

Voltage Regulation using Zener Diodes

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Abstract

In digital or mixed-signal applications, there is a need to precisely regulate the voltage entering or exiting a circuit. The Zener diode has a unique property that offers a simple, low-cost solution to this problem. This application note discusses the implementation of this voltage regulator and its advantages and drawbacks.

Keywords: Zener diode, Circuit, Voltage regulator, Digital, Mixed Signal

Introduction

Low voltage, low current applications like digital or mixed-signal circuitry require precise voltages for certain tasks like powering a microcontroller, or providing a reference voltage for measurements.

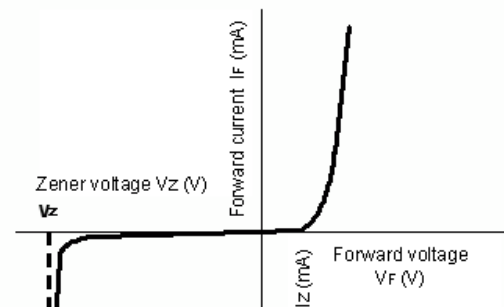
In the laboratory, voltage regulation may be viewed as unnecessary or redundant when fine control over circuit inputs exists. In most real-world applications, however, the environments in which our circuits exist are much more harsh and unforgiving. It then becomes necessary to properly protect circuitry, especially in those which may be sensitive to spikes in voltage or current.

There are many integrated circuit voltage regulators on the market today. These tend to be expensive, unnecessarily complex, may be subject to temperature effects, and typically require a much higher voltage in order to maintain its listed voltage.

In applications where current draw is sufficiently small, a more attractive solution exists which only uses a resistor and a unique semiconductor called a [Zener diode](http://en.wikipedia.org/wiki/Zener_diode) (http://en.wikipedia.org/wiki/Zener_diode)

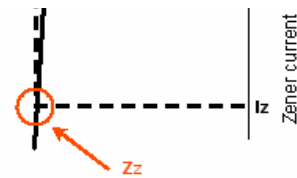
Zener Diode Properties

The Zener diode is a unique device which exploits a property of diodes that is generally avoided in standard diode applications. Typical diodes have a very high reverse breakdown voltage, the voltage at which the diode begins to conduct in the reverse direction. This voltage is generally avoided in standard diodes, but Zener diodes are designed and manufactured to have a very specific reverse breakdown



voltage. On top of that, the transition into reverse breakdown is very sharp. Figure 1 shows the V-I characteristics of a typical Zener diode.

Exploiting this characteristic of Zener diodes allows for simple, inexpensive voltage regulators. There are several drawbacks, however, that will be discussed shortly.



Voltage and current characteristics

Figure 1: V-I characteristics of a typical Zener diode.

Source: http://www.necel.com/en/faq/f_diode.html

Building a Voltage Regulator

With an ideal Zener diode, construction of a voltage regulator is easy, simply connect the diode between the unregulated voltage and ground. Since the exploited property of Zener diodes is the *reverse* breakdown voltage, connect the anode of the diode to ground, not the cathode.

Unfortunately, this is only an ideal circuit. Like most passive elements, if enough current is allowed to pass through the diode, it will be destroyed. A resistor will be added to our circuit to limit the current through the diode.

First, select the Zener diode based on the voltage requirements of the circuit.

Next, determine the maximum current draw of your circuit. For a robust solution, the diode must be able to handle the entirety of this current. Zener diodes have power ratings, so to determine the maximum power the diode will take, multiply the maximum current draw by the Zener voltage.

The resistor will shoulder the rest of the voltage drop not handled by the Zener diode, which is the difference of the source voltage and the Zener voltage. Select the resistor value using Ohm's Law, where the resistance is the voltage drop across the resistor divided by the maximum current draw. The Zener diode itself requires some current to stay in reverse breakdown, typically in the order of 5mA, so the resistor value may be lowered slightly to accommodate.

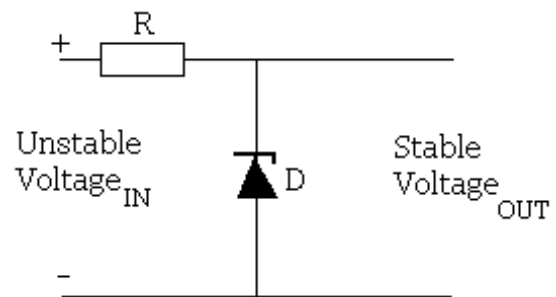


Figure 2: Shunt voltage regulator.

Source: <http://www.reuk.co.uk/Zener-Diode-Voltage-Regulator.htm>

Drawbacks and Recommendations

As with most voltage regulators, the source voltage must be slightly higher than the Zener voltage in order to keep the Zener diode in reverse breakdown. Otherwise, the output voltage will simply follow the input

voltage.

As touched on earlier, both the diode and resistor must have power ratings high enough to handle all the current should the circuit suddenly stop drawing current. This means that this solution may be impractical for circuits that require high voltage or high current. An 8V regulator with a 12V source that requires 1A of current requires a 250Ω resistor rated at 4W and an 8V Zener diode rated at 8W. Typically, Zener diodes are only available at up to 5W, so in even a medium voltage/current application like this example, it may be more practical to use an integrated circuit regulator.

Conclusion

The Zener diode, with its accurate and specific reverse breakdown voltage, allows for a simple, inexpensive voltage regulator. Combined with the right resistor, fine control over both the voltage and the supply current can be attained.

However, the low power ratings of standard Zener diodes and resistors make this solution impractical for high power devices.

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