

Modeling Diode Circuits with MicroCap 7.0

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Abstract

This tutorial describes how to model diodes using the MicroCap 7.0 circuit simulation program. We will focus on models appropriate for use in DC and low frequency AC circuits. High frequency models will be the topic of a future tutorial.

The basic diode model parameters are first described. We then discuss how to set model parameters to match a particular diode characteristic curve. Finally we develop appropriate models for ideal, small-signal, rectifier, LED, and Zener diodes.

Modeling the Forward Bias Region

The Basic Model Parameters: LEVEL, IS and N

Suppose that we want to simulate a diode circuit using MicroCap. We start by placing a diode in the schematic diagram. You can do this by selecting *Diode* from the *Component*→*Analog Primitives*→*Passive Devices* menu. After dropping the diode onto the schematic diagram the following window should appear:

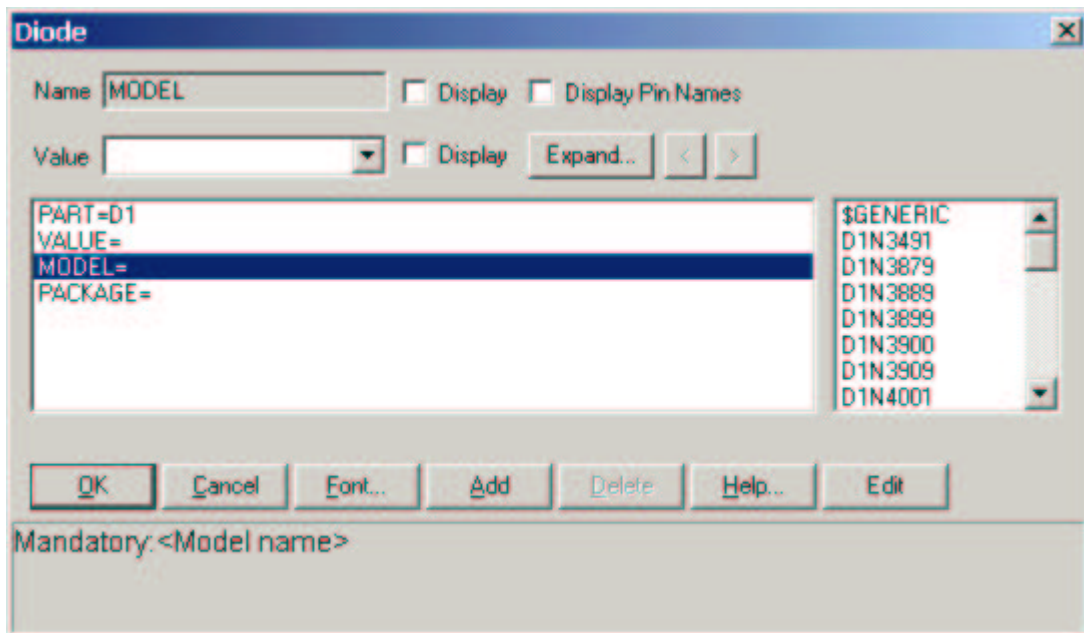


Figure 1: MicroCap Diode Model Parameter Window

You can select one of the standard diode models from the list on the right side of the window. For most of our homework and project problems we will want to create our own diode model. This is easy to do. Just type in a model name. (I will use the name *simple* as an example.) Click on the **Edit** button in the lower right portion of the window. The window should now look like this:

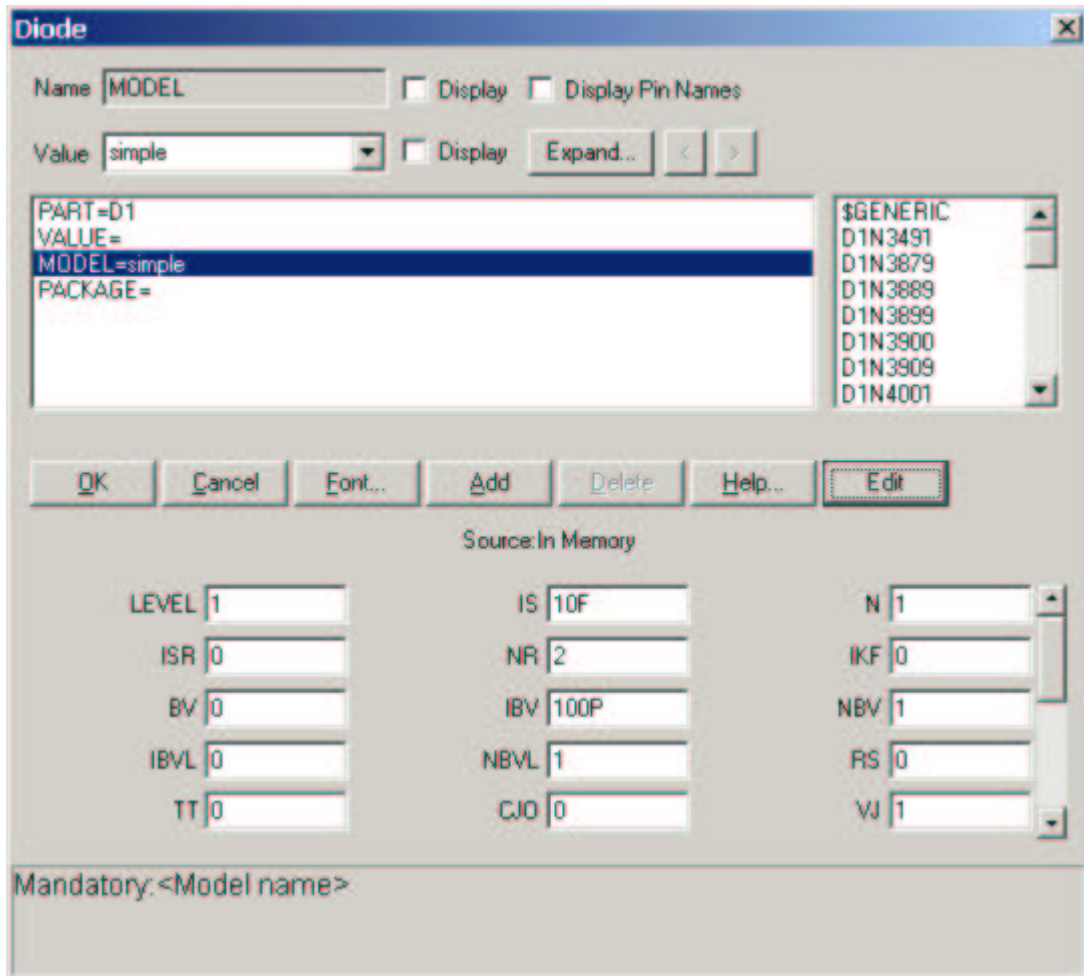


Figure 2: MicroCap Diode Model Parameter Window

The window now includes a list of model parameter files that may be changed as required. There are over 30 parameters values that may be used in the MicroCap diode model, fortunately only a few of these affect the low-frequency behavior of the diode. The complete list of parameters is shown in Table 1 on the last page of this tutorial.

The three most important parameters to us are the first three shown in Figure 2: **LEVEL**, **IS**, and **N**. MicroCap provides two different diode models. We can select which model we want to use by setting the value of **LEVEL**. The default value of 1 selects the simpler of the two models, but this is a model which is sufficiently accurate for problems which we will encounter, so leave **LEVEL** set to 1. **IS** is the saturation current and **N** is the

emission coefficient. **IS** and **N** appear in the equation describing the ideal diode current-voltage relationship:

$$i_D = IS \left(e^{\left(\frac{v_D}{N V_T} \right)} - 1 \right)$$

In this equation, v_D and i_D are the diode voltage and current and V_T is the thermal voltage. ($V_T = kT/q$, k = Boltzmann's constant, T = absolute temperature, and q = the magnitude of the charge on an electron.) At room temperature ($T = 300$ °K), $V_T = 26$ mV.

To accurately model an arbitrary diode we just need two points (two $i_D - v_D$ pairs) from the forward region of the diode characteristic curve. We can then find corresponding values of **IS** and **N** from:

$$N = \frac{v_{D2} - v_{D1}}{V_T \ln(i_{D2}/i_{D1})}$$

$$IS = i_{D1} / e^{v_{D1}/(N V_T)}$$

For example, assume we want to model a diode that has a characteristic curve that passes through the points (0.70 V, 10 mA) and (0.72 V, 20 mA). Using the above formulas yields:

$$\begin{aligned} N &= 1.11 \\ IS &= 2.91 \times 10^{-13} \text{ A} \end{aligned}$$

The circuit shown in Figure 3 was simulated using MicroCap. The values of **N** and **IS** just found were used in the diode model. All other parameters were left set to their default values. Figure 4 shows a plot of the diode current versus the diode voltage as the source voltage is swept from 0 V to 50 V.

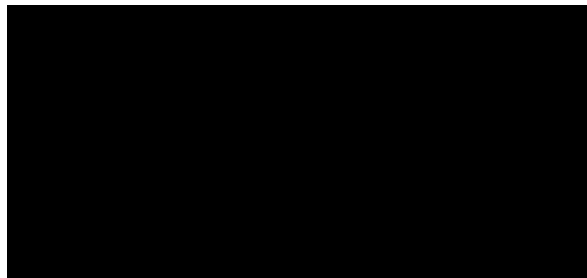


Figure 3: MicroCap Simple Diode Test Circuit

We can see from Figure 4 that the simulated current-voltage characteristic passes through the same two points as the characteristic curve we are modeling.

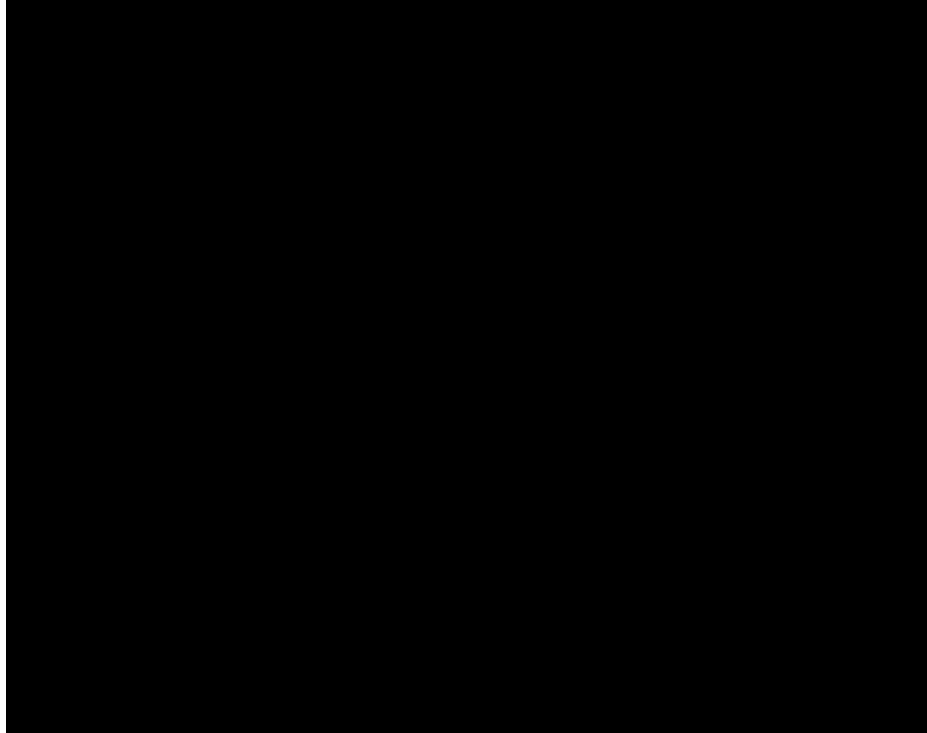


Figure 4: MicroCap Simple Diode Test Results

Modeling the Reverse Bias Region

The Reverse Breakdown Parameters: **BV** and **IBV**

The default reverse breakdown (Zener) voltage is infinite. Obviously we need to change this if we are trying to accurately model a Zener diode. There are two parameters that need to be set to model the Zener breakdown region: **BV** is the breakdown voltage and **IBV** is current at the breakdown voltage. To model an 8 V Zener diode, typical values for these parameters might be:

$$\mathbf{BV} = 8 \text{ V}$$

$$\mathbf{IBV} = 20 \text{ mA}$$

Note that **BV** is set to a positive value although on a typical characteristic curve the breakdown voltage is negative. These values were used in the diode in Figure 3. A DC analysis was performed and the source voltage was swept from -60 V to 50 V. Figure 5 shows the result.

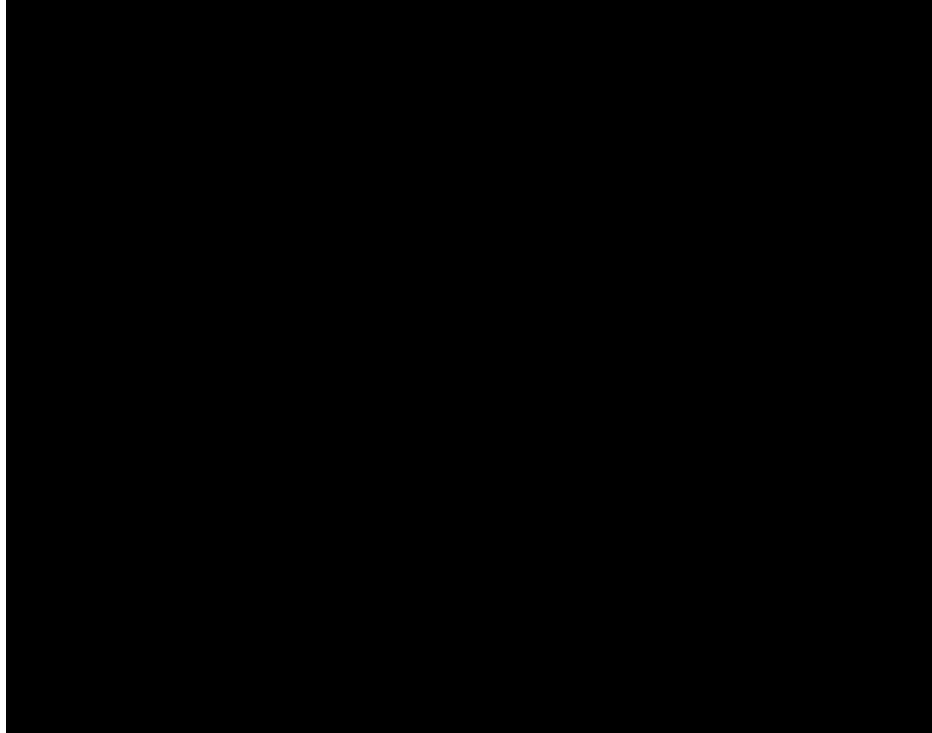


Figure 5: MicroCap Zener Diode Test Results

Standard Diode Models

The Ideal Diode

An ideal diode would have a 0 V knee or threshold voltage. We can find values of **N** and **IS** to approximate an ideal diode using the formulas given earlier. Assuming the approximate ideal characteristic passes through the two points (10 mV, 10 mA) and (20 mV, 2000 mA) the corresponding values of **N** and **IS** are:

$$\begin{aligned} \mathbf{N} &= 0.072 \\ \mathbf{IS} &= 5 \times 10^{-5} \text{ A} \end{aligned}$$

Figure 6 shows a circuit in which we compare two half-wave rectifiers. One uses the simple diode from an earlier circuit and the other uses an "ideal" diode using the values of **N** and **IS** from above. The voltage source is a 60 Hz, 5 V_{PEAK} sine wave source. Figure 7 shows the results. The approximate 0.7 V drop across the simple diode and the 0 V drop across the "ideal" diode during the positive half-cycle of the input can clearly be seen in the figure.

Small Signal Diodes

Using the data sheet of a 1N4148 diode for data, two points on a typical characteristic

curve are (0.62 V, 1 mA) and (0.70 V, 5 mA). Corresponding values of **N** and **IS** are:

$$\mathbf{N} = 1.91$$

$$\mathbf{IS} = 3.83 \times 10^{-9} \text{ A}$$

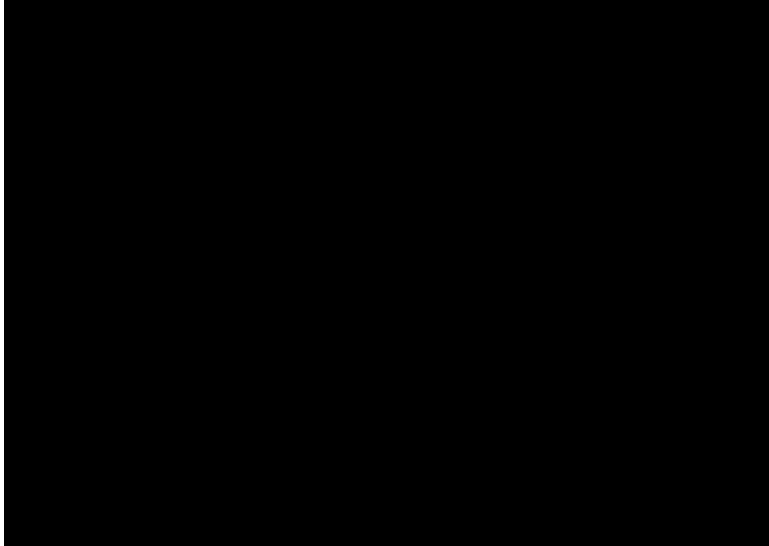


Figure 6: MicroCap "Ideal" vs Standard Diode Test Circuit

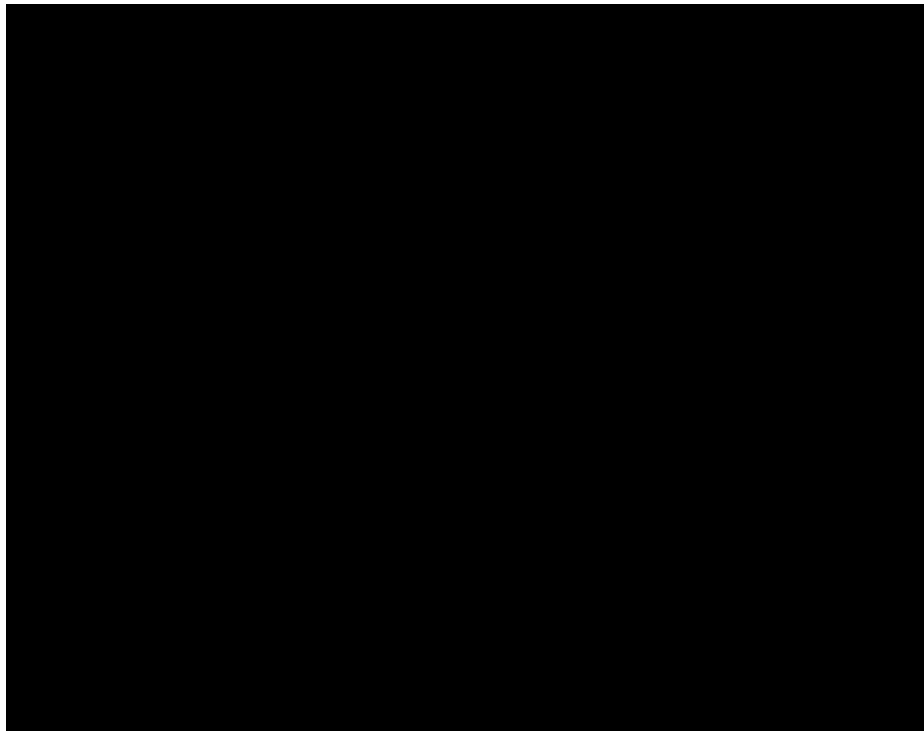


Figure 7: MicroCap "Ideal" vs Standard Diode Test Results

Rectifying Diodes

Using the data sheet of a 1N4001 diode as representative of a rectifying diode, we find:

$$\mathbf{N} = 2.57$$
$$\mathbf{IS} = 1.25 \times 10^{-6} \text{ A}$$

Light Emitting Diodes (LEDs)

LEDs have greater forward voltage drops than small-signal or rectifying diodes. The forward voltage drop depends on the color and 2 V is a typically value for red LEDs. Using (2.0 V, 20 mA) and (2.3 V, 50 mA) as points on the characteristic curve and calculating **N** and **IS** gives:

$$\mathbf{N} = 12.59$$
$$\mathbf{IS} = 4.45 \times 10^{-5} \text{ A}$$

Zener Diodes

Zener diodes have forward characteristics similar to that of a small-signal diode, so use the same values of **N** and **IS** as for the small-signal diode. The paramter **BV** should be set to the magnitude of the zener voltage and **IBV** should be set to a typical value of reverse current (20 mA is often used on data sheets).

$$\mathbf{BV} = V_z$$
$$\mathbf{IBV} = 20 \text{ mA}$$

Diode Model Parameter Table

Name	Parameter	Units	Default	Area	Level
LEVEL	1=Spice2G 2=PSpice		1		
IS	Saturation current	Amps	1E-14	*	1,2
N	Emission coefficient		1.0		1,2
ISR	Recombination current parameter	Amps	0	*	2
NR	Emission coefficient for ISR		2		2
IKF	High-injection "knee" current	Amps	INF	*	2
BV	Reverse breakdown "knee" voltage	Volts	INF		1,2
IBV	Reverse breakdown "knee" current	Amps	1E-10	*	1,2
NBV	Reverse breakdown ideality factor		1		2
IBVL	Low-level rev. breakdown "knee" current	Amps	0		2
NBVL	Low-level rev. breakdown ideality factor		1		2
RS	Series resistance	Ohms	0	/	1,2
TT	Transit time	sec	0.0		1,2
CJO	Zero-bias junction capacitance	Farad	0.0	*	1,2
VJ	Junction potential	Volts	1.0		1,2
M	Junction grading coefficient		0.5		1,2
FC	Forward bias depletion coefficient		0.5		1,2
EG	Energy gap	eV	1.11		1,2
XTI	Temperature exponent for IS		3.0		1,2
TIKF	IKF temperature coefficient (linear)	1/Celsius	0		
TBV1	BV temperature coefficient (linear)	1/Celsius	0		
TBV2	BV temperature coefficient (quadratic)	1/(Celsius^2)	0		
TRS1	RS temperature coefficient (linear)	1/Celsius	0		
TRS2	RS temperature coefficient (quadratic)	1/(Celsius^2)	0		
KF	Flicker noise coefficient		0.0		1,2
AF	Flicker noise exponent		1.0		1,2
RL	Junction Leakage Resistance	Ohms	INF		1
T_MEASURED	Measured temperature	Celsius	undefined		1,2
T_ABS	Absolute temperature	Celsius	undefined		1,2
T_REL_GLOBAL	Relative to current temperature	Celsius	undefined		1,2
T_REL_LOCAL	Relative to AKO model temperature	Celsius	undefined		1,2