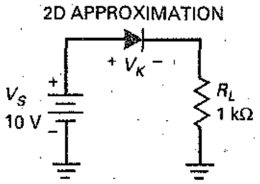
Figure 3-15 Up-down analysis of a circuit.



3-6 Up-Down Circuit Analysis

There is nothing quite like **up-down analysis** to help you understand circuits. The idea is this: Any circuit has independent variables (like source voltages and branch resistances) and dependent variables (like voltages across resistors, currents, and powers). When an independent variable increases, each of the dependent variables will usually respond by increasing or decreasing. If you understand how the circuit works, you will be able to predict whether a dependent variable will increase or decrease.

Here is how it works for Fig. 3-15. A voltage V_S of 10 V is applied to a diode in series with a load resistance R_L of 1 kΩ. In the second approximation of a diode, there are three independent variables for this circuit: V_S, R_L, and V_K. We are including the knee voltage as an independent variable because it may be slightly different from the ideal value of 0.7 V. There are five dependent variables as follows: V_L, I_L, P_D, P_L, and P_T. These are the load voltage, load current, diode power, load power, and total power.

Suppose the source voltage V_S increases slightly, say 10 percent. How will each of the dependent variables respond? Will each go up (U), go down (D), or show no change (N)? Here are some of the thoughts that might pass through your mind as you solve this problem:

> ***In the second approximation, the diode has a voltage drop of 0.7 V. If the source voltage increases slightly, the diode drop is still 0.7 V, which means that the load voltage has to increase. If the load voltage increases, the load current increases. An increase in load current means that the diode power and load power increase. The total power is the sum of diode power and load power, so total power must increase.***

The first row of Table 3-1 summarizes the effect of a small increase in source voltage. As you can see, each dependent variable increases.

What do you think happens when the load resistance of Fig. 3-15 increases slightly? Since the diode voltage is constant in the second approximation, the load voltage shows no change, but the load current will go down. This implies less diode power, load power, and total power. The second row of Table 3-1 summarizes this case.

Finally, consider the effect of knee voltage. If the knee voltage increases slightly in Fig. 3-15, the dependent variables decrease, except for the diode power, as shown in the third row of Table 3-1.

Look at Fig. 3-25 (at the end of the chapter). How do you use this to find dependent changes?

The way you can practice up-down analysis for the circuit is by selecting one independent variable (V_S, R_1, R_2, R_3, or V_K). Next, select any dependent variable (V_A, V_B, V_C, I_1, etc.). Then try to figure out whether the dependent variable goes up, goes down, or shows no change.

Table 3-1 Up-Down Analysis

	V_L	I_L	P_D	P_L	P_T
V_S increase	U	U	U	U	U
R_L increase	N	D	D	D	D
V_K increase	D	D	U	D	D

For instance, how does an increase in knee voltage affect the current in R_3? In Fig. 3-25, a stiff voltage divider drives the diode in series with the 100 kΩ. Therefore, a slight increase in knee voltage will decrease the voltage across the 100 kΩ. Then, Ohm's law tells us that I_3 should decrease.

A final point: Do not use a calculator for up-down circuit analysis. This would defeat the whole purpose of this type of thinking. Up-down circuit analysis is similar to troubleshooting because the emphasis is on logic rather than equations. The purpose of up-down analysis is to train your mind to get in touch with the circuit action. It does this by forcing you to think about how the different parts of the circuit interact.

3-7 Reading a Data Sheet

A data sheet, or specification sheet, lists important parameters and operating characteristics for semiconductor devices. Also, essential information such as case styles, pinouts, testing procedures, and typical applications can be obtained from a component's data sheet. Semiconductor manufacturers generally provide this information in data books or from the manufacturer's website. This information can also be found on the Internet by companies that specialize in cross-referencing or component substitution.

Much of the information on a manufacturer's data sheet is obscure and of use only to circuit designers. For this reason, we will discuss only those entries on the data sheet that describe quantities in this book.

GOOD TO KNOW

Internet search engines, such as Google, can quickly help locate semiconductor specifications.

Reverse Breakdown Voltage

Let us start with the data sheet for a 1N4001, a rectifier diode used in power supplies (circuits that convert ac voltage to dc voltage). Figure 3-16 shows a data sheet for the 1N4001 to 1N4007 series of diodes: seven diodes that have the same forward characteristics but differ in their reverse characteristics. We are interested in the 1N4001 member of this family. The first entry under "Absolute Maximum Ratings" is this:

	Symbol
Peak Repetitive Reverse Voltage	V_{RRM}

The breakdown voltage for this diode is 50 V. This breakdown occurs because the diode goes into avalanche when a huge number of carriers suddenly appears in the depletion layer. With a rectifier diode like the 1N4001, breakdown is usually destructive.

With the 1N4001, a reverse voltage of 50 V represents a destructive level that a designer avoids under all operating conditions. This is why a designer includes a *safety factor*. There is no absolute rule on how large to make the safety factor because it depends on too many design factors. A conservative design would use a safety factor of 2, which means never allowing a reverse voltage of more than 25 V across the 1N4001. A less-conservative design might allow as much as 40 V across the 1N4001.

On other data sheets, reverse breakdown voltage may be designated *PIV*, *PRV*, or *BV*.