DI-163 Design Idea
TinySwitch®-III

Wide Range Set Top Box Power Supply with Latching Overvoltage (OVP) Shutdown Protection

Application	Device	Power Output	Input Voltage	Output Voltage	Topology
Set Top Box	TNY277PN	15 W	85 – 300 VAC	3.3 V, 5 V, 8 V, 22 V	Flyback

Design Highlights
- Multiple output power supply
- Excellent cross regulation
- Two outputs sum-regulated
- Highly energy efficient
- Meets CEC/ENERGY STAR 2008 requirements for active mode efficiency (77 % vs 68.1% requirement)
- Low no-load power consumption (<150 mW at 230 VAC)
- Meets CISPR-22/EN55022B conducted EMI limits
- Auto-restart withstands shorted output condition indefinitely

Operation
The TinySwitch-III multiple output power supply shown in Figure 1 provides 15 W of output power. Typical applications include set-top boxes or DVD players where a multiple output flyback supply is required.

Diodes D1, D2, D3 and D4 and capacitors C2 and C3 rectify and smooth the AC input. Capacitors C2, C3, C8 and inductor L2 provide differential as well as common-mode EMI filtering. The controller in U1 receives feedback from the secondary through optocoupler U2, and based on that feedback, it enables or disables the switching of its integrated MOSFET to maintain output regulation. A portion of both the 3.3 V and the 5 V outputs are fed into the shunt regulator (U3), which controls the current through the LED in U2. A proportional current is then pulled out of the EN/UV pin. Switching cycles are skipped once the EN/UV disable threshold current (115 µA) is exceeded. When the current out of the EN/UV pin falls below the disable threshold, switching cycles are re-enabled. The disable threshold is modulated to reduce group pulsing and ensure evenly spaced current pulses thereby improving output ripple and overall efficiency.

Output overvoltage protection is provided via the latching shut-down feature of U1. Should the feedback loop open due to component failure, the resulting rise in output voltage is reflected through the bias winding output voltage across C6. Once the output voltage is above the sum of the rating of VR1 and the BP/M pin voltage (~53 V), current flows into the BP/M pin. Latching shutdown is triggered when this current exceeds 7 mA. MOSFET switching is disabled until the BP/M pin capacitor (C4) is discharged below 4.8 V after removal of input AC.

Good cross-regulation on 5 V and 3.3 V outputs is achieved by minimizing secondary leakage by placing the 3.3 V and 5 V windings on the same layer next to the primary and by sum regulating (obtaining feedback from both outputs).

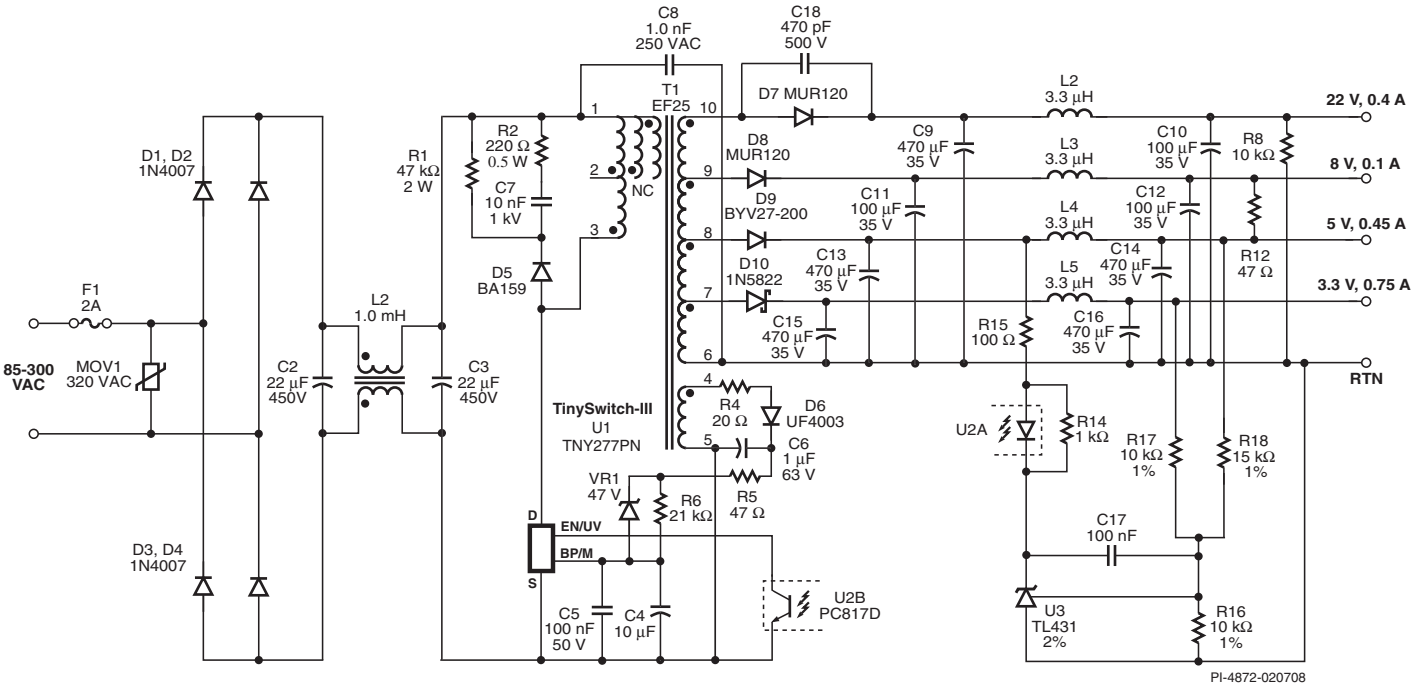

Figure 1. Schematic of a 15 W, Set Top Box Power Supply Using TinySwitch-III.

Key Design Points

- Components D5, R1 and C7 form an RCD clamp circuit, absorbing leakage inductance energy during turn off. This energy is partly recovered when C7 resonates with the transformer primary leakage inductance and couples into the secondary side. Resistor R2 damps this resonant ring and improves EMI.
- Diode D5 is a fast diode with reverse recovery t_{RR} of 250 ns. It may be substituted with a cheaper 1N4007GP (glass passivated) diode
- The selectable current limit of U1 allows the current limit and device size to be optimized for the thermal environment. For example, in open frame applications, the TNY276PN part could be used by changing the value of C5 from 0.1 µF to 10 µF.
- To prevent an increase in no-load consumption or false OVP triggering, VR1 should be selected to conduct only when the output voltage is outside the normal regulation range. Resistor R5 prevents excessive current from flowing into the BP/M pin.
- To increase coupling between primary and secondary windings, the 3.3 V, 5 V and 8 V windings are all placed on the same layer
- To route currents away from U1 during common-mode surges, the Y1 capacitor C8 is connected between secondary return and the DC bus.

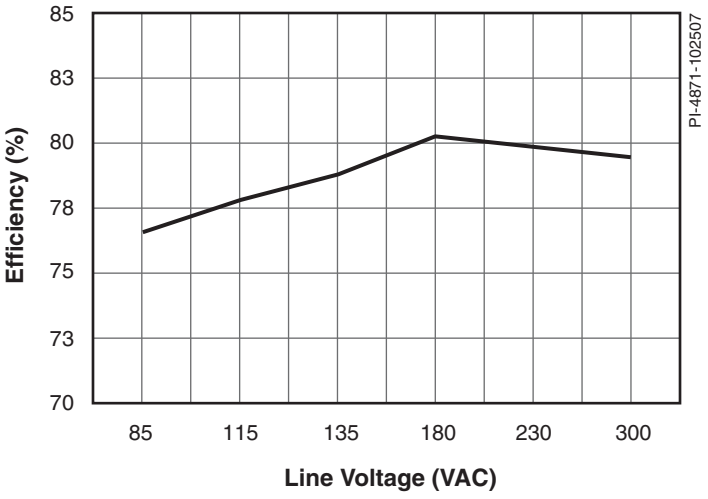

Figure 2. Full Load Efficiency vs Line Voltage.

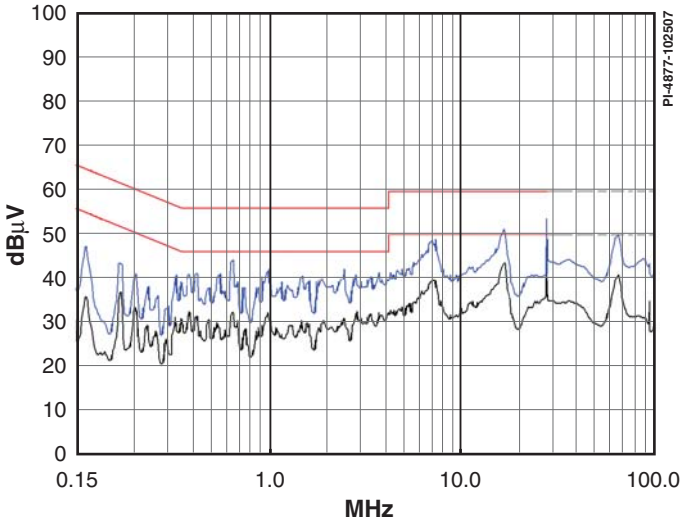

Figure 3. Worst Case Conducted EMI at 230 VAC With Output Grounded (CISPR-22 Limit Lines Shown).

Transformer Parameters	
Core Material	EF25 NC-2H or equivalent, gapped for ALG of 420 nH/t^2
Bobbin	EF25, 10 pin, Horizontal
Winding Details	3 mm margins on both sides of bobbin to meet safety Shield: 14T × 2, AWG29, tape Primary-1: 29T × 1, AWG29, tape Bias: 11T × 2, AWG29, 3 layers tape 3.3 V: 2T × 2, AWG25 5 V: 1T × 1, AWG25 (same layer as 3.3 V) 8 V: 1T × 1, AWG25 (same layer as 3.3 V), 1 layer tape 22 V: 8T × 2, AWG29, 3 layers tape Shield: 1T Foil 2 mils thick, tape Primary-2: 29T × 1, AWG29, 2 layers tape
Winding Order	Shield (1 - NC), Primary-1 (3-2), Bias (4-5), 3.3 V (7-6), 5 V (8-7), 8 V (9-8), 22 V (10-9), Shield (NC-1), Primary-2 (2-1)
Primary Inductance	1547 µH, ±10%
Primary Resonant Frequency	500 kHz (minimum)
Leakage Inductance	40 µH (maximum)

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

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