

Chip Diode Application Note

Introduction

The markets of portable communications, computing and video equipment are challenging the semiconductor industry to develop increasingly smaller electronic components. Today, designers of compact electronic systems are faced with board space constraints, thus driving the requirement for alternative packaging technologies. Functional integration and miniaturization is the key to success!

To aid this miniaturization campaign, a new generation of Chip Diodes from Bourns has emerged that offers the capability to provide a silicon diode with minimal packaging overhead. The small signal diodes are lead-free with Cu/Ni/Au plated terminations and are compatible with lead-free manufacturing processes, conforming with many industry and government regulations on lead-free components.

Description

Bourns is offering small signal diodes (forward current less than 0.5 A) and power diodes (forward current greater than 0.5 A). The small signal and power diodes can be further categorized as follows:

Small Signal

- Switching Diodes: Mainly for switching of digital signals.
- Schottky Barrier Diodes: Mainly for switching and rectification of low power signals.

Power Diodes

- Schottky Rectifier Diodes: Mainly for current rectification in power supplies.

The diagrams in Figure 1A and 1B illustrate how these parts are packaged:

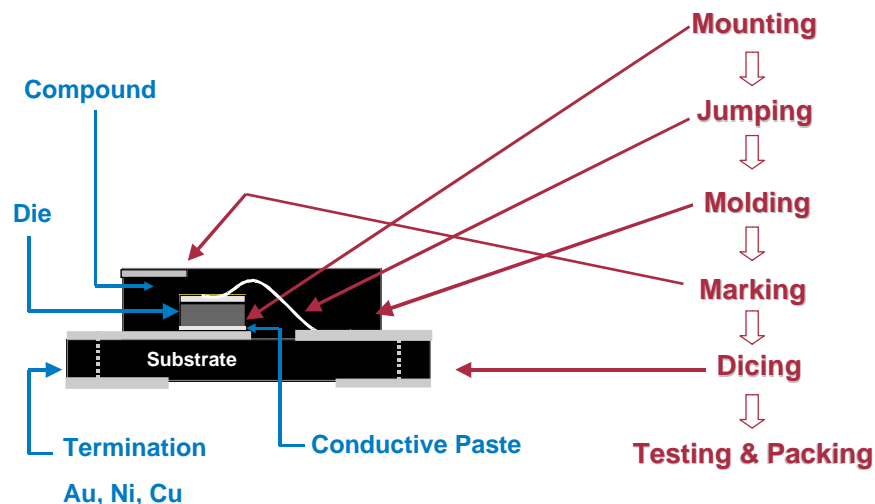


Figure 1A: Cross Section of 0805/1206 Package Structure

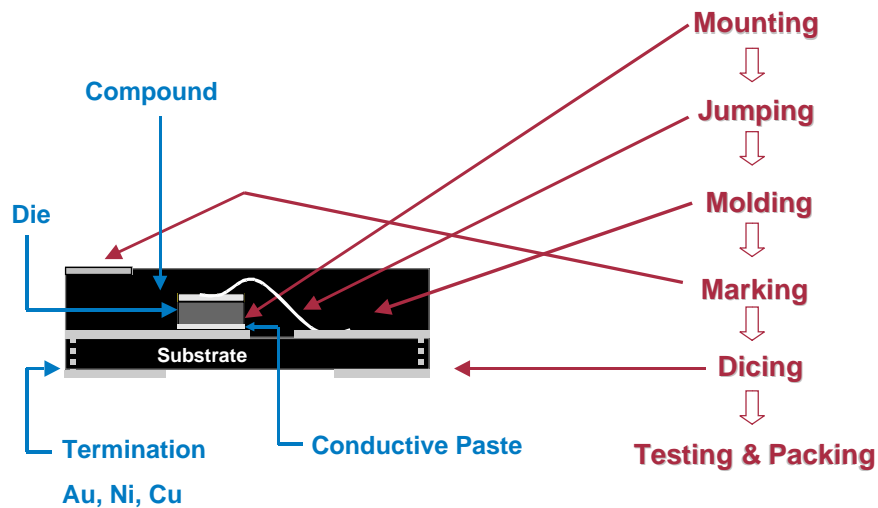


Figure 1B: Cross Section of 0603/1005 Package Structure

Chip Diode Advantages

The Chip Diode product range provides distinct advantages over some of our competitors, such as:

- **Package Size:** The Chip Diodes are *LEADLESS*, allowing designers to make real estate savings on PCB layouts. Chip Diodes offer a lower profile and provide height savings over competing SOD80 (MiniMELF) product.
- **Environmental:** All small signal diode terminations are *LEAD-FREE* with termination Cu/Ni/Au plating. Units meet many worldwide industry and government regulations on lead-free components.
- **Manufacturing Friendly:** Chip Diodes allow the use of industry standard pick & place equipment. The Chip Diode package makes it easy to handle and the flat configuration makes rollaway difficult in production operations.

Figure 2 compares the leadless package of the Chip Diode with a conventional leadframe package:

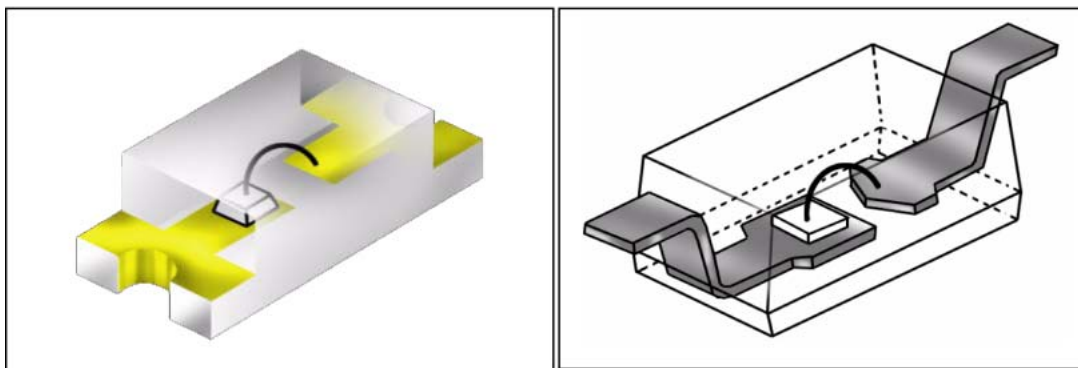


Figure 2: Comparison of Chip Diode Without Leads and a Standard Leaded Package

Technical Characteristics

PN Junction and Schottky Barrier Diodes have different characteristics, which can be useful depending on the application.

A PN Junction Diode consists of two types of semiconductors, *n*-type and *p*-type. Placed adjacent to each other, there is a spontaneous flow of electrons between the two pieces until an equilibrium state is created and no electrons flow. A barrier voltage now exists between the two pieces. A forward voltage can easily overcome this once it is greater than the barrier. Applying an opposite voltage, the current is essentially zero unless the voltage is so great that it destroys the diode. The current voltage (I-V) characteristics of the PN diode have the following format as shown in Figure 3.

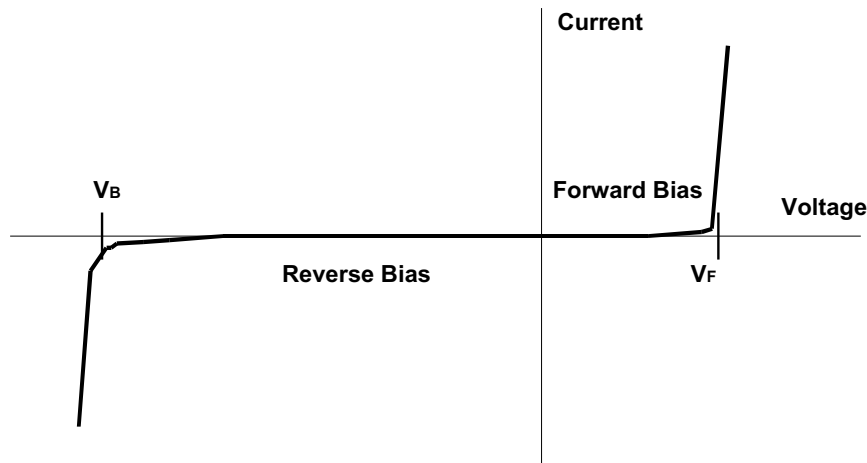


Figure 3: I-V Graph of a PN Junction

The Schottky Barrier Diode is a rectifying metal-semiconductor contact formed between a metal and *n* or *p* doped semiconductor. When a metal semiconductor junction is formed, free electrons flow across the junction from the semiconductor. The flow of electrons builds a depletion potential across the junction. Under forward bias (metal connected to positive in an *n* doped Schottky) there are many electrons with enough thermal energy to cross the barrier potential into the metal. Once the applied bias exceeds the built in potential of the junction the forward current will increase rapidly with the increase in V_f . When the Schottky Diode is reverse biased the potential barrier for electrons becomes large and only a leakage current in the nanoampere range will cross the junction.

In contrast to a conventional *p-n* junction, only majority carriers carry the current in the Schottky Diode. Because no minority carriers are present, Schottky Diodes have carrier lifetimes of less than 100 ps and are extremely fast switching semiconductors.

The following section illustrates the key parameters for designers:

- V_f : The barrier potential which must be overcome before the diode conducts in the forward sense. P-Ns have a higher barrier than Schottky Diodes. For battery-powered applications a lower voltage drop can imply longer battery times. Also voltage levels in battery-powered circuits are generally dropping and the margin between logic high and low is dropping. A voltage drop of 0.6 V may have a significant effect on whether a signal will be read as high or low. Schottky Diodes with a potential of 0.3 V typically have a big advantage in this regard. For example, the wireless modem amplifier shown in Figure 4 can keep a tighter margin on the voltage it is limiting across its gain resistor.

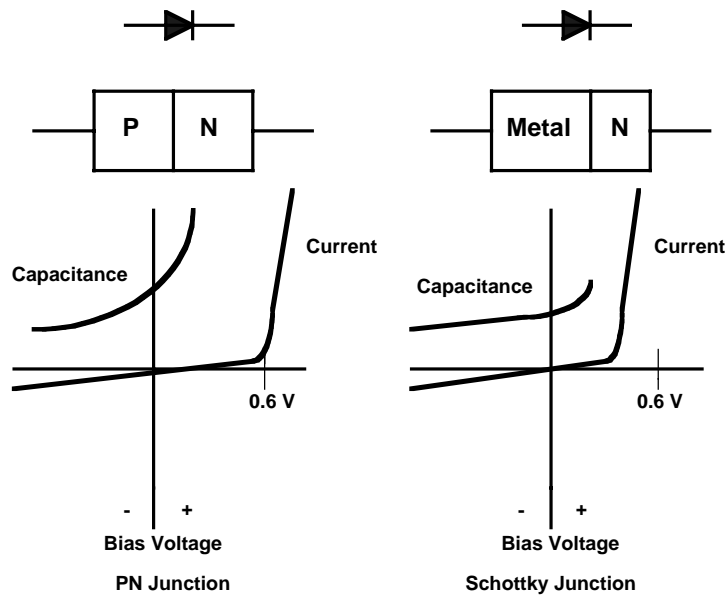


Figure 4: Current and Capacitance versus Voltage for PN Junction and Schottky Diodes

- T_{rr} (Reverse Recovery Time): The transition from conduction to open circuit when the bias is reversed. The figure below shows what happens when the diode bias is switched from forward to reverse. At the switch time, the current reverses and stays at a constant level for a period of time called the storage time (t_s). During this time the diode acts essentially as a short circuit. Then the current decreases to the reverse leakage current value. This latter time is called the transition time. The sum of the storage and transition times is the reverse recovery time. It depends on the forward current, and data sheets give the reverse recovery time along with the test conditions.

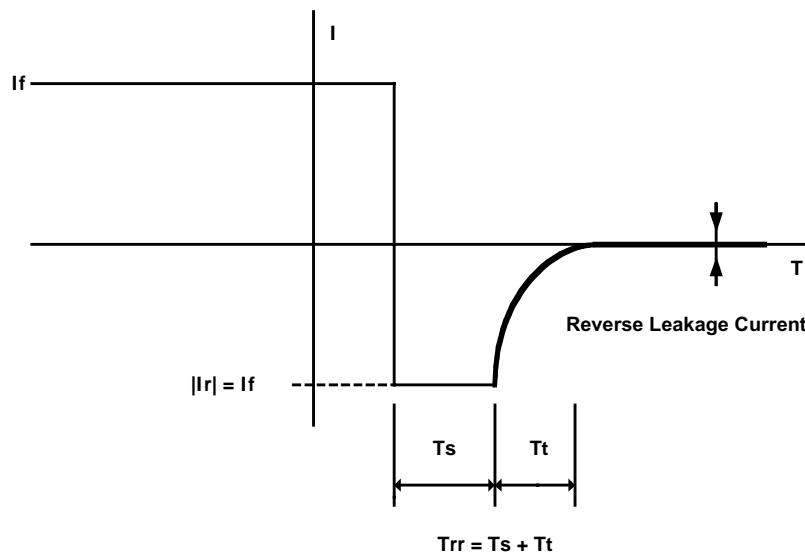


Figure 5: Illustration of the Reverse Recovery Time for a Diode

When a diode is employed to rectify a 60-Hz voltage in a power supply, a reverse recovery time of 1 microsecond is irrelevant. However, when the diode is used as a switch in a circuit that runs at 100 KHz, then 1 microsecond is a substantial part of the conduction cycle, and the diode will dissipate a lot of energy. In switching applications such as DC-DC converters this can seriously impact efficiency.

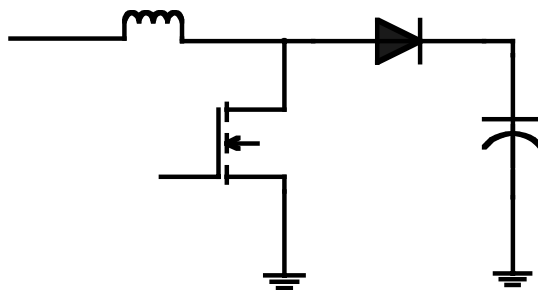


Figure 6: DC-DC Converter Circuit

For very small switching times, Schottky Barrier Diodes are used. These diodes are not PN junctions, but consist of a semiconductor-metal junction, and there are no stored minority carriers. Switching times can be as small as a few hundred picoseconds. This is very useful when protecting MOS devices and in lower level switching and steering applications.

- CT (Terminal to Terminal Capacitance of Schottky Diodes): Schottky Diodes generally have much smaller capacitances than p-n junctions and this parameter allows one to compare different models if fast switching speeds are desirable. In devices designed for rectification, and larger amounts of semiconductor and junction, the capacitance will be higher than for small signal devices.
- Ir (Reverse Current): The leakage current that a diode conducts when reverse biased. For example, in a peak detector circuit, low leakage is fundamental. Any leakage will cause the capacitor shown to discharge and the waveform to dip. See Figure 7 below.

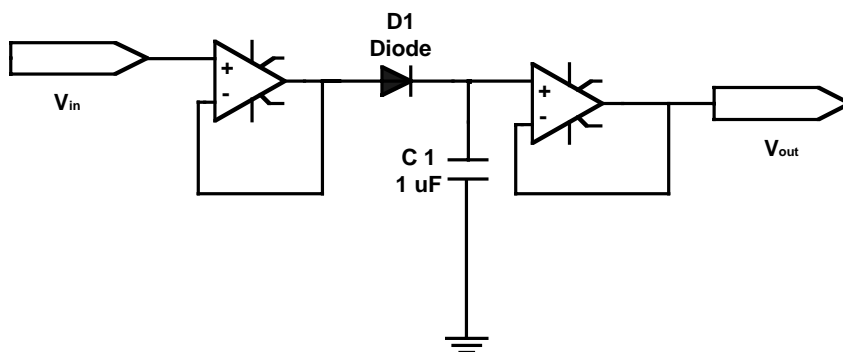


Figure 7: Peak Detector Circuit

- Thermal Resistivity: This has implications for applications involving rectification and dc-dc converters where devices will be expected to safely dissipate large amounts of power. A steady state static mathematical model explains the main principles involved.

The relationship between the power dissipated on the chip's surface, the temperature at the chip's surface and the ambient temperature can be presented in a format analogous to Ohms law.

$T_i - T_a = P_v R_{thja}$ where:

T_i = Temperature on the surface of the chip

T_a = Ambient temperature

P_v = Power generated on the chips surface

R_{thja} = Thermal Resistance between the chip's surface and ambient temperature

And this is similar to $V (T_i - T_a) = I (P_v) \times R (R_{thja})$

This can be written as $P_V = (-1/R_{thja}) \times T_a + (1/R_{thja}) \times T_j$

This can be represented visually by a straight line equation with a slope of $(-1/R_{thja})$ as shown in Figure 8.

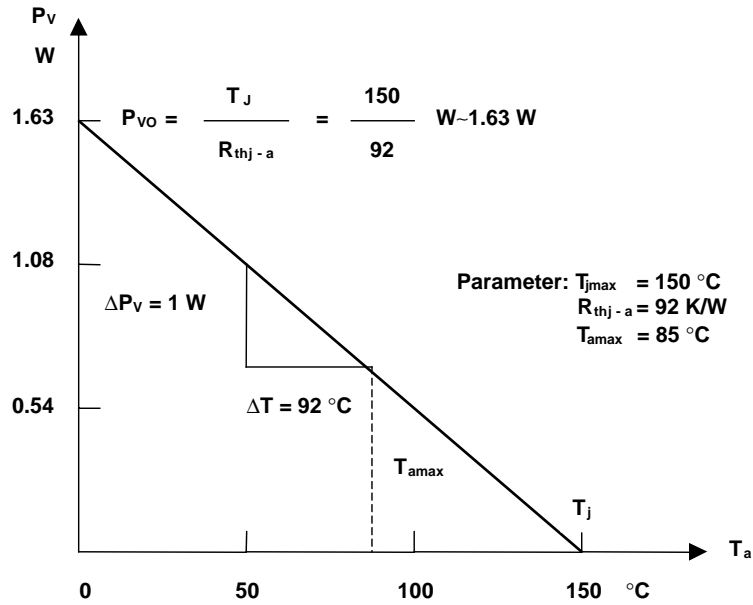


Figure 8: Graph of Power versus Temperature

So at an ambient temperature, which reaches the maximum temperature on the chip, no power can be dissipated. Conversely, the maximum power can be generated at an ambient temperature of zero degrees.

It is important to be aware of the operating temperature of the device as it affects power dissipation. Power is related to direct current and the Chip Diodes for rectification show the current rating as opposed to power rating. The maximum forward current is set to a level well below the overall maximum power that could be generated. This gives a flat response until it meets the line of slope $(-1/R_{thja})$. See Figure 9 below.

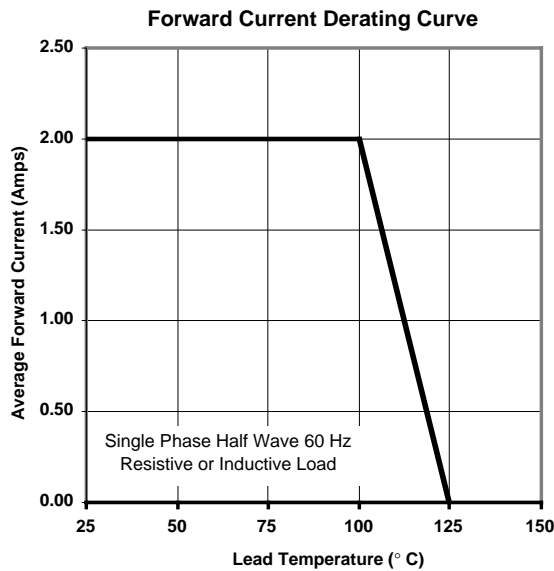


Figure 9: Typical Derating Curve for a Diode

Therefore, the thermal resistivity (in degrees C/W) is a good measure of the ability of the device to dissipate power over its operating temperature range.

Chip Diode Applications

Diodes have many applications depending on the amount of power consumption, voltage and switching speed involved. Examples of several applications are shown below:

- Protection Applications: Consumer electronic products often involve driving inductive loads such as motors (cooling fans) or buzzers (mobile phones). The MOSFET used to pilot such transducers is sensitive to surges of current once gated off. A Diode is frequently used to shunt the current away from the device. The following diagrams show some examples.

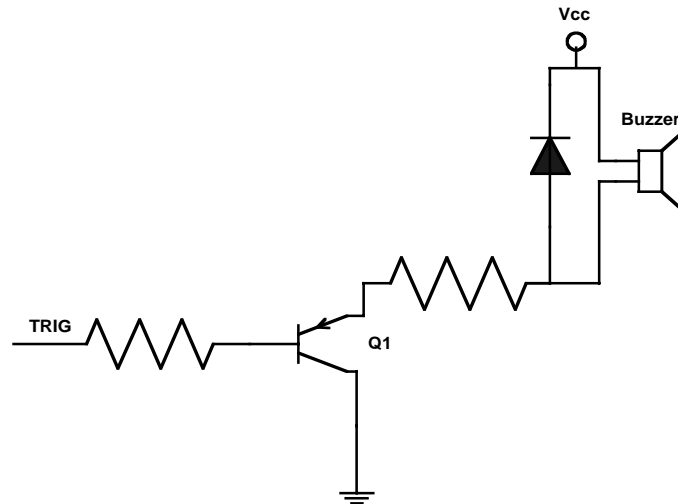


Figure 10: Buzzer Circuit

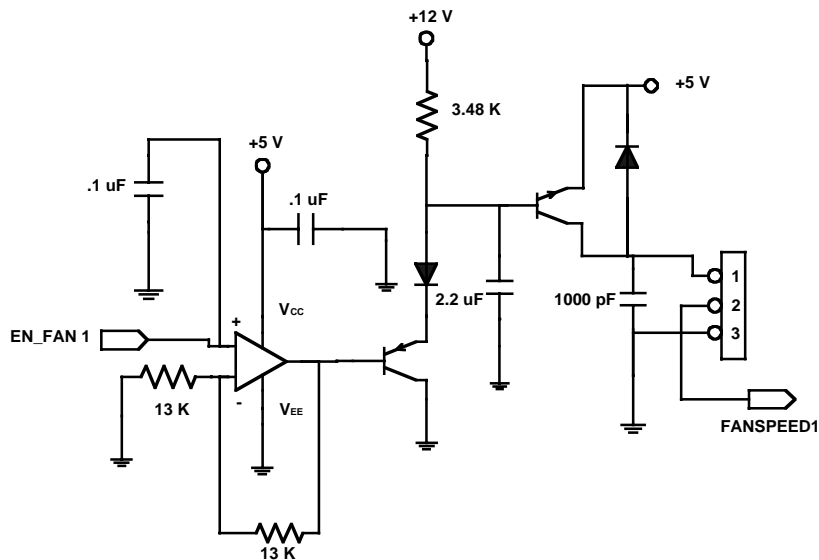


Figure 11: Fan Control Circuit

- Voltage Clamp: Diodes are also used to clamp voltage levels. Often integrated circuits may be sensitive to excessive voltages across certain pins. Figure 12 illustrates an example of a wireless modem amplifier.

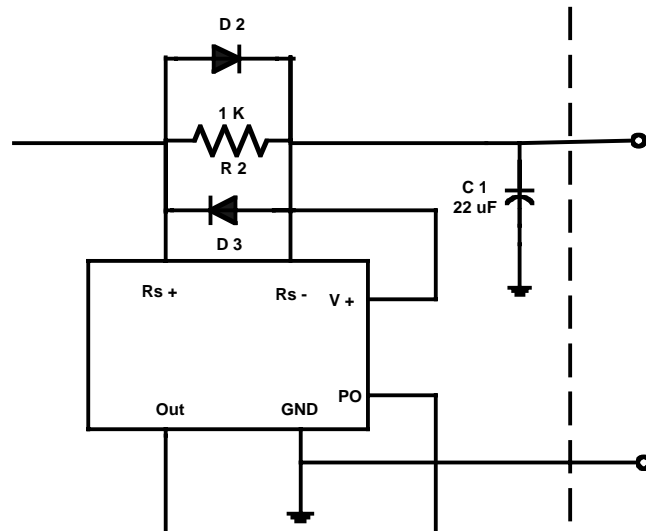


Figure 12: Part of a Circuit of a Wireless Modem

- Switch: Diodes can be used simply to protect sensitive inputs in CMOS devices. For example, an RF chip which shares a pin on a microcontroller will require isolation from high voltages coming from that pin when it is being used for other functions such as flash programming. See Figure 13 below.

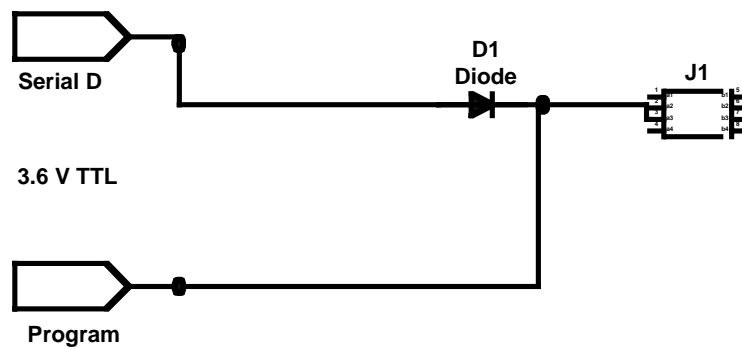


Figure 13: Using a Diode as a Switch

- Rectification: Power supplies use Diodes, not only for rectification but also in later stages in a protection capacity. For example, a desktop computer power supply uses diodes both as a block for reverse polarity and also as a flyback or shunt path for current spikes. See Figures 14 and 15 below.

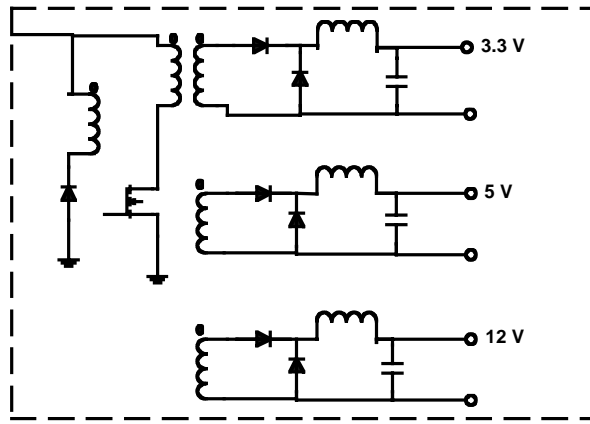


Figure 14: Part of a Power Supply for a Desktop Computer

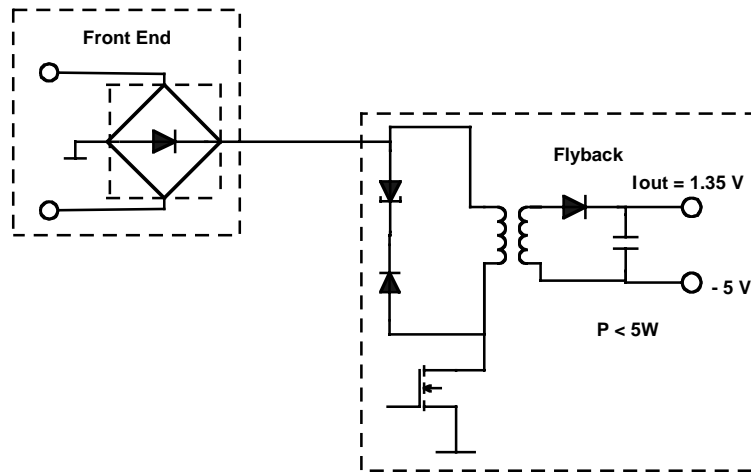
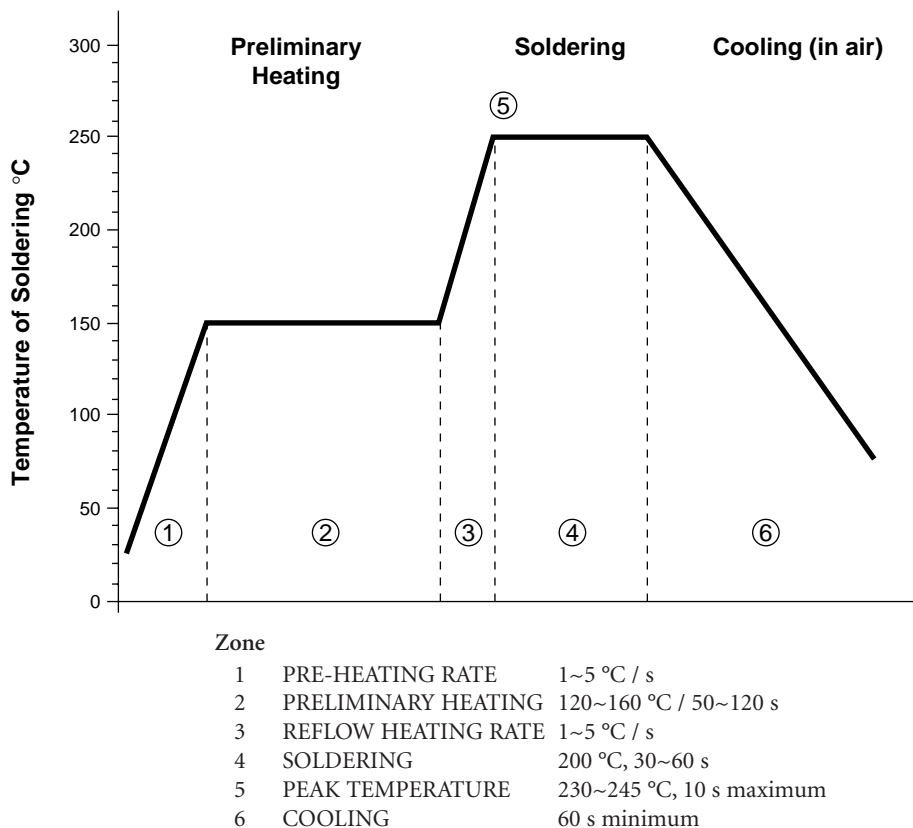


Figure 15: Part of a Power Supply for a Desktop Computer

Infrared Reflow Soldering (IR)

Soldering with IR has the highest yields due to controlled heating rates and solder liquidus times. Dwell time and peak temperature is a consideration for resin molded components.



Conclusions

Leadless packaging and low profile Chip Diodes have opened the door to a new level of board real estate savings and improved electrical performance. These devices are attractive to portable electronic products designers not only for the above, but for eliminating the disadvantages attributable to the previous packaging forms.



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