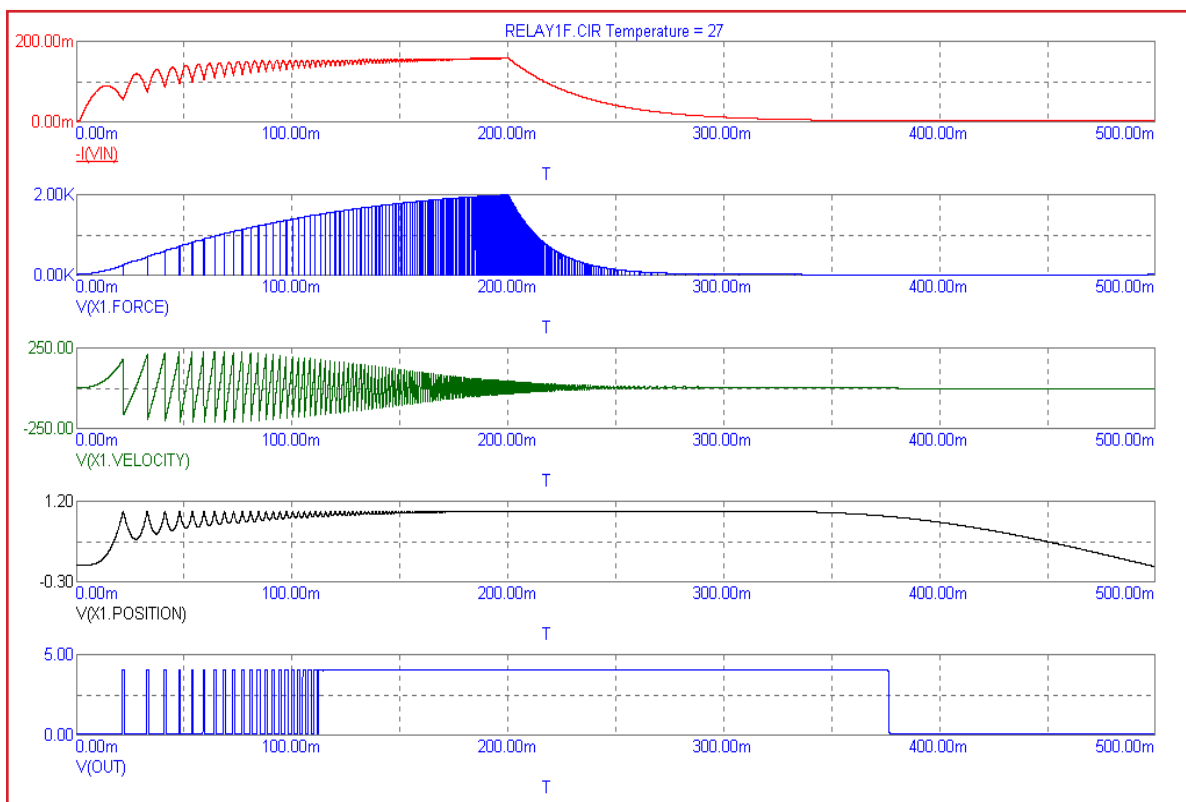


Fall 2000

Relays Models



Featuring:

- How to Model an LED
- How to Model a Zener Diode
- Two Models For Relays

News In Preview

This newsletter describes how to model some common components.

The first article describes how to model LED devices. In particular it describes how to get the large forward drop seen in LEDs.

The second article demonstrates how to translate spec sheet values into a good working model of a zener diode.

The last article describes several models for relays. The first is a simple model that includes coil resistance, inductance, switch on and off resistance, and turn-on and holding current in the relay. The second model is an electromechanical model that simulates the physical mass and motion of the relay plunger and includes additional effects as switch bounce and coil field fringing.

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Book Recommendations

Micro-Cap / SPICE

- *Computer-Aided Circuit Analysis Using SPICE*, Walter Banzhaf, Prentice Hall 1989. ISBN# 0-13-162579-9
- *Macromodeling with SPICE*, Connelly and Choi, Prentice Hall 1992. ISBN# 0-13-544941-3
- *Semiconductor Device Modeling with SPICE*, Paolo Antognetti and Giuseppe Massobrio McGraw-Hill, Second Edition, 1993. ISBN# 0-07-002107-4
- *Inside SPICE-Overcoming the Obstacles of Circuit Simulation*, Ron Kielkowski, McGraw-Hill, First Edition, 1993. ISBN# 0-07-911525-X
- *The SPICE Book*, Andrei Vladimirescu, John Wiley & Sons, Inc., First Edition, 1994. ISBN# 0-471-60926-9
- *SMPS Simulation with SPICE 3*, Steven M. Sandler, McGraw Hill, First Edition, 1997. ISBN# 0-07-913227-8
- *MOSFET Modeling with SPICE Principles and Practice*, Daniel Foty, Prentice Hall, First Edition, 1997. ISBN# 0-13-227935-5

German

- *Schaltungen erfolgreich simulieren mit Micro-Cap V*, Walter Gunther, Franzis', First Edition, 1997. ISBN# 3-7723-4662-6

Design

- *High Performance Audio Power Amplifiers*, Ben Duncan, Newnes, First Edition, 1996. ISBN# 0-7506-2629-1

High Power Electronics

- *Power Electronics*, Mohan, Undeland, Robbins, Second Edition, 1995. ISBN# 0-471-58408-8



Micro-Cap 6 Questions and Answers

Question: I just installed a new HP Photo Smart printer and now when I run Micro-Cap I get the error message, "IO Error on LPT1". Everything was working fine before. What is wrong now?

Answer: The Photo Smart printer is a bidirectional type. That means it both reads and writes to the parallel (LPT1) bus. The Micro-Cap 6 Hasp key also is bidirectional and the two are not sharing the bus successfully. Here is a way to minimize the conflict. Assuming the Micro-Cap 6 CD is in the drive, click on the Windows Start menu, select the Run item, browse to the CD drive, and type in this:

```
hinstall -r -kp -alldrv
```

Then type in this:

```
hinstall -i-cnt=yes
```

This should remove the bus contention and get rid of the error.

Question: I want to create a new model name, different from those already in the model list that is displayed in the Attribute dialog box. How can I do this?

Answer: When the Attribute dialog box (ADB) comes up, just type in the new model name. The ADB model parameter editor will pop-up allowing you to type in the parameters for the new model. When you are finished, click OK and Micro-Cap 6 will place a model statement with your newly entered parameters in the text area of the circuit. The new model name will also appear in the model list box the next time you place another part of this type.

Question: I just got Micro-Cap 6 and I need to read some old Micro-Cap III circuit files. How do I go about converting the Micro-Cap III files to a format Micro-Cap 6 can read?

Answer: Micro-Cap 6 can read Micro-Cap IV and Micro-Cap V files, but Micro-Cap III files must be converted to Micro-Cap IV format first. To do that you must use the CONVERT program. To obtain a copy of that program email your request to Spectrum at support@spectrum-soft.com and we will email a copy to you.

CONVERT.EXE runs under MSDOS and has a command syntax that can be seen simply by typing "CONVERT" at the MSDOS prompt.

Question: I need a voltage source that is a time-domain function of both current through an inductor and voltage across a resistor. Is there a simple way to make one of these?

Answer: Yes, the NFV source (Component menu / Analog Primitives/ Function Sources) is just what you need. Simply type in the expression you want in the VALUE attribute. Here is a sample VALUE expression similar to the one you might need.

```
1E-3*I(L2) + 2E-3*V(R10)
```

This says the instantaneous time-varying voltage across the NFV source is to be calculated as 1E-3 times L2's time-varying current added to 2E-3 times R10's time-varying voltage drop.

Easily Overlooked Features

This section is designed to highlight one or two features per issue that may be overlooked because they are not made visually obvious with an icon or a menu item.

Select Waveform Color Option

A very useful option, included in Micro-Cap 6, but defaulted off, is the Select Waveform Color option. This option, enabled from the Preferences dialog box (SHIFT+CTRL+P), colors the waveform branch where the left cursor is with the primary color and the waveform branch where the right cursor is with the secondary color. The primary and secondary colors are set from the Properties dialog box (F10).

Saving Waveforms

Saving waveforms is a useful feature for comparing the results of one run with another. Waveforms are saved as numerical lists in text files called user files. Saving is done from the Properties dialog box (F10) after the analysis run is over.

Once a waveform has been saved, it will show up under the Variables List (described below) and is available for plotting. It may also be used with a User Source to drive parts of the circuit.

Variables List

Can't remember how to express a variable you want to plot? Use the Variables list. With the cursor in either the Y or X Expression fields of the Analysis Limits dialog box, click the right mouse button. This pops up a hierarchical list of every variable that you can plot. It also shows math operators and lists of already saved waveforms that are available to plot.

If you select the X or Y expression first (CTRL + A), then any item picked from the list will replace the selected expression, other wise the item picked will be placed after the cursor location.

Math functions will generally wrap the expression. For example, if the expression was $V(1)$ and the ABS functions was selected, then the result will be $ABS(V(1))$.

Math operators will generally be placed to the right of the text cursor. For example, if the expression was $D(1) D(2)$ with the cursor between the $D(1)$ and $D(2)$ and the OR operator was selected, then the result will be $D(1) OR D(2)$.

This list also shows waveforms that have been saved to the data directory and are thus available for plotting. These waveforms are typically used for comparison with actual waveforms from the circuit. Note that, not just time-domain waveforms, but any plot from transient, AC, or DC analysis can be saved and displayed here.

How to Model an LED

Modeling LEDs is generally a simple proposition. Modeling is done with the diode primitive and the primary objective is to match the LED forward characteristic. The normal forward drop of the diode with typical parameters is about 0.7 volts for currents in the 10m to 100ma range. In an LED the drop will be much larger. Typically the forward drop is 2.5 to 4 volts. To achieve the larger drop you must decrease the diode IS model parameter value from its typical value of 1E-15 to as low as 1E-55. The smaller the IS the larger the forward drop.

To simplify the process, consider the following test circuit.

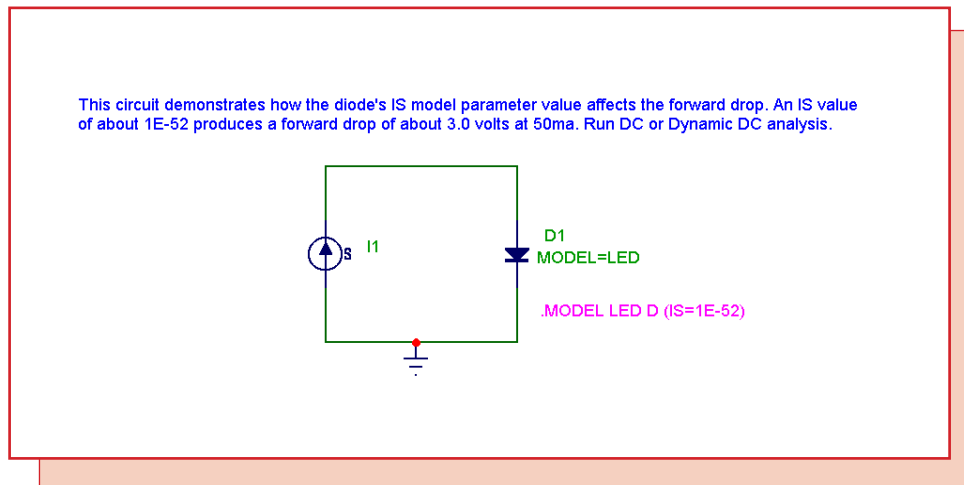


Fig. 1 - LED Test Circuit

This circuit, when run in DC analysis with the analysis limits of Fig 2, plots the diode's current vs. its voltage, stepping the value of IS from 1E-20 to 1E-52 to cover a broad range of possible LED forward characteristics.

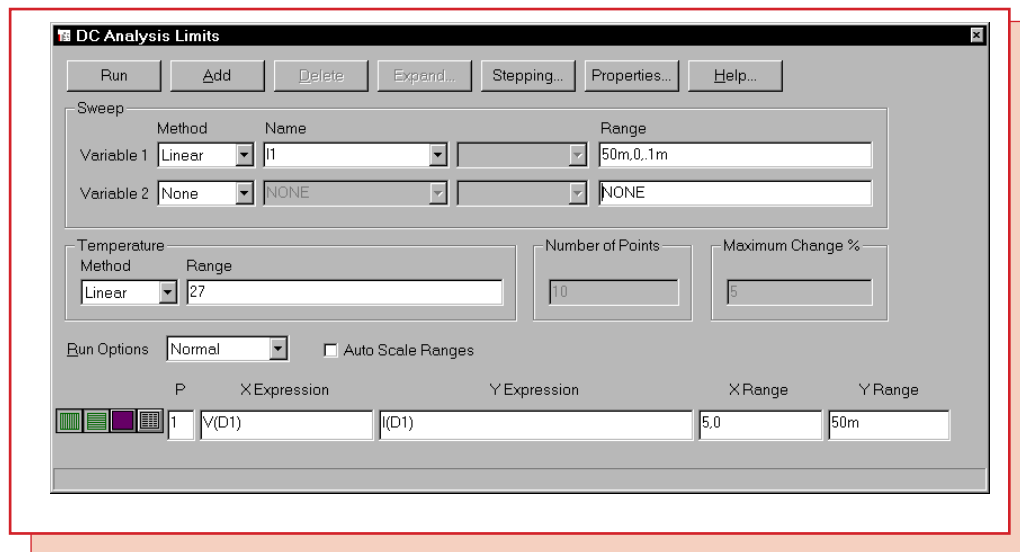


Fig. 2 - LED DC analysis limits

Fig. 3 shows what the DC analysis looks like. All you have to do is find the closest fit to the characteristics of the LED you are modeling and select that value of the IS parameter in your diode model for the LED.

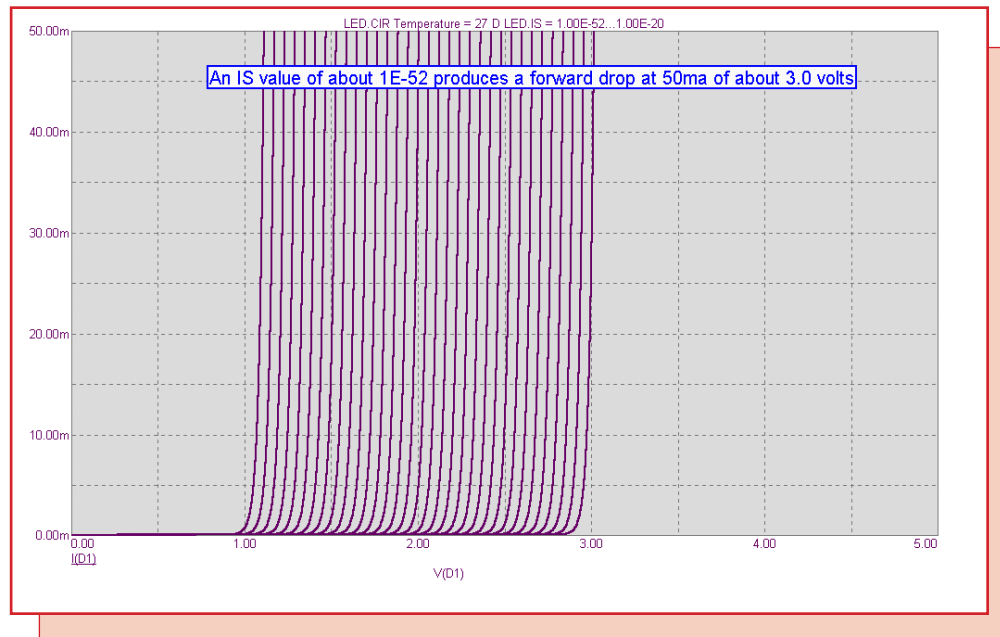


Fig. 3 - LED DC analysis forward characteristic plot

This plot shows the I_d vs V_d curve for 33 values of I_S from $1E-20$ to $1E-52$. The forward resistance is that of the intrinsic diode alone which, for these currents, is usually below 10 ohms. If you need a higher incremental resistance you should make R_S , the series diode resistance, larger. Of course, doing so will alter the above curves so some adjustment in I_S will probably be needed.

How to Model a Zener Diode

Modeling zener diodes is not much more complicated than modeling LEDs. As with LEDs, modeling is done using the diode primitive and the primary objective is to match the reverse characteristic. To model a zener diode, set the diode model parameters to the indicated data sheet values.

Model Parameters	Data Sheet Values
BV	VZ
IBV	IZT
RS	ZZT
RL	VR/IR
TBV1	(TC in mV/C)/1000

To simplify the process, consider the following test circuit.

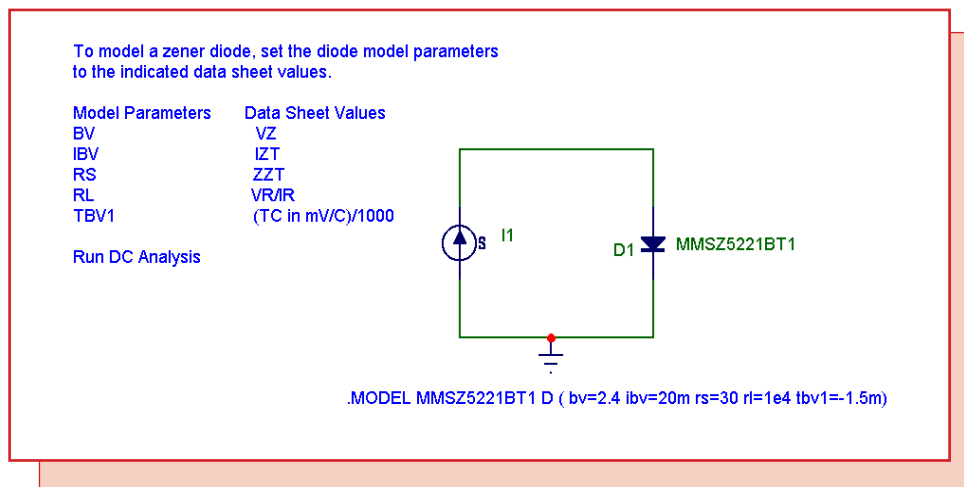


Fig. 4 - Zener Test Circuit

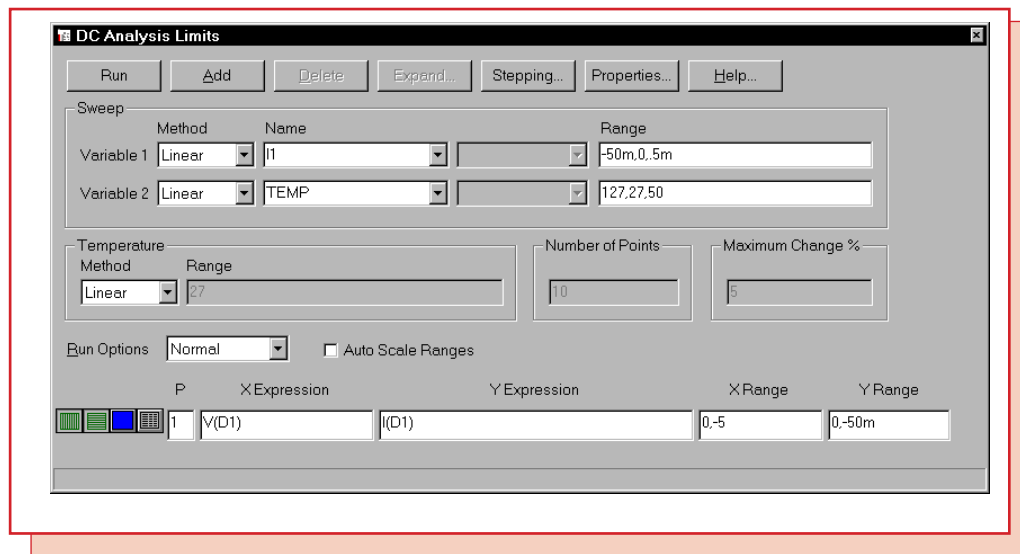


Fig. 5 - Zener DC analysis limits

This circuit, when run in DC analysis with the analysis limits of Fig 5, plots the diode's reverse current vs. its reverse voltage, stepping the value of temperature from 0 to 127 in steps of 50 degrees.

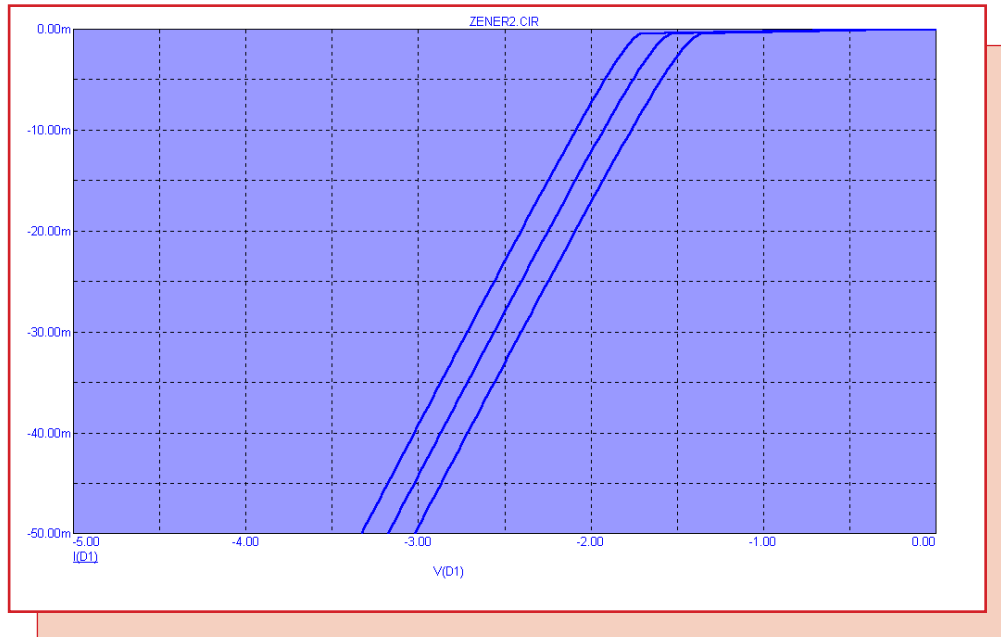


Fig. 6 - Zener DC analysis reverse voltage plot

Fig. 6 shows what the DC analysis looks like for the MMSZ5221BT1 zener.

Note that Micro-Cap 6 adjusts the saturation current parameter, I_S , to match the BV , IBV point exactly by taking into account the R_S value.

For example, the R_S of 30 in this case produces an additional drop when the diode current is at the IBV value of 20ma of 600mv, which, without compensation, would push the BV at 20ma to $2.4 + 600\text{mv} = 3.0$ volts.

You can also add the CJO parameter from the C vs. nominal zener voltage curves, if they are given in the data sheet. Use the 0 volt bias curves.

Two Models for Relays

Occasionally a relay model is needed. Here are two models that work well. The first model, called RELAY1, is a simple model that includes coil series resistance and inductance, and turn-on and turn-off currents. The other is a more sophisticated but slower running electromechanical model of the relay that includes such effects as coil resistance and inductance, turn-on and turnoff delays, nonlinear fringing inductance, plunger rebound and the associated switch bounce.

Here is the RELAY1 model:

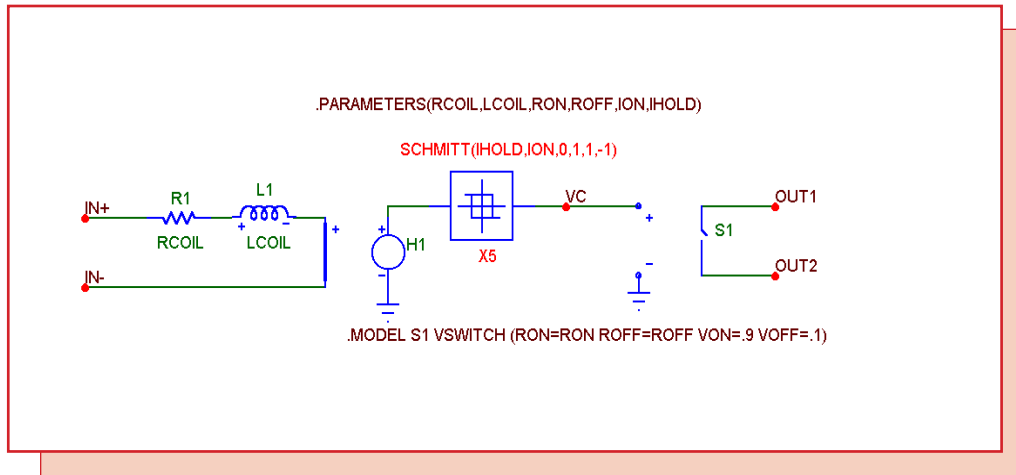


Fig. 7 - Relay1 Model

The input circuit of this model includes a user-specified coil resistance and inductance. The coil current is sensed and converted to a voltage by H1 which drives a Schmitt macro to provide hysteresis between the ION and IHOLD currents. The output of the Schmitt drives a standard voltage controlled switch S1.

Figure 8 shows the test circuit used. Figure 9 shows the transient analysis limits.

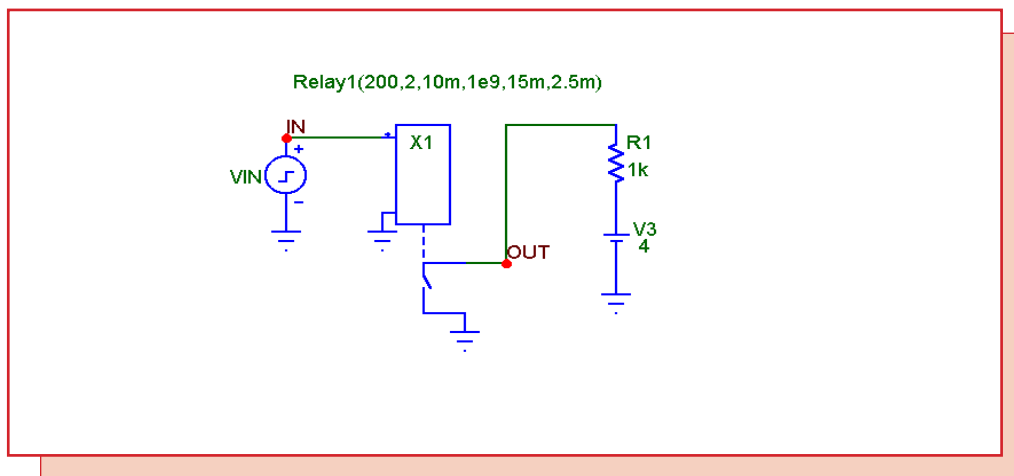


Fig. 8 - Relay1 test circuit

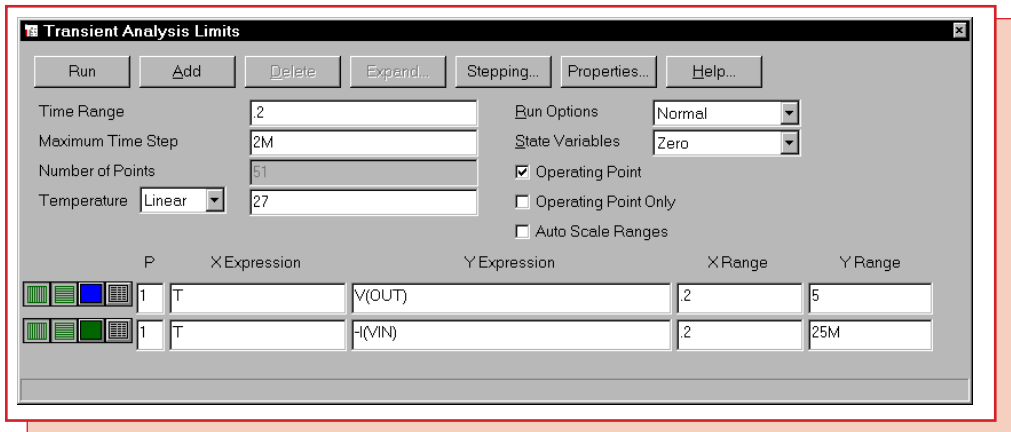


Fig. 9 - Transient analysis limits for Relay1 test circuit

The transient analysis in Figure 10 shows the input current waveform and the voltage at the output switch. The switch changes closes at the specified current of 15mA and stays closed until the input current goes below the specified 2.5mA holding current.

The parameters for the RELAY1 model are as follows:

- RCOIL Resistance of the relay coil
- LCOIL Inductance of the relay coil
- RON Closed resistance of the output switch
- ROFF Open resistance of the output switch
- ION Input current required to close the relay contacts
- IOFF Input current required to hold the relay contacts closed

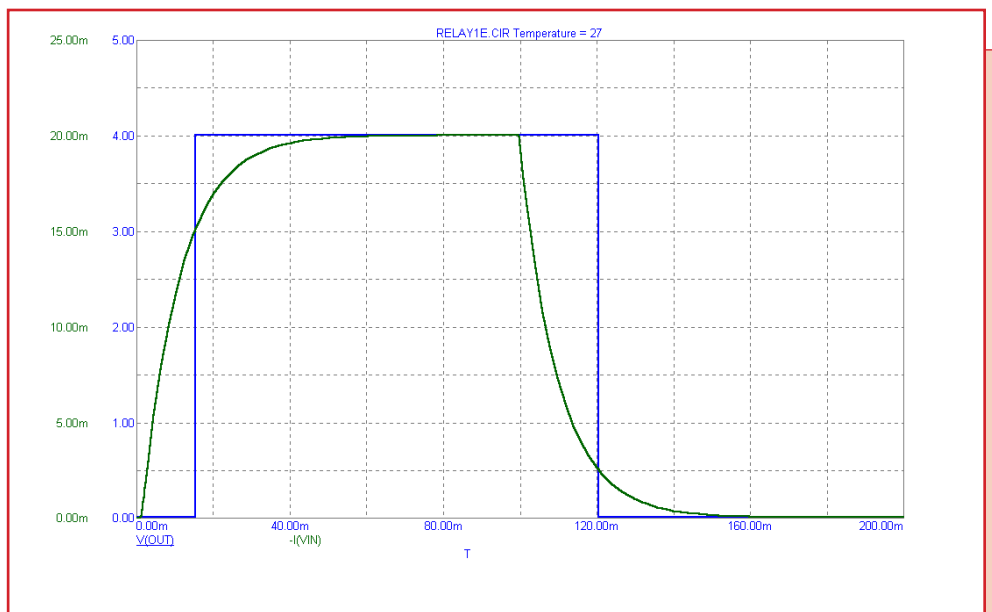


Fig. 10 - Transient analysis of the Relay1 model



RELAY2 is a more complicated electromechanical model. It includes a flux circuit and derives a magnetizing force from the flux. It then algebraically sums the magnetizing, stop, friction and restoring spring forces acting on the plunger to arrive at a net force which is integrated once to get the plunger velocity and again to get the plunger position. This plunger position directly controls the switch contacts.

Here is the RELAY2 model:

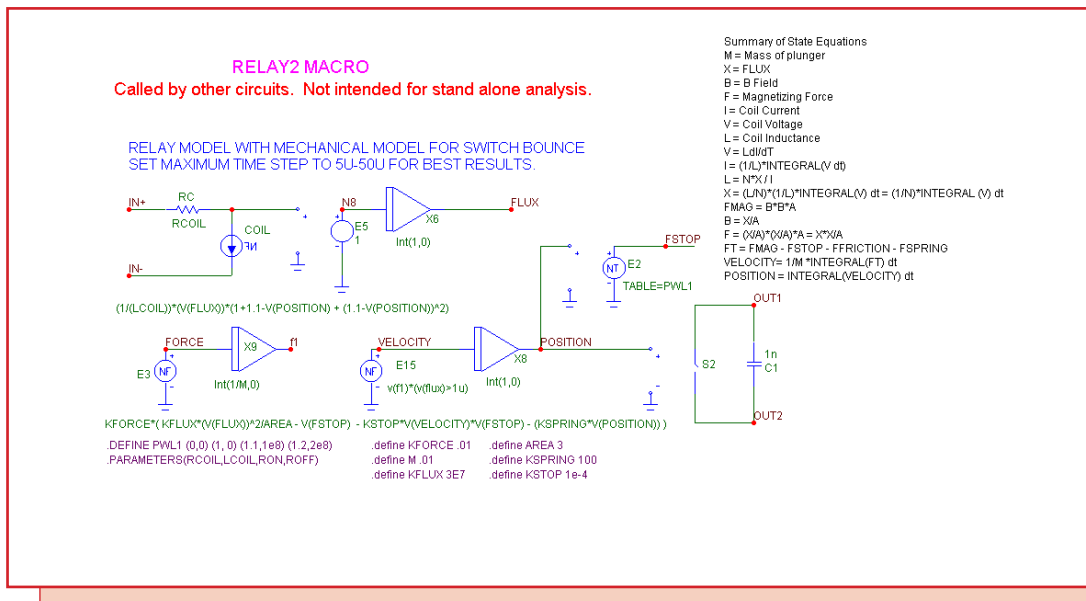


Fig. 11 - Relay2 Model

Figure 12 shows the test circuit used. Figure 13 shows the transient analysis limits.

The transient analysis in Figure 14 shows the input current waveform and the voltage at the output switch. The display also shows the internal waveforms for the net force, plunger velocity, and plunger position.

The parameters for the macro are shown below. Other constants are defined within the macro and may be modified to produce different mechanical models.

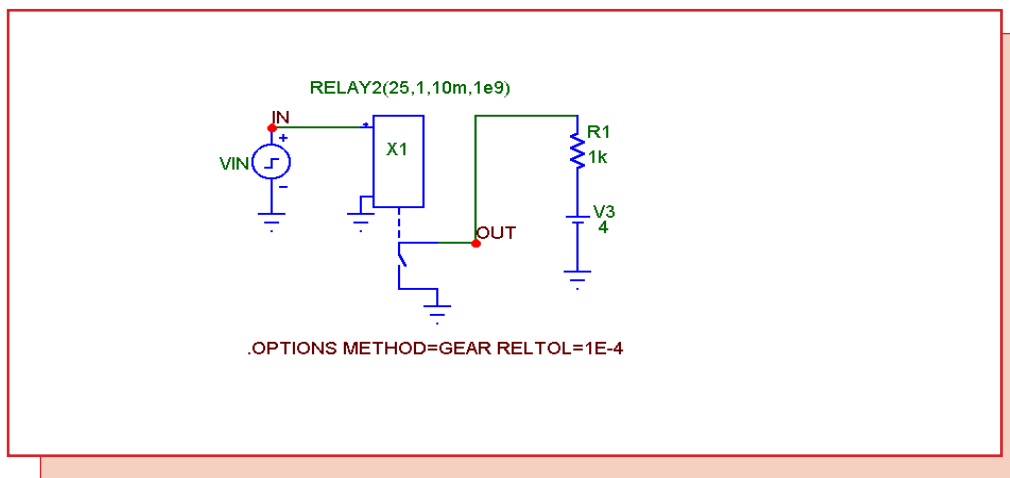


Fig. 12 - Relay2 test circuit

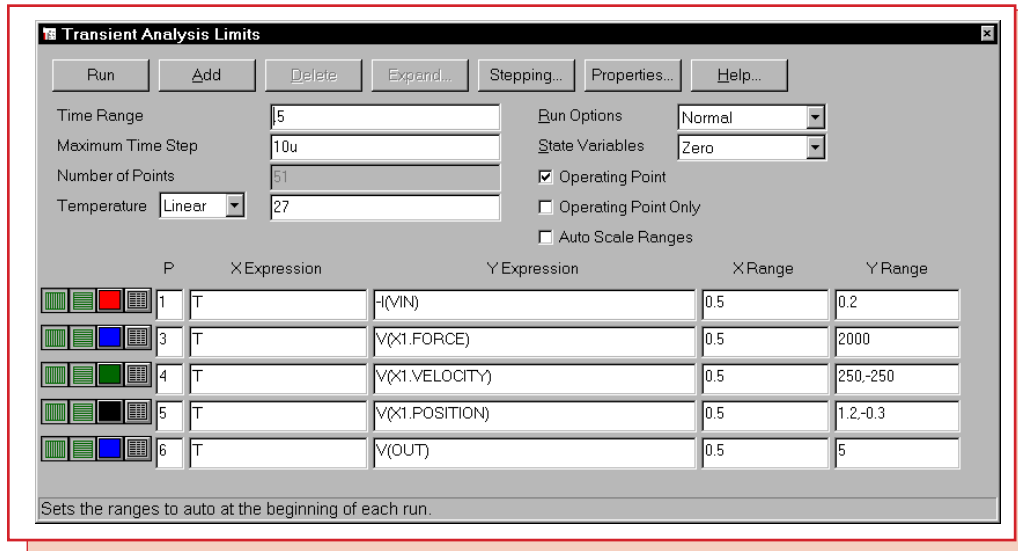


Fig. 13 - Transient analysis limits for Relay2 test circuit

Parameters

RCOIL Resistance of the relay coil
 LCOIL Inductance of the relay coil
 RON Closed resistance of the output switch
 ROFF Open resistance of the output switch

Constants

AREA Plunger area in square mm
 M Plunger mass in kilograms
 KSPRING Spring constant
 KFLUX Flux force constant
 KSTOP Stopping force constant
 KFORCE Net force scaling constant

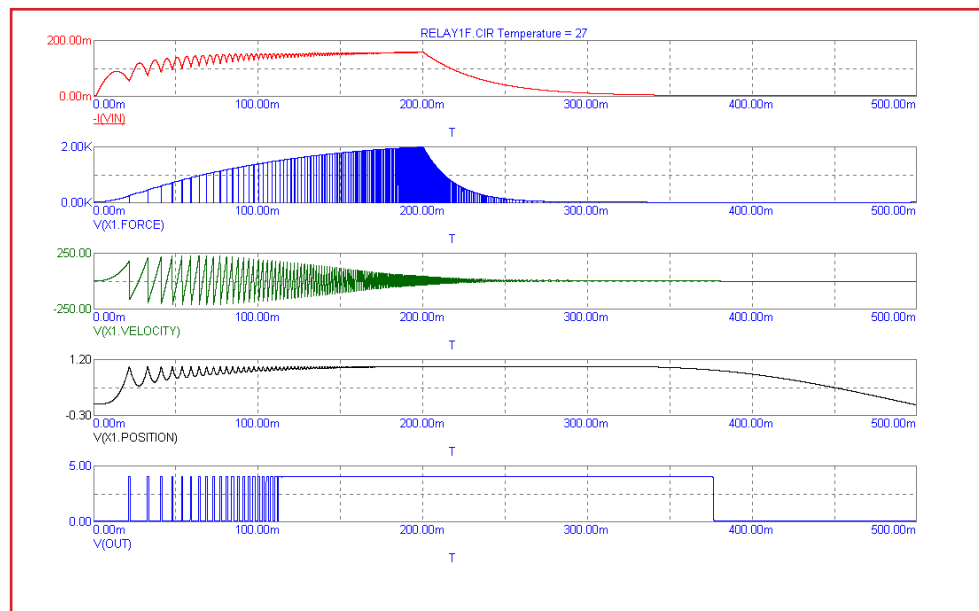


Fig. 14 - Transient analysis of the Relay2 model

Product Sheet

Latest Version numbers

Micro-Cap 6 Version 1.3.0
Micro-Cap V Version 2.1.2

Spectrum's numbers

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