC28750
Feedback Isolation	TL431 + PC817 Optocoupler
USB-PD Controller	IP2721
Efficiency (target)	≈ 85 %
Transformer	Custom 2P:1S Flyback, optimized for 25 W

Functional Description

1. AC Rectification & Filtering

- Input 220 VAC enters through a Phoenix terminal block.
- A GBU4K full-bridge rectifier converts AC to DC.
- Three 10 µF electrolytic capacitors connected in parallel smooth the rectified DC.
- High-value resistor divider (R1–R3) provides startup and reference bias for the control stage.

2. Snubber & Protection Network

- The RC-D snubber (R4, R5, C4, D4) suppresses voltage spikes caused by transformer leakage inductance.
- D4 is an ultrafast Schottky diode, protecting the primary switch and improving efficiency.

3. Control Stage – UCC28750

- UCC28750 operates in primary-side regulation (PSR) with valley-switching PWM for low switching loss.
- It drives the Q1 NMOS transistor, switching current through the transformer's primary winding.
- Current-sense resistor (R7) monitors switch current, while gate resistor (R6) limits EMI and overshoot.
- The controller dynamically adjusts frequency and duty cycle based on optocoupler feedback.

4. Feedback Regulation

- The secondary voltage is sensed through a TL431 precision reference (U3) and PC817 optocoupler (U2).
- When output voltage rises, TL431 conducts more, driving the optocoupler LED to adjust the duty cycle, maintaining stable regulation.
- This ensures precise and isolated voltage feedback between primary and secondary sides.

5. Output Rectification & Filtering

- The flyback transformer's secondary output is rectified by D5 Schottky diode (low forward drop).
- Three 820 µF capacitors (C10–C12) filter the output to achieve low ripple and stable DC.

6. USB-PD Communication

- The IP2721 controller (U4) handles USB Power Delivery negotiation through CC1/CC2 lines.
- It communicates desired voltage/current profiles to the connected device (5 V / 9 V).
- Q2 NMOS acts as a high-side switch for VBUS control during protocol handshakes.
- Final output is provided via a USB Type-C receptacle, with shielding and ESD protection.

PCB Design Overview

- 2-Layer PCB with bottom GND plane and isolated high-voltage creepage clearances.
- Primary and secondary grounds separated with safety isolation gap.
- Short and wide switch-node trace for reduced ringing and EMI.
- Transformer footprint (T1) centered for balanced heat distribution.
- Compact layout suitable for integration in a USB-C wall charger enclosure.

Applications

- USB-C fast chargers (5 V / 9 V profiles)
- Compact SMPS adapters up to 25 W
- Isolated DC power sources for embedded systems
- Educational design for USB-PD + Flyback topology integration