

SimSmith Primer

This primer is written for the experienced Smith Chart user. If you are new to Smith charts you would be well advised to watch the tutorials provided at www.ae6ty.com/Smith_Charts.html.

Let me emphasize this a bit. This primer is really a set of notes. It is not an introductory tutorial. Basic operation of SimSmith is best learned by watching the videos. These notes explain some things in detail not covered by the tutorials.

Reading the QRP Quarterly article is probably worthwhile. It is available on my web site or in the 'help' menu if you are running SimSmith.

Let me start out by pointing out a few important aspects of SimSmith.

- Signal flow is "right to left". Yes, this bugs the engineer in me. Still, all of Smith chart software that I have used before work this way so, I decided not to break with tradition.
- (Almost) Everything you might want to update is visible on the screen all the time. I've tried really hard not to have difficult to find information. Version 7 introduced a 'preferences' menu under the 'file'. The preferences menu allows you to specify seldom (if ever) changed items such as 'units' for length.
- Creating a schematic is done using drag and drop. Click on the component you want and drag it to the place you want it. Components can be rearranged in the schematic in the same way.
- There is no limit on the number of components. As you add components, SimSmith will endeavor to resize them to fit the window.
- The window can be resized to just about anything and SimSmith will attempt to resize everything accordingly. I have relatively poor eyesight so I tend to set the window very large. SimSmith always tries to maximize the font within the area provided. Thus, not all text is the same size but it is maximally readable.
- Values for each element can be set directly by clicking on the field below the component.

- Values for each element can be ‘tuned’ using the buttons labeled “<<< << < > >> >>>”. Left being reduce, right being increase.
- Standard values for things like resistors can be forced using the “next”, “closest”, and “previous” tune buttons. The values may be specified using files. See “standard values” below.
- In SimSmith, every component you add will, by default, have at least SOME loss (except transformers which are non-ideal enough). You can set the losses to zero manually if you like. I consider this a major feature of SimSmith, all devices have some loss, especially transmission lines when used as reactances. *Smith chart software which does not model transmission line losses mislead you and can waste your time.*
- SimSmith provides two basic graphs: the traditional Smith chart and an SWR (or Scattering Parameter) charts.
- Version 5 of SimSmith can read circuit and library descriptions from earlier versions. However, some of the information will get ignored. Specifically, information contained in the old control panel (library, scan limits, standards files). Generally, older versions of SimSmith cannot read newer saved circuits.
- If you use Transformers: PLEASE READ THE UPDATED SECTION ON TRANSFORMERS.
- IN GENERAL... SimSmith circuits are NOT BACKWARD COMPATIBLE. It is simply too time consuming to ensure. Make sure and save any circuit files in a safe place before invoking the newest version of SimSmith.

The remainder of this primer discusses important features of the various components and menus.

THE MENU BAR (new in version 4.1) contains several pull down menus. The most important ones are ‘file’ and ‘help’.

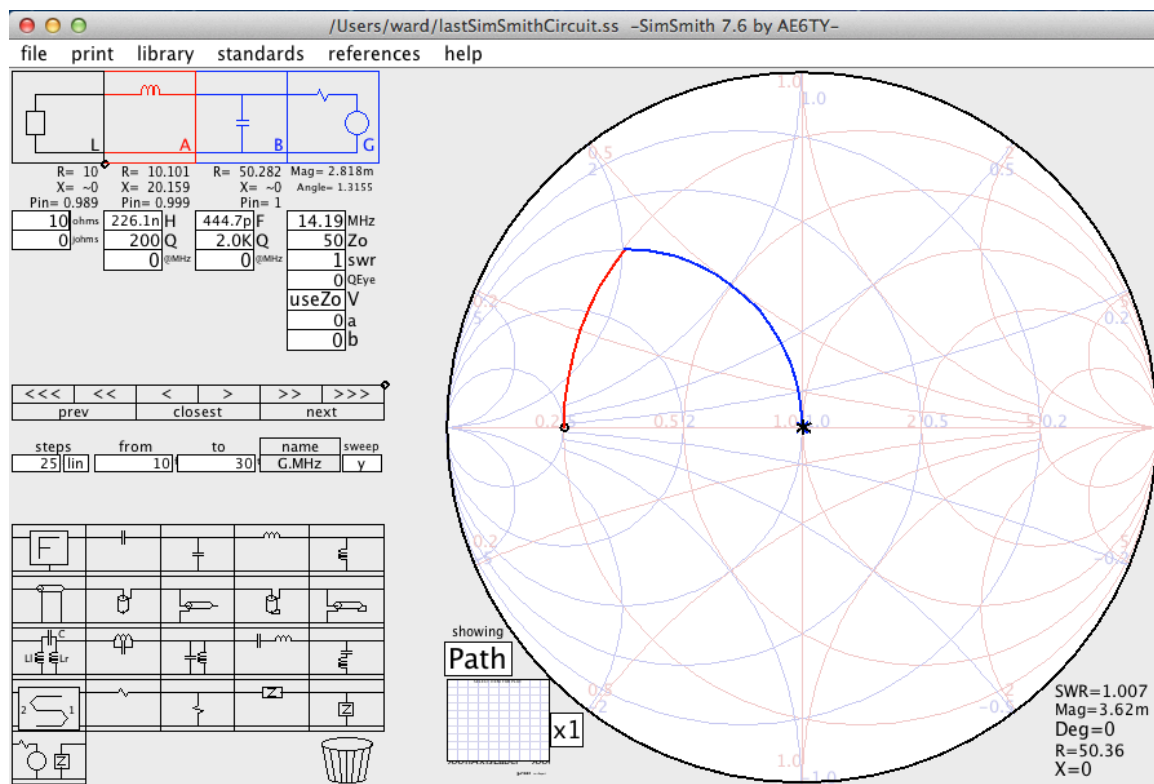
Seldom used functions are generally put in the toolbar at the top of the screen. These include the specification of a library repository, the specification of ‘standard value’ files, and ‘references’. References are discussed in detail below.

The circuit is generally constructed by dragging components from the menu on the lower left hand corner to the appropriate place in the

circuit. Items can be re-arranged in the circuit in the same way. Components can be selected from the library by clicking on the library icon at the bottom left of the screen next to the garbage can.

Items can be deleted from the circuit by dragging them to the garbage can. Items can be removed from the library in the same way. Items can also be removed by holding down the control key and left mouse clicking on the item to be removed.

SimSmith has essentially two modes of operation: 'single frequency' and 'sweep'. An example of a 'single frequency' is:

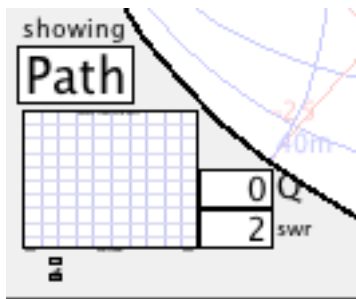


Notice that SimSmith traces the path of the impedance as it progresses from the load (at 10 ohms), through the series inductor (in red) and past the capacitor (blue). The 'showing' field indicates the display mode. Clicking on the 'Path' above will change to 'Sweep'. Clicking on 'Sweep' will change the mode to 'Both'; both the Path and Sweep traces will be displayed.

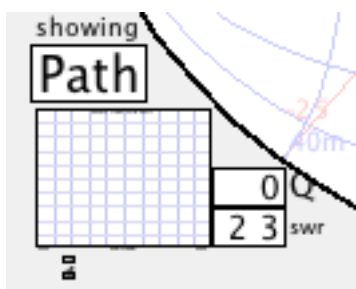
The scale of the Smith chart is controlled by the mouse wheel. Moving the mouse when will zoom in or out around the mouse location. The chart can be repositioned with the mouse by clicking and dragging the chart well away from any trace.

Clicking on the Smith chart will generate a report in the lower right hand corner of the screen. Clicking on a line will generate a report of the frequency (or other swept variable values) at that point AND highlight the associated component.

The Smith chart can display SWR circles and Q curves. The values of these curves are controlled by the parameters in the lower left hand side of the Smith Chart. Multiple SWR circles or Q curves can be displayed by specifying multiple values in the provided fields separated by whitespace. For example, to display the SWR=2 curve:



To display SWR=2 and SWR=3:



DRAG TUNING:

You can adjust the value of a component parameter simply by 'right clicking' the mouse on the associated arc of the Path display. Simply 'right click' and drag. By default, SimSmith will adjust the value of the arc selected and the arc immediately 'before' the arc selected.

Mouse right clicking on a 'Sweep' arc will change the value of the sweep variables to those necessary to reach that point in the sweep. Please see the video "IntroToSimSmithV7" parts 1 and 2 from at www.ae6ty.com/Smith_Charts.html.

NOTES BOX:

The 'file' pull down menu contains an entry called "show Notes Box". Clicking on this option will display a box. You can move this box by dragging the upper left hand corner. You can resize the box by dragging any of the other corners. For some silly reason I've been unable to deduce, if a corner falls within a parameter field you won't be able to selected it. To recover from this go to 'help' and click on: "recover Notes Box".

The box can contain multiple lines.

Clicking on the "PATH" button will change the display of the Smith chart and show how the final impedance changes as a variable is swept. Which variable is swept is controlled by the sweep menu. Here is an example of the sweep menu:

steps		from	to	name	sweep
25	lin	10	30	G.MHz	y

In this example, there is only one sweep variable which is the "MHz" parameter of the "G" or generator circuit element. This entry indicates that the G.MHz parameter will be swept from 10 to 30 MHz in 25, 'lin'ear steps. The 'y' indicates that the sweep has been enabled.

More parameters may be added by clicking on the 'name' button in the sweep menu. When you click on the 'name' button, a menu of possible sweep parameters will appear:

					L.file
					L.ohms
					L.johms
<<<	<<	<	>	>>	A.H
prev		closest		next	
					B.F
					G.a
					G.b
steps		from		to	name
25	lin	10	30	G.MHz	sweep
					y

You can 'click and drag' a parameter do the sweep menu. Here is the menu after the addition of two items:

steps		from	to	name	sweep
25	lin	10	30	G.MHz	y
25	lin	56.08n	5.608u	A.H	n
25	lin	22.43p	2.243n	B.F	n

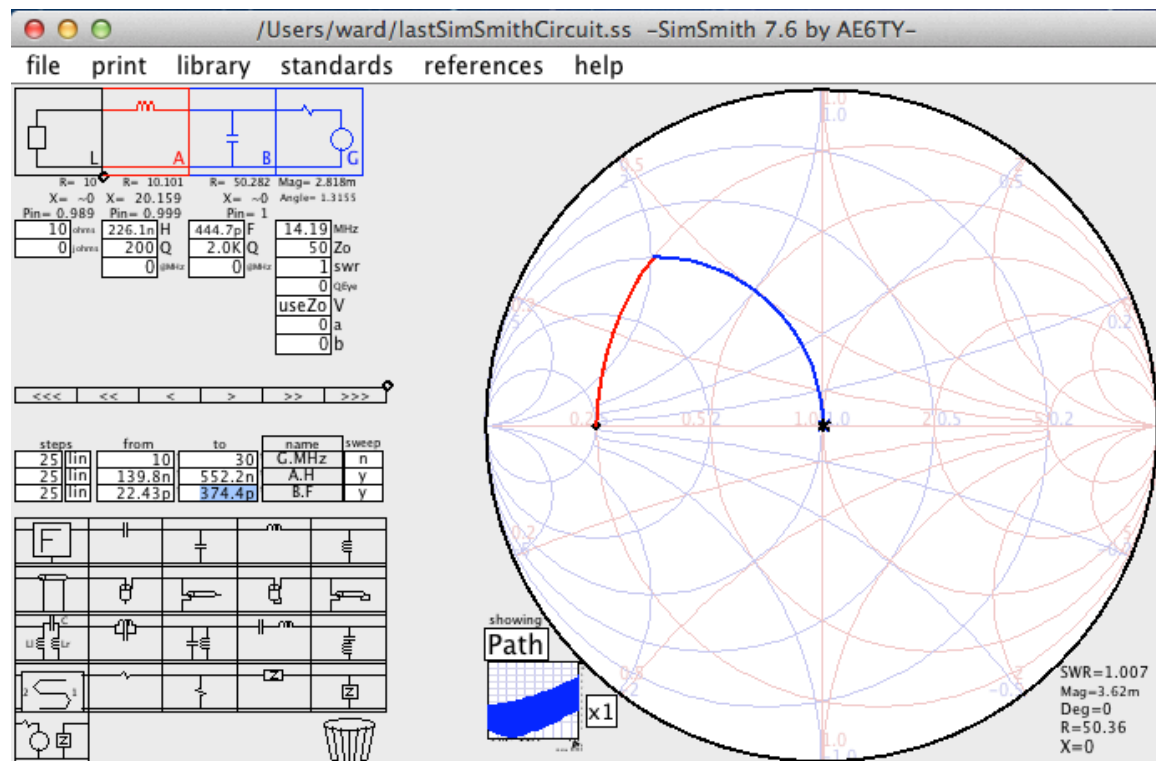
In this example there are three sweep parameters listed. However, only one is being used: G.MHz. The A.H and B.F parameters are NOT being swept as indicated by the 'n' next to their names.

Clicking on the 'y' or 'n' in the sweep column toggles the sense. Here is the menu after having clicked on the 'A.H', then the 'B.F' and then the 'G.MHz', y/n buttons:

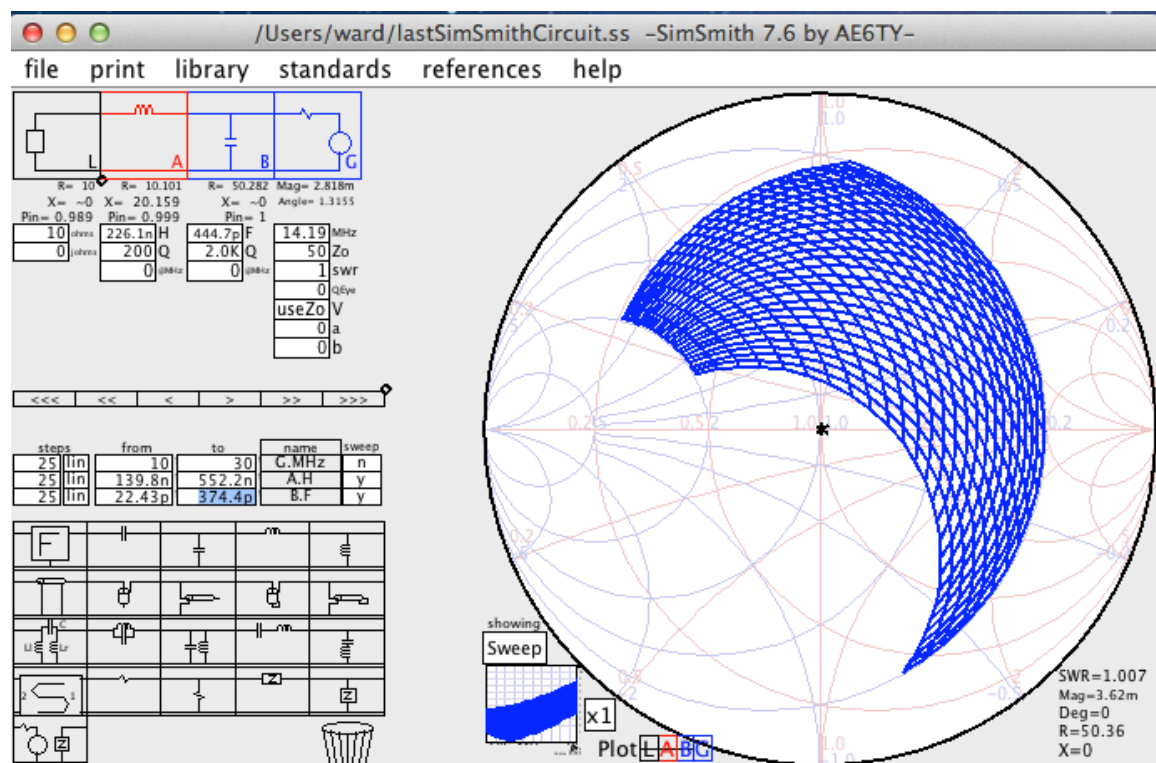
steps		from	to	name	sweep
25	lin	10	30	G.MHz	n
25	lin	139.8n	552.2n	A.H	y
25	lin	22.43p	374.4p	B.F	y

WARNING: SimSmith insists on having at least one sweep variable enabled. If you try to turn off all the sweeps then SimSmith will automatically enable "G.MHz". This can cause some confusion, if you can't seem to turn off "G.MHz" it is because there are no other sweep variables enabled and SimSmith will simply turn G.MHz back on.

Here is a complete picture of the screen after showing the "PATH" but having the two sweep variables set:



The Smith chart display can be switched to sweep mode by clicking on the 'Path' button:



During a sweep, the steps can be equally spaced (lin) or logarithmically spaced (log). You can select which is being used by clicking on the button in the 'steps' column. Of course, you can change the lower and upper bounds of the scan and the number of steps to take. You can even reverse the direction of the scan if you wish.

When displaying the Smith Chart a menu at the bottom called "plot" lists which signals can be displayed on the chart. A letter with a line through it means the signal is not being displayed. Clicking on the letter will add or remove the line thereby displaying or not displaying the signal.

You can zoom into the center of the Smith chart by clicking on the "x1" button that is found to the right of the small SWR icon on the lower left hand corner of the Smith chart; right above the "Plot" menu. (Not shown above).

FILES AS SWEEP PARAMS

Load and Scattering parameter files can be used as sweep controllers. Simply click on the 'name' button of the sweep menu, select the appropriate parameter and drag it to the sweep menu. If the sweep is enabled the frequencies specified in the file will be used for a sweep. Only one 'frequency' parameter may be enabled at a time. Thus, if you enable the "L.file" sweep parameter, SimSmith will disable the "G.MHz". If you then enable "G.MHz" then the "L.file" will be disabled.

For 'Load' files, the Sweep menu provides a secondary function. Consider the following sweep menu:

steps		from	to	name	sweep
386.93	lin	12	18	G.MHz	y
25	lin	139.8n	552.2n	B.H	n
25	lin	22.43p	374.4p	A.F	n
vertical.txt			clr	L.file	n

Here the 'L.file' parameter has been added to the sweep menu. This means that the impedance of the 'L' circuit element is being specified by the file 'vertical.txt'. This is true EVEN IN THE SWEEP IS NOT ENABLED.

To stop using the file you can remove then 'L.file' parameter from the sweep menu by dragging it to the trash can.

If you enable the sweep of the 'L.file' parameter, SimSmith will sweep the frequency based on the contents of the 'vertical.txt' file.

ONE OF TWO TYPES OF CHARTS:

The CHART section of the SimSmith window can display either the Smith chart or one of two Square charts. If the Smith chart is being displayed, a small copy of the Square chart is shown. Clicking on this small Square chart will change SimSmith from 'Smith' to 'Square' mode.

There are two types of square charts. The type of square chart being displayed is controlled by clicking on the button below the 'showing' label. The most commonly used chart is the 'SWR' chart. When the SWR chart is showing there are two menus at the bottom of the chart, one called "Pwr" and one called "SWR". Which signals traces are displayed is controlled with these menus.

The "Pwr" trace shows the power being dissipated by that component. The "SWR" trace shows just that.

The scale of an axis may be changed using the mouse wheel. Simply move the mouse pointer over the axis of interest and move the mouse wheel. The scale will move up and down accordingly. The chart is zoomed in and out around the grid line closest to the mouse.

The offset of an axis may be changed by clicking and dragging the axis up or down as desired.

The second square chart format is 'Sprm' or 'scattering parameters'. This chart displays the reflection coefficient (γ) looking in either direction. It also displays the Transfer voltage. Note that this is NOT the transfer coefficient.

The horizontal axis of the Square chart can be either "linear" or "logarithmic". The mode is selected by clicking on the button. The label of the button indicates what is being displayed (rather than what will be

displayed). Usually, if you are displaying things with a logarithmic scale you'll want your sweep to be logarithmic as well. It is not automatic, though, because this is not ALWAYS the case.

In the logarithmic scale with a descending scan range (say 10u to 10n), the logarithmic scale is 'reversed'. It can look strange and so I mention it here.

Clicking on the square chart near a line will generate a report about that point on the line. If the mouse is not close enough to a computed point, the report will not be generated; no interpolation is provided.

When displaying the Square chart you can switch to the Smith chart by click on the small Smith chart at the lower left hand corner.

Component specific notes:

TRANSMISSION LINES:

Transmission lines have 7 parameters: length in degrees at a given frequency, the given frequency, the length in feet (or meters), the velocity factor, the character impedance (only real right now), the loss in db at a given frequency and that given frequency. The formula " $\sqrt{f/f_0}$ " is used to calculate the loss at other frequencies.

Changing one value of a transmission line can cause others to change so that things remain consistent. For example, if you change the velocity factor, SimSmith will change the length to keep the 'degrees' constant. When you change the length, the degrees will change. When you change the degrees, the length will change, etc.

CAPACITORS:

Capacitors have three parameters: value, Q at a given frequency and the given frequency. The losses associated with Q do not change as a function of frequency. This means, that the MHz field is unnecessary. I leave it there for future compatibility. Specifying a Q of zero is really setting it to infinity.

INDUCTORS:

Inductors have three parameters: value, Q at a given frequency and the given frequency. The losses associated with Q go up with the

square root of frequency: $Q = Q_0 / \sqrt{F_{\text{operating}} / F_0}$. Specifying a Q of zero is really setting it to infinity.

RESISTORS:

Nothing special about resistors.

GENERATOR:

The generator is always present and is always at the right hand side of the schematic. The generator has many parameters. The Z_0 specifies the impedance of the center of the Smith chart and “SWR=1” for the SWR chart.

The MHz indicates the frequency for “PATH” displays and for the frequency at which all component impedances are presently reported on the circuit elements.

The V parameter is an equation that controls the voltage delivered by the generator. The equation can have up to four arguments whose values are controlled by the ‘a’ through ‘d’ parameters.

LOAD:

The load is always present and is always at the left hand side of the schematic. It always has two parameters showing, the ‘R’ and the ‘X’. If the ‘L.file’ parameter has been added to the sweep menu then the ‘R’ and ‘X’ fields will be grey and cannot be changed since they are being derived from the provided file.

The load file can be provided in several formats and SimSmith uses heuristics to figure out what the file format must be. These formats and the heuristics are:

- EZNEC: the EZNEC file format is recognized by observing the string “Freq MHz”, quotes included. The remainder of the file has lines of the form: srcNumber,R,X,SWR,altSWR. SimSmith pays attention to the R and X fields which are floating point numbers.
- EZNEC: SimSmith also recognizes the ‘GAM’ files produced by EZNEC. I’ve been told that the GAM file will be deprecated in the next release of EZNEC but I’ve no idea when that will be.
- miniVNA and miniVNAPro: the miniVNA file format is recognized by observing a line of the form Freq,R,X. Subsequent lines are of the form F,R,X and SimSmith pays attention to all fields which are, of course, floating point numbers.

- AIM4170: the AIM4170 file format is recognized by observing a line of the form: Freq(MHz). Subsequent lines are of the form: Freq,SWR,Rs,Xs,Zmag,Theta,Rho,ReturnLoss,%ReflectedPower. SimSmith pays attention to Freq, Rs and Xs fields which are floating point numbers.
- CocoaNEC: cocoaNet files are recognized by observing the words: NUMERICAL ELECTROMAGNETICS CODE (nec2d). The file format is verbose and I won't try to say how SimSmith extracts the Frequency, Resistance and Reactance values. Sorry.
- Kok Chen (W7AY) provides some support for the Rig Expert antenna analyzer. His '.aaplot' file format is supported by SimSmith.
- Support for "Touchstone S1P" files is provided. SimSmith looks at the extension ("s1p") to determine that it should expect a touchstone one port file.
- When an S2P file is being used to describe a load impedance, SimSmith examines the file name further. If the file name contains the string "shunt" or "shnt" or "snt" then SimSmith assumes the component was characterized in 'shunt'. Otherwise, it is assumed to have been measured in 'series'.

The easiest format to make by hand is, of course, the Freq,R,X file. A sample would be:

```
Freq,R,X
1,10,0
21,50,0
```

SimSmith does a linear interpolation to compute the load for frequencies not explicitly described. Thus, in the above example, at 11 MHz SimSmith would compute the load to be 30 ohms, real.

F BLOCK:

The F Block allows you to write equations rather than use the components. See the "F Block Syntax" button on the 'help' menu for details.

N BLOCK

The N Block allows you to enter an arbitrary netlist of RLC components. It uses numerical methods to analyze the circuit. See the “N Block Syntax” entry in the ‘help’ menu for details.

STANDARD VALUES:

The standard values for resistors, capacitors and inductors can be overridden by loading from files. The file contains comments and numbers. Comments start with “//” and continue to the end of the line. Numbers can be simple floating point numbers or engineering numbers like:

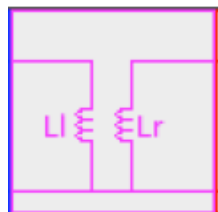
```
// comment.  
10p // another comment.  
20p 1u  
8M 2k
```

The numbers need not be in any particular order.

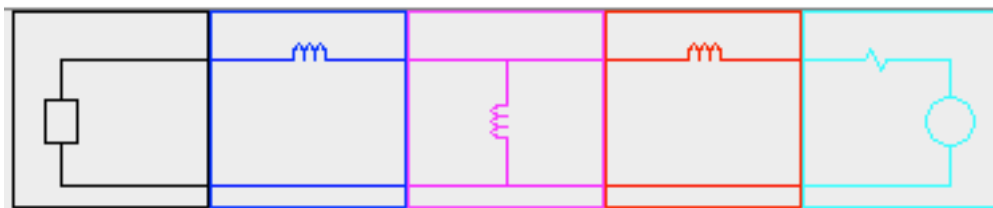
SimSmith tries to warn you if it can’t make sense of the line but it is assumed the file is well formed.

Transformers as of 4.12:

Transformers are notoriously non-ideal devices. Transformers in SimSmith are specified much the same way as is done in PSpice. You specify the inductance of the two inductors (call L_l and L_r) and the coupling coefficient ‘k’. The transformer symbol is unchanged from version 4.4 and is:



The internal model for the transformer is a T network of inductors:



La Lm Lb

Where:

$$L_m = k \sqrt{L_l L_r}$$

$$L_a = L_l - L_m$$

$$L_b = L_r - L_m$$

SimSmith's transformer is 'lossless' but distinctly NOT ideal. Ideal transformers are those in which L_m is infinite. You can, of course, set L_l and L_r so high as to make L_m practically infinite.

This model of a transformer is unfamiliar to many folks who prefer to think of transformers as more simplified devices. Specifically, if one is willing to assume k is equal to 1, then a simpler model can be used. Here, you need only specify the primary magnetizing inductance and the turns ratio.

To use this model you need only click on the 'mdl' property of the transformer circuit element. When you click on 'mdl', SimSmith will change the available parameters to 'Hr' and "n". 'n' is the turns ratio so, for example, if you have a 4->1 impedance transform the turns ratio will be 2 OR, if the transformer must be reversed, ".5".

If you don't know the primary magnetizing inductance simply set it to a big number. For example, '1' which would be one Henry... a truly large inductance.

One final note: as one might expect, the transformer also represents a difficult component to 'trace' on the smith chart. To keep things simple, SimSmith draws an arc from the input impedance to the output impedance. The arc is drawn as though the transformer were a shunt device.

S Block:

Version 4.9 adds the S block. S blocks require a TouchStone two port, S parameter file. SimSmith expects the file name extension to be "s2p". The touchstone file format allows the specification of a wide range of data and formats. The frequency units may be "HZ KH MH GH" and the data format can be "RI" "DA" and "MA".

SimSmith does a linear interpolation between provided data points. The default S block has port 1 on the right. This can be a bit disturbing but is a result of SimSmith's power flow being right to left. You can reverse the direction by clicking on the 'dir' parameter.

Z Block:

The Z block allows you to read in any 'load' file and place it anywhere in the circuit.

LIBRARY:

There are times when you develop a component (say in an F block) and you would like to save a copy of it. SimSmith provides this capability using the library function.

At the bottom of the control panel section you'll see a parameter called the 'library'. When you click on this field, you will be prompted for the file name of the library. You can make up your own file name for a new library OR provide the name of an old library. Once you do that, a new library icon will appear next to the garbage can.

To add a component from the library, simply click on this library icon, select the component you would like to add drag it to the circuit.

To add a component to the library, just drag it from the circuit and drop it on the library icon. The element will be added to the library and the library file updated.

WARNING: if you accidentally specify an existing SimSmith design as a library, SimSmith may trash that design. IT IS GENERALLY BEST TO KEEP LIBRARY AND DESIGN FILES SEPARATE. Sorry for the all caps....

You can delete things from the library by clicking on the library icon and then selecting and dragging the component to the trashcan. This will remove the component from the library and update the library file.

A few notes about the library desktop. You can't rearrange the elements on the desktop. When you add a component, it will be add to the 'end' of the library which is the lowest row and the rightmost column. SimSmith will scale things on the desktop so that they all fit no matter how many there are. Of course, if you have too many then they get unreadable.

SESSION AUTO SAVE AND RESTORE

Under normal circumstances, SimSmith keeps a copy of your last circuit in a file called "lastSimSmithCircuit???.ss" which is stored in your home directory. The ??? can change depending on the version of SimSmith you are using. If you exit a session and then restart it, SimSmith will attempt to read in this file to restore your session.

REFERENCES

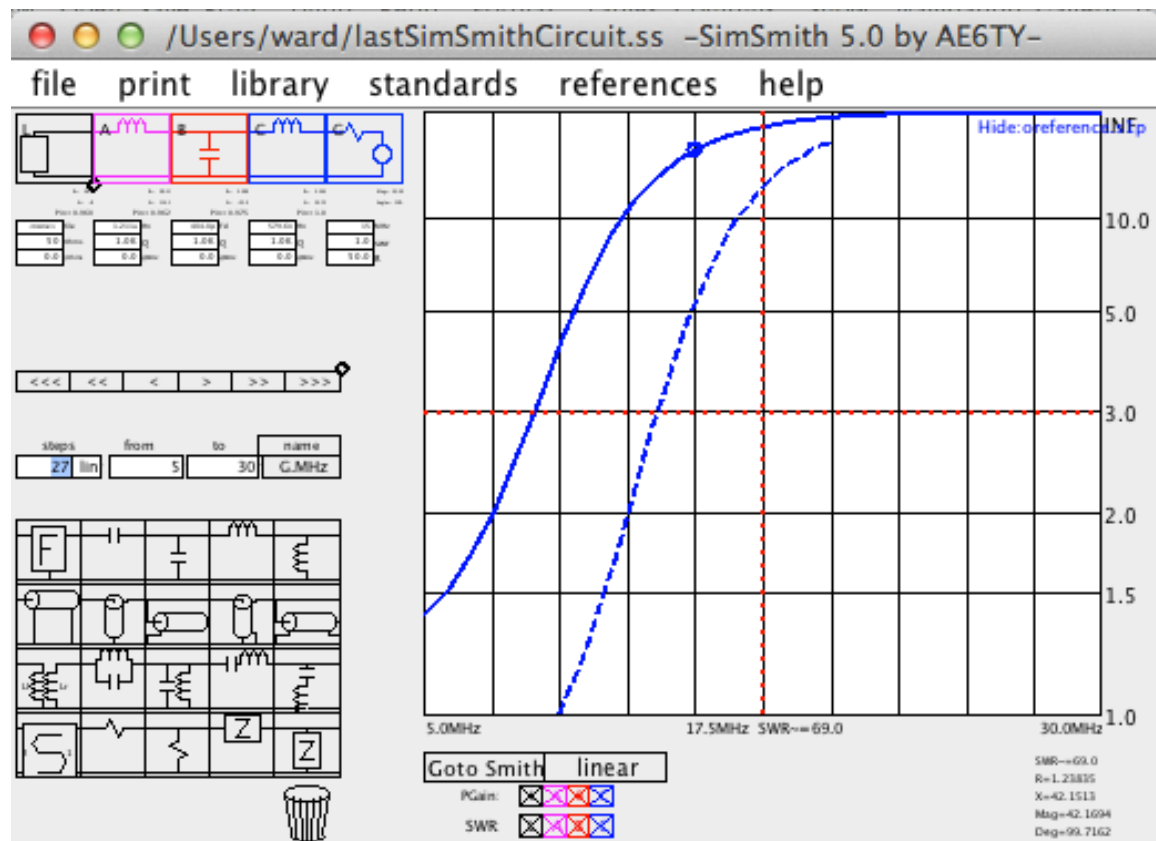
You can write out trace files and read them back in as references. You can also read in a load file of any of the supported formats including EZNEC, COCOANEC, AIM4170, miniVNA FRX files, and touchstone S1P files. Others are occasionally added. Please check the web site for a complete list.

These load files can be displayed as a 'reference' on the Smith and SWR charts. You can add a reference file by clicking on the 'reference' button of the tool bar, selecting 'add' and then selecting a file in a supported format. To remove the reference file, simply click on the 'references' button and then then appropriate 'close:...'.

The reference trace can be 'hidden' or 'displayed'. When added, the trace is always shown and named on the upper right hand part of the chart. Clicking on the name will hide it. Clicking on a 'hidden' signal will then display it.

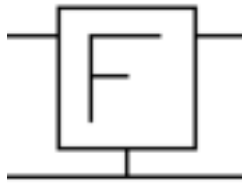
On the Smith chart, all the data of the reference chart are drawn. The lower frequency end is marked with a small dot and the upper frequency end is shown with an x. When the 'generator frequency' is within the range of the reference trace a small circle will be drawn on the reference at that frequency. If the frequency is out of range no circle will be drawn.

When displaying things on the SWR chart, the references are only shown when the horizontal axis is frequency. The reference trace may not cover the entire swept frequency. Only ranges where the data is valid are displayed. For example, below you'll see a reference which covers 10 to 20 MHz while the scan covers 5 to 30.



Please see my tutorial video “SmithTutorial7” for more details.

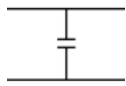
CIRCIUT ELEMENTS:



The F block is provided as an escape hatch. It allows you to write an equation for the impedance transformation. The equation syntax is described in “help/F block syntax”.



Series Capacitor.



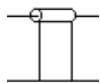
Shunt Capacitor



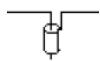
Series Inductor



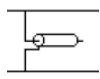
Shunt Inductor



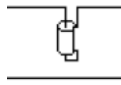
Series Transmission line. Two models are provide. The ‘Simplified’ model which takes a single loss parameter (dB/foot or dB/meter) and decomposes that loss into K0/K1/K2 as defined by Dan Maguire AC6LA. The other the K0/K1/K2 model as provided by Dan. He uses manufacturer’s data. Click on the ‘mdl’ to change models.



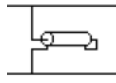
Series Open transmission line stub.



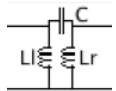
Shunt, Open transmission line stub.



Series, Shorted transmission line stub.



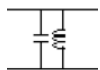
Shunt, Shorted transmission line stub.



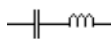
Transformer with winding/winding capacitance C . The transformer is modeled as two 'coupled' inductors. Two models are provided. The first, called 'coupled' specifies the winding inductances L_r and L_l and the coupling coefficient ' k '. The second, called 'simplified' specifies the L_r and the winding ratio. The winding ratio can be any positive number.



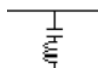
Series, Parallel LC. Commonly called a 'trap'. At resonance the impedance is very high. Losses can be important to consider.



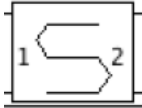
Shunt, parallel LC. This can be modeled as two independent elements. The combination is provided to simplify the circuit description and to allow for coupled 'tuning' of the LC pair.



Series, Series LC. This can be modeled as two independent elements. The combination is provided to simplify the circuit description and to allow for coupled 'turning' of the LC pair.



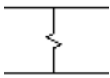
Shunt, Series LC. Sometimes called a 'trap' or a 'tuned shunt'. This circuit has very low impedance at resonance. Can be used as part of a filter circuit.



S Block. This block allows you to describe a circuit element using 'Scattering parameters'. The parameters may be specified on the element or using a 'touchstone s2p' file.



Series Resistor.



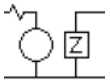
Shunt Resistor.



Series impedance. This allows you to specify a complete impedance. It is essentially a resistor except that you can specify a reactance as well. The impedance can be specified on the component or using a 'load file'. Many load file formats are supported. The best specified would be the 'touchstone s1p' file format.



Shunt impedance. This allows you to specify a complete impedance. It is essentially a resistor except that you can specify a reactance as well. The impedance can be specified on the component or using a 'load file'. Many load file formats are supported. The best specified would be the 'touchstone s1p' file format.



Generator/Load block. This block is generator to the left and a load on the right. Using this block allows you to evaluate two circuits at the same time.



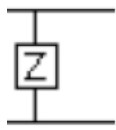
Generator. This block creates the signal entering the circuit being analyzed. You can write an equation for the voltage using the same syntax as the F block's. Three 'predefined' options are provided:

‘useZo’ which provides a Thevenin equivalent with $V_{\text{th}} = 2\sqrt{Z_0}$ and $R_{\text{th}} = Z_0$. Thus, the equation is $V = 2\sqrt{z}I/(1+z)$.

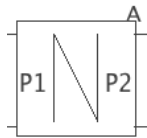
‘xMtch’ which adjusts V so that 1 watt enters the circuit. The equation is, therefore, $V = \sqrt{1/\text{Real}(1/I)}$. There may be an easier equation...

‘fixedV’ which sets $V = \sqrt{Z_0}$;

‘forXfer’ for scattering parameter transfer measurements which sets $V = 2I/(1+Z_0)$



Load. Essentially a Z with nothing connected to the left.



Network block. Enter an arbitrary netlist of RLC, independent and controlled voltage and current sources.

Touchstone S2P Files as loads

Touchstone S2P files can be used as load files. SimSmith assumes the S2P file was created using a 'shunt' test fixture.