Linear AC/DC Adapters
Application Overview

Problem/Solution

Linear AC/DC adapters, or "wall warts", have applications in both battery charging applications and as low-cost DC power supplies for a variety of consumer equipment. In using a separate AC/DC adapter, the end equipment design is often simplified and regulatory approval is more straightforward. A typical circuit diagram of an unregulated supply is shown in Figure 1 with its equivalent circuit in Figure 2.

Adapters have their own safety and reliability requirements. Principally these are associated with short-circuit current-limiting and overtemperature protection as a result of excessive heating in the transformer windings. If the windings reach a temperature in excess of that specified for the insulation, the resulting insulation breakdown may result in short-circuits within the transformer and a corresponding fire hazard. Winding overtemperature can occur as a result of high ambient temperatures, external short-circuits, or fluctuating input power conditions.

While the benefits of overcurrent protection with a PolySwitch device are easily understood, it may be less clear that the inherent thermal derating characteristic of PolySwitch devices is capable of providing protection during an overtemperature fault as described above.

3

Figure 1. Example of an Unregulated Linear Adapter Protected by a PolySwitch Device

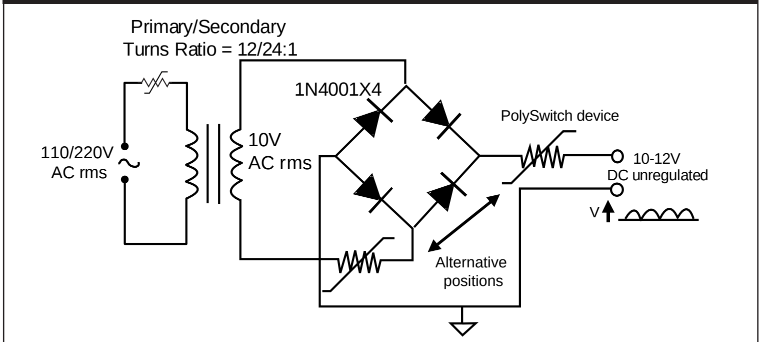
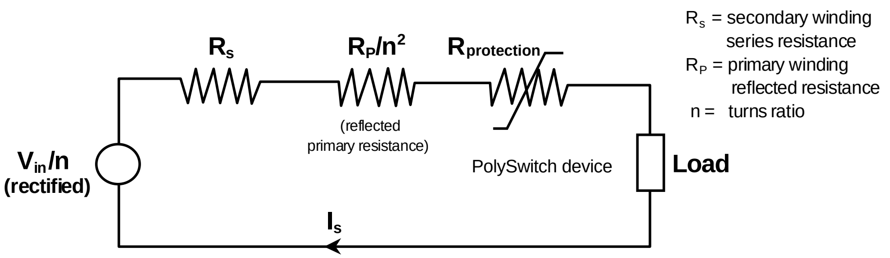
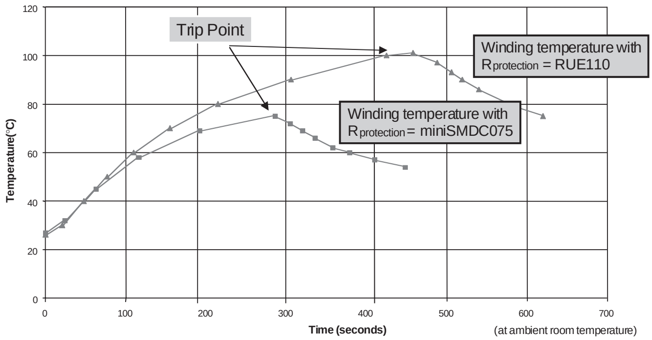


Figure 2. Transformer Equivalent Circuit



- **Source impedance =** $R_s + R_P/n^2 + R_{protection}$
  - optimized to the load by adjusting resistance seen in the secondary side (winding gauge and number of turns)
- **Power dissipation =** $I_s^2 R_P/n^2 + I_s^2 R_s + I_s^2 R_{protection}$
  - minimized by reducing winding and protection resistance

Figure 3. PolySwitch devices can limit transformer winding temperatures to well below UL/IEC specifications



Protection Requirements

Regulatory requirements for AC adapters are defined by UL. They are classified as a Listed Device and are subject to the Class 2 UL1310 specifications. UL1310 further specifies whether the adapters are inherently limited or not inherently limited. For 0-20V adapters the maximum specified output current in any condition is 8A and the maximum specified winding temperature is defined as a function of the insulation class. Typically, for the majority of low-cost consumer adapters, the choice of winding insulation is classed as Type A by UL with a maximum permitted temperature of 65°C above ambient in normal operation and an overall maximum of 150°C in fault conditions.

Technology Comparison

A thermal fuse embedded in the transformer winding is sometimes used but has the disadvantage that it is a one-shot device and is therefore less suitable for transient fault conditions such as output short-circuit or a fluctuation in input voltage. Ceramic PTC devices have the disadvantage of a higher impedance in the nontripped state, resulting in excessive power dissipation during normal operation. A higher class of insulation may also be considered for the transformer winding to avoid the need for further protection, but this generally results in a significantly more expensive transformer.

PolySwitch Device Selection

The PolySwitch device is selected by considering the maximum load current to be delivered, the highest ambient temperature, and the minimum time to trip with rise in transformer temperature. New Polyswitch LVR devices are capable of operating at line voltages of 85 V_{AC} to 265 V_{AC}, making them suitable for protection on the primary side of linear transformers. These devices help protect against excessive voltage on the primary side and short circuits on the secondary side. In addition to their current limiting ability, their ability to sense and respond to elevated temperatures makes them ideal for protecting the primary windings. Depending on these parameters, either a radial-leaded or surface-mount device can be considered. For designs of about 5W, devices typically used might include a miniSMDC075 or RUE110. For 10W adapters, an RUE185 device is commonly used. For primary side protection, LVR devices are available in hold currents from 50mA to 400mA.

An example of the overtemperature protection characteristics of a PolySwitch device in this application is shown in Figure 3. The linear adapter output is intentionally shorted and the output current is limited by the winding resistance to about 1A. The secondary winding temperature starts to increase and when it reaches 100°C the combined thermal and electrical energy trips the PolySwitch device, limiting the secondary winding current further and reversing the winding temperature rise. The PolySwitch device is included in the secondary circuit and also protects the primary winding, as limiting the secondary winding current automatically reduces the primary current.

Table 1. Secondary Side Device Selection Summary

Adapter Power	Form Factor	Typical Device Series
<5W	Radial-leaded	RUE, RXE
	SMT	nanoSMD, microSMD, miniSMD
5–10W	Radial-leaded	RUE, RXE
	SMT	nanoSMD, microSMD, miniSMD
>10W	Radial-leaded	RGE
	SMT	miniSMD, SMD
<60W	**Primary Side**	
	Radial-leaded	LVR