

DI-152 Design Idea

TinySwitch-III

3 W, Ultra-Wide Range Input Power Supply for Industrial Controls

Application	Device	Power Output	Input Voltage	Output Voltage	Topology
Industrial Controls	TNY280PN	3 W	18 – 265 VAC	5 V	Flyback

Design Highlights

- Ultra-wide input voltage range (18 – 265 VAC)
- Highly energy efficient
 - 65% efficiency
 - Very low no-load power consumption (<200 mW at 230 VAC)
- Meets CISPR-22/EN55022B conducted EMI limits with >10 dB μ V margin (see Figure 4)
- Floating current source provides supply current to BP/M pin
- Auto-restart indefinitely withstands shorted output condition

Operation

This design uses a TNY280PN in reduced current limit mode to implement a 5 V, 600 mA, ultra-wide input voltage range (18 to 265 VAC) power supply. Applications of such a power supply include auxiliary power supplies for industrial controls.

The AC mains are rectified by D1. Capacitors C1 and C2 smooth the half-wave rectified waveform to provide a high voltage DC source for the flyback supply. Inductor L1, placed between C1 and C2, creates a π filter to reduce differential mode conducted EMI. Y-capacitor C6 is used across the primary and secondary windings of the transformer to minimize common-mode noise.

The datasheet limit for minimum drain voltage to guarantee proper startup and functionality for U1 is 50 V. However, if a charging current is externally fed into the BYPASS pin, the chip can be powered

externally and can start up and operate at lower input voltages.

The startup circuit, comprising Q1, Q2, VR2, D2, D4, R4, R5 and R6, is a floating constant current source (shown separately in Figure 2) and provides a constant current of approximately 600 μ A into the BP/M pin of TinySwitch-III over the complete input voltage range.

The circuit is derived from the basic single transistor current source, which uses a Zener diode (VR2) to set reference voltage for base terminal of Q2 (NPN), which in turn programs the fixed voltage across resistor R5, thus setting the constant current value. However, given the very wide range of the input supply, the bias current for the reference Zener diode varies over a large range. This causes both increased power dissipation and shifting of the programmed constant current. To overcome this difficulty, the bias current is provided by another current source formed by Q1 (PNP) and R4. A constant voltage equal to V_{BE} is imposed across R4, which fixes the bias current into the reference Zener throughout the operating range. Q2 delivers the constant current at lower input voltages, Q1 at higher input voltages. Figure 2 also shows the simulation results of the current flow through Q1 and Q2. Up to an input voltage of about 50 VDC, the constant current is supplied by Q2. Above 50 VDC, the current through Q2 decreases linearly, and the current through Q1 increases linearly. At the maximum input voltage of 375 VDC, the constant current is provided primarily by Q1.

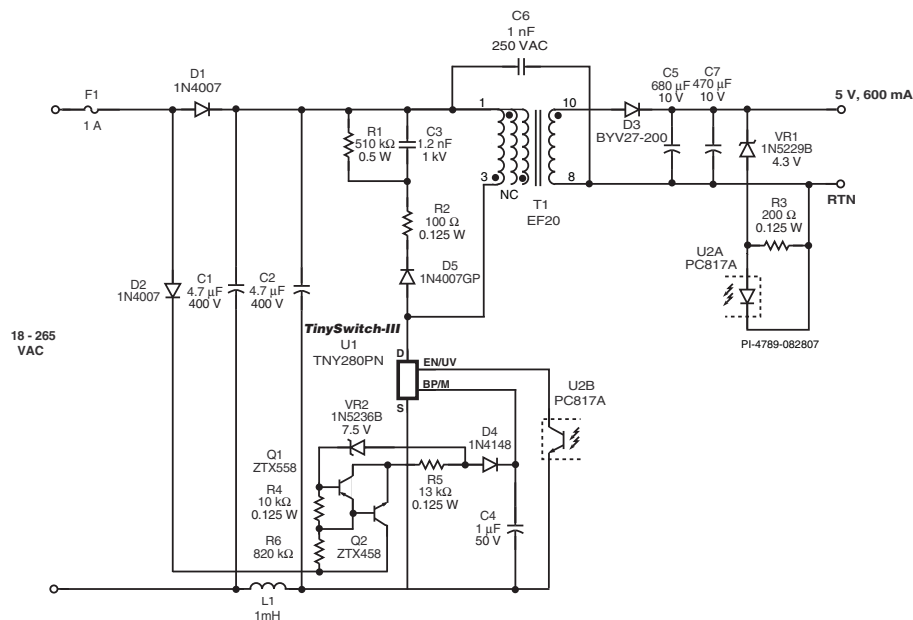


Figure 1. Schematic of a Wide Range Input, 5 V, 600 mA Power Supply Using TinySwitch-III

The TinySwitch-III (U1) uses on/off control, which offers a very simple feedback scheme and very fast dynamic response capability. The controller in U1 receives feedback from the secondary through optocoupler U2, enabling or disabling the switching of its integrated MOSFET to maintain output regulation. The current through the LED in U2A represents the output voltage. A proportional current is then pulled out of the EN/UV pin. Switching cycles are skipped once the EN/UV disable threshold current (115 μ A) is exceeded. When the current out of the EN/UV pin falls below the disable threshold, switching cycles are re-enabled.

Key Design Points

- Verify that the maximum drain voltage is <650 V at high line and maximum overload condition. Adjust the values of R1 and C3 as necessary. However, avoid making the clamp circuit too dissipative (i.e., low value of R1 and high value of C3), as this will increase the no-load power consumption.
- Use a slow blocking diode D5 with a 100 Ω series resistor. Use only a glass-passivated (GP) diode type to ensure a reverse recovery time of 2 μ s or less. If unavailable, a fast diode such as FR107 may be used instead. These diode selections recycle some of the clamp energy and improve efficiency at no load.
- Due to the wide range of input voltage, the primary inductance needs to be low enough to avoid an excessively continuous design. However, this low inductance leads to a large di/dt at 265 VAC and may cause excessive drain current overshoot due to the finite current limit delay time.
- Figure 3 shows the drain current measured at 265 VAC input and at full load. The peak drain current was measured as 900 mA. The datasheet absolute maximum current for the TNY280PN is 1.36 A, leaving sufficient safety margin.
- Resistor R5, together with VR2, determines the constant current value (600 μ A) according to $I = (V_{VR2}) / R5$.

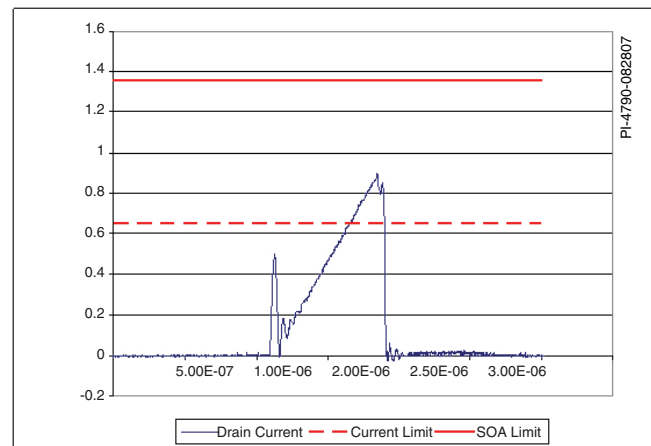


Figure 3. Peak Current Overshoots the Current Limit But is Within Limits Specified in the Data Sheet.

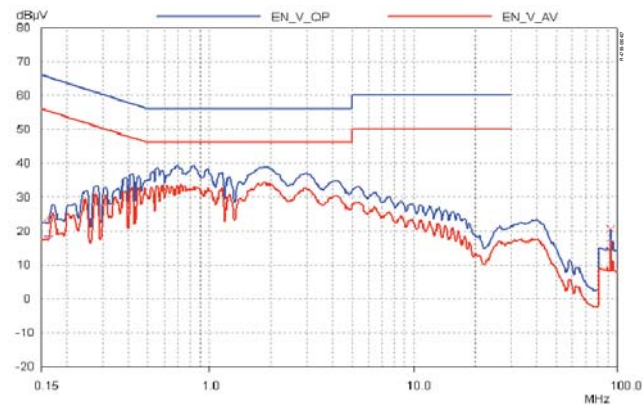


Figure 4. Worst Case EMI Measured at 230 VAC With Artificial Hand Connected to Output RTN

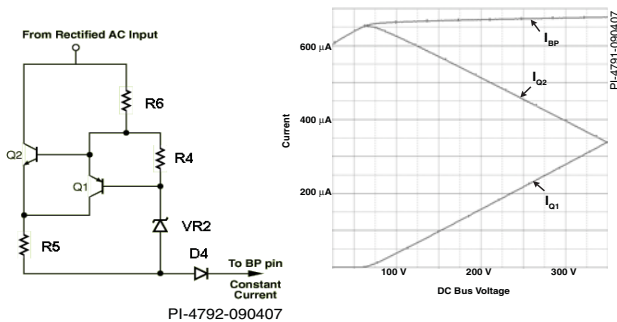


Figure 2. Floating Constant Current Source Provides Charging Current at Low Input Voltages

Transformer Parameters

Core Material	EF20 NC-2H or equivalent, gapped for ALG of 272 nH/t ²
Bobbin	EF20, 10 pin, Horizontal
Winding Details	Shield: 17T x 2, AWG28, tape Primary: 32T x 1, AWG28, tape Shield: 7T x 4, AWG27, 3 layers, tape 5 V: 8T x 1, AWG26, TIW, 1 layer, tape
Winding Order	Shield (1,2 - NC), Primary (3-1,2), Shield (NC-1,2), 5 V (10-8)
Primary Inductance	278 μ H, \pm 12%
Primary Resonant Frequency	1 MHz (minimum)
Leakage Inductance	12 μ H (maximum)

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

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