Creating Subcircuits and Hierarchical Blocks in LTspice

Mike Kelsch
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This tutorial gives some techniques for creating Subcircuits and Hierarchical Blocks using LTspice /SwitcherCAD III Version 2.19p (available free from Linear Technology at: http://www.linear.com/company/software.jsp).

Subcircuits:

Subcircuits allow the designer to create a model or circuit for a device that may be used many times in a schematic (and saved for later use in other circuits). Each instance of the device can use the same "parameters" (values) or the parameters can be changed on an instance-by-instance basis. The advantage of a subcircuit is that one symbol on a schematic can represent another circuit. Whenever that symbol is placed on the schematic, the entire subcircuit is placed. This allows for ease of design with more clarity on the schematic.

Procedure:

1) Create a netlilst using a text editor such as notepad.
   a) use the *.subckt* statement followed by the name of the subcircuit followed by the pins (e.g. *.subckt myopamp 1 2 3*) (see example). The numbers will be used as node numbers for connection to other components (0 is ground). The order of the numbers will be the order used for the "pin/port netlist order" on the symbol.
   b) End the subcircuit with the *.ends* statement (e.g. *.ends myopamp*).
   c) Save the netlist as *filename.lib* or *filename.sub*, the name does not have to be the same as the name of the subcircuit (in fact, more than one subcircuit can be included in a .lib or .sub file. See "Notes on Saving"
2) Draw a symbol to represent the device.
   a) Select File → New Symbol, to open the Symbol Editor.
   b) Draw the symbol using the Draw menu and the Line, Rect, Circle, etc. commands.
   c) Place the pins. Select Edit →Add Pin/Port to get the Pin/Port Properties dialog box. At the top right is the Netlist Order box. This order corresponds to the order of the pins in the subciruit. A label can be inserted using the Label box (e.g. Vin), but has nothing to do with the function of the pin. The pin's function relates to the connection specified in the subcircuit netlist. To make the label visible select one of the Pin Label Position buttons.
   d) Some information, such as, Instance Name can be added by selecting Edit →Attributes → Attribute Window and selecting the information. Clicking OK will allow pasting on the symbol

3) Open the Symbol Attribute Editor to enter the appropriate information.
   a) Select Edit →Attributes → Edit Attributes.
      i) Select Cell in the Symbol Type drop-down box.
      ii) Select Prefix, type X in the Prefix = box. X tells LTspice that this is a subcircuit.
      iii) In the Value field type the name of the .subckt (e.g. *myopamp*)
      iv) SPICELine can be used to pass parameters.
      v) Leave ModelFile blank.
   b) Save the symbol, File → Save As saves the file as a *.asy. See "Notes on Saving"
4) On the schematic, include a SPICE Directive with the path of the subcircuit file (e.g. *.lib C:\Program Files\LTC\SwCADIII\My Work\OpampExample.lib*).

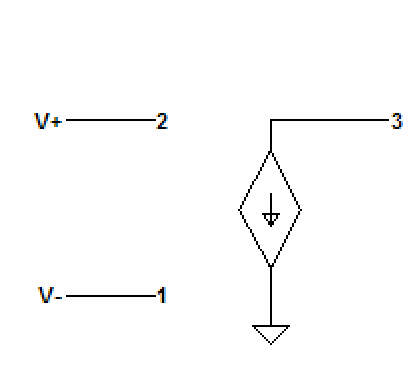
Here is an example of an ideal op-amp subcircuit:

Step 1.

Create a subcircuit netlist using a text editor.

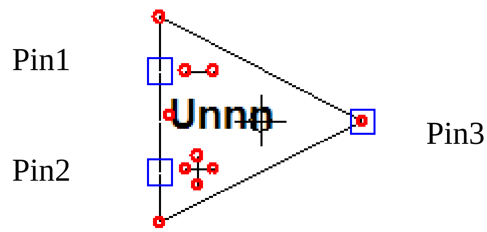
*Ideal Op-Amp	"*" means this is a comment
* V- V+ Out	This line is for clarity only
.subckt myopamp 1 2 3	Subcircuit named myopamp with three pins
g1 3 0 2 1 100Meg	Dependent source with nodes and gain
.ends myopamp	End of the subcircuit

Save As →OpampExample.lib (in this example the full path is:
C:\Program Files\LTC\SwCADIII\My Work\OpampExample.lib)



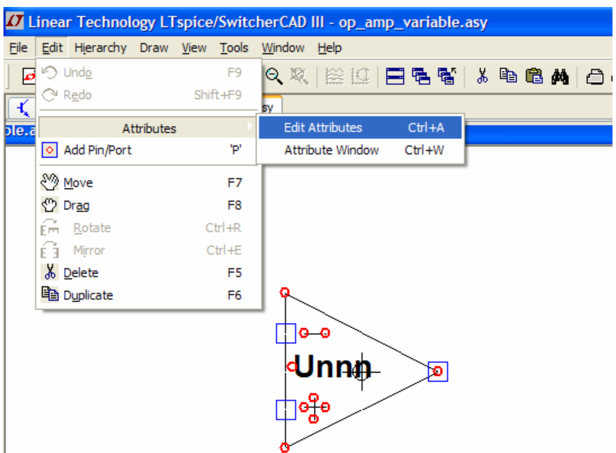
This is what a schematic of the subcircuit would look like. "g1" is a linear voltage controlled current source with pins of <+node><-node><+controlling node> <-controlling node><gain>. Now when the symbol is made the "netlist order" of the pins will be Inverting Input (pin 1), Non-Inverting Input (pin 2), Output (pin 3).

Step 2.

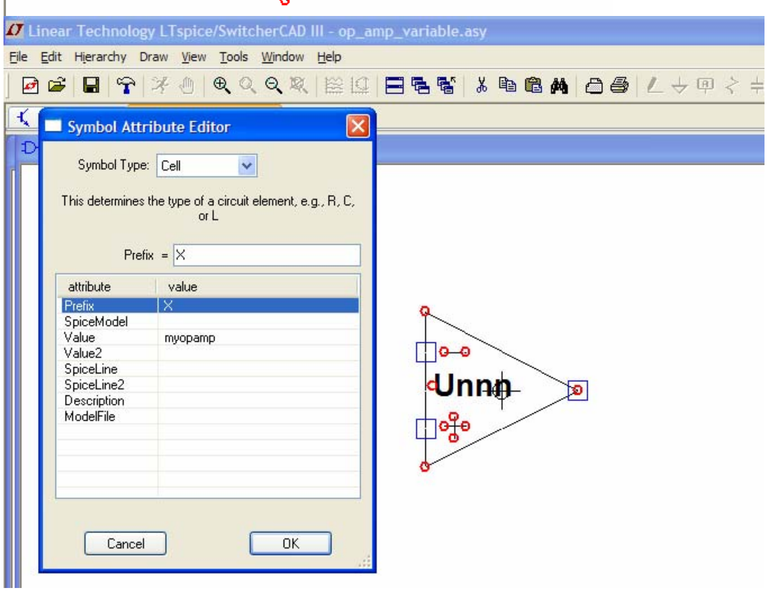


The Inverting pin is on top and has a "netlist order" of 1. The Output is pin 3. Unnn was created by Edit →Attributes → Attribute Window and selecting InstName. This will appear as U1, U2, etc on the schematic.

Step 3.



Select Edit →Attributes → Edit Attributes.

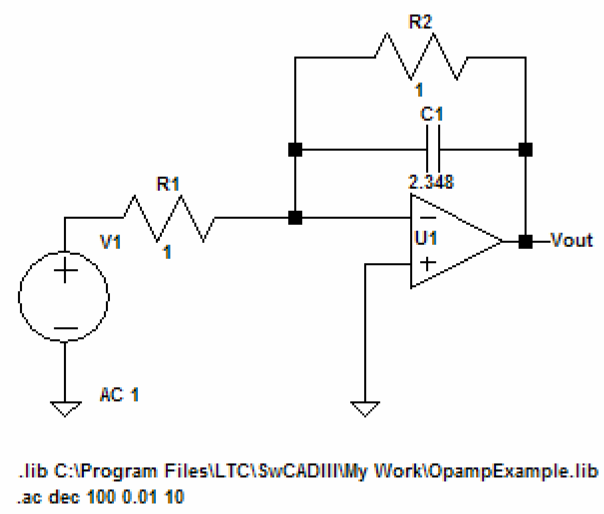


Symbol Type → Cell
Prefix → X
Value → myopamp

The name of the subcircuit, "myopamp," is placed in the Value field. This is the name that follows the .subckt statement in the netlist, not the name of the file.

File → Save As → myopamp.asy

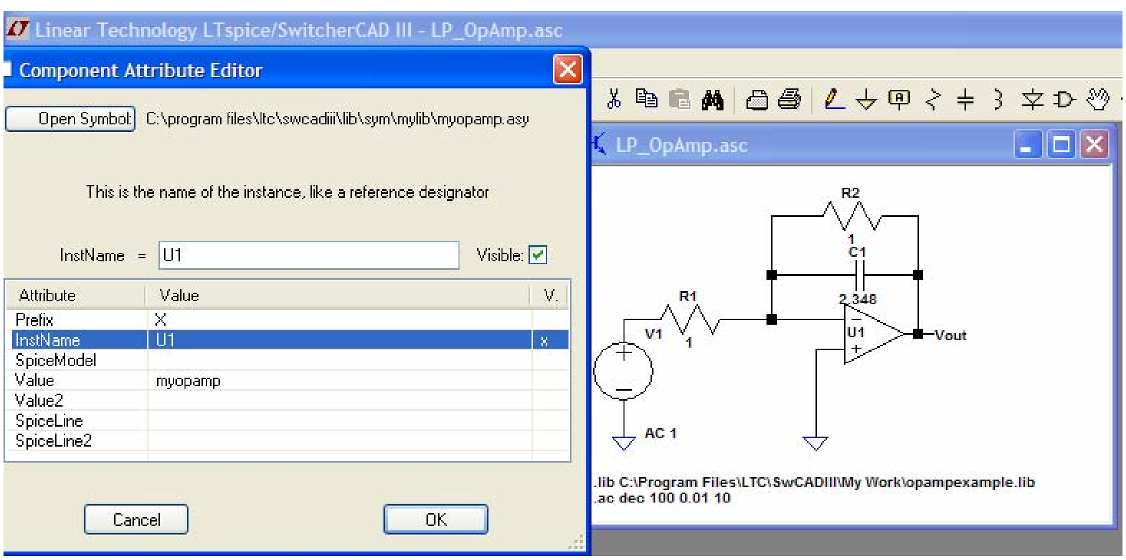
Step 4.



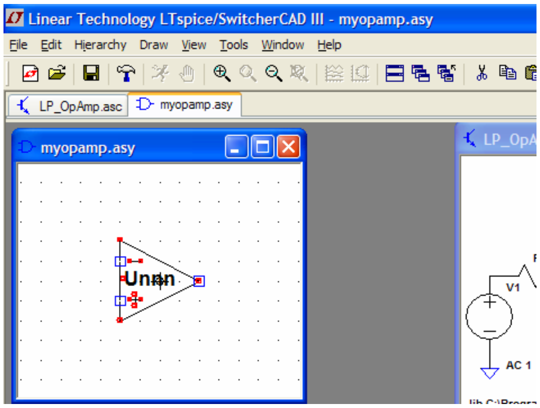
.lib statement tells LTSPICE where to find the file "OpampExample.lib" which contains the subcircuit "myopamp."

Notes:

Right clicking on U1 will bring up the Component Attribute Editor. Here information can be made visible on the schematic by selecting the desired line and checking the Visible box. Notice an x is shown in the V column indicating the instance name (U1) will be visible on the schematic. This editor will also allow changes to the attributes listed. The path of the device symbol is shown to the right of the Open Symbol button.



Selecting the Open Symbol button opens the symbol for the device. With the symbol opened the Edit → Attributes commands can be used in the same manner described in steps 2d and 3.



The open symbol can be edited using the Edit → Attributes commands.

Hierarchical Blocks:

Creating Hierarchical Blocks is similar to using a subcircuit in that a symbol can represent another circuit in a schematic. The hierarchical block is a schematic that is represented on a higher-level schematic by a symbol. In the example on subcircuits, a netlist represented an op-amp then a symbol representing that subcircuit was placed on the schematic. For a hierarchical block, a schematic is created to model the op-amp and a symbol is made to represent the schematic of the op-amp. The op-amp's schematic is a lower-level schematic. Selecting the symbol on the higher-level schematic allows viewing of the lower-level circuitry. Once open the voltages and currents can be probed just as in the higher-level schematic.

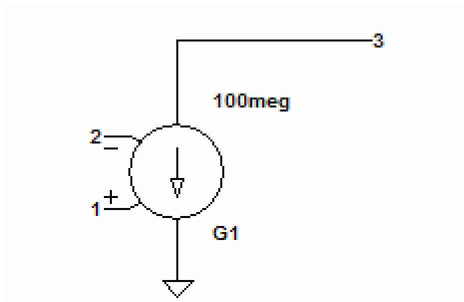
Procedure:

1) Create a schematic of the device to be represented by a block.
   a) Use LTspice's schematic capture to draw the circuit. If semiconductor models or subcircuits are used, add a .lib directive with the path and name of the file.
   b) Label any nodes that will be connected to the higher-level circuit. Select Edit → Label Net. In the box next to ABC type a name or number. Port Type select None (or as desired).
   c) Save the schematic as a *.asc file (e.g. *oaBlock.asc*). This can be saved in a working directory. "Notes on Saving"
2) Create a symbol to represent the lower level schematic.
   a) Select File → New Symbol, to open the symbol editor.
   b) Draw the symbol using the Draw menu and the Line, Rect, Circle, etc. commands.
   c) Place the pins. Select Edit →Add Pin/Port to get the Pin/Port Properties dialog box. At the top right is the Netlist Order box. The Netlist Order is not crucial but the Label box (left of the Netlist Order box) is very important. The Label box must match the Net labels from step 1b. To make the label visible select one of the Pin Label Position buttons (if desired).
   d) Some information, such as, Instance Name can be added by selecting Edit →Attributes → Attribute Window and selecting the information. Clicking OK will allow pasting on the symbol.

3) Open the Symbol Attribute Editor. Select Edit →Attributes → Edit Attributes. Select Block from the Symbol Type drop-down box. Leave all attributes blank. Save the symbol, File → Save As saves the file as a *.asy. See "Notes on Saving"
4) Now the component can be placed in a new schematic.

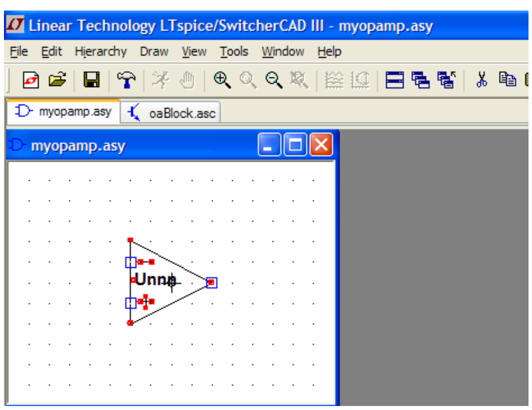
Here is an example of an ideal op-amp using a hierarchical block:

Step 1.

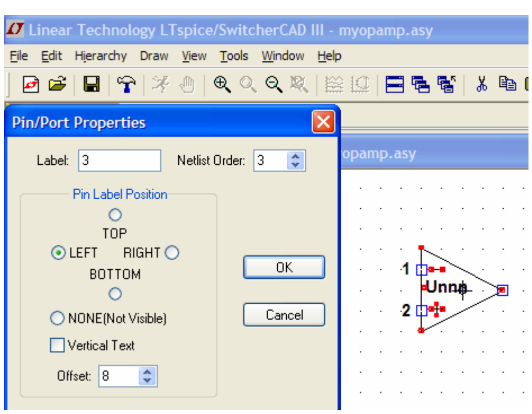


Schematic created using "g" from the symbol library using the Select Component Symbol dialog box (Edit → Component).
Nodes Labeled using Edit → Label Net. Numbers or names can be used.
File → Save As oaBlock.asc

Step 2.



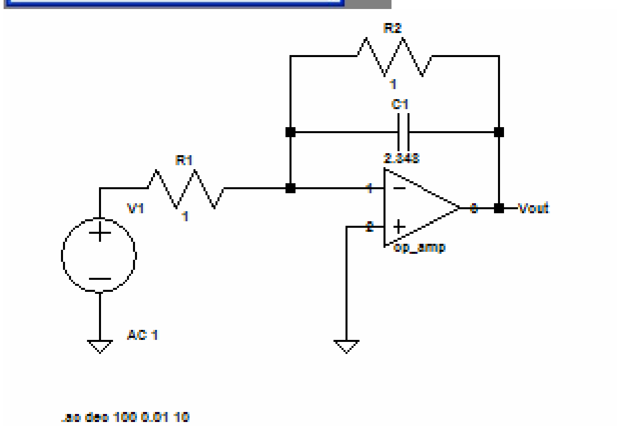
A new symbol can be created or a previously created symbol can be used. Here myopamp.asy from the previous example is used.



In the Label box of the Pin/Port Properties dialog box enter the label that matches the schematic oaBlock.asc.
If making a new symbol from scratch use
Edit → Add Pin/Port.
If using a previously created symbol Right Click on the pin to get the Pin/Port Properties box.
Here the pin labels are visible, this is optional.

Step 3.

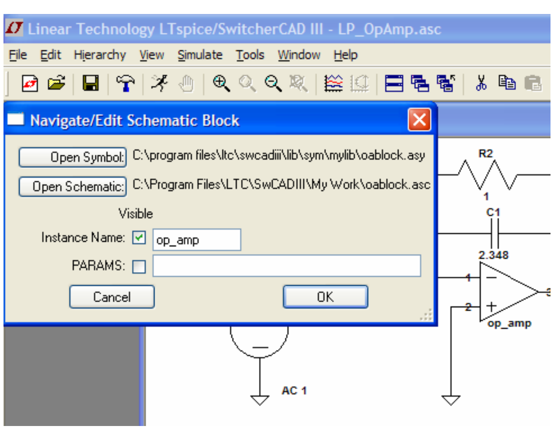
Select Edit → Attributes → Edit Attributes. Select Block from the Symbol Type drop-down box. Leave all attributes blank. Save the symbol File → Save As oaBlock.asy

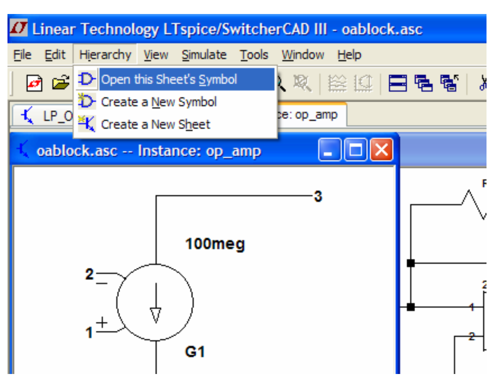


Insert the component in the schematic. The displayed name was X1. Change its name (if desired) by placing the cursor over the label, Right Clicking and replacing X1 with op_amp.

Notes:

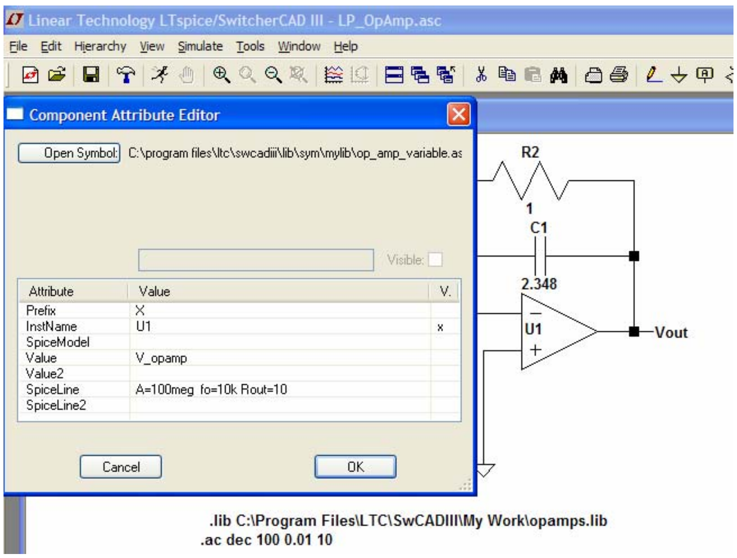
Right clicking on the component brings up the Navigate/Edit Schematic Block dialog box. The Symbol or its Schematic can then be opened. If the lower level schematic is opened it's symbol can be opened from the Hierarchy menu.





Passing Parameters:

Curley Brackets {} and the .param statement can be used to pass parameters to components.
Curley brackets enable the use of variables. The .param statement can be used to specify values for the variables. For example:

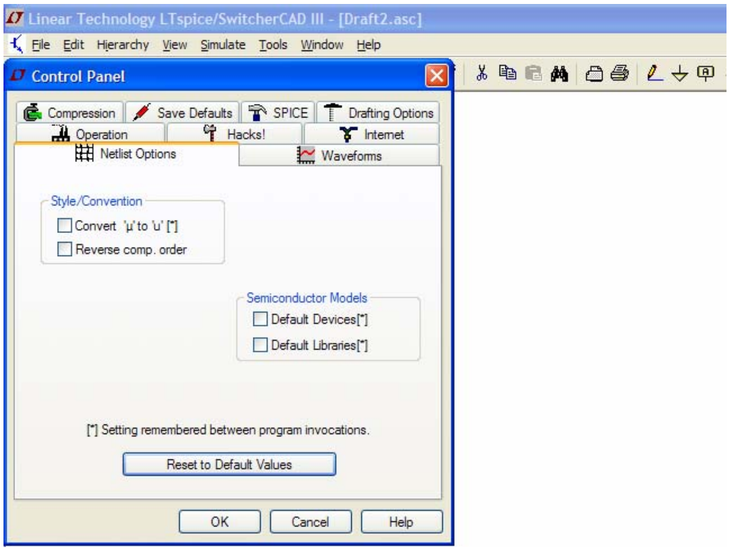



```
.subckt V_opamp 1 2 3
ro 3 0 {Rout}
co 3 0 {Cout}
e1  3 0 1 2 {Ao}
.param Cout={1/2/pi/fo/Rout}
.param Ao={-A}
.ends V_opamp
```

Here variables are set using a combination of curly brackets and .param statements. This allows the use of one subcircuit with parameters being changed on the schematic, using the Component Attribute Editor, instead of in the netlist. Right Clicking the component can access the editor. To use this method add the variable names and values to the SpiceLine and SpiceLine2 values (e.g. A=100meg) when first creating a symbol (see number 3 of the subcircuit procedure). Alternatively, for an existing symbol use the Component Attribute Editor. Each instance of a component can have different parameters through use of the Component Attribute Editor. A .param statement can also be placed on a schematic as a SPICE Directive.

Model Statements:

Some devices, such as, transistors and diodes require information on the device in order to make calculations. A .model statement tells LTspice what parameters to use for modeling semiconductors. However, LTspice uses default models even if a model file is included. To use models other than the default select Tools → Control Panel → Netlist Options tab and uncheck the Semiconductor Models boxes. Remember to use a .lib or .include directive to include the path of the model file (e.g. .lib C:\Program Files\LTC\SwCADIII\My Work\CMOS.lib).



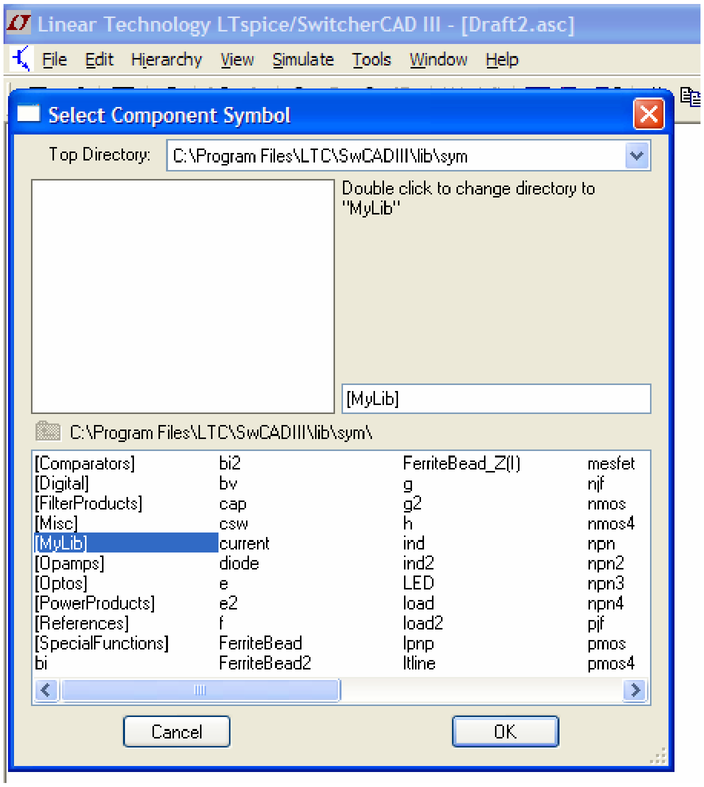
Uncheck the Semiconductor Models boxes when not using LTspice default models.

When not using default models a .model statement must be included on the schematic with the path and name of the model file (e.g. .lib C:\Program Files\LTC\SwCADIII\My Work\CMOS.lib).

<u>Notes on Saving:</u>

LTspice searches for the needed files as specified in the .lib or .include statement that is placed on the schematic or in a netlist. If no statement exists, LTspice looks in the SwCDIII\lib\cmp, SwCDIII\lib\sub, or the path of the schematic. It is recommended to always use the .lib or .include directive to avoid error messages. Here are a couple of techniques that might avoid headaches later.

1) Make a working directory in the SwCADIII folder (e.g. C:\Program Files\LTC\SwCADIII\My Work). Save all your schematics in this directory.
2) Make a directory in the C:\Program Files\LTC\SwCADIII\lib\sym directory to save all newly created symbols. This allows selection of a device from the Select Component Symbol dialog box by locating the directory and selecting from the list. Now custom components can be kept separately from Linear Technology's library of symbols. Creating a directory called MyLib (C:\Program Files\LTC\SwCADIII\lib\sym\MyLib) is shown. Double clicking on MyLib opens the new directory and lists the available symbols.



A directory called “MyLib” was created in the C:\Program Files\LTC\SwCADIII\lib\sym directory. Closing and restarting LTspice then opening the Select Component Symbol dialog box (Edit → Component) shows the directory. Double clicking on the directory opens it. Save all symbols (*.asy files) in this directory and they will now be available. Each time a new symbol is saves, close and restart LTspice.

Setting User Preferences:

Color preferences for background, schematic components and text, and plots can be changed using the Color Palette Editor. Select Tools → Color Preferences. To eliminate the saving of files generated during simulations (.raw .log files etc.), select Tools → Control Panel →Operations Tab and select yes to Automatically Delete…. Schematic font sizes can be found on the Control Panel → Drafting Options Tab. Also on the Drafting Options Tab is the Hot Keys Button. This screen allows for customizing Keyboard shortcuts for commonly performed tasks. The SPICE Netlist and Error Log can be accessed from the View menu and come in handy during troubleshooting. A Netlist can be exported as a .net file using Tools → Export Netlist.

I hope this information is useful. To leave comments: mk104mk@mindspring.com

Mike Kelsch

Additional information is available from the following:

LTspice user’s manual http://ltspice.linear.com/software/scad3.pdf
LTspice user’s group http://tech.groups.yahoo.com/group/LTspice/
Linear Technology http://www.linear.com/

Works Cited

Sennewald, Helmut 2006 *Third Party Models*
http://tech.groups.yahoo.com/group/LTspice/

Tront, Joseph G. 2004 Pspice for Basic Circuit Analysis New York: McGraw Hill

LTspice Users Manual
http://ltspice.linear.com/software/scad3.pdf

Winspice Tutorial

Glossary

Device: A circuit component. This could simply be a resistor or a complex circuit (e.g an op-amp) which is represented on the schematic by a symbol.

Instance: each time a component or device is placed on a schematic, it is called an instance of that device. For example if a circuit contains three Op-amps, each individual op-amp is an “instance” of that op-amp. Each instance is identified by a letter representing the type of component (e.g. R for resistor) followed by a unique number. Instance numbers can be changed and can contain numbers and or letters as long as no two instances have the same label. Instances can have different parameters (values).

Netlist: A text file representing a circuit. LT Spice recognizes files ending in “.cir .net, and .sp” as netlists. The first line of a netlist is taken to be a comment, so begin all netlists with a comment. End a netlist with the “.end” statement. WinSPICE uses *filename.cir* and PSPICE uses *filename.net.*

Parameters: Values for a device or used for calculating the values for the device. Parameters can be assigned by use of a .param statement or by use of curly brackets{ } in a subcircuit.

SPICE Directive: A command telling a SPICE program to perform an operation. SPICE directives can be included in netlists (as for a subcircuit) or placed on the schematic. These directives begin with a period. Some examples: .lib, .include, .subckt, .model, .tran. Place a SPICE directive using Edit → SPICE Directive or use the “.op” icon.

Symbol: A user created drawing used to represent a device. The device could be described by a subcircuit or a hierarchical block. To make a symbol select File → New Symbol. Then use the Draw menu to add shapes and text. The shapes have no electrical connection. The electrical connection is established by placing pin/ports using the Edit → Add Pin/Port command.