Zener Diodes: still useful

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These days, voltage regulator I/Cs are quite cheap and to establish a voltage regulated rail, the common approach is to use one of these. However there is still a place for the Zener Diode and they are useful for such applications as providing a further break down in voltage for some part of the circuit or providing a voltage reference. Here are a few notes on how to use them to get best voltage regulation.

The Zener diode is the name given to a silicon diode which is operated in a reverse connected mode beyond the point where voltage breakdown occurs. At this point there is a sharp turn over of the voltage versus current curve to a condition where voltage across the diode approaches a fairly constant value independent of current. Typical circuit for Zener reference is given in figure 1. The complete diode curve including the reverse characteristic is shown in figure 2.

The name Zener was given to this breakdown effect because it was first believed to be due to the mechanism described by Zener in his theory of breakdown phenomena in dielectrics. Later on it was realised that not one but two mechanisms were responsible for the characteristics of Zener Diodes.

We are told that the Zener effect is a quantum mechanical effect in which electron pairs are generated directly from the energy of the electric fields. This effect is responsible for breakdown in diodes designed to have a breakdown voltage less than about 5 volts. Such a mechanism produces a negative temperature coefficient. That is, a decrease in developed Zener voltage as temperature rises.

As such, the general name given to a Zener diode is somewhat of a misnomer because for diodes with breakdown voltages greater than 7 volts, the breakdown is caused by a different mechanism called the Avalanche or Avalanche Multiplication effect. This mechanism produces a positive temperature coefficient, opposite to the Zener effect.

For diodes between 5 and 7 volts, both mechanisms occur and hence the temperature coefficients tend to cancel and such diodes have a very low temperature coefficient.

Figure 3 taken from some data sheets of the very early STC Z2 series Zener diodes is a very good illustration of how temperature coefficient varies with breakdown voltage. In selecting a Zener voltage for best temperature stability, 5 volt has been a favoured value. The curve (figure 2) supports this selection.

One idea for voltage rails above 5 volts is to use two Zener diodes in series to

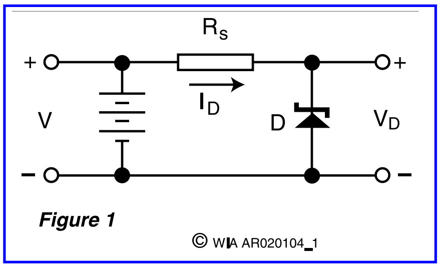

Figure 1. Typical Zener regulator circuit

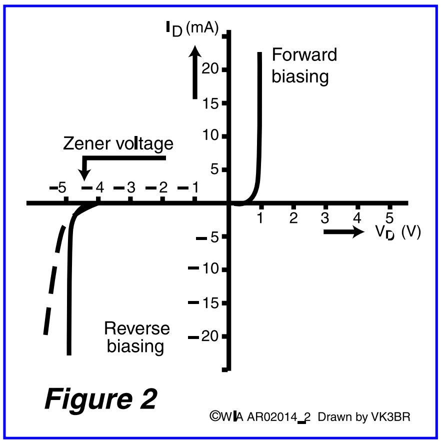

Figure 2 - Forward & Reverse characteristics of a silicon Zener

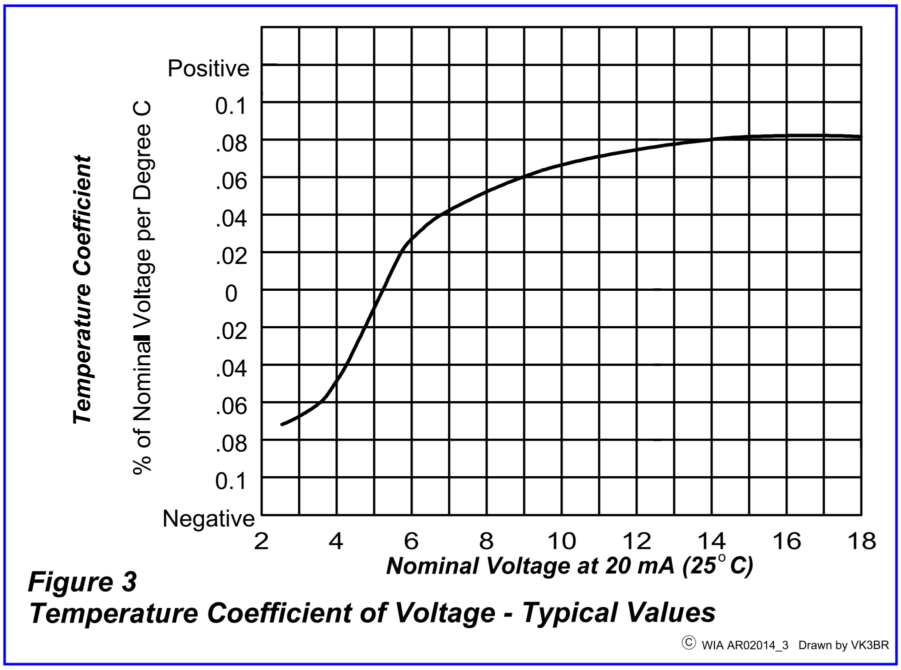

Figure 3 - Temperature Coefficient of voltage Typical values.

make up the required rail voltage, one above 5 volts and one below 5 volts so that the different temperature coefficients tend to cancel.

Another idea is to select the rail voltage a multiple of 5 volt and connect 5 V Zeners in series eg for 10 V rail use two 5 V Zeners. For 15 V rail use three in series.

A further idea suggested in a number of publications is to connect an ordinary silicon diode, forward connected, in series with the Zener diode so that the negative coefficient of the ordinary diode cancels the positive coefficient of the Zener diode. Of course this would only work for Zener diodes above 5 V and the 0.6 V drop of the ordinary diode would have to be added to the resultant regulated voltage.

In setting up the regulator circuit shown in figure 1, resistor Rs is chosen to ensure that the current through the Zener diode is sufficient to place operation beyond the bend in the reverse curve and into the almost vertical section of the curve. One interesting point is that diodes operating above 7 V using avalanche breakdown have a sharper turning curve than those below 5 V using Zener breakdown.

This is fine for a constant load at the Zener diode regulator output. However if the load is variable, there is also the further consideration of voltage regulation determined by the slope of that near vertical section of the curve. In figure 2, the solid line shows good regulation whereas the dotted line shows poor regulation. The regulator dynamic resistance is equal to the reciprocal of the slope of that section of the curve (ie. dV/dI). Hence the lower the dynamic resistance, the better the voltage regulation. Another point concerning the two types of breakdown is that diodes operating above 7 V give better regulation than those below 5 V do.

Figure 4 shows an interesting set of curves that plot dynamic resistance against breakdown voltage for different currents through the diode. This shows that lowest dynamic resistance (and hence best regulation) is achieved using diodes around 7 to 8 volt. It also shows that the dynamic resistance falls as the diode current is increased.

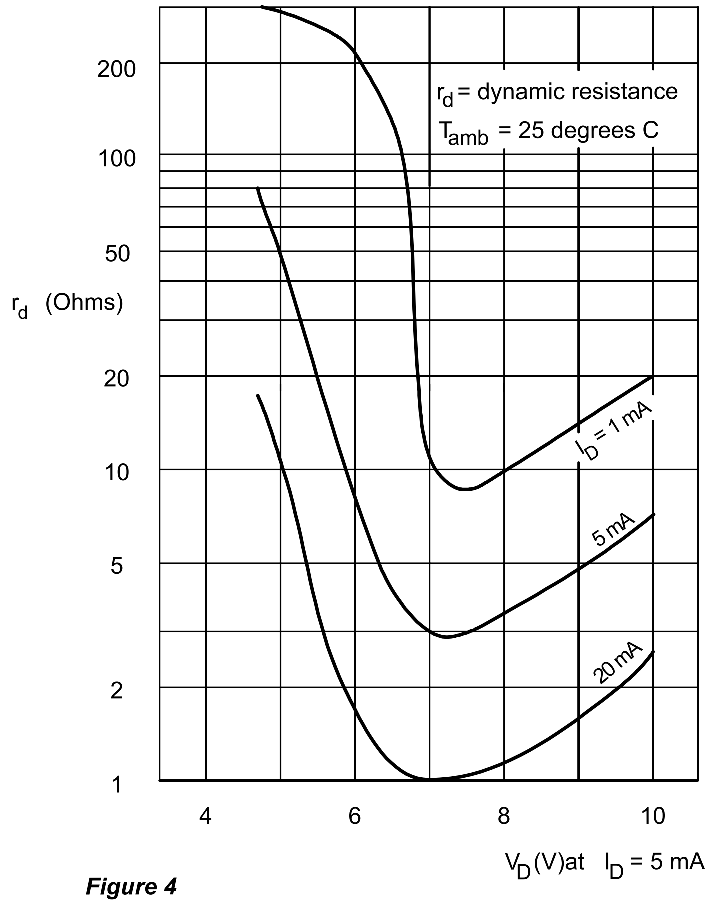

Figure 4

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Figure 4 - Dynamic Resistance as function of Zener voltage for various values of constant inverse current

So for best regulation, we might use zener diodes around 7-8 volts (or a series multiple of them) and run plenty of current through them. On the second point we might call a halt and rather than waste power in the diode we might choose instead to use the more efficient series regulator I/C for the variable load application. It really all depends on the particular circuit operation.

Most of us have used a Zener diode at some time or other to derive a lower voltage or provide a voltage reference. It's all very simple - a shunt Zener diode and a series resistor. However a little thought to the characteristics I have discussed might be useful in better achieving the desired circuit operation.

Reference

Zener Diodes & their Application - Miniwatt Digest, July 1966

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