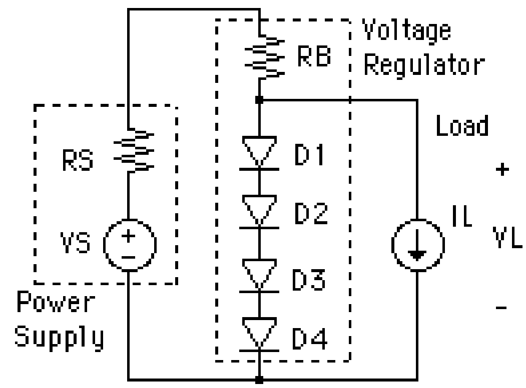
Diode Voltage Regulator

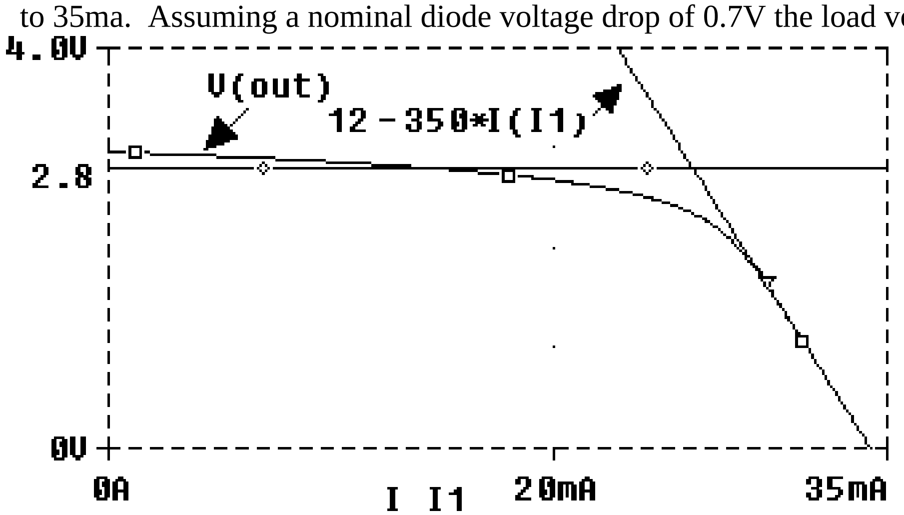
Forward-biased diodes may be used as a kind of voltage reference in integrated circuits. Although there are other much more preferable means to serve the purpose used in this illustration nevertheless it is instructive to examine the principles involved. The basis for a regulating application is the exponential nature of the diode characteristic; the junction voltage varies only a small amount for large changes in diode current.

A Thevenin equivalent for a power supply consists of a voltage source VS in series with the 'internal' resistance RS of the supply. There is a voltage drop across RS that increases with increasing load current, so that the terminal supply voltage decreases. To limit this voltage change in so far as the load is concerned a 'regulator' is added; in this illustration the diode 'tree' in series with a resistor RB. The idea is to use the diode forward-bias property that large diode current changes involve exponentially smaller diode voltage changes. To the extent that the voltage drop across the four diodes is substantially constant the current drawn from the power supply also is constant.



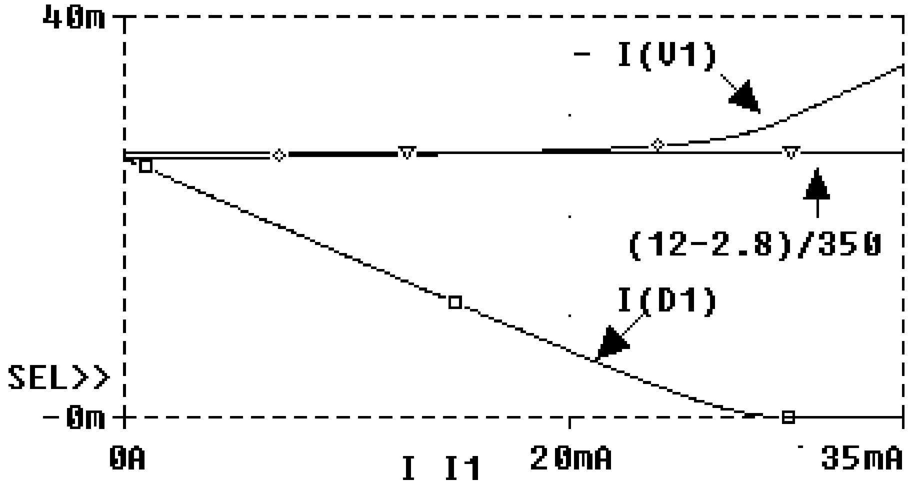
The circuit is designed to draw from the power supply a current greater than the <u>maximum</u> required by the load. This current then is divided, part drawn off by the load and the remainder shunted through the diodes. As the load current demand changes the current division ratio changes. Provided the <u>minimum</u> current through the diodes (i.e., for maximum load current) is sufficient for diode operation above the ‘knee’ of the exponential characteristic the voltage across the load will not vary greatly. And of course the maximum diode current, for minimum load current, should not exceed the diode ratings.

A PSpice computation was performed for a circuit using a 12V source, RS = 200Ω, RB = 150Ω, and four 1N4002 diodes. A DC current source provides a convenient load; the load current is swept from 0 to 35ma. Assuming a nominal diode voltage drop of 0.7V the load voltage is estimated at 2.8V. The data show a substantially improved regulation up to a load current of about 20ma.

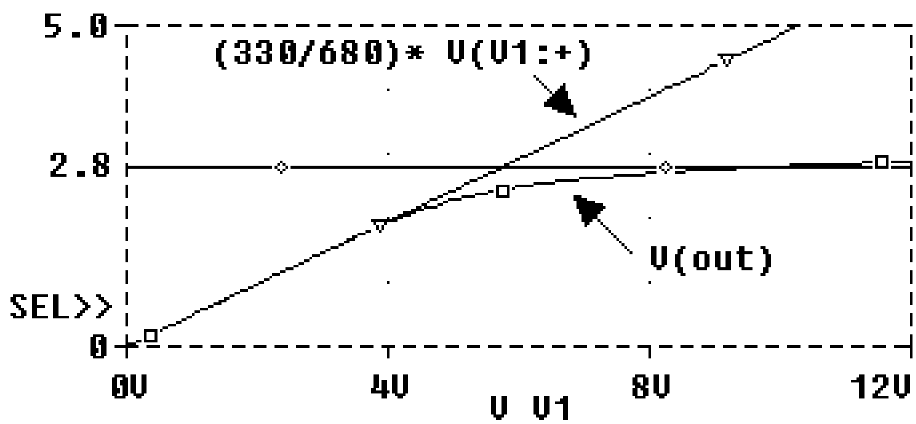


Regulation fails as the current increases further, indicating the diode branch current is inadequate to hold the junction voltage. Absent the diodes the load voltage becomes 12 –IL(200+150), and this line is shown on the plot.

The next plot compares the current in the diode branch to the source current. Assuming regulated operation (and a load voltage of 2.8V) the source current would be essentially constant at (12–2.8)/(200+150) = 26.3 ma; this is plotted as a reference for the source current. The diode branch current is plotted for comparison, and decreases linearly as the load current increases. When the diode current becomes small the regulation fails.



A second computation was performed with the DC current source load replaced by a 330Ω resistor, and with the source voltage varied from 0 to 12V. When the circuit is regulating the load current will be 2.8/330 = 8.48ma, and the source voltage will be 2.8 + (8.48m)(200+150) = 5.77V. This will be (about) the minimum voltage at which h regulation will begin, an expectation borne out by the computed data drawn below. Note that before regulation begins (essentially no diode branch current) the load voltage is obtained as a simple resistive voltage divider calculation; this is plotted for comparison.



The diode branch current is plotted below; note that it begins to be significant about where expected. When the circuit is regulating the load voltage and load current remains substantially constant. As the source voltage increases the source current also increases. And as the load current is constant an increase in source current must be carried in the diode branch.