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*.

Figure 3-16 Data sheet for 1N4001-1N4007 diodes.

FAIRCHILD SEMICONDUCTOR®

1N4001-1N4007

1N4001 - 1N4007

Features

- Low forward voltage drop.
- High surge current capability.

DO-41
COLOR BAND DENOTES CATHODE

General Purpose Rectifiers

Absolute Maximum Ratings*

T_A = 25°C unless otherwise noted

Symbol	Parameter	Value							Units
		4001	4002	4003	4004	4005	4006	4007	
V_{RRM}	Peak Repetitive Reverse Voltage	50	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current, .375 " lead length @ T_A = 75°C	1.0							A
I_{FSM}	Non-repetitive Peak Forward Surge Current 8.3 ms Single Half-Sine-Wave	30							A
T_{stg}	Storage Temperature Range	-55 to +175							°C
T_J	Operating Junction Temperature	-55 to +175							°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

Thermal Characteristics

Symbol	Parameter	Value	Units
P_D	Power Dissipation	3.0	W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	50	°C/W

Electrical Characteristics

T_A = 25°C unless otherwise noted

Symbol	Parameter	Device							Units
		4001	4002	4003	4004	4005	4006	4007	
V_F	Forward Voltage @ 1.0 A	1.1							V
I_{rr}	Maximum Full Load Reverse Current, Full Cycle T_A = 75°C	30							µA
I_R	Reverse Current @ rated V_R T_A = 25°C T_A = 100°C	5.0 500							µA µA
C_T	Total Capacitance V_R = 4.0 V, f = 1.0 MHz	15							pF

(a)

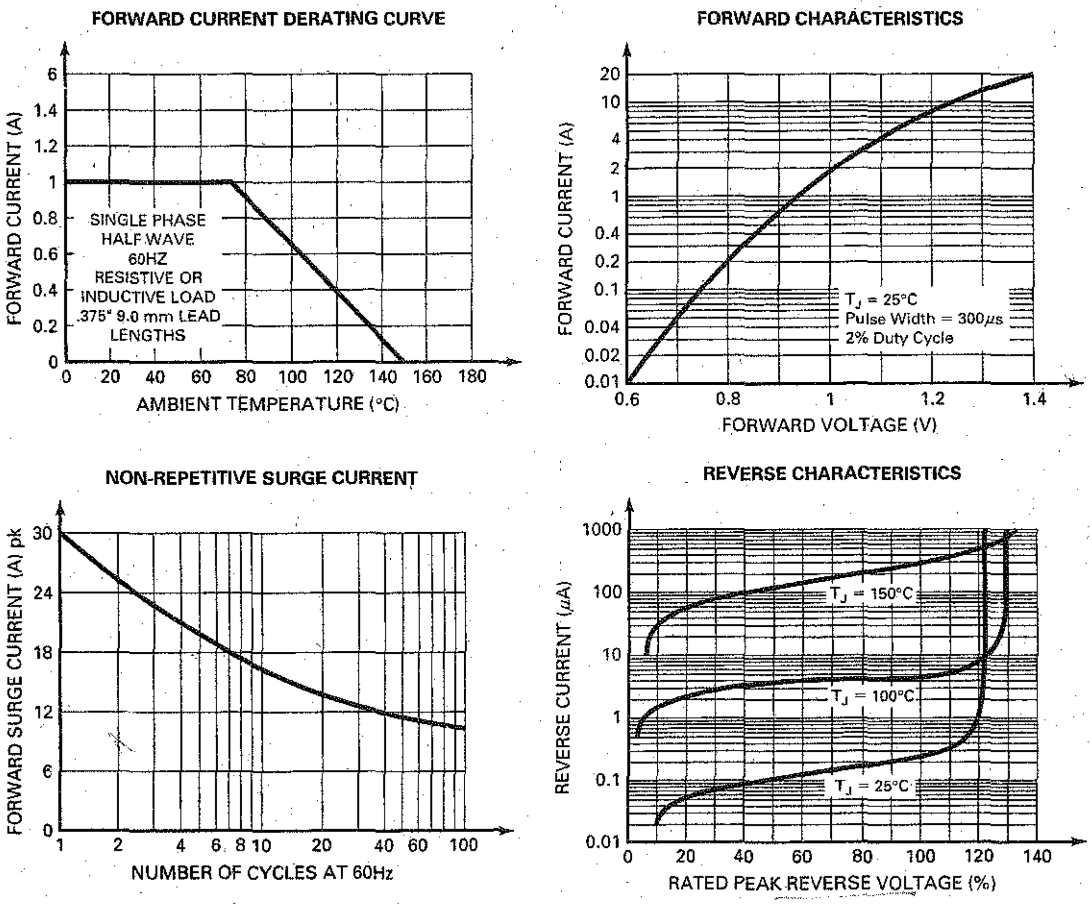
1N4001-1N4007, Rev. C1

Figure 3-16 (continued)

General Purpose Rectifiers
(continued)

1N4001-1N4007

Typical Characteristics



(*b*)

1N4001-1N4007, Rev. C1

Maximum Forward Current

Another entry of interest is average rectified forward current, which looks like this on the data sheet:

	Symbol	Value
Average Rectified Forward Current @ T_A = 75°C	$I_{F(AV)}$	1 A

This entry tells us that the 1N4001 can handle up to 1 A in the forward direction when used as a rectifier. You will learn more about average rectified forward current in the next chapter. For now, all you need to know is that 1 A is the level of forward current when the diode burns out because of excessive power dissipation. On other data sheets, the average current may be designated as I_o.

Again, a designer looks upon 1 A as the absolute maximum rating of the 1N4001, a level of forward current that should not even be approached. This is why a safety factor would be included—possibly a factor of 2. In other words, a reliable design would ensure that the forward current is less than 0.5 A under all operating conditions. Failure studies of devices show that the lifetime of a device decreases the closer you get to the maximum rating. This is why some designers use a safety factor of as much as 10:1. A really conservative design would keep the maximum forward current of the 1N4001 at 0.1 A or less.

Forward Voltage Drop

Under "Electrical Characteristics" in Fig. 3-16, the first entry shown gives you these data:

Characteristic and Conditions	Symbol	Maximum Value
Forward Voltage Drop $(i_F) = 1.0$ A, $T_A = 25°$C	v_F	1.1 V

As shown in Fig. 3-16 on the chart titled "Forward Characteristics," the typical 1N4001 has a forward voltage drop of 0.93 V when the current is 1 A and the junction temperature is 25°C. If you test thousands of 1N4001s, you will find that a few will have as much as 1.1 V across them when the current is 1 A.

Maximum Reverse Current

Another entry on the data sheet that is worth discussing is this one:

Characteristic and Conditions	Symbol	Typical Value	Maximum Value
Reverse Current	I_R		
$T_A = 25°$C		0.05 μA	10 μA
$T_A = 100°$C		1.0 μA	50 μA

This is the reverse current at the maximum reverse dc rated voltage (50 V for a 1N4001). At 25°C, the typical 1N4001 has a maximum reverse current of 5.0 μA. But notice how it increases to 500 μA at 100°C. Remember that this reverse current includes thermally produced saturation current and surface-leakage current. You can see from these numbers that temperature is important. A design that requires a reverse current of less than 5.0 μA will work fine at 25°C with a typical 1N4001, but will fail in mass production if the junction temperature reaches 100°C.

3-8 How to Calculate Bulk Resistance

When you are trying to analyze a diode circuit accurately, you will need to know the bulk resistance of the diode. Manufacturers' data sheets do not usually list the bulk resistance separately, but they do give enough information to allow you to calculate it. Here is the derivation for bulk resistance:

$$R_B = \frac{V_2 - V_1}{I_2 - I_1} \tag{3-7}$$