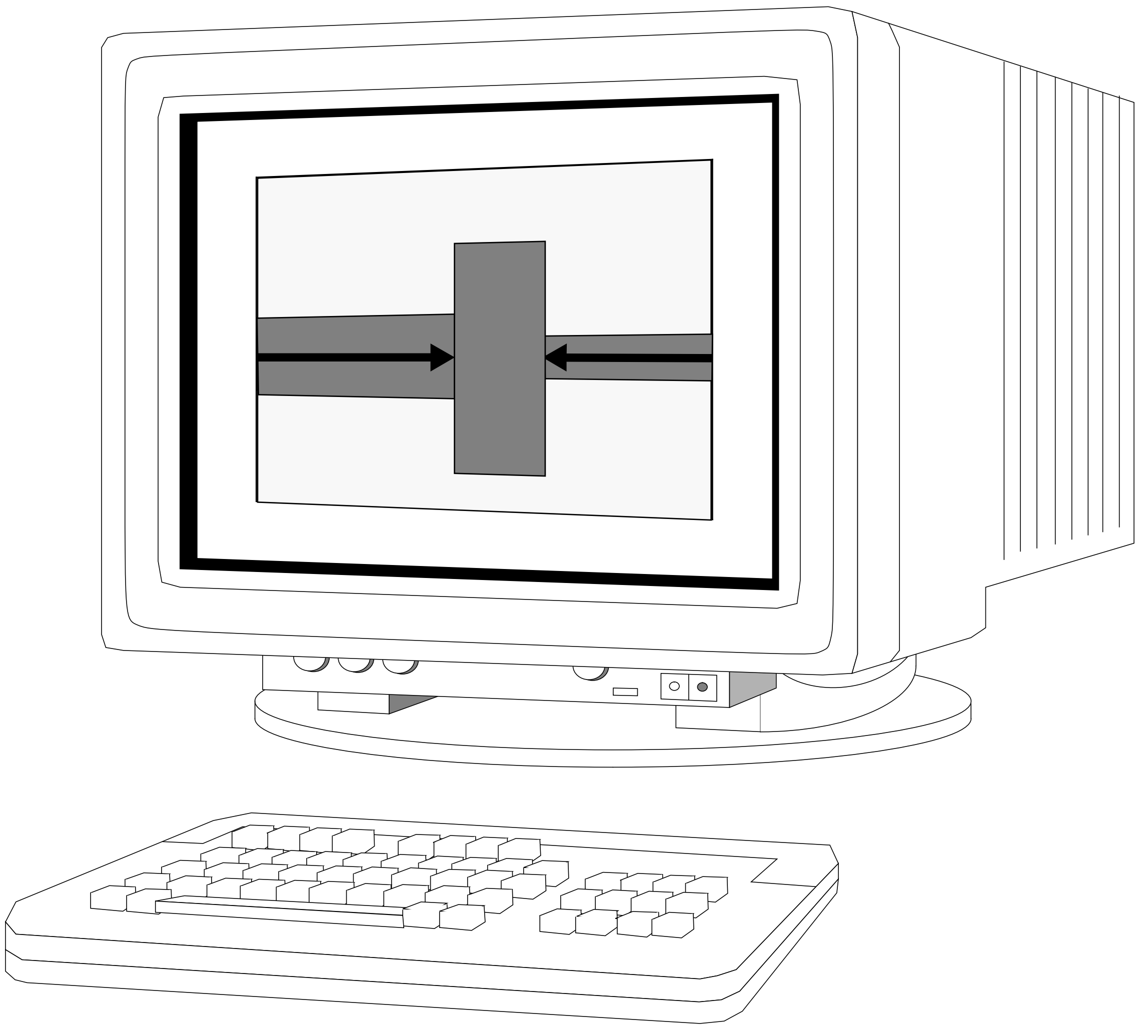
# Xgeom User's Manual



# Xgeom User's Manual

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## Release 2.4

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## Disclaimer of Warranties And Limitation of Liabilities

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# Chapter 1 Introduction

This manual is intended for microwave literate engineers who have some familiarity with computers and are interested in using ***xgeom*** and ***em*** for the precise analysis of high frequency circuits.

Familiarity with the use of X Window System is assumed. If not familiar with the X Window System, obtain documentation for your system describing the use of the X Window System. A half hour spent using the X Window System is more than adequate.

***Xgeom*** is an X Window System mouse based program used to capture microstrip circuit geometry for input to the electromagnetic analysis program, ***em***. Any X Window System based program (such as ***xgeom***) can be used on any platform in a network provided (see Appendix I, "The Xgeom Command Line"):

- The user's platform has the X Window System installed. ***Xgeom*** need not be resident on the user's platform.
- The network has at least one node on which ***xgeom*** can run.
- System networking files are set up for the X Window System.

# ♦ A Brief Overview

***Xgeom*** provides a straightforward user interface which allows specification of all needed information concerning the circuit to be analyzed. After capturing the circuit with ***xgeom*** and saving the resulting file to disk (with a name ending in ".geo"), the user may then run ***em*** using the ".geo" file as input. ***Em*** automatically subsections the circuit (using variable size subsections) and performs a complete (all effects included) electromagnetic analysis. ***Em*** saves the resulting S-Parameters, in a file format selected by the user, ready for input to major microwave design programs.

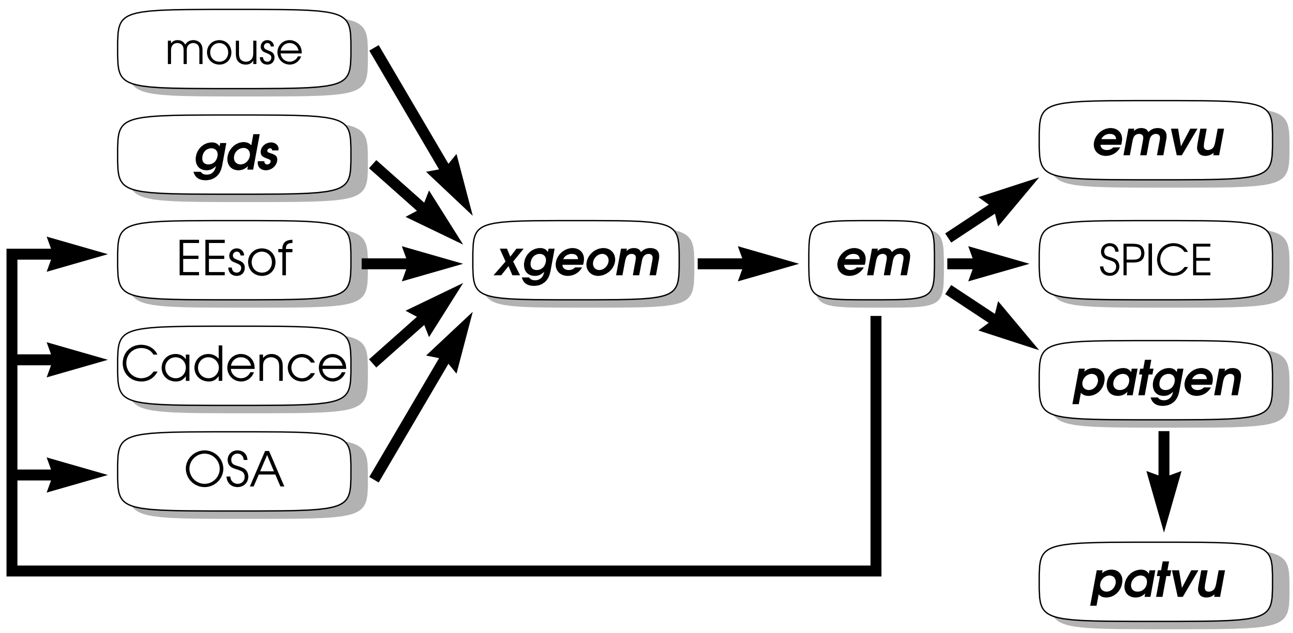



**Figure 1** Relationship of Sonnet programs. "Mouse" indicates manual capture or modification of circuit geometry. "SPICE" is any SPICE software. Other non-bold text indicates software developed by other companies which interfaces with Sonnet. Sonnet products are listed in bold. Arrows indicate data flow.

# ♦ Enhancements In This Release

Release 2.4 has many new features. Below is a summary of enhancements found in ***xgeom*** since release 2.3. Users already familiar with ***xgeom*** should refer to the cross-references.

- **Auto Save:** Every 5 minutes your work is automatically saved for you in case of a system failure. See the Appendix for more information on this command line option.

- **Easier Menus:** The dielectric and metallization menus have been enhanced. To make a change in one of these menus, you just click on the value you want to change and enter in the new value.
- **Undo:** You can undo most ***xgeom*** actions by selecting *Edit ⇒ Undo*.
- **Pan:** A new menu item, *View ⇒ Pan* allows you to pan across your circuit. See "Menu: View - Pan" on page 78.
- **Zoom Out:** A new menu item, *View ⇒ Zoom Out* has the reverse effect of *View ⇒ Zoom In,* allowing you to shrink your circuit a small amount.
- **Unselect:** A new menu item, *Select ⇒ Unselect* allows you to unselect unwanted objects that have already been selected. See "Menu: Select - Unselect" on page 77.
- **Vias:** Laying out vias has become more intuitive. In release 2.3, the via subsections (“via posts”) were sometimes added to the outside of your polygon and sometimes to the inside of your polygon. With release 2.4, the vias posts are placed inside polygons. When loading files created with release 2.3, xgeom does not automatically convert the vias. You must delete the existing vias and add the new ones back in. See "Menu: Objects - Vias" on page 70.
- **Cal Length:** This feature allows you to specify the calibration length used for de-embedding. Please note that you may specify a reference plane or a cal length for each side, but not both. See "Menu: Param - Cal. Length" on page 88.
- **Parallel Subsections:** This new feature allows the removal of X or Y subsections for a specified distance from each wall. See "Menu: Param - Parallel Subs." on page 88.
- **Subsectioning:** The method of subsectioning has changed in this release. If you have used the advanced features X,Y Min and X,Y Max for your circuits, the number of subsections created by ***em*** will change in this release.
- The default file extension “.geo” will be used if a file extension is not specified.
- The *Backspace* key functions the same as the *Delete* key.

# ♦ Software Un-Limits

A major objective of Sonnet has been to eliminate all software limits usually associated with microwave design software. As such, ***xgeom*** can capture (and ***em*** can analyze) circuits with any number of dielectric layers with any thickness, dielectric constant and loss tangent.

***Em*** can also handle metallization between any or all layers including the effect of DC and skin effect loss as well as circuits with any number of ports. ***Em*** automatically subdivides the circuit into subsections (freeing the user from this tedious task). There is no arbitrary, software specified, limit on the number of subsections.

# ♦ The Tutorial

The first few sections (Chapter 2 through Chapter 10) of this manual form a step-by-step tutorial illustrating the use of ***xgeom***, the user interface for the electromagnetic analysis ***em***. The second portion of the manual (Chapter 11 through Chapter 12) forms a guide to using ***xgeom***, to be read once you have tried a few of your own examples. The last portion (Chapter 13) of the manual forms a concise reference for ***xgeom***'s functionality, suitable for use once one has a working knowledge of the program. The tutorial section of the manual requires one to two hours to complete.

If you decide to skip the tutorial section of the manual and start using ***xgeom*** directly, please be sure there is another user nearby who is already familiar with ***xgeom***. There are a few conventions, described in the tutorial section, which are needed to use ***xgeom*** effectively.

# ♦ Conventions Used in This Manual

The following section discusses conventions used in this manual. Familiarity with the use of the X Window System is assumed. If not familiar with the X Window System, obtain documentation for your system describing the use of the X Window System. A half hour spent using the X Window System is more than adequate.

## ✧ *Xgeom* Button Menus

***Xgeom***'s functions are accessed by "pressing" the appropriate menu buttons. To "press" an ***xgeom*** button on the main menu, use the mouse to position the cursor directly on the desired button. Press and hold down the left mouse button and a menu appears. Holding the mouse button down, drag the cursor down until the desired item is highlighted. Then release the button. For example, move the mouse so that the cursor is on the *Objects* button. Press (and hold down) the left mouse button. The ***xgeom*** button is highlighted (changes color) and a menu appears. Notice that the cursor has changed its shape. To select a menu item, such as *Polygons*, move the cursor (mouse) down so that *Polygons* is highlighted and then release the left mouse button. If the button is released while the cursor is outside the menu, no action results. If, for some reason, no item on the menu is wanted, just move the cursor off the menu so that no item is highlighted and then release the mouse button. Once a main menu item is selected, a new button menu is usually displayed.

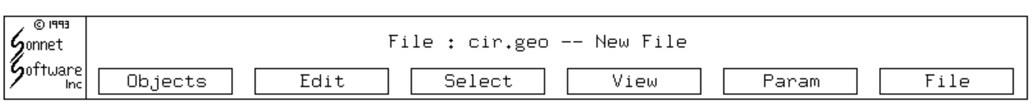



**Figure 2** ***Xgeom***'s Main Button Menu.

Please note that the main ***xgeom*** button menu is the ONLY button menu which uses “hold and drag” (i.e., holding down the mouse button and moving it before releasing). All other button menus are “click and release”. To “press” an ***xgeom*** button on all remaining button menus, use the mouse to move the cursor to the desired menu button, then press and release the left mouse button. Notice that some menu items have an ellipsis (...) after them. This means that this item calls another button menu. These menu items require more information before an action can take place. Other menu items (such as the *Metal* option under the *View* menu) have a word in angle brackets (“< >”). These items are toggles. Clicking on an item marked “<On>” turns that particular attribute off and clicking on an item marked “<Off>” turns that attribute on.

Most button menus have a *Done* or *Skip* button as the right most button. Clicking on this button returns you to the next higher menu level, eventually always ending in the main button menu.

Depending on the mode and parameters selected, some menu buttons may not be available. The text in these buttons will be a lighter color and will not become highlighted if you drag the cursor on them. In this manual, we refer to these buttons as “shadowed”. Releasing the mouse button with the cursor on a “shadowed” button will not select the menu item. You must select the appropriate mode or parameter to activate the button. In the reference section of this manual, we list which buttons are shadowed, why they are shadowed, and how to activate them. Please note that on monochrome monitors the text for the “shadowed” buttons will appear the same as the available buttons. However, the “shadowed” buttons won’t become highlighted and can’t be selected.

Occasionally, keyboard input is required. In this case, an appropriate prompt appears on the button menu and anything you type appears there also. Pressing the *Return* key without typing anything leaves the present value of the parameter unchanged.

## ✧ Clicking on a Button

When we tell you to click on a menu button, you should use the mouse to move the cursor to the desired menu button, then press and release the left mouse button.

## ✧ Describing Button Presses

In the rest of this manual, we describe accessing the menu items of ***xgeom*** using a “pointer” description to illustrate selecting the desired menu buttons.

For example, *Objects* $\Rightarrow$ *Polygons* $\Rightarrow$ *Add* means to move the cursor to the *Objects* button in the main button menu, press (and hold down) the left mouse button, drag the cursor down the menu which appears until *Polygons* is highlighted, and release the mouse button. When the new button menu appears, click on *Add*.

## ✧ Shortcut Keys

Some menu buttons have a shortcut associated with them. These menu buttons can be “pressed” by typing the associated shortcut key. Shortcuts are shown in parentheses at the end of the name of the menu item. Typing the shortcut key has the same effect as “pressing” the menu button but you don’t need to go through the menus. Most of the shortcut keys are “control” keys, i.e. you must first hold down the *Control* key, and then press the key. The “control” keys are abbreviated with a “^” symbol. Any time you see a “^” symbol before a letter, e.g., “^U”, you should interpret this as meaning a control key. As an example, to type a Control-U (^U), hold down the *Control* key and press the *U* key. A list of the shortcut keys is found in section "Keyboard Shortcuts" on page 91 of this manual.

# Chapter 2 Getting Started

For Unix systems, log into your account. At this point, system specific actions may be required which are not described here. If needed, consult your system administrator.

Now make and change to a new directory, type:

**mkdir test**

**cd test**

If this is unfamiliar, see Appendix IV, "Summary of Unix Commands" in the ***Em*** **User's Manual** or seek assistance from another user or the system administrator.

Next, if the X Window System is not already automatically running, start it. For Unix systems, a (system specific) command like “xstart”, “x11start”,”xinit”, “openwin” or “motif” should do it. For MS-DOS systems, ‘dvx’ should start it. If not, again, seek assistance from another user or the system administrator.

There are several window systems, which provide a friendly “look and feel”, built on top of the X Window System. These include Motif, OpenWindows and DESQview/X. Not included are proprietary window systems such as Sun View, which is, or will soon be, obsolete.

# ♦ Running *Xgeom*

Once the X Window System is started, you can start ***xgeom***, provided it has been properly installed (as described in the **Sonnet Installation Manual**). For the first example, type the following command line:

**xgeom steps.geo**

When you press the *Return* key, ***xgeom*** starts and the display should appear on your screen (See Figure 3). Since "steps.geo" is a new file, there is no circuit. The window displays only the square outline of the default substrate (as viewed from above).

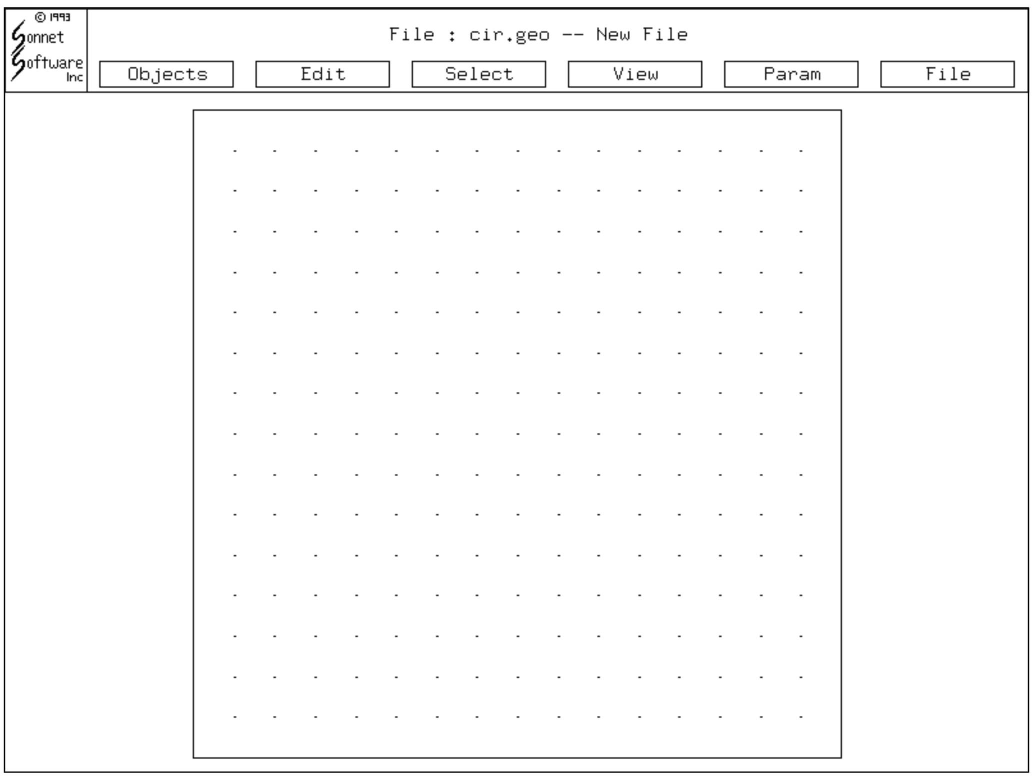



**Figure 3** The ***xgeom*** window just after starting up with no pre-existing circuit.

On the screen, a grid is displayed as a set of small dots. The dots mark the corners of each cell. ***Em*** divides the metallization into small variable size subsections. Each subsection is made up of one or more cells.

# ♦ The *Xgeom* Command Line

The ".geo" at the end of the file name indicates a Circuit Geometry File which is used for input to ***em***. All information about the microstrip circuit to be analyzed is stored by ***xgeom*** in this file. The file name is not required to end in ".geo", but it is recommended. If you don't specify a file extension, ***xgeom*** will automatically use ".geo".

There are numerous command line options available for ***xgeom***. They can be used to set, for example, window size and location, background and foreground colors, etc. These options are detailed in Appendix I, "The Xgeom Command Line".

# Chapter 3 How Does *Xgeom* Work?

With ***xgeom*** displayed on your screen you may start capturing a circuit (see Figure 4). At the top left hand corner of the window is the Sonnet Software logo. ***Xgeom***'s main button menu occupies the remainder of the top of the window. Why is it called a button menu? Note the six small labeled rectangles, the first one is labeled *Objects*.

Each of the six rectangles is called a button.

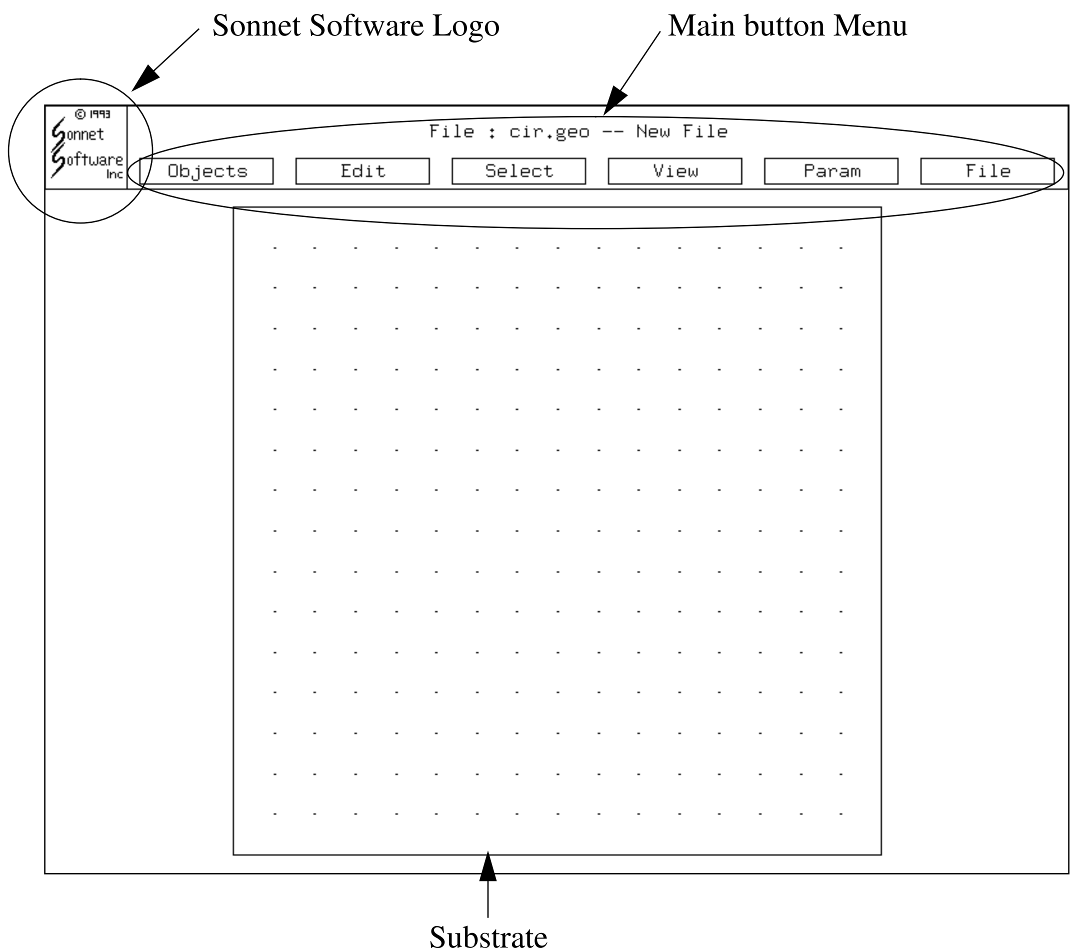



**Figure 4** ***Xgeom***'s window provides the tools to draw a microstrip circuit.

# ♦ For a Little More Room

If you need more room on the display for your circuit, you can either increase the size of the window (see your X Window System documentation) or click on the logo (upper left corner). A click on the logo turns the main button menu off. A second click turns it back on.

The microstrip circuit is displayed in the rest of the ***xgeom*** window. Since we are starting fresh, only the edges of the microstrip substrate are displayed, the circuit has not yet been entered.

# Chapter 4 Specifying Box Parameters

The next few chapters form a step-by-step tutorial illustrating the use of ***xgeom.*** The tutorial describes how to capture a microstrip dual-step discontinuity enclosed in a six sided metal box. If you want to know what the final circuit is going to look like, see Figure 13 on page 32.

Before drawing the circuit, we must specify the parameters of the enclosing box, which includes the dimensions of the microstrip substrate. To do so, use the mouse to move the cursor to the *Param* button (in the main button menu). Press and hold the left mouse button. When the button is pressed, a menu appears below the *Param* button (note that the cursor has changed shape). While holding the left mouse button down, drag the cursor down until the *Box* item is highlighted and then release the button. The *Box* button menu (see Figure 5) appears, replacing the main button menu.

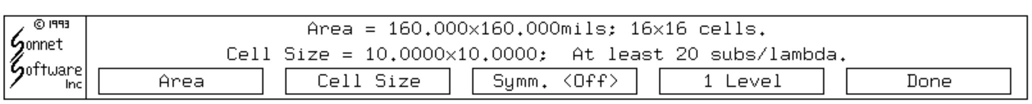



**Figure 5** The box selection button menu allows specification of substrate size, as well as other box parameters.

To illustrate the use of the box selections, move the cursor to the *Area* button. Click (i.e., press and release) the left mouse button. Another button menu appears. At this point you have the option of entering the box dimensions by using the mouse or by typing in the coordinates from the keyboard. Click on *Keyboard*. ***Xgeom*** allows you to hold either the number of cells or the cell size constant when changing the area. For this example, click on *# of Cells* to keep the number of cells constant. The button menu is then replaced by a prompt asking for the desired X (horizontal) dimension of the substrate. The prompt also informs you of the present X dimension.

For this example, we want a substrate of 160 mils by 170 mils. To leave the X dimension of the substrate at the default 160 mils, just press the *Return* key. Just pressing *Return* without typing anything else causes the present value to remain unchanged. This is typical of ***xgeom*** prompts.

Set the Y (vertical) dimension of the substrate by typing the number "170" and pressing the *Return* key. The cursor location is not critical. Note that all dimensions in our example are in mils. We will discuss later how to change the default units.

After both prompts are answered, the button menu returns to the original box display, (see Figure 5). Do not click on *Done* yet. We must still set the cell size.

# ♦ Setting the Smallest Subsection Size

There is one more option to set before we are done with *Param ⇒ Box*, and that is the *Cell Size* option (*Param ⇒ Box ⇒ Cell Size*). Click on the *Cell Size* option and the display in Figure 6 is presented.

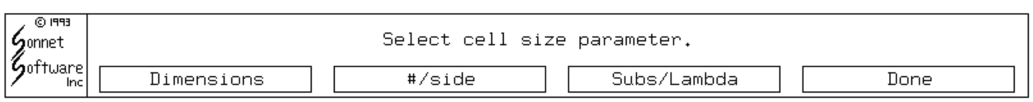



**Figure 6** The *Cell Size* option allows specification of the resolution to which ***em*** subsections the circuit.

The electromagnetic analysis starts by automatically subdividing your circuit into small rectangular subsections. ***Em*** uses variable size subsections. Small subsections are used where needed and larger subsections are used where the analysis does not need small subsections. The smaller the subsections are made, the more accurate the result is and the longer it takes to get the result. This menu gives you control over the size of these subsections.

A "cell" is the basic building block of all subsections, and each subsection is "built" from one or more cells. Thus a subsection may be as small as one cell or may be multiple cells long or wide. Thus the "Dimensions" of a cell determine the minimum subsection size.

Note that the dimensions of a cell need not be a “round” number. For example, if you want to analyze a line that is 9.5 mils wide, you need not set your cell dimension to 0.5 mils. You may want to set it to 4.75 mils (9.5 mils divided by 2) or 3.16667 mils (9.5 mils divided by 3). This will speed up the analysis because less subsections will be used. Also, the X dimension of the cell does not need to be the same as the Y dimension.

When viewing your substrate, notice that ***xgeom*** displays a grid made up of regularly spaced dots. The distance between each grid point is the cell size.

The first two cell size options (*Dimensions* and *#/side*) perform the same function, setting cell size, in two different ways. The *Dimensions* option allows the specification of actual cell dimensions. Since an integer number of cells must fit on the substrate, the closest dimension allowing an integer number of cells is then actually used.

The *#/side* cell size option lets you specify the (integer) number of cells per substrate side, thus implicitly specifying the cell size.

For our example, select either option. For *Dimensions*, specify 10 mils for both X and Y dimensions. For *#/side*, specify 16 per X side and 17 per Y side. Once you have set one of the two options, the other need not be used.

With these numbers, a very fast, yet accurate analysis results. If more accuracy or a more intricate geometry is desired, *#/side* can be as large as several hundred (several thousand in special cases). When the number of cells per side is large, selection of a power of two provides ***em*** with a slight speed increase.

# ♦ Setting the Largest Subsection Size

The third Cell Size button, *Subs/Lambda*, specifies the largest permissible subsection size. ***Em*** subdivides the circuit into the smallest possible subsections at the edges of the circuit and uses larger subsections on the interior. This option limits the largest subsection size in terms of subsections/wavelength, where the wavelength is calculated by ***em*** at run time. The default of 20 is fine for most work. Increasing this number decreases the maximum subsection size until the limit of 1 subsection = 1 cell is reached.

The *Dimensions* and the *#/side* buttons set the smallest possible subsection size. If the *Subs/Lambda* value requires a subsection size smaller than the cell size as set in *#/Side* or *Dimensions*, the *Subs/Lambda* figure is ignored and all subsections are the same (smallest) size equal to one cell.

After specifying the cell size, ***xgeom*** automatically returns to the *Box* menu. For this circuit, do not change the default value for the *Subs/Lambda*.

# ♦ Circuit Symmetry

The circuit we are to specify has symmetry, but we won't take advantage of it right away, so make sure one of the buttons is labeled *Symm. <Off>*. If it is labeled *Symm. <On>* instead, just click on it to toggle it to *Symm. <Off>*.

# ♦ Number of Levels

***Em*** and ***xgeom*** can handle any number of metallization levels, but since we are dealing with only one level of metallization (two dielectric layers) leave the *1 Level* button as it is. We typically refer to metallization "levels" and dielectric "layers". Each metallization level is sandwiched between two dielectric layers. When you are in the main button menu, you are viewing a metallization level of your circuit.

We are now finished specifying the box geometry, click on *Done* and the main button menu returns (see Figure 3 on page 8).

# Chapter 5 Specifying the Substrate Parameters

From the main button menu, select *Param* ⇒ *Dielectric* (see Figure 7). You are now looking at an approximate “side view” of your circuit, showing two dielectric layers. Between these two layers is a single metal level, called “0”. This is where your microstrip circuit metal will go.

Remember that ***em*** analyzes the circuit in a six-sided metal box. All six sides are set to 0 volts (ground).

All the parameters of the dielectric layers are called out in the main portion of the ***xgeom*** window. Be sure the top layer is highlighted, if not click on *Next*. With the parameters of the top layer highlighted (i.e., foreground and background colors reversed), click on *Param*. You are then prompted for the thickness, dielectric constant (Erel), and loss tangent.

Now type a large number for the thickness, say “100”, and press the *Return* key. Press the *Return* key two more times to leave the relative dielectric constant at 1.0 (because this dielectric is air) and loss tangent at 0.0 (lossless).

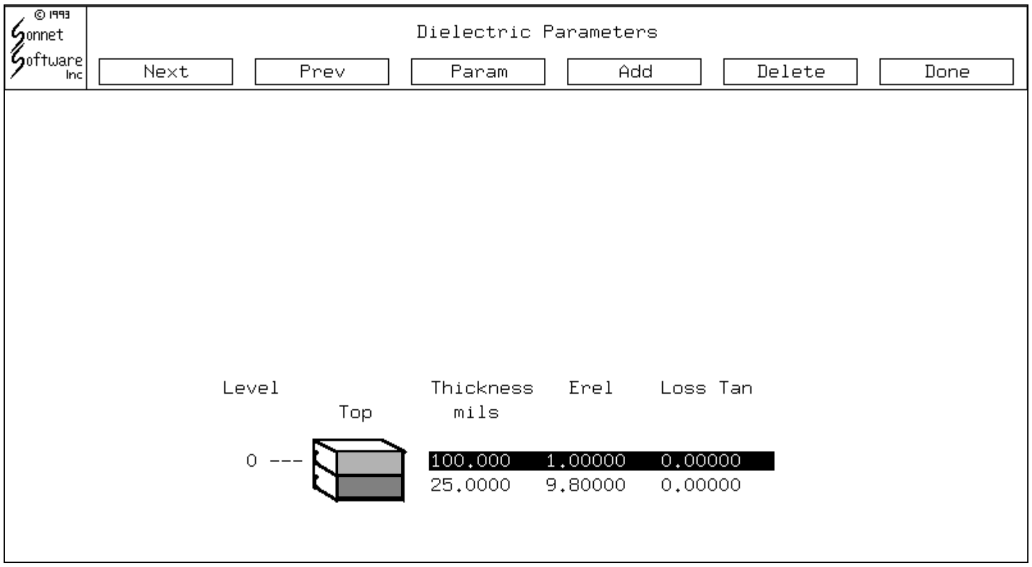



**Figure 7** The ***xgeom*** dielectric menu provides access to layer thickness, dielectric constant and loss for any number of layers.

# ♦ Air is One of the Two Layers

Why is this dielectric layer so thick? It is the air above the actual microstrip. The layer thickness has absolutely no impact on execution time or accuracy, it can be anything at all (polarization charge effects for thicknesses less than a few hundred Angstroms are not included). Remember, the analysis is done inside of a six-sided metal box, so there is a metal top cover above the 100 mils of air. Specifying a small number for this thickness moves the top cover closer to the circuit metallization, providing stronger coupling between the top cover and the circuit metallization. If you do not know the actual dimensions of the box, or if you do not have a top cover, a good rule of thumb for microstrip is to set the air thickness to several (3-5) substrate thicknesses.

# ♦ Clicking on a Parameter Value

Another way of specifying dielectric parameters is to click on the actual value, and simply type in the new value. In our example, we want a 25 mil thick alumina (Erel = 9.8) substrate. Click on the “0.0” value specified under the “Thickness” column for the lower dielectric. You are prompted for a new value for thickness. Type in “25”. In a similar way, change the Erel for the lower dielectric from 1.00000 to 9.8. When finished, click on *Done*.

Note that the thickness of each layer must be specified. If not, the default value, 0.0, causes ***em*** to complain and refuse to analyze the circuit.

The number of dielectric layers is unlimited. To change the number of layers, click on “Add” and add the number of layers that you want. If there are more layers than can appear on the screen, ***xgeom*** scrolls the display as needed.

When finished, click on *Done* to get back to the main button menu. We now have a 25 mil Alumina substrate 160 mils long and 170 mils wide, enclosed in a box 125 mils high. We are ready to set up a circuit.

# Chapter 6 A Trial Run

To get an idea of how ***xgeom*** works, this section describes how to draw a simple rectangle. This involves setting the active mode to “Add Polygons”, starting the polygon, drawing the polygon and finishing the polygon. When complete, the rectangle is removed so the actual circuit can be drawn.

# ♦ To Capture a Polygon

To set the active Objects option, select *Objects* ⇒ *Polygons* ⇒ *Add*. The result of your selection is displayed at the top of the ***xgeom*** window. To capture a rectangular polygon, move the cursor to the first point and click (press and release) the left mouse button. The exact location is not important. A small "X" appears highlighting the first point of your polygon (see Figure 8).

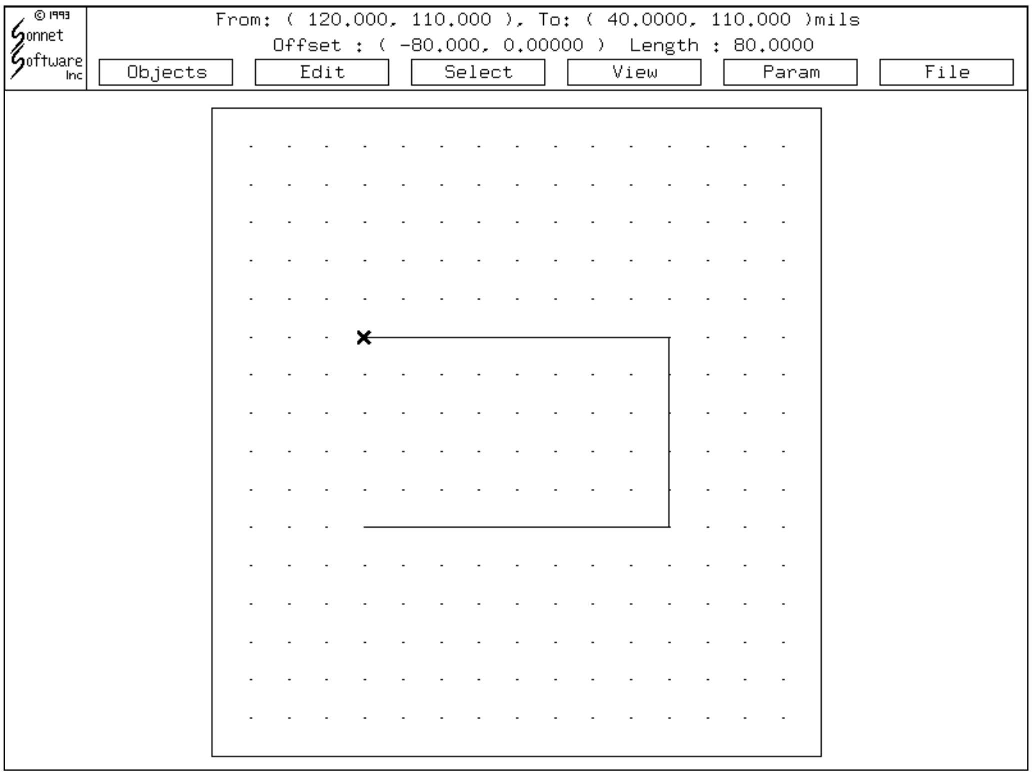



**Figure 8** Capturing a rectangle, in progress above, is effected with *Objects* ⇒ *Polygons* ⇒ *Add*.

Note that all points are snapped to the cell grid. There are other snap options available (see section "Menu: Param - Snap" on page 87). If you want to capture a circuit to, say, the nearest mil, we recommend you use this option.

Next, move the cursor to the next corner of the rectangle and click again. If you want to see where the line is going to be drawn, hold the left mouse button down and move the mouse. As you move the mouse, a "rubber band" appears, showing how the line will be drawn. When satisfied, release the mouse button. Repeat for each corner of the rectangle.

# ♦ Two Ways to Finish a Polygon

As long as the first point is highlighted with a small "x", ***xgeom*** is still adding a polygon. There are two ways to tell ***xgeom*** that you are finished. One way to finish a polygon is to add a final point on top of the polygon's first point.The polygon is finished immediately.

A second way is to click a second time on the same point and ***xgeom*** finishes by drawing the closing line segment (from the last double-clicked point to the first point).

# ♦ Clearing Your Circuit

When finished (and the first point is no longer highlighted), select *File* ⇒ *Clear*, answer the verification question at the top of the screen and proceed to enter a real circuit as described next.

# Chapter 7 Drawing a Circuit

In order to draw, you need to be in the “Add Polygons” mode. If you have been following the tutorial, you are probably still in this mode. However, if you are not sure, select *Objects* ⇒ *Polygons* ⇒ *Add*. There are many *Objects* options. We discuss only a few here, but that should be enough to get the general idea.

After selecting this option, the main button menu returns and displays the active mode as being “Add Polygons”. The active mode specifies what happens when the left mouse button is clicked on the substrate. In this case, it adds a polygon to the circuit.

If an error is made while drawing the circuit, press the *Delete* or *Backspace* key. This deletes the last point added. See Chapter 11, "Editing Your Circuit", for more details.

# ♦ Metal Goes All the Way to the Edge

The circuit we are going to capture is the step discontinuity circuit (see Figure 9). Note where the metal goes all the way to the edge of the substrate (the fill pattern on your computer might not be the same as shown). This is important because ports always go on the edge of the substrate.

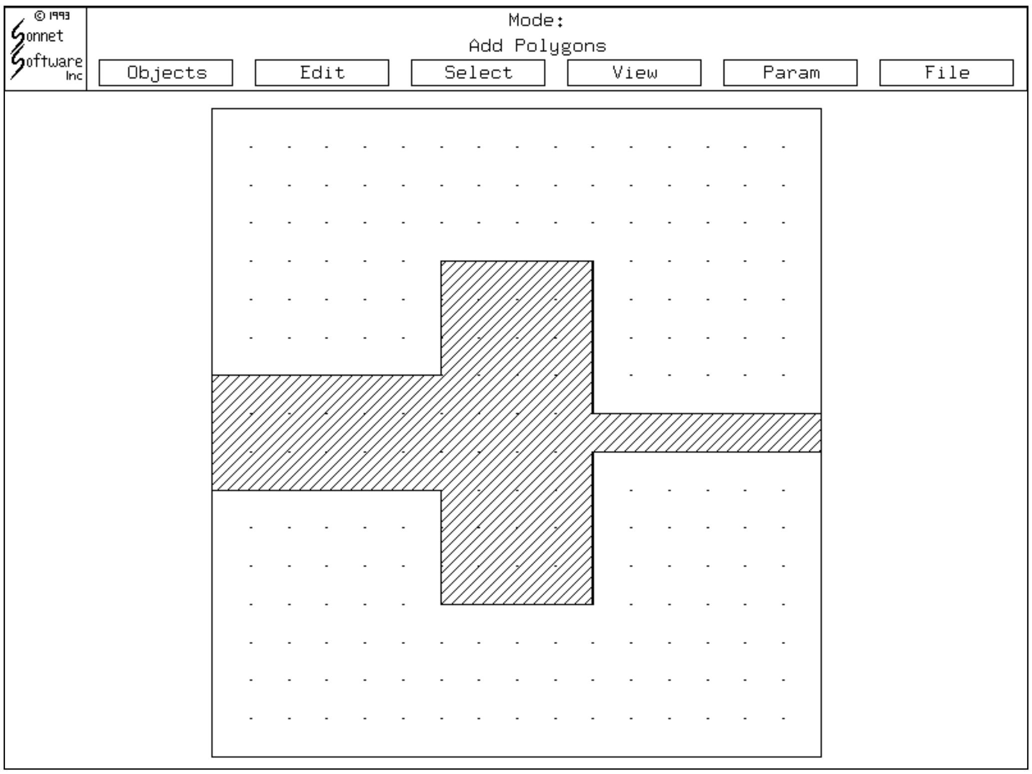



**Figure 9** The “steps.geo” circuit metallization outline complete.

# ♦ Click on Each Corner of the Circuit

First, pick one corner of the circuit. Move the cursor to that location and click (press and release, there is no need to hold the mouse button down). All you need to do is position the cursor close to the desired point (see Figure 10). As with all points, it is snapped to the cell grid. There are several other snap options, see section "Menu: Param - Snap" on page 87.

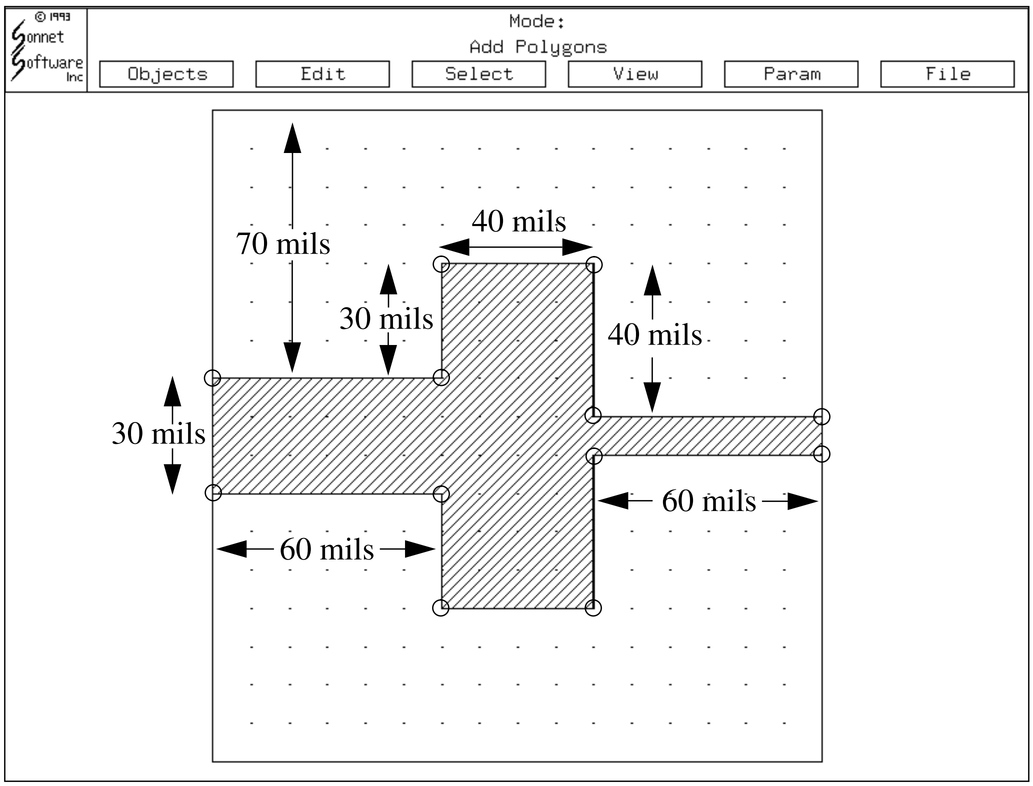



**Figure 10** Enter in the above circuit with the specified dimensions. Click on the vertices shown above. (Each cell is 10 mils by 10 mils).

A small “x” is drawn at the first point you click on, identifying it as the starting point.

Move to the next corner of the polygon. When you get close, click the mouse button. Repeat for each point. Do not click on each point of the displayed grid. Click only on the corners of the polygon. If an error is made while adding a polygon, you may press the *Delete* or *Backspace* key and the last point entered is deleted. If you are having trouble clicking on the exact location, the following section may help.

# ♦ Rubber Banding the Next Point

If you want to see where the next line segment is going before adding the next point, press the mouse button and hold it down. As you move the mouse, a “rubber band” follows the cursor along showing how the next line will snap. At the top of your screen, ***xgeom*** displays the distance from the previous point. When satisfied with the location, release the mouse button. This is the only time you must hold the button down while drawing polygons.

While using the rubber band feature, you may notice that the top of the ***xgeom*** window changes to show several sets of numbers (see Figure 11). As you move your cursor you will notice that the numbers are constantly updated. The field of interest in this example is the “offset” field. The offset field gives the x- and y-coordinates of your cursor with respect to the last point entered. This feature can be very useful in completing the example. For example, to enter a point that is 50 mils to the right of the last point, move the cursor until the offset field reads “( 50.000,    0.0 )”.

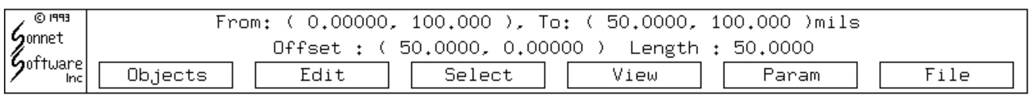



**Figure 11** The “offset” field is constantly updated while using the rubber band feature.

# ♦ Circuit Outline is Finished

One way to let ***xgeom*** know the polygon is complete is to click one final time on top of the first (highlighted) point.

After terminating input for the polygon, ***xgeom*** redraws the circuit and fills in the cells which ***em*** uses. In our example, the outline we entered falls everywhere on a cell boundary. If there were, say, a diagonal line, ***em*** does the best “staircase” approximation to the given circuit geometry.

# Chapter 8 Specifying Ports

With the circuit outline specified (see Figure 9 on page 26), circuit ports may now be called out. Select *Objects* $\Rightarrow$ *Ports* $\Rightarrow$ *Add*.

All circuit ports should fall on the edge of the substrate. This is so they have access to ground (i.e., the sidewall of the box). A port which is not on the edge does not have access to ground. This situation has the physical equivalent of a coaxial (to microstrip) connector with the outer shield left unconnected. Strange things happen. Place ports on the edge of the substrate (there is an exception for advanced users described section "Menu: Objects - Ports" on page 66).

With *Objects* ⇒ *Ports* ⇒ *Add* selected, move the cursor to the desired location of the first port and click the left mouse button. The circuit is redrawn with port 1 labeled. Do the same for port 2 (see Figure 12).

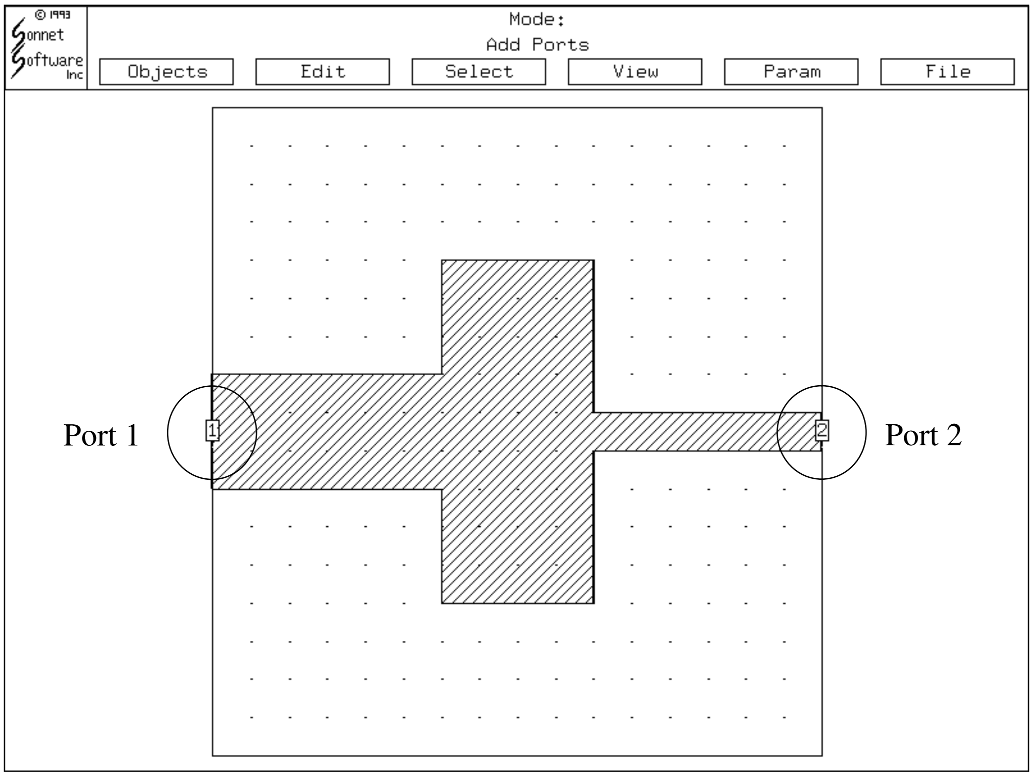



**Figure 12** The "steps.geo" circuit with ports installed.

# Chapter 9 Setting Reference Planes

To complete the circuit we specify reference planes. Reference planes are frequently needed when analyzing discontinuities. In this case, we wish to remove the length of transmission line between the port on the edge of the substrate and the discontinuity of interest. The length of line to be removed is specified by the selected reference plane. Select *Objects ⇒ Ref. Planes*. There is no secondary button menu - the main button menu remains after the option is selected. In specifying a reference plane, the end of the reference plane is specified first, by clicking inside the box at the location of the desired reference plane. Then a new button menu appears and you may select from which side of the box the reference plane is to extend.

For this example, move the mouse so that the cursor is near the face of the first step. Click the left mouse button. Now, a new button menu appears. We want this reference plane to be associated with the left side (the port 1 side) so click on the *Left* button. Set the port 2 reference plane in a similar manner (see Figure 13).

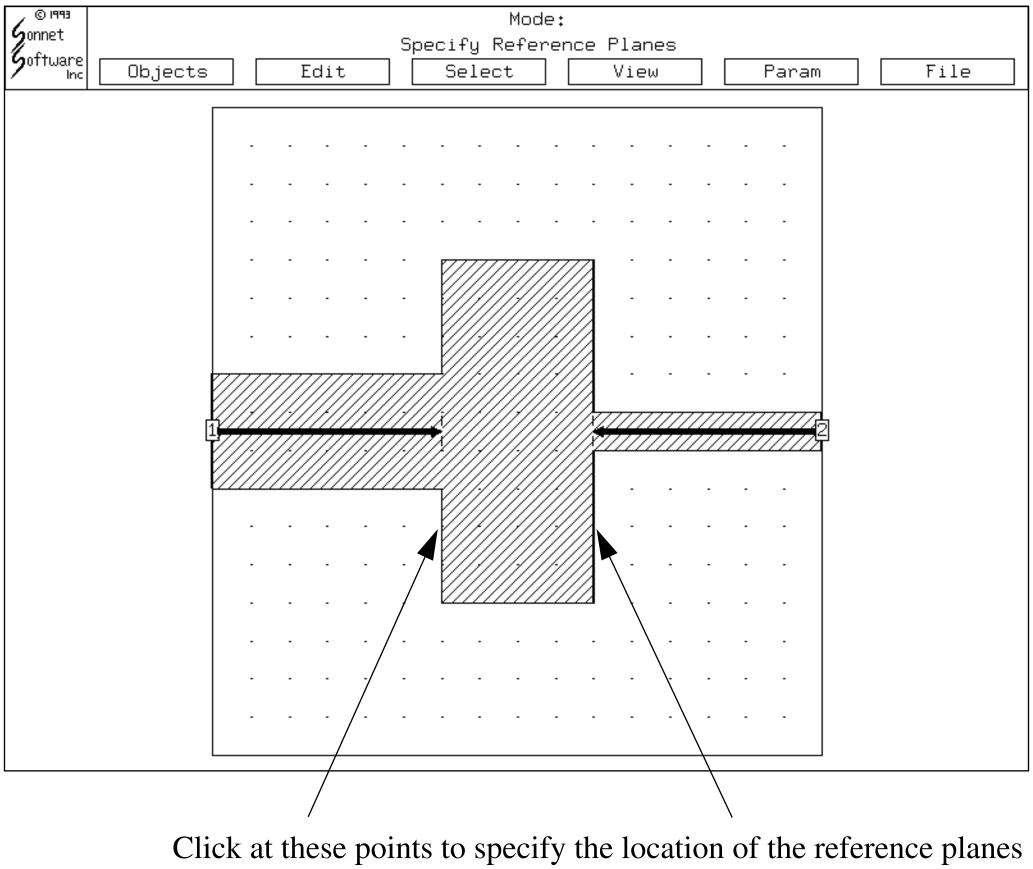



**Figure 13** The complete circuit, with ports and reference planes installed, is used as an example in the ***Em*** **User's Manual**.

# ♦ Removing Reference Planes

If you want to remove a reference plane, select *Objects* ⇒ *Ref. Planes* and click just outside the box on the side that you want removed. When the reference plane button menu is displayed, select the side for which you want the reference plane removed.

# Chapter 10 Saving the Circuit on Disk

With the circuit complete, the next operation is to save the circuit on disk. Select *File* ⇒ *Save*. The resulting button menu gives you a choice of the present file name “steps.geo”, *Another Name*, or, in case you select this option by mistake, a *Skip* option to bail out.

Select the default name, “steps.geo”, by clicking the mouse on the button so labeled.

## ♦ Adding Comments to the File

The next prompt asks if you want to store the existing comments without change. Any comments stored in the “.geo” file are copied by ***em*** into ***em***’s Output Data File. This can be helpful when it comes time to track down just where a specific result came from and what it means. ***Em*** also generates a number of comments automatically, but they are no substitute for your own comments.

Since this is a new file, there are not yet any comments. If you select *Yes*, the existing comments are stored, without change, in the file. If there are no existing comments (which is our case), then, no comments are stored in the new file.

If you want to add or change comments, select *Add/Change*. This option lets you review and modify (or delete) each existing comment. When finished, ***xgeom*** asks for any new comments. In our case, there are no existing comments, so ***xgeom*** immediately asks for new comments. You may enter as many comments as you want (this is in keeping with our “No Limits” philosophy).

When finished, just press *Return* (without entering any comment) and the file is saved on disk.

# ♦ Wrapping Up

Having completed your first microstrip circuit using ***xgeom***, you may wish to proceed directly to the ***Em*** **User’s Manual** and use “steps.geo” in the first example there.

Alternatively, you can continue with this manual. What remains is information on using more features of ***xgeom***. Chapter 11, "Editing Your Circuit", contains information on how to manipulate polygons and points. Chapter 12, "Using Vias", describes how to connect metal between layers or to ground. Chapter 13, "Function Reference", contains concise reference information that allows you to quickly take advantage of ***xgeom***’s full functionality. This includes measuring distances, keyboard entry of dimensions, conductor loss, and additional drawing functions.

# ♦ Exiting Xgeom

If you would like to exit from the ***xgeom*** program, select *File* ⇒ *Quit.*

# Chapter 11 Editing Your Circuit

Changing the circuit is accomplished with Edit and Select options described in this section.

## ♦ Selecting Points and Polygons

Many of the ***xgeom*** functions require you to “select” a point or polygon prior to choosing the menu item. To select a point, you must first be in the “select” mode. This is accomplished by choosing *Select* ⇒ *Single Layer*. This menu item is used so often that ***xgeom*** provides two shortcuts for single-layer select mode. The first shortcut is to type the *Escape* key. The second shortcut is to position the cursor on the *Select* menu button and press and release the left mouse button.

### ✧ Select by Clicking

Once in the select mode, you may now select a point by clicking the left mouse button on that point. The selected point should become highlighted. To select more points, continue clicking on points. If you select all of the points of a polygon, then the entire polygon is selected and becomes highlighted. To select a polygon, click inside the polygon.

Separate polygons sometimes have several vertices in common. If you want to select a vertex of, say, polygon A, but not the co-located vertex of polygon B, be sure the cursor is close to the vertex and just inside polygon A. The polygon A vertex is then selected.

## ✧ Multiple Selects

You may select multiple polygons, multiple points or any combination of the two. When a port is connected to a polygon or a set of points that are selected, the port moves with the polygon or the set of points. This also holds true for edge-vias (See section "Edge-vias" on page 44 for the definition of an edge-via).

Multiple polygon selects are very useful when you want to change the attributes of many polygons at once. The following menu items operate on multiple polygons:

- *Objects ⇒ Polygon ⇒ Param*
- *Edit ⇒ Cut*
- *Edit ⇒ Copy*
- *Edit ⇒ Duplicate*
- *Edit ⇒ Flip*
- *Edit ⇒ Rotate*
- *Edit ⇒ Magnify*
- *Edit ⇒ Snap*

## ✧ Select by Lassoing an Area

Another way of selecting points and polygons is to “lasso” an area which contains these objects. To lasso an area while in the select mode, move the cursor to the upper left corner of the region you want to select and press the left mouse button without releasing it. Holding the mouse button down and drag it to the right and down. A rectangular box shows the area that will be selected. Now release the mouse button. All objects in the region are selected.

## ✧ Multi-Layer Selects

Some circuits require metallization on more than one layer. If this is the case, you may want to modify the polygons on some or all of these layers simultaneously.

To select points or polygons on more than one layer at a time, choose *Select ⇒ Mult. Layer*. This puts you in the Multi-Layer mode. When in this mode, the select by lassoing applies for all layers. This mode is usually used for moving and copying multilayer structures such as vias. Note, however, that only the lassoing feature is modified. Select by clicking still only applies to one layer.

### ✧ Unselecting

*Select ⇒ Unselect* puts you in the unselect mode. This item is unavailable (“shadowed”) when nothing is selected. While in the unselect mode, pressing the left mouse button with the cursor inside a selected polygon or on a selected point unselects it. Only points and polygons on the current layer are affected. You may also lasso points and polygons that you want to unselect. Any point or polygon that is inside the lasso region is unselected. If only a portion of a polygon is inside the region, then only that portion of the polygon is unselected. Sometimes, it may be quicker to select the entire drawing and then unselect the objects you don’t want. For example, if you wanted to select nine points on a drawing with ten points, you could click on each of the nine points to select them. Alternatively, it would be simpler to click on *Select ⇒ Select All, Select ⇒ Unselect,* and then, click on the one point you don’t want selected.

### ✧ Unselecting All Objects

While in the select mode, you can unselect all of your selected objects at once by clicking anywhere on the substrate that is not inside a polygon. Whenever you are in the select mode or the multi-layer select mode, clicking on the substrate where there is no metal unselects everything. Note that this method does not require you to use the menus.

### ✧ Reselecting

If by accident you unselect the points or polygons you wished to select, choose *Select ⇒ Reselect*. The objects previously unselected, are selected again. This item is unavailable (“shadowed”) if any objects are presently selected.

## ♦ Moving Points and Polygons

If you need to move a polygon (or a point), you must first be in the “select” mode as described in the previous section. Then position the cursor inside the polygon and press, without releasing, the left mouse button. The polygon is highlighted. With the button held down, move the mouse. The polygon moves as you move the mouse. Drag the polygon to the desired location and release the button.

Notice that the polygons or points that you are moving always “snap” to the nearest grid point. If you want to move a point or polygon between your grid points, you must change a property called the “snap distance”. See section "Menu: Param - Snap" on page 87 for information on how to do this.

If you want to move a group of polygons in unison, start by selecting all of the polygons you want included in the move. Each polygon is highlighted. When all polygons are selected, click on one of the polygons. Holding the button down, drag the polygons to their new location.

Moving points is accomplished in the same way as moving polygons. Start by selecting the point or points that you want to move. Then position the cursor over one of the selected points and press the left mouse button without releasing it. The points, and the adjoining line segments, move as you move the mouse. Drag the points to the desired location and release the mouse button.

Any combination of polygons and points may be moved in this fashion.

# ♦ Shift Selecting

Another way of selecting an object is “shift selecting”. To shift select an object, hold down the *Shift* key while selecting the object.

Shift select is the same as single layer select except that it does not allow:

1. selected objects from accidentally moving,
2. objects to be unselected.

Normally, when you select a polygon, and you move your cursor before releasing the mouse button, the polygon moves with your cursor. To keep the polygon from moving while you are selecting it, do a shift select. This is useful when selecting multiple polygons and you want to avoid accidentally moving or unselecting the polygons.

Sometimes, you may need to lasso an area that requires you to start “dragging” in the middle of a polygon. Using single layer select, this would undesirably select and move the polygon. To avoid moving the polygon while lassoing, do a shift select.

# ♦ Deleting Points and Polygons

If you want to delete some points in a polygon, select the points that you want to delete. Then press the *Delete* or *Backspace* key and the points are removed. The *Delete* and *Backspace* keys are shortcuts for *Edit* ⇒ *Cut.* To delete a polygon or polygons, select the polygon(s) that you wish to delete, and then press the *Delete* or *Backspace* key (or *Edit* ⇒ *Cut*).

# ♦ Adding Points to a Polygon

Every ***xgeom*** polygon is composed of a series of points. These points can be moved or deleted as mentioned before. Sometimes you may want to change the number of points that make up a polygon. For example, you might wish to change a triangle to a square or a pentagon.

To change a triangle to a rectangle, select *Objects* ⇒ *Add Points*. Then click on one of the sides of the triangle that you want to modify. Both end points of the triangle side are highlighted. Now click the left mouse button on the desired location for the new point that will make up the rectangle. A new line segment connects the original point (shown as an "X") to the new added point. You may keep adding points in this fashion for multi-sided polygons. When done, either click twice on the last point added or once on the unconnected highlighted end point. If you make an error, you may press the *Delete* or *Backspace* key and the last point entered is deleted.

# ♦ Cutting and Pasting Polygons

When you delete a polygon using *Edit* ⇒ *Cut* (or use the shortcut key), it is removed from your circuit and inserted into the ***xgeom*** *buffer*, a temporary storage area for polygons. You can cut and paste from one layer to another or within the same layer. ***Xgeom*** uses a single buffer for all ***xgeom*** windows.You can cut or copy polygons from one ***xgeom*** window and paste it into any other ***xgeom*** window. The polygon(s) remains in the buffer until you replace it by cutting or copying again. Only polygons are copied into the buffer; i.e., single points are not copied into the buffer. Ports and edge-vias associated with a polygon are also copied into the buffer. See section "Edge-vias" on page 44, for the definition of an edge-via.

To insert a polygon or polygons into the ***xgeom*** buffer (called "cutting"), first select the polygon(s) that you wish to cut. Now choose *Edit* ⇒ *Cut*. The selected polygon(s) are deleted. To retrieve the polygon(s) from the ***xgeom*** buffer, choose *Edit* ⇒ *Paste*. The polygons are copied from the buffer to your circuit. Also note that the polygon(s) that were pasted in are still selected. This makes it easy to move them to a new location. Cutting and pasting using *Edit* ⇒ *Cut* and *Edit* ⇒ *Paste* can be used to move polygons from one layer to another layer.

*Edit* ⇒ *Copy* is the same as *Edit* ⇒ *Cut* but the selected polygon(s) are placed into the buffer without being deleted. Use this menu item when you want to keep the original polygon(s) where they are and make a copy of them somewhere else.

*Edit* ⇒ *Duplicate* combines *Edit* ⇒ *Copy* and *Edit* ⇒ *Paste* into one menu item. This menu item provides a fast way to copy a polygon to another location on the same layer. To do this, first select the polygon and then choose *Edit* ⇒ *Duplicate*. The selected polygon is inserted into the buffer and a duplicate of the polygon is then pasted on top of the original polygon. The pasted polygon is highlighted to remind you that it is still selected.

The ***xgeom*** buffer is actually a file, called “.xgeomcut” on Unix systems and “xgeom.cut” on MS-DOS systems. On Unix systems, the file is invisible and is located in your home directory. On MS-DOS systems, the file is located in the Sonnet directory.The manipulation of this file is completely transparent to you and is only mentioned here for completeness.

# ♦ Moving Polygons to Another Layer

To move polygons to another layer, first select the polygons that you wish to move. Then choose *Edit ⇒ Cut*. Now move to the new layer where you wish to place the polygons. This may be done by using the shortcut keys ^D (down) and ^U (up). Now choose *Edit ⇒ Paste* and the polygons are placed on the new layer.

# ♦ Flipping, Rotating, and Magnifying

***Xgeom*** provides you with a way of flipping, rotating, and magnifying polygons. To use these features, first select the polygon(s) that you wish to change, and then choose the appropriate menu item. You are then prompted for more information.

For example, to create the mirror image of a polygon, first select the polygon, and then choose *Edit ⇒ Duplicate* so that the original polygon remains unchanged. Now choose *Edit ⇒ Flip* and choose either *Left-Right* or *Up-Down* orientation. The polygon is flipped about a line passing through the center of your circuit. You also have the choice to flip (or rotate) about a line passing through the ***xgeom*** ruler by toggling between *Use <Center>* and *Use <Ruler>*. See section "Measuring Dimensions" on page 55 for information on the ***xgeom*** ruler.

For a complete description of the *Flip*, *Rotate*, and *Magnify* functions, see the appropriate sections in Chapter 13 starting on page 72.

# ♦ Undoing a Change

If you make a change that you did not want to do, you can undo the last change by using *Edit ⇒ Undo*. Most *Objects* and *Edit* commands, as well as moving points and polygons, can be corrected by using *Edit ⇒ Undo*.

# ♦ To Start Over

If all else fails, select *File* ⇒ *Clear* to start the circuit over (the box and substrate parameters are unchanged). Alternately, you may use *Edit* ⇒ *Cut* to get rid of polygons one at a time. See section "Menu: Edit - Cut" on page 71 for more information.

# ♦ Emergency Backup

In case of system failure, ***xgeom*** creates a backup of your circuit every five minutes. The name of the backup file is the same name as your circuit file but has a ".bck" suffix. For example, if your circuit file is "filter.geo", the backup file is named "filter.bck". This file is deleted when exiting ***xgeom***, but will remain in your directory if your system crashes.

# Chapter 12 Using Vias

The example in the first few chapters of this manual show a circuit that uses only planar (X-Y) currents. Vias allow current to flow in the Z-direction. Vias can extend from ground to the substrate surface (a ground via), as well as between levels in a multilayer structure. They can also extend to the top cover of the box.

## ♦ Via Concepts

To create a via that connects one layer to another layer, you must follow these steps:

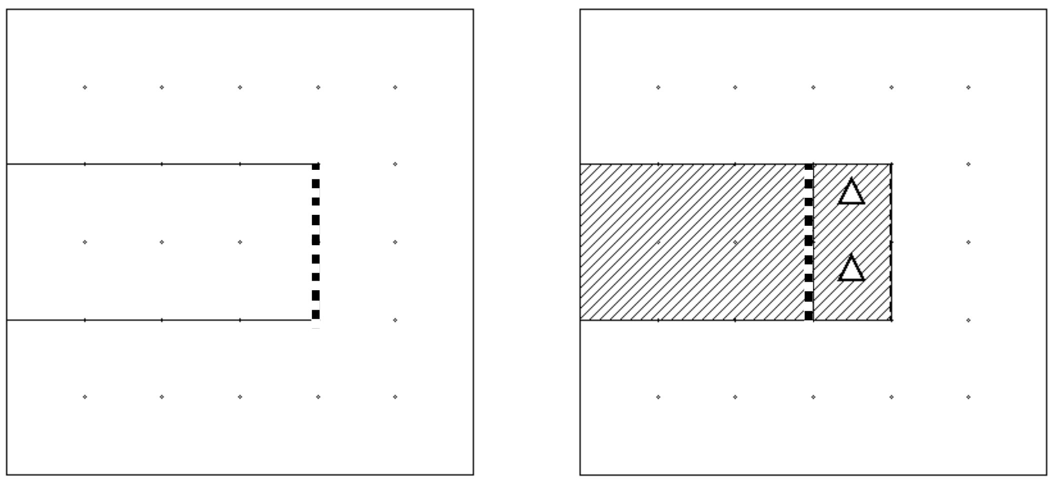
- Draw a polygon on each of the two layers that you want to connect.
- Define the position of the via by creating an “edge-via” (defined later).
- If needed, modify the polygons so that vias are as desired.

### ✧ Creating the Polygons

First, you must create the two polygons that you want to connect with a via. This is true even if you want to connect a via to ground. The polygons must be on adjacent levels. If they are not, you will need to create a series of vias - each one connecting polygons on adjacent levels. Type ^U and ^D to move up and down between the two levels that you want to use, and create a polygon on each level. If the via is going to ground, create a "dummy" polygon on the ground level (bottom of the ***xgeom*** box). It is called a "dummy" polygon because the ground level is already completely metallized and the polygon does not change this characteristic.

## ✧ Edge-vias

To connect two polygons with a via, you must first create an "edge-via". An edge-via is an edge of a polygon that a via originates from. To create an edge-via, go to the lower of the two polygons (using *View* ⇒ *Level*) that you want to connect a via to. Now use *Objects* ⇒*Vias* ⇒ *Add* and click on the edge of the polygon where you want the via to go. A dark dashed line appears showing the position of the edge-via (see Figure 14).



a) Metal "Off" b) Metal "On"

**Figure 14** ***Xgeom*** uses edge-vias to define the position of via-posts. When the metal is turned "On", the via-posts can be seen as arrow symbols.

## ✧ Via-posts

With the metallization turned on (*View* ⇒ *Metal* set to "On"), the via subsections, called "via-posts", are also displayed (see Figure 14b). Each via-post has an "up" via symbol (an "up" triangle) indicating that the via connects this level to the next level above. When ***xgeom*** subsections the circuit, it subsections each edge-via, which you specify, into subsectional vias called "via-posts". Each via-post is a rectangular cylinder of current, extending between the present level to the next level above. A via-post has a horizontal cross-sectional area equal to one cell and a height equal to the thickness of the dielectric layer. If you change the cell size, then the edge-via is resubsectioned into via-posts with the new cell size. ***Xgeom*** places enough via-posts to cover the entire length of the edge-via. We will refer to this series of via-posts as a "via-fence." (See Figure 15).

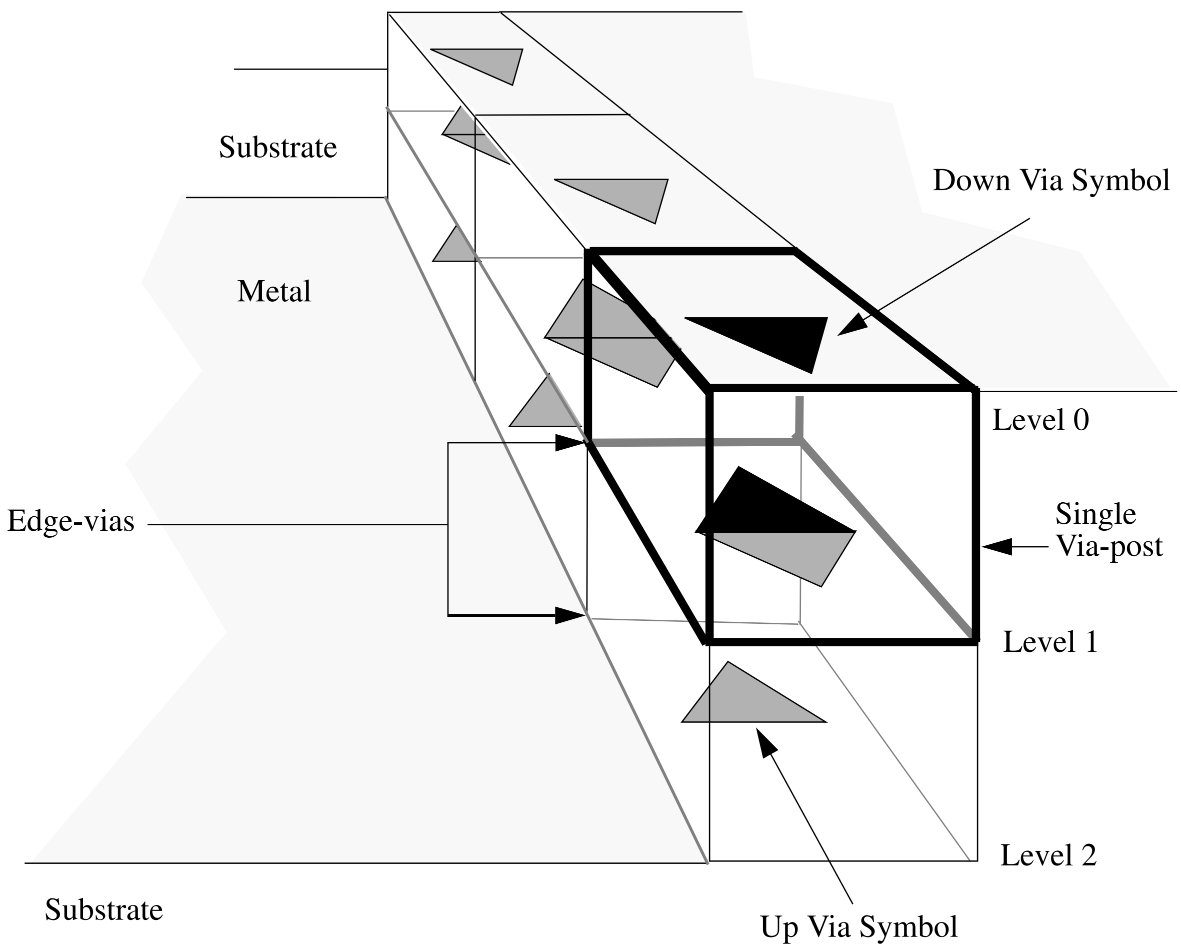



**Figure 15** The figure shows a via going between two non-adjacent levels. The dielectric layer was split into two distinct layers so that the height of each via-post is small in comparison to the wavelength. The highlighted box illustrates one via-post. See Figure 16 for ***xgeom***'s view of this circuit.

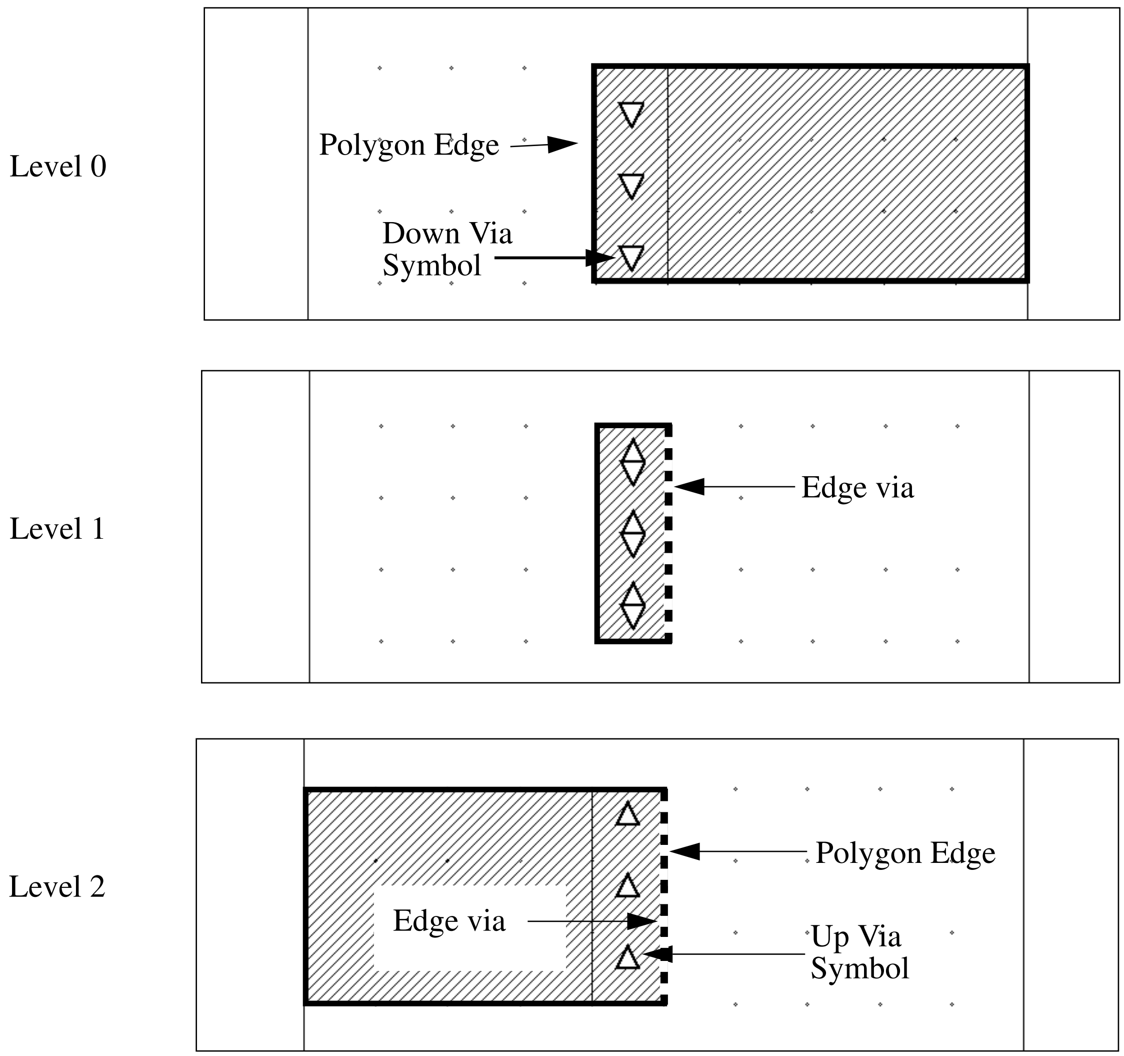



**Figure 16** ***Xgeom***'s view of the via circuit shown in Figure 15. The edges of the polygons are highlighted.

To view vias as they are being captured, it is convenient to be able to change the viewed level in ***xgeom*** quickly. To do so, just type ^U (*Control-U*) to go up one level (towards the top cover) or ^D to go down one level.

If you want a level to be displayed as a "ghost" outline whenever you are not on that level, type ^V (Visible) while on that level. Then you can see how different levels of metallization line up. To turn off the visibility, type ^I (Invisible) while on the desired level. By default, ***xgeom*** starts with all levels visible.

The “up” via symbol indicates that the via-post connects this level to the next level above (see Figure 16). Move up one level. The via-posts are shown on this level with a “down” via symbol (“down” triangle). The “down” via symbol was generated automatically when the via-edge was added on the lower level. Via-posts that are too small to be seen individually have a single via symbol representing multiple via-posts.

## ✧ Making an Entire Polygon a Via

To turn an entire polygon into a via, first select the polygon, then choose *Objects ⇒ Vias ⇒ Add.* Edge-vias will be attached to all sides of the polygon simultaneously. If your polygon has diagonal lines or points not on the grid, ***xgeom*** does a staircase fit to the polygon. ***Xgeom*** only attaches via-posts to the edges of the polygon, creating a hollow “cylinder” of metal. Since current tends to flow on the surfaces of conductors, creating a solid cylinder would just waste subsections.

## ✧ Adding a Via to Ground

To add a via to ground, first go to the ground level and add a polygon to the bottom of the box (ground level), then add an edge-via to the polygon edge. The polygon on the ground level is not subsectioned and does not change the characteristics of the ground. The ground level is completely metallized, with or without the polygon. The polygon is created only to provide a polygon edge so a via can connect to the ground level.

## ✧ Deleting Vias

To delete an edge-via select *Objects ⇒ Vias ⇒ Delete*, then click on the edge-via that you want deleted. Make sure that you are on the level where the via-post starts (and goes up) and not on the level above where the via-post ends. Deleting an edge-via deletes the via-fence associated with it.

## ✧ Via Loss

The loss for the via-post is determined by the metallization of the polygon that the via is associated with. See section "Menu: Param - Metallization" on page 85 for an explanation on how to set the metallization loss.

## ✧ A Common Error

One common error when using vias is to create an edge-via that is adjacent to a port (see Figure 17). This shorts the port to the box wall. In general, never allow a via-post to touch the edge of the box.

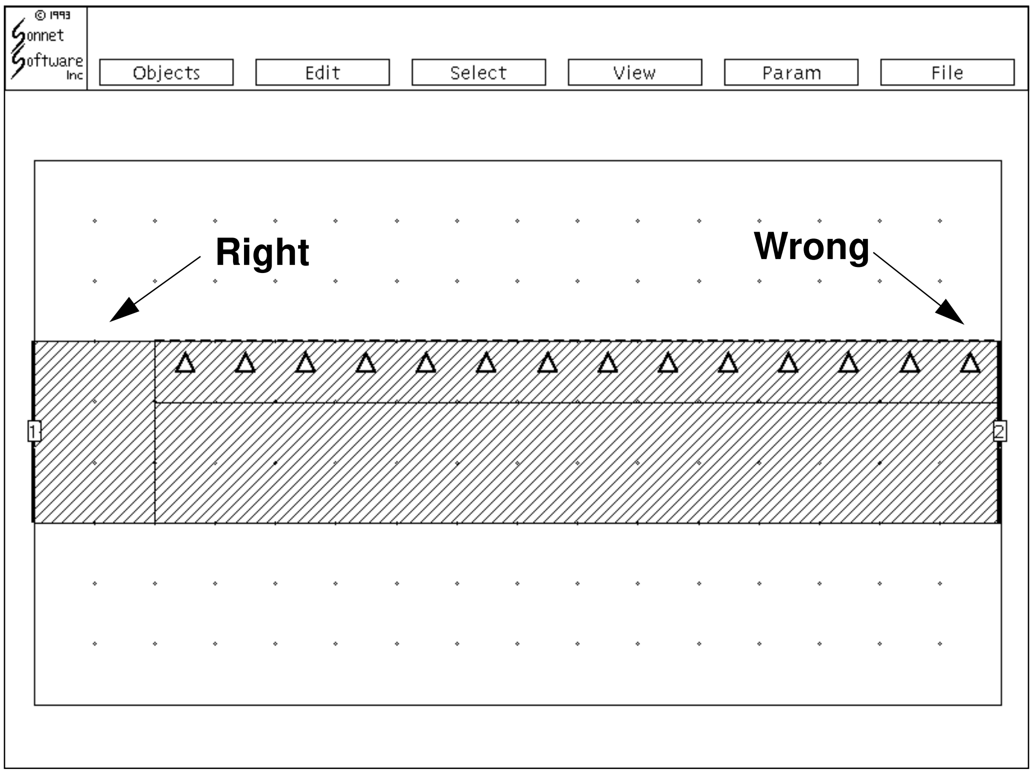



**Figure 17** Do not create an edge-via that is adjacent to a port on the box wall. This shorts the port to the box wall.

## ✧ Via Ports

Vias to ground may also be ports. This is a special case of the internal port described in section "Menu: Objects - Ports" on page 66. The port is inserted between the via and the ground. This is analogous to a coaxial connector underneath a circuit, with its center conductor penetrating the substrate and connecting to the circuit. Thus, when ports are desired on the interior of a circuit, capture a via to ground and add a port to the edge-via, (see Figure 18). The example "patch.geo" included with your software has an example of using a via-port.

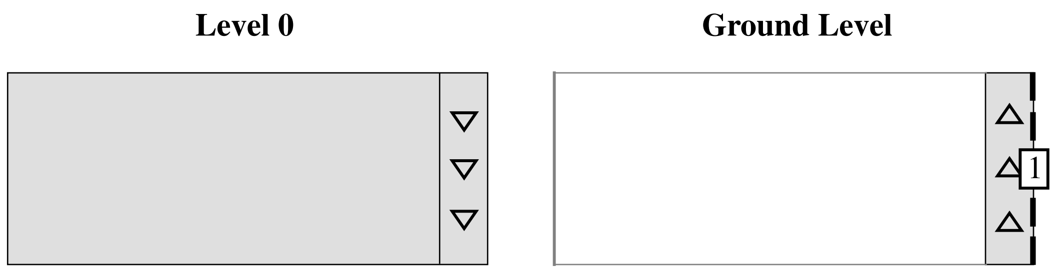



**Figure 18** A via port with both levels shown.

# ♦ Creating an Air-Bridge: An Example

A good example of the use of vias is an air-bridge. This section is a tutorial on creating a transmission line that bridges over another transmission line.

## ✧ Loading in the Example File

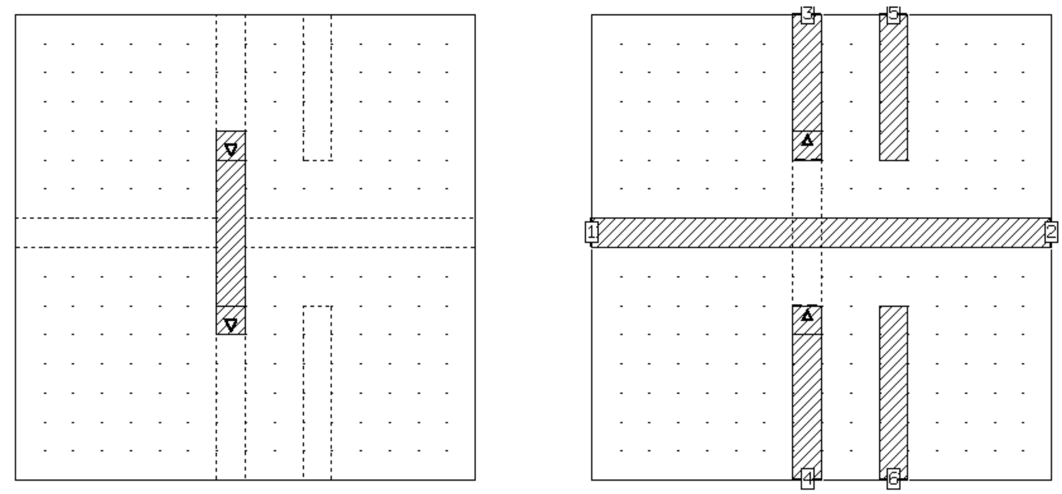
If you are currently running ***xgeom***, select *File* ⇒ *Quit*. Now copy the example file called "bridge.geo" into your directory by typing the following command:

**copyex bridge.geo**

Now load the example file into ***xgeom***. This may be done by typing the following command:

**xgeom bridge.geo**

Your screen should look like Figure 19a.




a) Upper level (#0) b) Lower Level (#1)

**Figure 19** Unfinished air bridge example. The text describes how to complete the example.

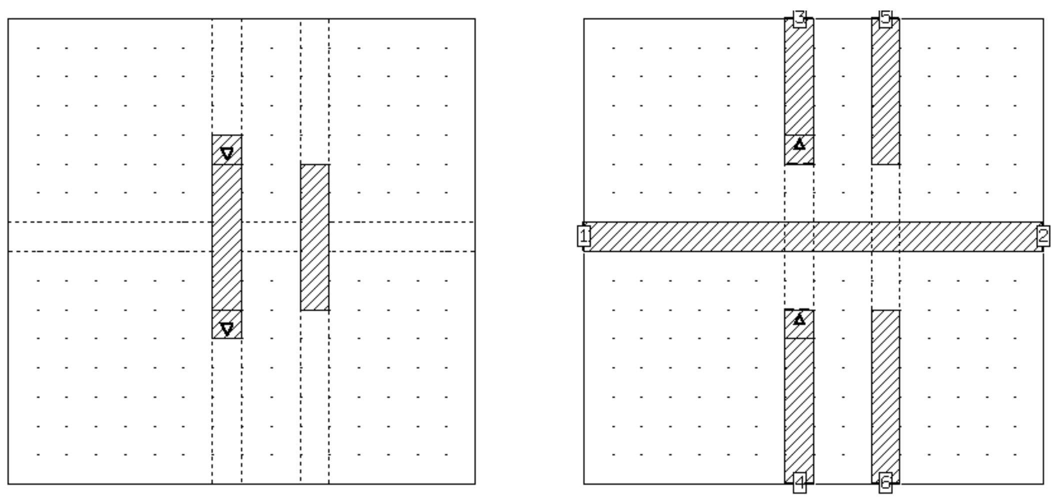
## ✧ Understanding the Circuit

This example file contains a 6-port circuit, however, the ports are on another level. Type ^D key to go down one level. Your screen should now look like Figure 19b. This level shows a transmission line going from ports 1 to 2, another transmission line going from port 3 to a via-post (notice the arrow-up symbol), a similar line at port 4, and two open stubs at ports 5 and 6.

Let's concentrate on what happens on the line connected to port 3. This line goes to a via-post (arrow-up symbol). The via-post connects the line to another line on the level above this one (shown as a ghost image). Type ^U to go up one level. You are now looking at the highest level again, level 0. There is a single rectangle of metal that acts as the "bridge" of the air-bridge. Notice the two arrow-down symbols. These were automatically created by ***xgeom*** and indicate that there is a via-post coming up from the level below this level. Remember, via-posts always project upward from the level that they were specified on.

## ✧ Creating the Polygons

Now let's connect the two open stubs connected to ports 5 and 6 to another air-bridge identical to the one that is already there. As a general rule, it is best to create the polygons on both layers first. In this example, the polygons on level 1 have already been entered for you and the only polygon left is the actual air-bridge. Type ^M to turn the metal off and create a new polygon similar to the one that is already there (Using *Objects* ⇒ *Polygons* ⇒ *Add* for example). It is good practice to create polygons such that the edges are in line with each other. This makes it possible to change your cell size without having to change your edge-vias. When you are done, turn the metal back on (Figure 20a).

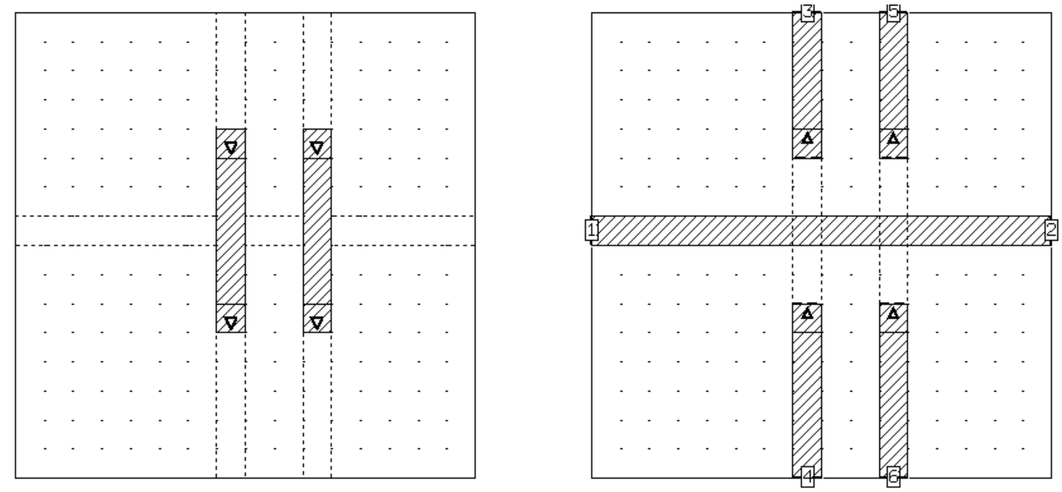



a) Upper level (#0)    b) Lower level (#1)

**Figure 20** Air bridge example after adding the polygon.

## ✧ Adding Edge-Vias

Now type ^D to go back to level 1 (Figure 20b). Select *Objects* ⇒ *Vias* ⇒ *Add* and click on the end of the each of the open stubs. Three things show up for each stub. First, a dark dashed line is displayed. This is the edge-via. Second, an arrow-up symbol is displayed, signifying a via-post that goes up to the next layer. Third, a new metallized polygon shows up. This shows you the actual size and position of the via-post. If you have not already done so, finish the example by adding an edge-via to the end of the other stub (Figure 21b). Now go up to level 0. Your circuit should look like Figure 21a. An arrow-down symbol and an extra metallized square polygon was automatically created by ***xgeom*** for each edge-via that you entered.



a) Upper level (#0) b) Lower level (#1)

**Figure 21** Completed air bridge example after adding two edge-vias.

### ✧ Changing Your Cell Size

One last thing that you might want to try is to change the cell size to see what happens. Notice as you decrease the cell size, more via-posts appear at the edge-via. Single arrows are used to represent multiple via-posts when there is not enough room for ***xgeom*** to place all of the arrow symbols on the screen. Zooming in on an area allows ***xgeom*** to show one arrow per via-post.

## ♦ Summary of Vias

Here is a summary of how to use vias:

- ***Xgeom*** uses edge-vias to determine the position of a via-post.
- When creating edge-vias, start on the lowest level and work up.
- To create a via to ground, start by specifying a polygon on the ground layer.
- Create your polygons before adding vias.

# Chapter 13 Function Reference

This section contains a brief, yet detailed description of ***xgeom***'s functionality. It assumes you have read the previous tutorial and understand ***xgeom***'s basic framework and purpose. Details on ***xgeom***'s command line can be found in Appendix I, "The Xgeom Command Line".

## ♦ The Mouse

The mouse has three buttons which ***xgeom*** uses (See Figure 22). Computers with only 2 mouse buttons are discussed in the section "Zoom Button" on page 54. The left button is used for most of the ***xgeom*** functions, like menu selections and polygon additions. The middle button allows you to zoom into a specific region on the circuit. The right mouse button allows you to measure dimensions of your circuits.

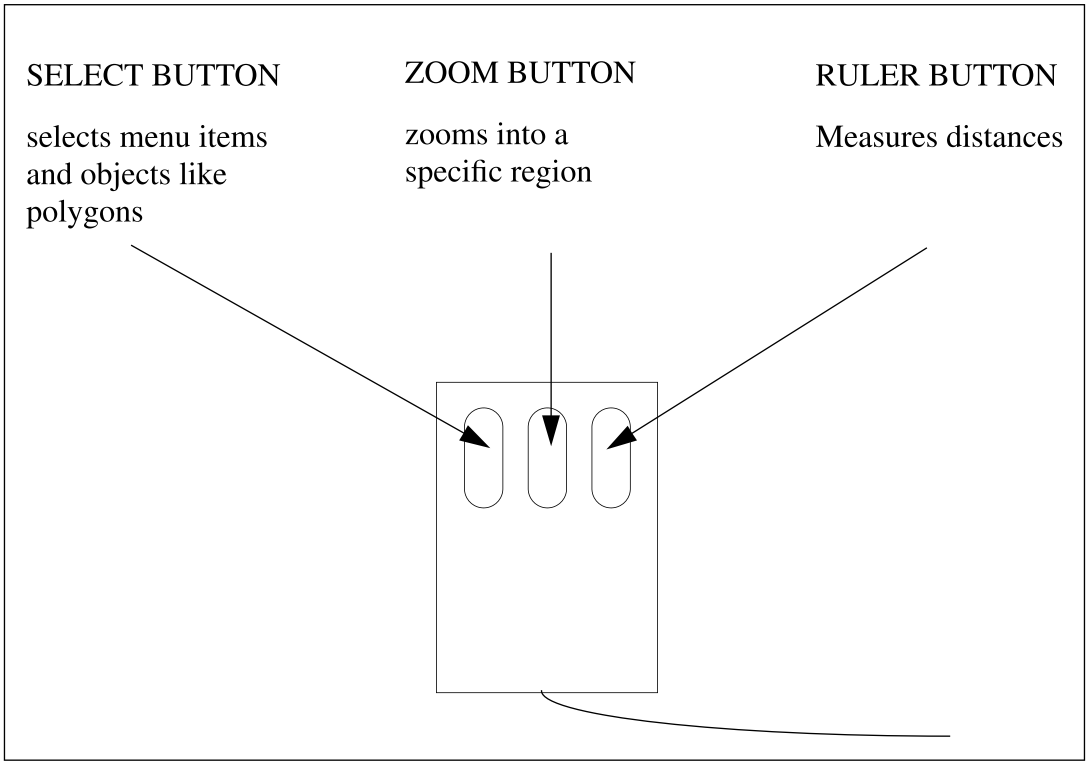



**Figure 22** The mouse buttons can be used to specify polygon vertices, to magnify the circuit, and to measure distances.

# ♦ Zoom Button

The zoom button, the middle button, may be used to magnify a specific area in the circuit. Move the cursor to the upper left corner of the region you want magnified, then press the middle button. Holding it down, drag the cursor to the lower right corner then release the button. The specified region is expanded to fill the screen. You can go back to the previous zoomed region by clicking the middle mouse button without moving the mouse. To reset the view so that the entire substrate surface is visible on the screen, double click the middle button. To double click, quickly click twice on the mouse button.

You may also type ^Z (*Control-Z*) to reset the view and ^Y to toggle to the previous view.

On some computers, due to timing problems, a double click may be interrupted as two single clicks and does not do a reset. If you experience this problem, you may use the ^Z key instead.

Computers with a two button mouse, are usually configured so that pressing both the right and left buttons at the same time is the same as pressing the middle button on a three button mouse. If this does not work, use *View ⇒ Zoom In* for the zoom function. See section "Menu: View - Zoom In, Zoom Out, Prev View, Full View" on page 78.

# ♦ Measuring Dimensions

The ruler button, (the right mouse button), is used to measure the circuit's dimensions. Move the cursor to the desired origin and click the right mouse button. The ruler is now on, and a cross hair appears at this location. Subsequent clicks with the right mouse button displays the x-y coordinates of both the origin and the point. Also, ***xgeom*** displays the offset from the origin as well as the total distance from the origin (see Figure 23). If you hold down the right mouse button and move the mouse, the ruler information is updated continuously.

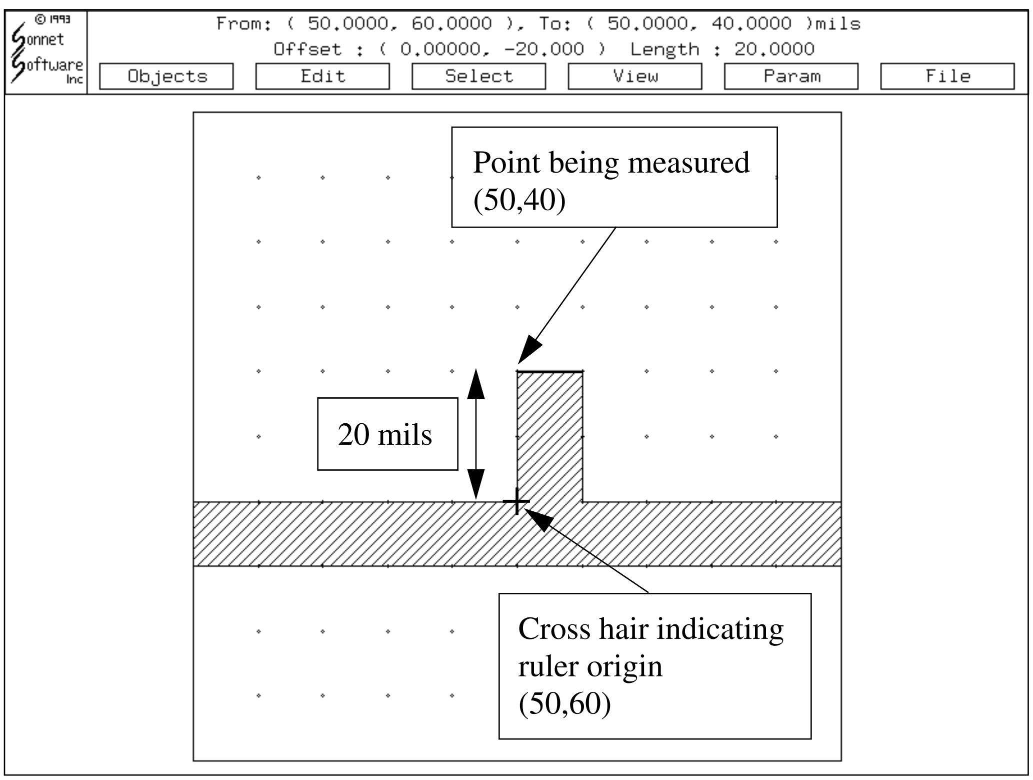



**Figure 23** Measuring distances using the ruler button.

All ruler button measurements are snapped to the nearest snap grid point. If you change the snap grid so that a desired point of measurement is not on the snap grid, an inaccurate measurement results. See section "Menu: Param - Snap" on page 87 for information about the snap grid.

To turn the ruler off, move the cursor to the cross hair and then click the right mouse button. The ruler is now off and ***xgeom*** no longer displays the cross hair.

To move the ruler's origin, click on the cross hair with the right mouse button. Then move the cursor to the new origin location and click again. You may also use a shortcut by moving the cursor to the new location, then double click with the right mouse button. To double click, quickly click twice on the mouse button.

If the ruler button is set, then all measurements are made from the ruler's origin. This includes when you are adding polygons, rectangles, and points. When the ruler button is not set, distances are measured from the previous point while adding points or polygons, even if you are using the right mouse button to measure the distances. With the ruler set, the distances are measured from the ruler origin.

For example, say you have a circuit with a stub in it and want to extend it to a specific length (see Figure 24). First set the ruler origin on the point you are measuring from. Next choose *Select* ⇒ *Single Layer* and lasso the end points of the stub. Now click the left mouse button with the cursor on one of the points and drag the cursor while keeping the left button pressed. The top of the ***xgeom*** window displays the new stub's length. If the ruler were off, then the distance at the top of the screen would show the changes in the stub length.

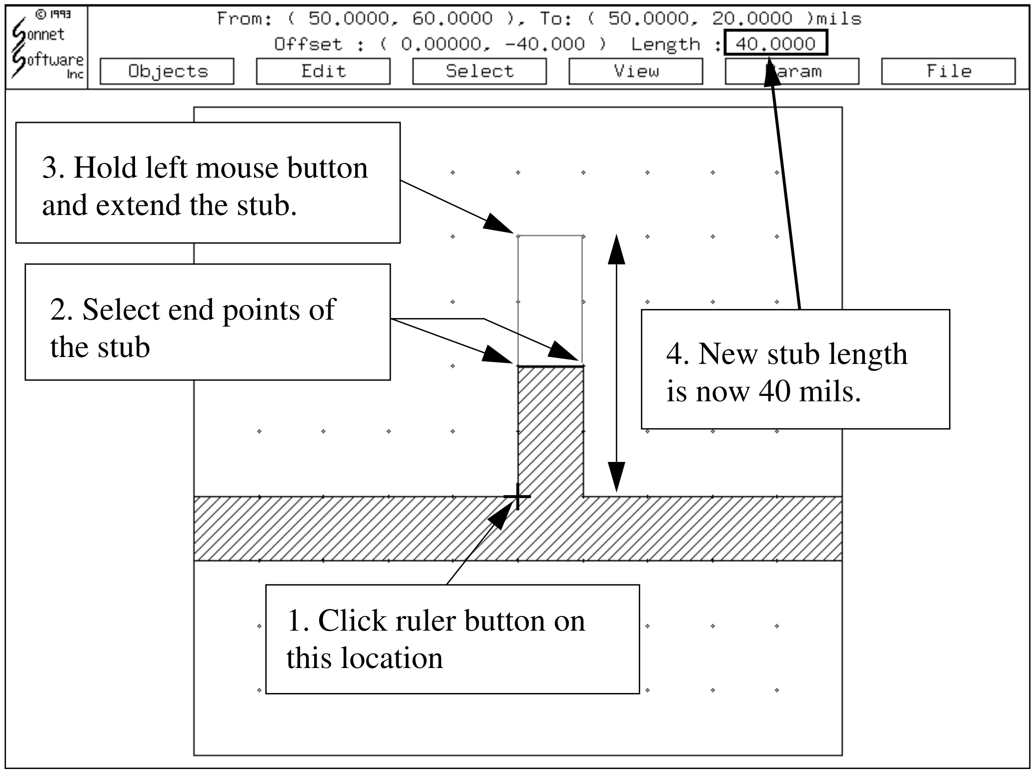



**Figure 24** Measuring the stub's length as it is being extended.

You can also set the ruler from the *View* ⇒ *Ruler* menu. You have three options:

| | |
|---|---|
| **(0,0)** | Set the origin to (0,0), the upper left corner of the substrate. |
| **Manual** | Set origin to a specific (x,y) coordinate. |
| **Off** | Turn ruler off. |

# ♦ Typing in Coordinates From the Keyboard

Polygons and points may be entered by using the mouse as first described in Chapter 6, "A Trial Run", or their coordinates may be typed in directly. You can type in polar or Cartesian coordinates and they may be absolute coordinates or relative coordinates. Relative coordinates are relative to the last point entered. The following section shows you how to enter in a rectangle by typing in the coordinates.

## ✧ An Example of Keying in Coordinates

For this example, we will draw a rectangle that is 60 mils wide and 30 mils high. First, start with a new ***xgeom*** window by typing the following:

**xgeom example.geo**

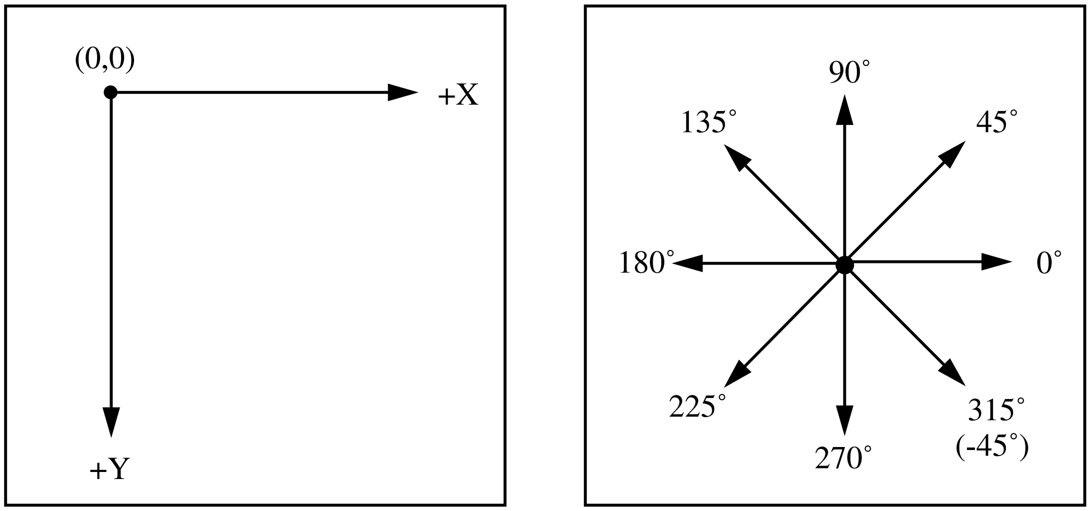
You can use any file name in place of "example.geo", however, make sure that the file does not already exist. Now select *Objects* ⇒ *Polygons* ⇒ *Add* and type in the X and Y coordinates of the first point of the polygon. If during this example you type in the wrong numbers, just press the *Delete* or *Backspace* key and the last entered point will be removed. For this example, type

**50,100**

and press the *Return* key. A small "x" shows up on your screen at the coordinates X=50 mils and Y=100 mils just as if you had clicked the left mouse button on that point (see Figure 26). Note that coordinates are snapped to the nearest snap grid point; i.e., typing in "50.01,99.98" would have the same result as "50,100". To enter the next point 60 mils to the right of this point, type

**@60<0**

A line appears starting from the first point you picked and ending 60 mils to the right of it. The at sign ("@"), tells ***xgeom*** that the distance you specify is from the last point that you entered. The 60 is the distance to move, and the less than symbol ("<") tells ***xgeom*** that the next number is the angle (in degrees) at which the point is to be placed. Angles are given based on the system shown in Figure 25.




Cartesian Coordinates (Default Origin)

Polar Coordinates

**Figure 25** The coordinate system used by ***Xgeom.*** Use *View* ⇒ *Origin* to change the origin used for Cartesian coordinates.

For the next point, let's use Cartesian coordinates. Cartesian coordinates given are based on the coordinate system specified with *View* ⇒ *Origin*. We will assume that you have not changed the default (0,0 is the top left corner of box). Type

**@0,-30**

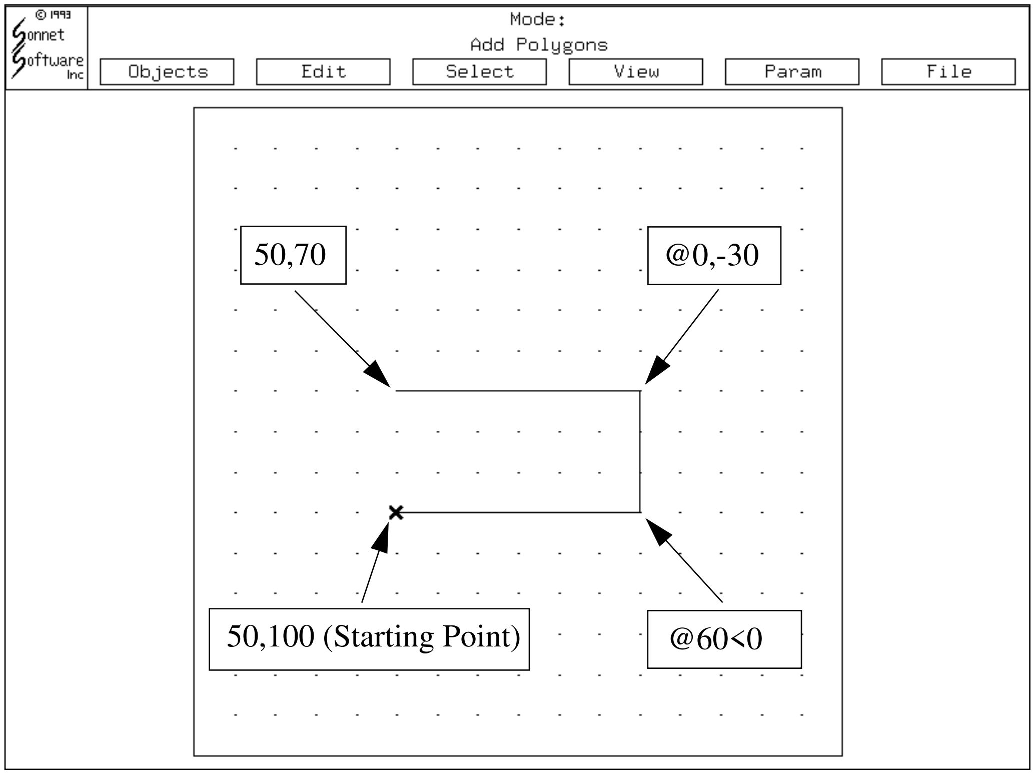



**Figure 26** Example of typing in coordinates by hand.

Another line of our rectangle appears. Once again we used the "@" sign to tell ***xgeom*** that the coordinates we entered are relative to the last point. The first number (0) is always the X value and the second number after the comma is the y value. In this case the Y value is negative, so the new point is 30 mils above the previous point. Now type

**50,70**

At this point, your screen should look like Figure 26. This time the number was entered as an absolute coordinate just to illustrate that you may mix absolute coordinates with relative coordinates. Mixing absolute coordinates with relative coordinates on the same line is not allowed; i.e., "50,@0" is not allowed. You may finish your polygon in the same method used when using the mouse: by clicking exactly on the last point entered, or clicking on the highlighted ("X") point. You may also type in the equivalent coordinates to finish. The easiest way to complete a polygon is to type:

@

This completes the polygon. ***Xgeom*** interprets the “@” sign as relative coordinates. When none are given, zero (0) is assumed. In this case “@” is equivalent to “@0,0” which is the same as clicking the mouse with the cursor on the last point. This completes the polygon. Note also that typing in “@5” is equivalent to “@5,0” and adds a point 5 units to the right of the last point.

You may mix mouse and keyboard entry of points. One word of caution however: stay away from using keyboard relative coordinates for the first point of the polygon. The point would be relative to some random point and results are unreliable.

The above example used *Objects ⇒ Polygons ⇒ Add*. Keyboard entry is also supported for *Objects ⇒ Add Rect*. and *Objects ⇒ Add Points.* As soon as you type a number or an at sign (“@”) while any of these functions are active, ***xgeom*** starts reading from the keyboard.

# ♦ The Objects Menu Button

The *Objects* menu button is used to add to or change objects in a circuit. For example, select *Polygons* from the *Objects* menu and the button menu displays a choice of *Add* and *Param*. Click (press and release) on the desired option.

## ✧ Menu: Objects – Polygons

You can either add polygons or change the parameters of a polygon with this menu option. See section "Menu: Edit - Cut" on page 71 to delete a polygon.

### ☆ *Objects ⇒ Polygons ⇒ Add*:

To add a polygon, select *Objects ⇒ Polygons ⇒ Add*, or use the shortcut ^P. Now click where you want the first point of the polygon to go. For the next point, depress and hold the mouse button and drag the resulting rubberband to the next location and release. The ruler information is constantly updated during the process.

When finished, click on the final point twice and the polygon is completed. An alternate way to terminate is to click once on the first (highlighted) point of the polygon. Unwanted points can be removed while still in the Add Polygons mode by selecting *Edit ⇒ Cut*. This deletes the last point added. Additional *Edit ⇒ Cut* operations delete additional previous points.

### ☆ *Objects ⇒ Polygons ⇒ Param*:

To change the parameters associated with a polygon, select *Objects ⇒ Polygons ⇒ Param*. Nothing happens until you click on a polygon. Clicking on a polygon produces a new button menu (Figure 27). Details of each parameter item are described in the following pages.

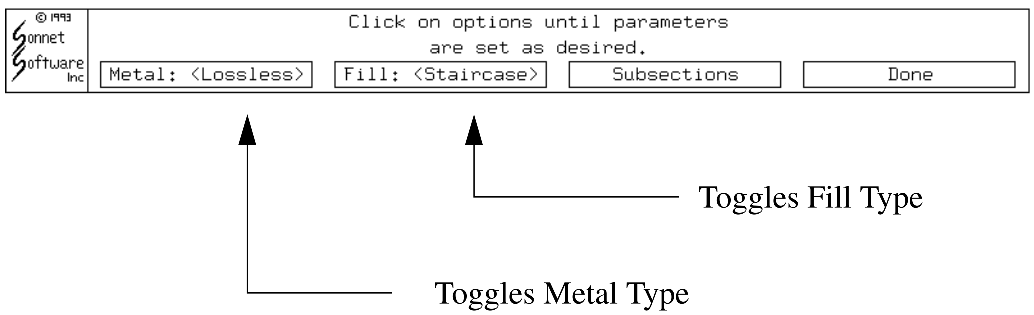



**Figure 27** Use *Objects ⇒ Polygons ⇒ Param* to change the parameters of a selected polygon.

You can change the parameters of multiple polygons all at one time. To do so, first select the polygons that you wish to change. Now select *Objects ⇒ Polygons ⇒ Param*. Any changes affect the parameters of all of the selected polygons.

---

**NOTE**

Please note that you must select a polygon to access the following buttons when using *Objects ⇒ Polygons ⇒ Param*.

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### ☆ *Objects ⇒ Polygons ⇒ Param ⇒ Metal*:

This menu button shows the current metallization associated with the selected polygon(s). Click on the *Metal* button to toggle through all of your choices. Changing the metallization changes only the metallization loss. The polygon is still on the same physical level (i.e., it is still between the same two layers of dielectric). See section "Menu: View - Level" on page 79 to change levels.

When ***xgeom*** starts, it initially only has one metallization, “lossless”. If you have not set up additional metallization choices in the *Param* ⇒ *Metallization* menu, then clicking on this button has no effect. To add new metallization choices, including thin film resistors, see section "Menu: Param - Metallization" on page 85.

### ☆ *Objects ⇒ Polygons ⇒ Param ⇒ Fill*:

The “edge fill” of a polygon is defined as the type of subsection used by ***em*** at the edges of a polygon. Staircase subsections are used in the middle of a polygon for all choices. By default, ***xgeom*** uses “staircase” edge fill everywhere. This may be changed for one or all of your polygons. To step to the next edge fill, click on the *Fill* button. This is used by ***em*** for subsectioning the metallization. Choose one of the following four options:

| | |
|---|---|
| **Staircase** | Provides a best rectangular fit to the metallization edge. (Default) |
| **Diagonal** | Allows triangular as well as rectangular subsections. This provides a better fit to diagonal edges but requires more analysis time (see Figure 28). For a more detailed explanation see section "The Triangle Fill Option Applied to a Coupled Open-Miter" on page 61 in the ***Em*** **User’s Manual**. |
| **Corner** | Provides an improved representation of the current at gap corners. For a more detailed explanation see section "The Effect of Corner Fill on a Gap" on page 60 in the ***Em*** **User’s Manual**. |
| **Both** | Includes both Corner and Diagonal fill. |

The resulting metallization edge is drawn if *View* ⇒ *Metal* is “On”.

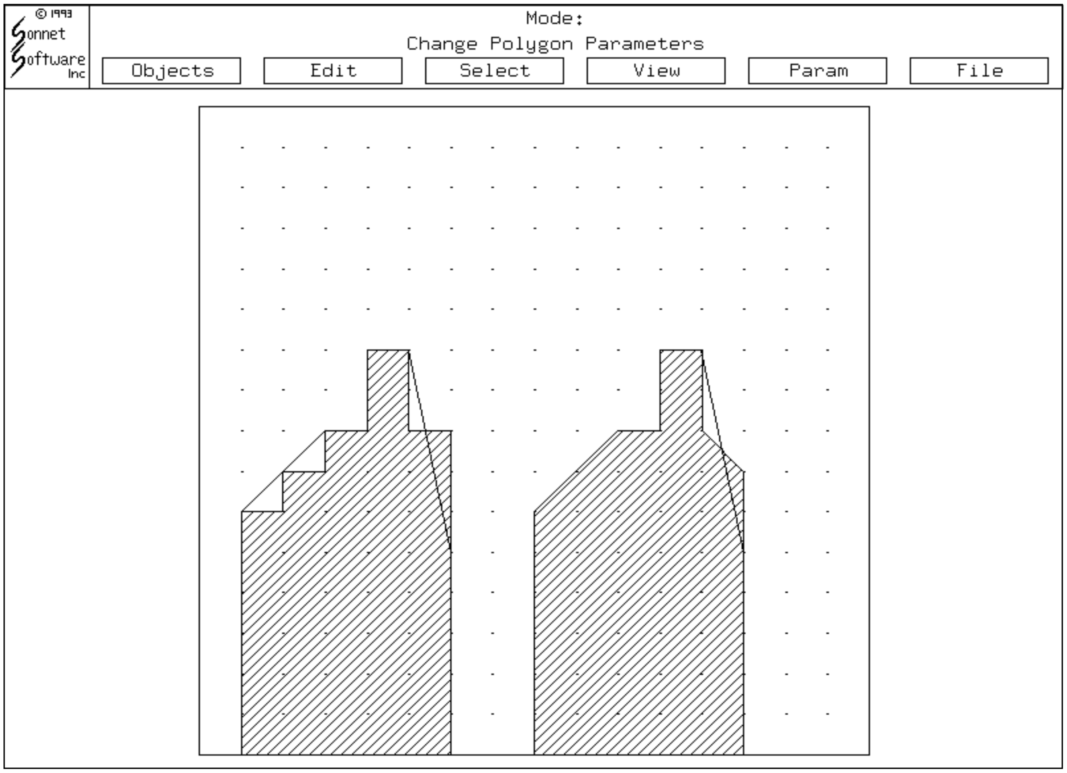



**Figure 28** Two identical polygons, on the left subsectioned with “Staircase” fill and on the right, subsectioned with “Diagonal” fill.

☆ *Objects ⇒ Polygons ⇒ Param ⇒ Subsections*:

This option allows you to change the subsectioning for a <u>selected</u> polygon or polygons (see Figure 29). First time users should leave the numbers set to the default values (1, 1, 100, 100).

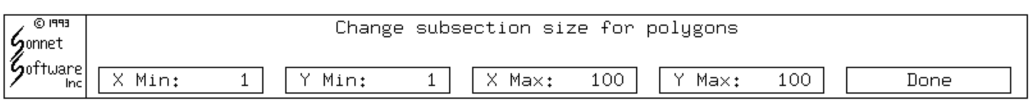



**Figure 29** The *Objects* ⇒ *Polygons* ⇒ *Param* ⇒ *Subsections* menu gives the advanced user control of the subsectioning of a selected polygon.

The X Min and Y Min values set the minimum size that ***em*** uses for calculating all subsection sizes. Moving toward the center of a polygon, ***em*** joins cells together into larger subsections. The subsection size continues to increase until it gets to the center of the polygon or it reaches the limits defined by X Max and Y Max. The maximum size of a subsection is controlled by the X Max and Y Max values. When X,Y Min = 1 (default), ***em*** uses one cell subsections on the edges of a polygon. When X,Y Min = 5, ***em*** uses five cell wide subsections on the edges of a polygon. If X Max is set to 100 (default), the subsection size in the x-direction will never be larger than 100 cells.

To use single-cell subsections everywhere in your polygon, set X Max and Y Max to one. To use as few cells as possible in your polygon, set all four parameters to a very large number.

Please note the following regarding the subsection parameters:

- The number of subsections may not exactly match the number of subsections calculated by ***em***. The above description is a simplification of the actual method used by ***em***.
- If X min or Y min is greater than your polygon size, ***Em*** uses subsections as large as possible to fill the polygon.
- If the maximum subsection size specified by X Max or Y Max happens to be greater than the subsections per wavelength (lambda) parameter, the subsections per wavelength takes priority.
- The default values of Min=1 and Max=100 are fine for most cases. Change large polygons that do not need as much accuracy from Min=1 to a large number.

To change the value for any of these items, click on the item that you want to change and enter in the new value. Click on *Done* when you are finished. Remember the numbers that you enter are integers that represent a multiplication factor based on the minimum cell size specified in the *Param* ⇒ *Box* ⇒ *Cell Size* button menu.

## ✧ Menu: Objects - Add Rectangles

***Xgeom*** provides you with a quick way to create rectangular polygons. To add a rectangle, select *Objects* ⇒ *Add Rect* or use the shortcut key ^R. Now place the cursor where you want one corner of the rectangle to be. Next, click and hold down the left mouse button and drag the cursor to form an outline of the desired rectangle. When the rectangle is the size and shape you wish, release the mouse button to make it permanent. You are still in the “add rectangles” mode until you choose another function. Once entered, the rectangle is converted to a polygon.

## ✧ Menu: Objects - Add Points

The *Add Points* menu option may be used when you want to add extra points to a polygon. To add points to a polygon, select *Objects* ⇒ *Add Points* and click the mouse with the cursor on the line segment of an existing polygon between whose endpoints you want to add points. Both endpoints of that line segment are highlighted. Now move the cursor close to where you would like a new point and depress and hold down the left mouse button. A “rubber band” appears connecting one of the highlighted points (highlighted by an “X”) to the cursor.

Move the cursor to the desired first point. When positioned properly, release the mouse button. To add another point, press and hold the left mouse button, move the cursor to the next point and release the mouse button. When finished, click the mouse button a second time with the cursor on the final point. As an alternative to double clicking on the last point, clicking once on the second highlighted point (the square symbol) also terminates the add operation.

As described previously, the ruler button, (the right mouse button), can be used to determine the correct position while adding points. Also, the *Delete* or *Backspace* key may be used while adding points to delete the last point entered.

## ✧ Menu: Objects - Ports

Use *Objects* ⇒ *Ports* to add or delete a port (*Add* and *Delete*) or to change the characteristics of a port (*Renumber* and *Param*).

### ☆ *Objects ⇒ Ports ⇒ Add*

To add a port, select *Objects* ⇒ *Ports* ⇒ *Add* and click on the center of the desired edge for the port. Ports are nearly always placed on the edge of the substrate so that the port has access to ground. Note that the edge must be on the substrate edge for the port to have access to ground. If this is not the case, ***em*** issues an error message and terminates.

**Internal ports**: Ports are allowed between two adjacent edges of polygons, (see Figure 30). Recall that a port actually consists of two terminals. In this case, one terminal is connected to one polygon, the other is connected to the other polygon. Ports on the edge of a single polygon are not allowed, with ***em*** generating a “port with no subsections" error message (see "Internal Ports and Via Ports" on page 48 of the **Em User's Manual**). Extreme care should be taken in interpreting the results since the port has no access to ground.

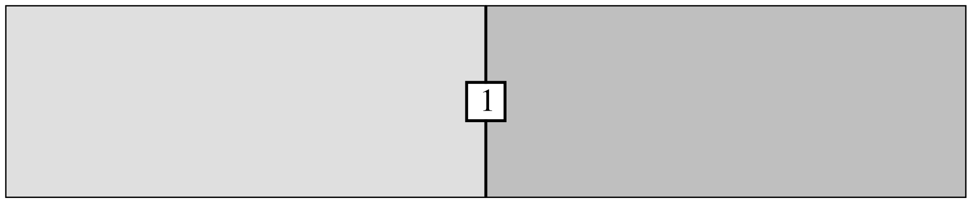



**Figure 30** An internal port shown connected between two rectangles.

**Via-ports:** Vias to ground may also be ports. This is just a special case of the internal port mentioned above with the port inserted between the via and the ground. This is analogous to coaxial connector underneath a circuit, with its center conductor penetrating the substrate and connecting to the circuit. Thus, when ports are desired on the interior of a circuit, capture a via to ground and add a port to the edge-via, (see Figure 31). The example "patch.geo" included with your software has an example of using a via-port.

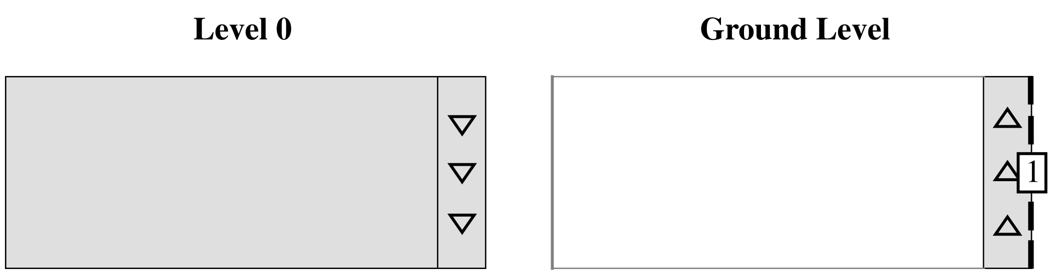



**Figure 31** A via port with both levels shown.

Ports are not allowed on diagonal lines and ports are not allowed to overlap each other (just touching is permitted). ***Em*** tests for these error conditions.

## ☆ *Objects ⇒ Ports ⇒ Delete*

To delete a port, select *Objects ⇒ Ports ⇒ Delete* and click on the port to be deleted. Port numbers are not renumbered when a port is deleted. For example, if you have three ports, numbered 1, 2, and 3, then delete port number 2, ports 1 and 3 remain.

### ☆ *Objects ⇒ Ports ⇒ Renumber*

Ports are numbered in the order that they are entered into the circuit. There is no limit on the number of ports and the number of ports has absolutely no impact on analysis time. To renumber a port, use *Objects ⇒ Ports ⇒ Renumber* and click on the port to renumber. Any non-zero integer, negative or positive, is valid.

As many physical ports as desired may be given the same numeric label, and all ports with the same label are electrically connected together (see Figure 32). Such ports can be called “push-push” ports and have many uses such as simulating thick metal. See Chapter 14, "Thick Metal with Arbitrary Cross-Section" in the ***Em* User’s Manual**.

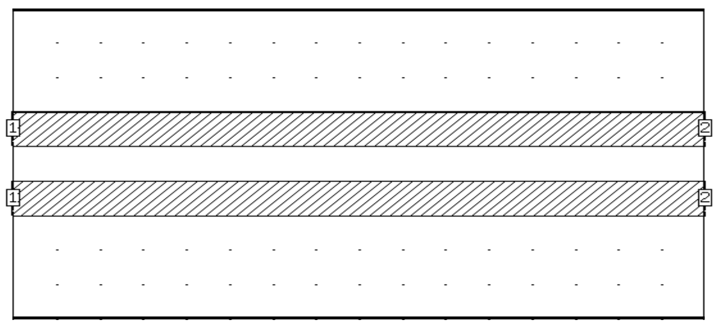


**Figure 32** Ports with identical port numbers are electrically connected together.

Ports may also have negative labels (see Figure 33). This feature can be used to redefine ground. Strictly speaking, ***em*** sums the total current going into all the positive ports with the same port number and sets that equal to the total current going out of all the ports with that same negative port number. For example, for a circuit with a +1 port and a -1 port, ***em*** sets current flowing into port +1 to be equal to the current flowing out of port -1. Thus the name “balanced”, or “push-pull” port. Both coplanar and slot line can be represented with balanced ports. See Chapter 13, "Co-Planar Waveguide Discontinuities and Balanced Ports" in the ***Em* User’s Manual**.

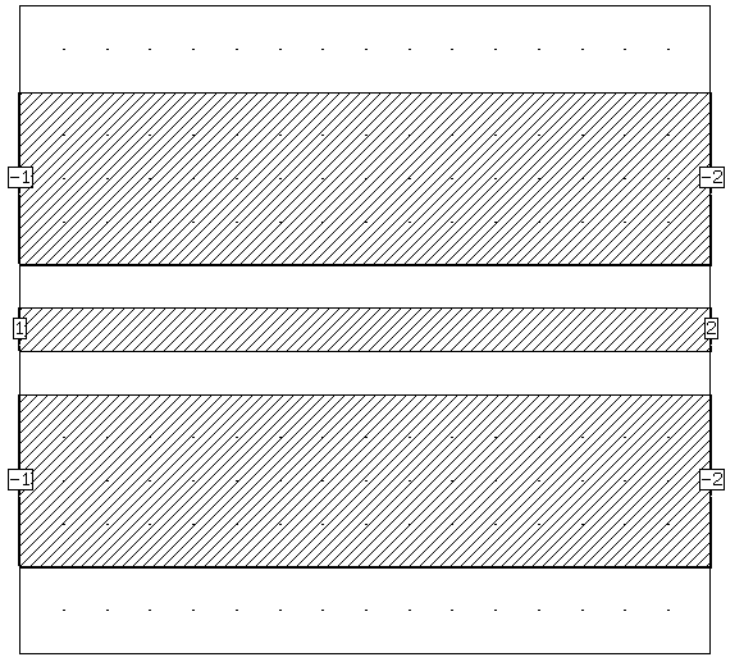



**Figure 33** An example of push-pull ports.

Ports may be non-sequential, i.e., you may have only 2 ports, one labeled “1” and the other labeled “4”. The port order for the S,Y, or Z parameters will be listed in increasing numeric order. For the example of a two-port with ports labeled “1” and “4”, the output would be as follows: S11, S14, S41, S44.

### ☆ *Objects ⇒ Ports ⇒ Param*

All ports are defined as 50 ohm ports by default. If you wish to change the port impedance, select *Objects ⇒ Ports ⇒ Param* and click on the port you wish to change. You are then prompted for the resistance, reactance, inductance, and capacitance in ohms,

ohms, nanohenrys, and picofarads respectively, (see Figure 34). Refer to section "Specifying Port Normalizing Impedances" on page 33 in the ***Em*** **User's Manual** for further discussion of these values.

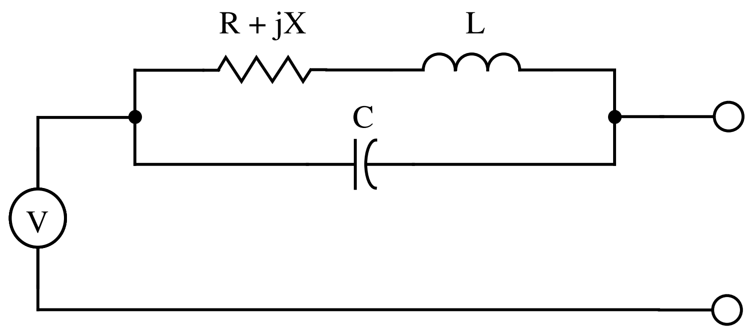



**Figure 34** Equivalent Circuit of an ***em*** Port

## ✧ Menu: Objects – Ref. Planes

***Em*** has an automatic de-embedding capability (-d option). When invoked, ***em*** removes the port discontinuity and a desired length of transmission line, moving the reference plane into the interior of the box. The reference planes used for de-embedding are set with this option. One reference plane per box side may be specified.

To set a reference plane, select *Objects* ⇒ *Ref. Planes* and click at the desired reference plane location. A new button menu appears with the selections *Left*, *Right*, *Top*, or *Bottom*. Select the side from which the reference plane is to extend. Any ports subject to the reference plane are drawn with an arrow extending to the specified reference plane. ***Em*** may change the reference plane slightly so that it is aligned with the edge of a cell. This modification is indicated with a short line at the actual reference plane location.

To remove a reference plane, click outside the box on the side of the reference plane you want to remove. There is only one reference plane per box side. The same reference plane is used on all ports on all levels on that side of the box. If you had previously specified a calibration length for that side, ***xgeom*** asks if you want to remove the reference plane. You can specify either a reference plane or a calibration length, but not both. See "Menu: Param - Cal. Length" on page 88.

## ✧ Menu: Objects - Vias

Use *Objects* ⇒ *Vias* to add or delete edge-vias. See Chapter 12, "Using Vias" for a detailed description of vias and definitions. To add an edge-via, select *Add*, then click on the polygon edge that you want the via added to. A dark dashed line appears showing where the edge-via is. With the metallization turned on, the via subsections are displayed. Each via-post has an "up" via symbol (an "up" triangle) indicating that the via connects this level to the next level above. Move up one level. The subsection vias are shown on this level with a “down” via symbol (“down” via triangle). Via-posts that are too small to be seen individually have a single via symbol representing multiple via-posts.

To delete a via select *Delete*, then click on the edge-via that you want deleted. Make sure that you are on the level where the edge-via starts (and goes up) and not on the level above where the via ends.

You may add edge-vias to all the edges of a polygon or multiple polygons at once. To do this, select the polygon(s) that you wish to add edge-vias to. Then choose *Objects ⇒ Vias ⇒ Add*. All edges of all selected polygons now have edge-vias associated with them. See section "Creating an Air-Bridge: An Example" on page 49 for more details on how to get the via metallization exactly where you want it to go.

You may also delete all vias associated with one or more polygons using the same approach. First select the polygons that you wish to have the vias removed from. Then choose *Objects ⇒ Vias ⇒ Delete*. All edge-vias connected to the selected polygons are deleted.

The length of the via must be small with respect to the wavelength. If not true, subdivide the dielectric layer into multiple layers and put vias on each of these layers.

# ♦ The Edit Menu Button

The Edit Menu Button contains functions that help you make changes to your circuit. Most of the items in this menu are unavailable (“shadowed”) until you select an object to edit. Chapter 11, "Editing Your Circuit", covers the basic concepts of how to use the *Edit* button. This section describes all of the edit menu items.

## ✧ Menu: Edit - Cut

*Edit ⇒ Cut* removes the selected polygons from your circuit and places them into the ***xgeom*** buffer. Any selected points are also deleted but are not put into the buffer. First, select the polygons that you wish to put into the buffer. These polygons may be on a single layer or multiple layers. Then choose *Edit ⇒ Cut.* The polygons are removed from your circuit and placed into the buffer. The polygons remain in the buffer until you replace them by doing another *Cut*, *Copy* or *Duplicate*. One use for *Edit ⇒ Cut* is to move polygons from one layer to another, but most of the time you will use *Edit ⇒ Cut* to delete polygons and points. The *Delete* and *Backspace* keys are shortcut keys for *Edit ⇒ Cut*.

## ✧ Menu: Edit - Copy

*Edit ⇒ Copy* leaves the selected polygons in their original locations but places a copy of the selected polygons into the ***xgeom*** buffer. First, select the polygons that you wish to copy into the buffer. The polygons may be on multiple levels. Then choose *Edit ⇒ Copy.* The polygons are copied into the buffer and remain in the buffer until you replace them by doing another *Cut*, *Copy* or *Duplicate*. *Edit ⇒ Copy* is the same as *Edit ⇒ Cut* except that the polygons are not deleted from your circuit. One use for *Edit ⇒ Copy* is to copy polygons from one layer to another so that you have identical polygons on both levels. This is sometimes done to simulate thick metal (see Chapter 14, "Thick Metal with Arbitrary Cross-Section" in the ***Em* User's Manual**). You can even use *Edit ⇒ Copy* to copy polygons from one ***xgeom*** window to another.

## ✧ Menu: Edit - Paste

*Edit ⇒ Paste* copies the polygons that are in the ***xgeom*** buffer to your circuit. The polygons remain in the buffer until you replace them by doing a *Cut*, *Copy* or *Duplicate*. *Edit ⇒ Paste* is typically used after using *Edit ⇒ Copy* to copy polygons from one layer to another or from one ***xgeom*** window to another.

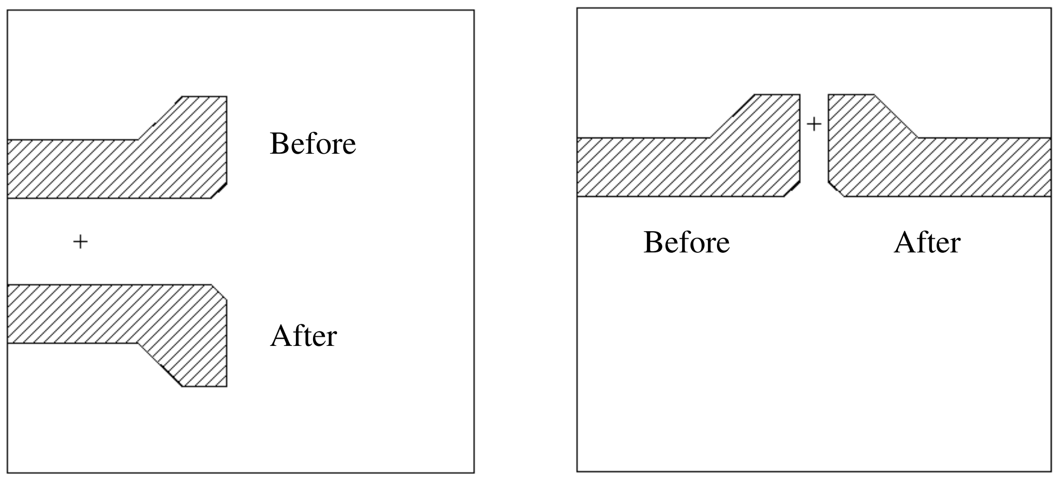
## ✧ Menu: Edit - Duplicate

*Edit ⇒ Duplicate* is a quick way of combining *Edit ⇒ Copy* and *Edit ⇒ Paste* into one command. *Edit ⇒ Duplicate* copies the selected polygons into the ***xgeom*** buffer, and places a duplicate of the polygons into your circuit. Use this option when you want to duplicate part of a circuit on the same layer. One example of this would be if you wanted to create a mirror image of a polygon. You would first Duplicate your polygon, and then Flip it (see next section on *Edit ⇒ Flip*).

## ✧ Menu: Edit - Flip

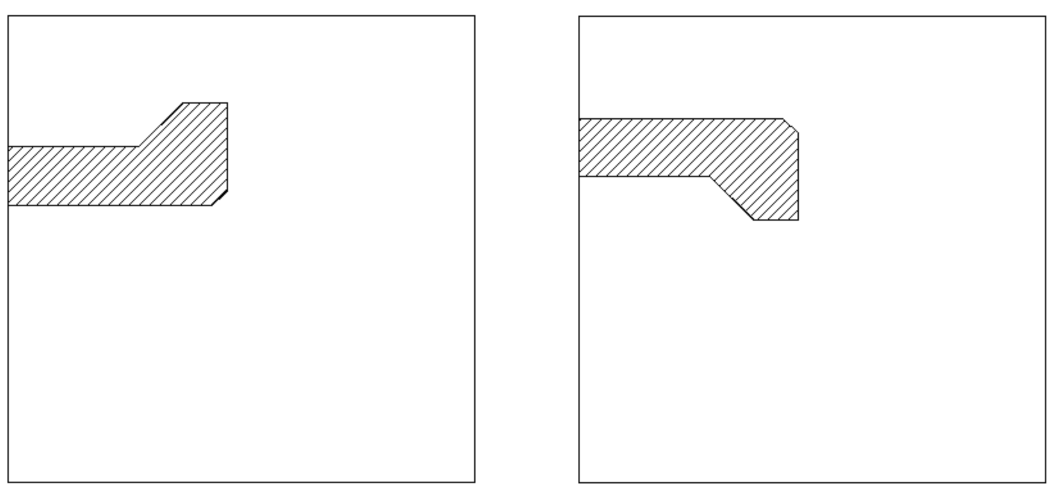
*Edit ⇒ Flip ⇒ Left-Right* flips a selected polygon about a vertical axis so that its left side is on the right. *Edit ⇒ Flip ⇒ Up-Down* flips a selected polygon about a horizontal axis so that its top is on the bottom.

You have the choice of flipping polygons about an axis passing through the center of the polygon or an axis passing through the ruler. The *Edit ⇒ Flip* menu displays the present mode for flipping: either *Use <Center>* or *Use <Ruler>*. To toggle from one mode to the other, click on the *Use <Center>* or *Use <Ruler>* button. Please note that you must set the ruler before you can select the “Ruler” mode. Figure 35 gives an example of flipping *Up/Down* vs. *Left/Right* (using the “Ruler” mode) and Figure 36 shows a polygon flipped about its center.




Flipping “Up/Down” Flipping “Left/Right”

**Figure 35** *Edit* ⟹ *Flip* can be used to flip a polygon about the ruler.



Before Flipping After Flipping

**Figure 36** *Edit* ⟹ *Flip* can be used to flip a polygon about its center. In this example the polygon was flipped “Up/Down”

## ✧ Menu: Edit - Rotate

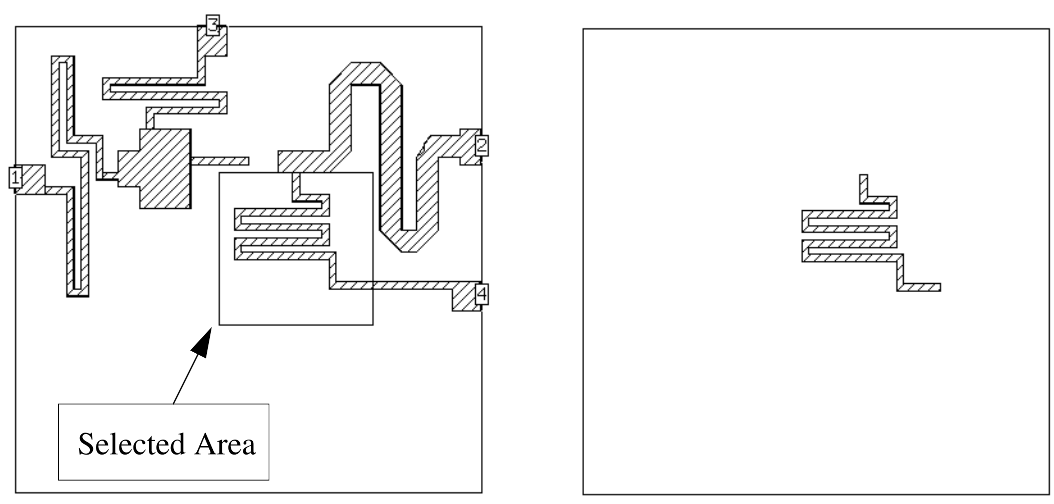
*Edit* ⇒ *Rotate* rotates a selected polygon or polygons 90˚ clockwise or counterclockwise. To rotate a polygon 90˚ clockwise, first select the polygon and then choose *Edit* ⇒ *Rotate* ⇒ *Right*. To rotate counterclockwise choose *Edit* ⇒ *Rotate* ⇒ *Left*. You may also rotate by an arbitrary angle by using *Edit* ⇒ *Rotate* ⇒ *Angle*. You are then prompted for the angle. See Figure 25 on page 59 for a description of the ***xgeom*** coordinate system. You also have a choice to rotate about the polygon's center (*Use <Center>*) or the ruler (*Use <Ruler>*) as discussed in the previous section entitled "Menu: Edit - Flip" .

## ✧ Menu: Edit - Magnify

*Edit* ⇒ *Magnify* magnifies (smaller or larger) the selected polygon(s). ***Xgeom*** prompts for a magnification factor. If you enter in a number smaller than unity, the polygon becomes smaller and if you enter in a number larger than unity, the polygon becomes larger. One use for this function is to scale a hard-to-draw polygon such as a circle. You could draw a circle once in ***xgeom*** and have it stored away in a common file. You could then copy it into your current ***xgeom*** window using *Edit* ⇒ *Copy* and then scale it to the proper dimensions using *Edit* ⇒ *Magnify.*

## ✧ Menu: Edit - Clip

*Edit* ⇒ *Clip* removes all of a circuit outside a selected area (see Figure 37).




Before Clipping After Clipping

**Figure 37** *Edit* ⇒ *Clip* can be used to remove metal outside of a selected area.

## WARNING

Save your file before using *Edit* ⇒ *Clip*. Clipping an area may delete large portions of your circuit.

You can use *Edit* ⇒ *Clip* if you have a complex circuit already entered into ***xgeom*** and you want to analyze just a portion of the circuit. To do this, choose *Edit* ⇒ *Clip* and window out the area that you wish to analyze. All metallization is removed except what is inside of your windowed area.

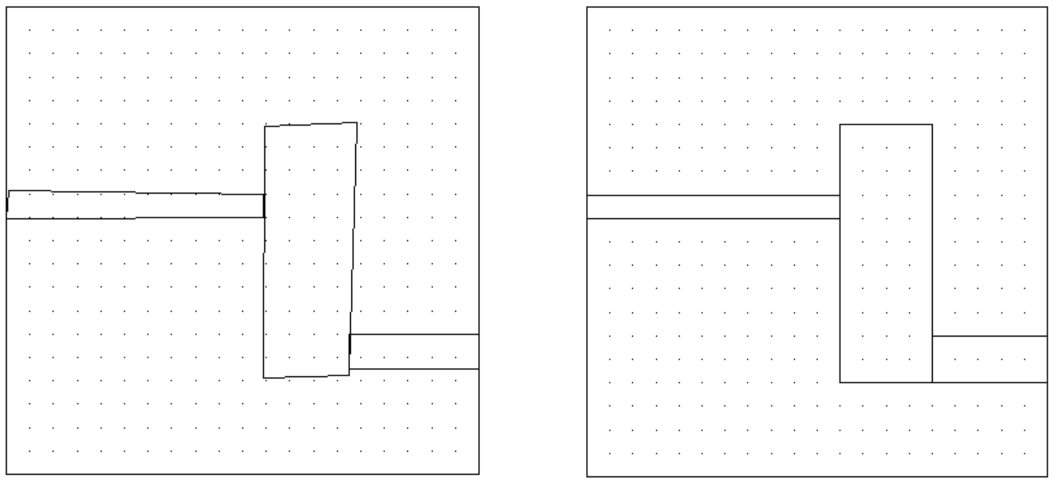
Note that *Edit* ⇒ *Clip* is a multi-layer operation. Any metal on another level inside the selected area will not be removed and any metal on another level outside the selected area will be removed.

Sometimes the selected area will pass through a polygon, i.e., only part of a polygon is clipped. In this case, any ports or edge-vias associated with that polygon are removed. This is true even if the port or edge-via is inside of the selected area. To maintain the port or edge-via, you must window out the entire polygon associated with the port or edge-via.

Another use of *Edit* ⇒ *Clip* is if you suspect that there may be polygons outside your substrate, you can select *Edit* ⇒ *Clip* and window out the entire substrate. Any polygons outside of the substrate are removed.

## ✧ Menu: Edit - Snap

*Edit* ⇒ *Snap* "snaps" the selected polygons and points to the nearest snap grid point. This is sometimes useful after converting a GDSII file. See Chapter 1 of the **Utilities Manual** for information on the ***gds*** program.



Before Snapping After Snapping

**Figure 38** Use *Edit* ⇒ *Snap* to snap polygons to nearest grid points.

The current snap dimensions are configured in the *Param* ⇒ *Snap* button menu. See section "Menu: Param - Snap" on page 87 for information about the snap grid. Note that the subsectioning of an unsnapped polygon can be visualized by turning the metal "on". Figure 38 shows a polygon before and after snapping.

## ✧ Menu: Edit - Undo

If you make a change that you did not want to do, you can undo the last change by using *Edit* ⇒ *Undo*. Most *Objects* and *Edit* commands, as well as moving points and polygons, can be corrected by using *Edit* ⇒ *Undo*. *Undo* is "shadowed" and unavailable if there is nothing to undo.

# ♦ The Select Menu Button

The Select menu button controls selecting points and polygons. Chapter 11, "Editing Your Circuit", covers the basic concepts of how to use the *Select* button. This section describes all of the Select menu items.

## ✧ Menu: Select - Single Layer

*Select ⇒ Single Layer* puts you in the single-layer select mode. This means that pressing the left mouse button with the cursor inside a polygon selects it. Only points and polygons on the current layer are selected. To select a point, press the left mouse button with the cursor near that point. You may also lasso points and polygons. See section "Selecting Points and Polygons" on page 35 for a complete description of selecting.

To unselect all selected points and polygons, click the left mouse button anywhere on your circuit that is not inside a polygon or close to a point.

## ✧ Menu: Select - Mult. Layer

*Select ⇒ Mult. Layer* puts you in the multilayer select mode. One use for *Select ⇒ Mult. Layer* is for moving multiple level structures such as via structures. As described in section "Selecting Points and Polygons" on page 35, only the "select by lassoing" is affected. "Select by clicking" is the same as in the single-layer select mode.

## ✧ Menu: Select - All

*Select ⇒ All* selects all polygons on all levels. One use for *Select ⇒ All* is to change the metal type of all polygons at once.

## ✧ Menu: Select - Unselect

*Select ⇒ Unselect* puts you in the unselect mode. This means that pressing the left mouse button with the cursor inside a selected polygon or on a selected point unselects it. Only points and polygons on the current layer are affected.To unselect a selected point, press the left mouse button with the cursor on that point. You may also lasso points and polygons that you want to unselect. Any point or polygon that is inside the lasso region is unselected. If only a portion of a polygon is inside the region, then only that portion of the polygon is unselected. This menu item is only available whenever objects are selected.

## ✧ Menu: Select - Reselect

*Select ⇒ Reselect* reselects all points and polygons that were selected at the end of the last operation. For example, if, at the end of a move, you are not happy with the final location, you can reselect all the points again with this single option, rather than manually reselecting the points. This item is unavailable ("shadowed") whenever objects are selected.

As a shortcut, you can type ^T key in place of *Select ⇒ Reselect*.

# ♦ The View Menu Button

The View menu options allow you to change how information is presented on the display.

## ✧ Menu: View – Zoom In, Zoom Out, Prev View, Full View

You can zoom into a particular area of your circuit by using *View ⇒ Zoom In*. After selecting the option, the cursor, when in the main window, changes to indicate that ***xgeom*** is waiting for you to tell it where you want to zoom. Move the cursor to the upper left corner of the region you want magnified and press the left mouse button. Holding it down, drag the cursor to the desired lower right corner and release the mouse button. The specified region is expanded to fill the screen.

You may also use the zoom button (middle mouse button on most computers) as a shortcut for *View ⇒ Zoom In*. See the section "Zoom Button" on page 54 for more details.

Use *View ⇒ Zoom Out* to shrink your circuit in your window. This option is quite useful when you accidentally zoom in a little too far, and need to zoom back out. Each time you select *View ⇒ Zoom Out* the circuit shrinks in size. As a shortcut, you can type ^W to zoom out. Repeatedly typing ^W will eventually shrink your circuit down to just a small dot on the screen. If this happens, use *View ⇒ Full View* to restore the display to full size.

*View ⇒ Prev. View* allows you to toggle between the present view and the previous view. *View ⇒ Full View* resets the area displayed so that the entire substrate surface is visible on the available screen. As a shortcut, you can type ^Y or click the middle mouse button to toggle to the previous view (*View ⇒ Prev. View*) and type ^Z to reset the view (*View ⇒ Full View*).

## ✧ Menu: View - Pan

*View ⇒ Pan* moves the view of the window by moving the selected point on your circuit to the center of the window. After selecting this menu item, ***xgeom*** prompts you for the new center location. The point that you click on is moved to the center of your window and the display is redrawn.

## ✧ Menu: View – Metal

*View ⇒ Metal* toggles the display of the actual metallization (as subsectioned by ***em***) on and off. When metal is “on”, metal is displayed using the pattern specified in the *Param ⇒ Metallization* menu. All via-posts (see Chapter 12, "Using Vias") are also displayed. The metallization is not displayed on the ground plane except for the via-posts. The edges of the metallization are the actual edges that are analyzed by ***em***. Selection of a finer grid in *Param* ⇒ *Box* results in a better approximation to the edge. (It also results in a better representation of the current distribution, more accurate results and a longer analysis time.)

Selection of the edge fill mode (*Objects* ⇒ *Polygons* ⇒ *Param*) can also improve the fit of the actual metal to the desired edge. Finally, moving the outline edge slightly can also provide a better fit (see section "Moving Points and Polygons" on page 37).

## ✧ Menu: View – Grid

This option toggles a grid on and off. It is related to the cell size selected (see *Param* ⇒ *Box* ⇒ *Cell Size*). The distance between two grid points is equal to the cell size. This grid is not to be confused with the snap distance (*Param* ⇒ *Snap*). By default, the snap coordinates are set to coincide with the cell grid, however, the snap coordinates may be set to any other value (*Param* ⇒ *Snap*).

When *View* ⇒ *Grid* is active, one dot is displayed at the corner of every possible cell. Metallization is allowed to cover an entire cell or none of the cell. If the Diagonal edge fill option is active (see section "Menu: Objects - Polygons" on page 61), half a cell, cut diagonally, may also be filled/empty. To modify the cell size, see section "Menu: Param - Box" on page 82.

## ✧ Menu: View – Level

In standard microstrip, there are two dielectric layers (the substrate and the air above it) allowing only one metallization level. In this situation, this menu item is not used unless you are using vias. If more than one metallization level is specified (see section "Menu: Param - Box" on page 82), you may view and then modify metallization on any and all levels. The number of levels is unlimited.

Select *View* ⇒ *Level* and specify the level desired and it is displayed. The levels are numbered starting with *0* for the uppermost and working down.To move to the ground level, press *GND* for the level. If in doubt, select *Param* ⇒ *Dielectrics*. All dielectric layers are displayed and the metallization level numbers are indicated graphically.

Note that changing the metallization of a polygon does not change the level on which the polygon is located.

As a shortcut, you can type ^U to move up one level and ^D to move down one level. Also, on many computers, the *up arrow* and *down arrow* keys function the same as ^U and ^D.

## ✧ Menu: View - Visible

With ***xgeom***, you can view multiple levels at the same time. Each level may be visible or invisible. To change the visibility of a level, select *View* ⇒ *Visible*. A button menu appears. The menu indicates the present visibility value for the current level. Initially, when ***xgeom*** starts up, all levels are visible. Selecting *On* or *Off* makes the current level visible or invisible, respectively. Now move to a different level. Polygons on all visible levels can be seen on the screen as a dashed outline (see Figure 39). If you have a color monitor, the color of the dashed outline is the color of the level that the polygon is on as specified by selecting *Param* ⇒ *Dielectrics* ⇒ *Param* ⇒ *Color* (see section "Menu: Param - Dielectrics" on page 83). If you are using a monochrome monitor, then the dashed outline for all of the layers has the same color. Note the color of the polygon outline indicates what level the polygon is on and not the metal type.

To make a layer invisible, go to the layer that you want to make invisible. Select *View* ⇒ *Visible* ⇒ *Off*. This changes the level from being visible to invisible. Click on *All On* or *All Off* to change the visibility of all levels at once.

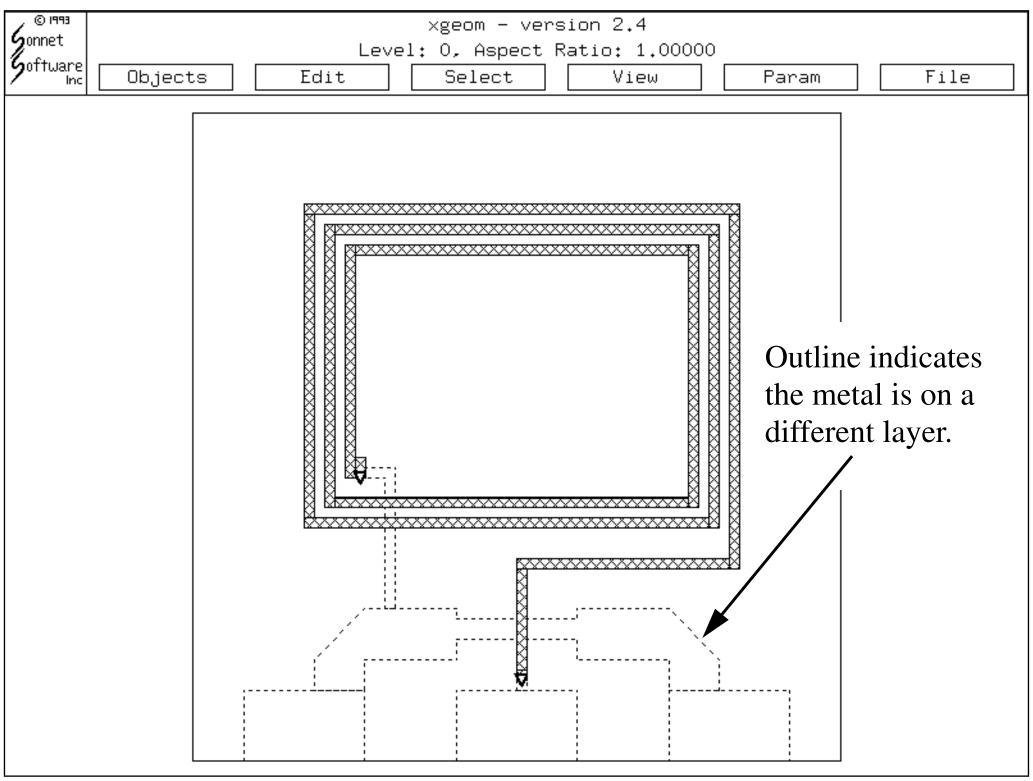



**Figure 39** Multiple levels may be seen at one time

As a shortcut, you can type ^I to make the current level invisible and ^V to make the level visible. Note that you will not see a change until you have moved to a different level.

### ✧ Menu: View – Aspect Ratio

You may specify the aspect ratio of the displayed plot. A value of 1.0 displays the circuit in its true proportions on any CRT. This option may be needed when obtaining hardcopy from devices with aspect ratios different from your CRT. When prompted for the aspect ratio, pressing *Return* leaves the existing value unchanged.

### ✧ Menu: View - Ruler

This menu item allows you to set the location of the ruler origin or turn the ruler off. You can also set the ruler origin from the ruler mouse button (see "Measuring Dimensions" starting on page page 55). Click on *(0,0)* to set the ruler origin to your circuit origin (default is the top left corner of the substrate). Click on *Manual* to set the ruler origin to a specific x, y coordinate. To turn the ruler off, click on *Off*. If you want to measure distances from the last added point while adding a polygon, you must turn off the ruler, otherwise you are measuring from the ruler origin.

### ✧ Menu: View - Origin

By default, the origin used for all coordinates is the top left corner of your substrate. This may be changed to the bottom left corner by selecting *View ⇒ Origin* and clicking on *Bottom Left*. All absolute coordinates for this ***xgeom*** window are now with respect to the bottom left corner of your box until you change it using *View ⇒ Origin* or until you exit ***xgeom***. If you think that you will always want the left bottom corner as your origin, see Appendix I, "The Xgeom Command Line" for instructions on how to make the bottom left corner your default origin.

### ✧ Menu: View - Redraw

This menu item redraws the ***xgeom*** window.

## ♦ The Param Menu Button

The Param Button allows specification of the parameters of the box, substrate and dielectric layers, metallization, length units, and the snap grid.

## ✧ Menu: Param – Box

Selection of this menu item displays parameters of the box which contains the circuit to be analyzed as well as a new button menu which allows those parameters to be changed.

### ☆ *Param ⇒ Box ⇒ Area*

Clicking on the *Area* button displays another button menu that gives you the option to enter in the substrate area by using the keyboard or mouse. If you select *Keyboard*, ***xgeom*** allows you to choose to keep either the cell size or the number of cells constant. Choose *# of Cells* to keep the number of cells constant or choose *Cell Size* to keep the cell size constant. After choosing, ***xgeom*** prompts for the X and Y dimensions of the box. Pressing *Return* without typing anything leaves the present value unchanged. Clicking on *By Mouse* allows you to use the mouse to resize the box area while keeping the cell size constant. You are prompted to window out the new substrate area. Press the left mouse button (without releasing) with the cursor on one corner of the new substrate and drag the cursor to the opposite corner. Now release the mouse button. The substrate is now resized.

### ☆ *Param ⇒ Box ⇒ Cell Size*

Selecting cell size is important. The ***em*** analysis automatically subsections the circuit based on the cell size. A smaller cell size means a more accurate analysis and a longer analysis. When the cell size option is selected, yet another button menu is displayed. The options include *Dimensions*, *#/side*, and *Subs/Lambda*:

### ☆ *Param ⇒ Box ⇒ Cell Size ⇒ Dimensions*

Specify the physical dimensions of a cell. Since an integer number of cells must fit onto the substrate area, ***xgeom*** picks the next smallest allowed size. Note that the X and Y values may be different.

### ☆ *Param ⇒ Box ⇒ Cell Size ⇒ #/side*

Specify the integer number of cells per box side. The cell size dimension is modified appropriately. Use either this option or the *Dimensions* option to specify cell size. The cell size is determined by whichever option you used last.

### ☆ *Param ⇒ Box ⇒ Cell Size ⇒ Subs/Lambda*

***Em*** uses a variable subsection size. Small subsections are used where needed (e.g., around corners) and larger subsections are used elsewhere. This reduces the size of the matrix (which must be inverted), often providing a dramatic increase in the speed of an analysis. In no case are the subsections smaller than the smallest size specified by the cell dimensions, above. This option allows the specification of a maximum subsection size, in terms of subsections per wavelength. For good accuracy, 20 subsections per wavelength is suggested. This means that the maximum size of a subsection is 18 degrees at the highest frequency of analysis. For extreme accuracy (say, when looking at a very small discontinuity) 100 subsections per wavelength may be useful. If the smallest possible subsection is larger than that required for this limit, this limit is ignored and all subsections are the same, minimum, size. See section "Menu: Objects - Polygons" on page 61 for information on how to specify the maximum and minimum subsection size on a polygon by polygon basis.

### ☆ *Param ⇒ Box ⇒ Symm*

Specify whether symmetry is turned on or off. Most circuits should have symmetry off. If a circuit is symmetric about the center line parallel to the X axis and has ports only on this center line on any layer, then activating Symmetry results in a faster analysis. When symmetry is turned on, everything below the line of symmetry is ignored, and all metal above the line of symmetry is “reflected” about the symmetry line. Therefore, you may enter in just half of your circuit, making sure that you enter in the half that is above the line of symmetry. Do not place ports below the line of symmetry. It is recommended that first time users capture the entire circuit when using symmetry, not just half the circuit, thus toggling symmetry on and off affects only the speed of the analysis, not the final result.

### ☆ *Param ⇒ Box ⇒ Levels*

Specify the number of metallization levels (microstrip = 1). The number of dielectric layers (*Param ⇒ Dielectrics*) is then just one more than the number of metallization levels (e.g., microstrip substrate and air). If a new specification of the number of levels results in loss of circuit, a verification is requested. You can also change the number of dielectric layers and thus the number of metal levels by using *Param ⇒ Dielectrics*.

With all of the above options, just pressing *Return* when prompted for input leaves the existing value unchanged.

## ✧ Menu: Param - Dielectrics

This option allows specification of the dielectric layers in the box and allows layers to be added or deleted. Each layer is drawn in the main window with the parameters of one of the layers highlighted in inverse video, (see Figure 40). For your convenience, the ***xgeom*** “level” number is shown on the left. A “level” is defined as the intersection of any two layers and is where your circuit metal is placed. Select the layer to be changed by clicking on either the *Next* or *Prev* (for previous) buttons.

When the desired layer is highlighted, the dielectric constant, thickness and loss tangent may be changed by clicking on *Param* and entering the desired values. You may also change a single item by clicking on the value and typing in the new one. Magnetic permeability and magnetic loss tangent can also be modified, but must be done with a text editor directly on the resulting ".geo" file. See Appendix III, "The Circuit Geometry File Format" in the ***Em*** **User's Manual** for a description of the ".geo" file format.

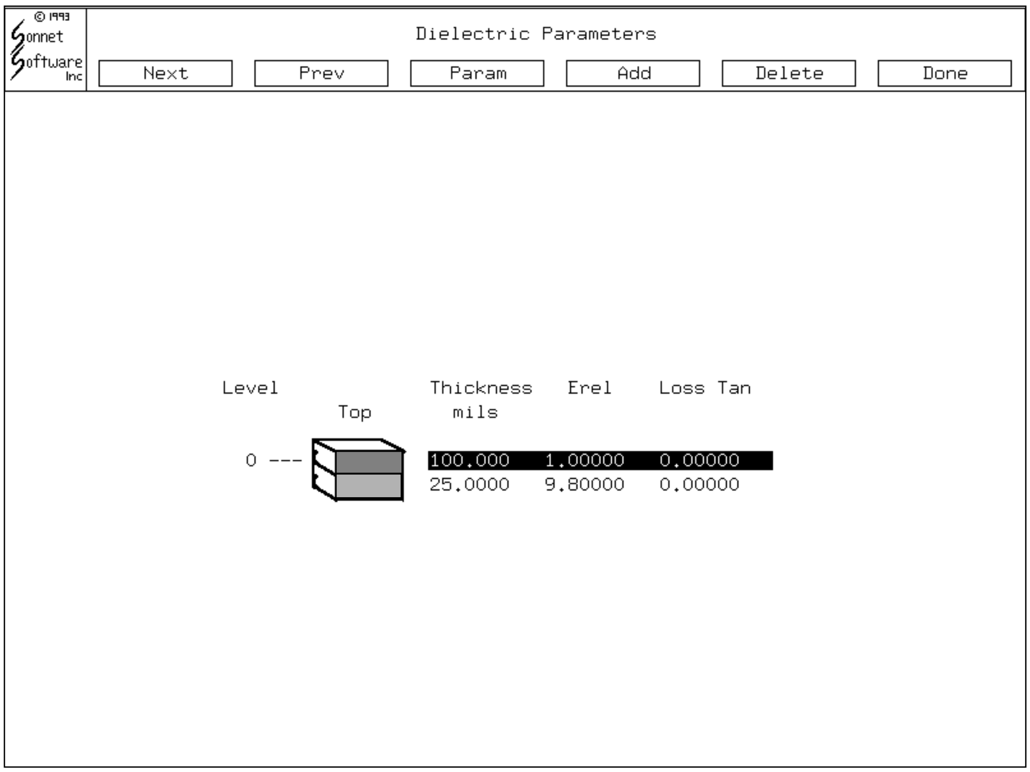



**Figure 40** The dielectric menu shows you a simplified side view of your circuit.

***Xgeom*** allows you to view multiple levels simultaneously. The *Color* option allows you to select the color you want to represent the level. Click on *Color* to toggle through different colors. You may also click on the actual color you want to change.

You may add or delete dielectric layers, by clicking on *Add* or *Delete*. Next specify how many layers you want to add or delete. When you add layers, the layers are added above the layer that is highlighted. If you need to add layers directly above the ground level, use *Param* ⇒ *Box* ⇒ *Level*. (See section "Menu: Param - Box" on page 82). When you delete layers, the layers are deleted beginning at the layer that is highlighted. If you specify more than one layer to be deleted, the extra layers are deleted below the highlighted layer.

## ✧ Menu: Param – Metallization

A metallization specifies the metallization loss used by ***em***. All metallizations may be used on all levels and with different polygons on the same level. Since the metallization loss is unrelated to the level on which a polygon is located, changing the metallization of a polygon does not change the physical location of the polygon, it changes only the metallization loss.

Selecting *Param* ⇒ *Metallization* displays a list of metallizations available. This section also allows you to change the resistivity of the top and bottom of the box. To add a new type of metal, click on *Add*. ***Xgeom*** now asks for a metal name. Choose a name that describes the type of metal, such as "air-bridge" or "copper". A new metal type is added to the end of the list with lossless parameters. ***Xgeom*** now prompts you for metallization resistivity (DC and skin effect) and metallization reactance.

To change the parameters of an existing metal, click on the *Next* button until the metal is highlighted. Now click on *Param* to change the parameters of the highlighted metal. Another way to change the parameters of an existing metal is to click on the value to be changed and then type in the new value.

To delete a metal type, first click on *Next* until the metal you want to delete is highlighted. Then click on *Delete*. The highlighted metal type is deleted. If any polygons currently refer to this metallization, the polygon is changed to lossless.

To change the name of the metallization, click on *Name*. ***Xgeom*** now prompts you for a descriptive name (just pressing *Return* leaves the existing name unchanged). Following specification of the name, you may step through patterns until you have a pattern (for display by the *View* ⇒ *Metal* option) as desired.

There are two kinds of metallization loss specified. The first is DC, low frequency loss. In this case, the skin depth is much thicker than the metallization. This is also known as the electrically thin case. Thin film resistors at any frequency fall into this case, as well as thin conductors at low frequency. DC resistivity loss is independent of frequency. The units are Ohms/square with the value given by:

$$R_{DC} = \frac{1}{\sigma t}$$

where:

$\sigma$ is bulk conductivity (Mhos/M).

t is the metallization thickness(M),

In contrast, at higher frequencies, the skin effect surface impedance is a function of frequency. The number that you type into ***xgeom***, $R_{RF}$, called the skin effect coefficient, is multiplied by the square root of the frequency (in Hertz) to arrive at the surface impedance (Ohms/square). The surface impedance is complex with the imaginary part equal to the real part. The skin effect coefficient that you type into ***xgeom*** is approximately given by:

$$R_{RF} = \text{ skin effect coefficient} \approx \sqrt{\pi\frac{\mu}{\sigma}}$$

where:

$$\mu = 4\pi \times 10^{-7}$$

The above equation assumes that all of the current travels on just one side of the conductor. This is a good approximation for microstrip. The equation should be modified for other structures. Stripline, for example, has current of equal amplitude on both the top and bottom of the conductor. In this case, you should divide the $R_{RF}$ value by two.

As an example, $\sigma$ for copper is $5.8 \times 10^{7}$ Mhos/M giving $R_{DC}$ = 0.006 Ohms/square (t = 3 uM) and a microstrip $R_{RF} = 2.6 \times 10^{-7}$ (enter “2.6e-7” into ***xgeom***). In an actual situation, the bulk conductivity of copper (or whatever metal) may not equal the laboratory value, so the figures as calculated above probably should be a bit higher. Table 1 gives calculated results of commonly used metals using the equations above. Ranges of $R_{DC}$ and $R_{RF}$ values are given because your actual metal may have more loss than the laboratory value.

**Table 1: Properties of Commonly Used Metals**

| **Metal** | $\sigma$ (S/M) | $\mathbf{R_{DC}}$ ($\Omega$/sqr) t = 1 uM | $\mathbf{R_{DC}}$ ($\Omega$/sqr) t = 1 mil | $\mathbf{R_{RF}}$ ($\Omega Hz^{-1/2}$/sqr) (microstrip) | $\mathbf{X_{DC}}$ |
|---|---|---|---|---|---|
| Aluminum | 3.72e7 | 0.028 - 0.056 | 1.1e-3 - 2.1e-3 | 3.3e-7 - 6.5e-7 | 0 |
| Brass | 1.57e7 | 0.070 - 0.140 | 2.5e-3 - 5.0e-3 | 5.0e-7 - 1.0e-6 | 0 |
| Copper | 5.80e7 | 0.017 - 0.034 | 6.8e-4 - 1.4e-3 | 2.6e-7 - 5.2e-7 | 0 |
| Gold | 4.09e7 | 0.024 - 0.048 | 9.6e-4 - 1.9e-3 | 3.1e-7 - 6.2e-7 | 0 |
| Nichrome | 1.00e6 | 1.000 - 2.000 | 3.9e-2 - 7.9e-2 | 2.0e-6 - 4.0e-6 | 0 |
| Silver | 6.17e7 | 0.016 - 0.032 | 6.4e-4 - 1.3e-3 | 2.5e-7 - 5.0e-7 | 0 |
| Tantalum | 6.45e6 | 0.155 - 0.310 | 6.1e-3 - 1.2e-2 | 7.8e-7 - 1.6e-6 | 0 |
| Tin | 8.70e6 | 0.115 - 0.230 | 4.5e-3 - 9.1e-3 | 6.7e-7 - 1.4e-6 | 0 |

The transition from electrically thin (DC) to electrically thick (RF) is properly modeled in ***em***. Thus ***em*** provides accurate results at low, high and transition frequencies. If $R_{RF}$ is set to 0.0, then the value of $R_{DC}$ is used over all frequencies. This is the usual case for resistors.

The resistivity of the top and bottom of the box can be specified. Set the DC resistivity to 377 Ohms/square to approximate removing the top of the box. This is useful for removing box resonances and for analysis of radiation loss, including microstrip antennas.

The surface reactance is specified in Ohms/square and is usually set to zero. See section "Surface Reactance" on page 55 in the ***Em*** **User's Manua**l for an explanation of surface reactance.

For vias, the metallization loss for the via-post is the same as the polygon that the via is associated with.

Whichever metallization is left selected (shown with an "X") is the metallization which is used for the subsequent creation of polygons in *Objects* ⇒ *Polygons* ⇒ *Add* and *Objects* ⇒ *Add Rect*.

## ✧ Menu: Param – Length Units

Upon selection of this option you can step through all built in length units (mils, microns, etc.) in ***xgeom*** as well as specify your own units, if desired. Nonstandard units (e.g., furlongs) may be specified by providing a name for the unit and a factor which allows conversion to meters.

## ✧ Menu: Param – Snap

This option prompts for a new snap distance. All captured coordinates and all ruler measurements are snapped to this grid. For example, with a snap of 0.1 mils, a captured point at 10.05 mils is impossible.

---

☞ **NOTE**

The snap distance of your circuit affects how the polygons are entered.
It does not change the size of your subsections.

---

*Param* ⇒ *Snap* ⇒ *Cell Snap* sets the snap coordinates to match the cell grid (*Param* ⇒ *Box* ⇒ *Cell Size*). If the cell size is changed and this option is in effect, the snap coordinates change to match the new cell grid.

Alternatively, one can select *No Snap*, in which case captured coordinates are exactly where the cursor is, which actually means all coordinates snap to the nearest pixel. Any arbitrary snap grid can be specified by selecting *Other*. ***Xgeom*** then prompts for X and Y snap distances. Use this option if, for example, you want to capture a polygon with all coordinates snapped to the nearest micron.

## ✧ Menu: Param – Cal. Length

*Param ⇒ Cal. Length* allows you to specify the calibration length used for de-embedding. ***Xgeom*** displays the current values for each of the four sides (top, bottom, left, and right) of the substrate. Choose a side of the substrate by clicking on the value you want to change. If you have already specified a reference plane for the selected side, ***xgeom*** will ask if you want to remove the reference plane. ***Xgeom*** allows you to specify a reference plane or a cal length, but not both. If you don't want to remove the reference plane, click on *Cancel*. Click on *Continue* to remove the reference plane. Type in the new value for the calibration length. Pressing the *Return* key without typing a value leaves the value and reference plane unchanged. Please note that it is possible for the calibration length to be greater than the box length. When finished, click on *Done* to get back to the main button menu.

## ✧ Menu: Param – Parallel Subs.

*Param ⇒ Parallel Subs.* allows the removal of X or Y subsections for a specified distance from a box wall. This feature is useful for reducing computational time although it may affect the accuracy of the results. It is referred to as "Parallel Subs" because all subsections in the specified region that are parallel to the selected box wall are removed. Refer to the ***Em* User's Manual** for more information about removing parallel subsections before using this function.

After selecting this option, ***xgeom*** gives you two choices: *Add* and *Delete*. If you select *Add*, you are then prompted for one of the four sides (top, bottom, left, and right) of the ***xgeom*** box. You then must click on a location in your circuit. ***Em*** will remove the appropriate subsections (Y for the left and right sides, X for the top and bottom) up to the specified distance, shown as a grayed-out area (see Figure 41).

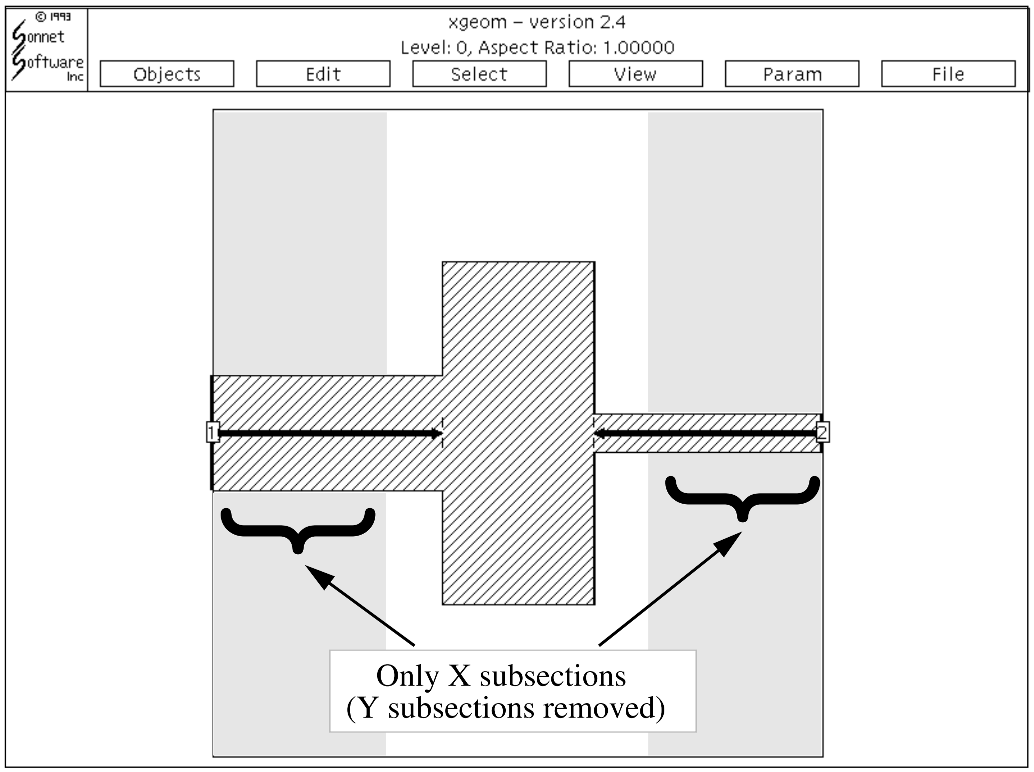



**Figure 41** The Parallel Subsections option removes either X or Y subsections over a specified distance from the box wall.

For a new circuit, values for all four box walls default to zero (i.e., no subsection removal).

To delete a parallel subsections region, choose *Delete* from the *Parallel Subs* menu.

# ♦ The File Menu Button

The File Button allows you to save a file to disk, load a file from disk, change the default directory and view the file comments. It also allows you to start over again.

## ✧ Menu: File - Save

You may use *File* ⇒ *Save* to save your circuit to disk. The next menu asks you to select a file name. The file is saved in the default directory under the name you specify. We recommend that you use a name that ends in ".geo". If you don't use a file extension, ***xgeom*** will automatically use an extension of ".geo". ***Xgeom*** allows you to have comments in the file so that you can remember its contents. If you were modifying an existing file, ***xgeom*** asks if you want to transfer comments from the previous version of the file. Click on *Yes* if you want to transfer the comments without changes. If you want to change the comments, click on *Add/Change*. ***Xgeom*** displays each comment line individually. You can either accept the line without change, delete the line or replace the line. After ***xgeom*** has displayed all the comments, it asks if you want to add any new comments. Simply enter each new comment line. Finish entering the comments by pressing the *Return* key at the beginning of the line. ***Em*** reads these comments and transfers them to the output file so that the resulting analysis can be easily traced to the ".geo" file it came from.

## ✧ Menu: File - Load

Select *File* ⇒ *Load* to load a file in from disk. ***Xgeom*** asks for the file name and then loads in this file from the default directory. ***Xgeom*** will automatically use a default file extension of ".geo" if a file extension is not specified after the file name. If you do not know the name of the file, simply open a window and use the appropriate command to list the directory files. You can of course specify full or relative path names. However, wildcarding is not allowed, so if you specified "fil*.geo", "filter.geo" would not be read in, but instead ***xgeom*** looks for a file with the exact name of "fil*.geo".

## ✧ Menu: File - Directory

Select this option to change the default directory where ***xgeom*** saves and loads in the ".geo" files. As part of the menu, the default directory is displayed. To change the default directory, type in the full or relative path to the new directory.

## ✧ Menu: File - Comments

Select this option to view the comments. To change the comments you must save the circuit to a file. To view the next comment, click on *Next Comment*. To stop viewing the comments, simply click on *Done*.

## ✧ Menu: File - Clear

This menu item completely clears the circuit after asking for verification. It does not erase the box, dielectric or metal parameters.

### ✧ Menu: File - Quit

Use *File* ⇒ *Quit* when you are finished. If you haven't saved your circuit to disk, you are asked for a verification.

## ♦ Keyboard Shortcuts

The table below describes a few keyboard shortcuts. All of these functions may also be implemented by the menu. Most shortcut keys are "control" keys, abbreviated with a "^" symbol. As an example, to type a *Control-P* (^P), hold down the *Control* key and press the *P* key. The *DEL* key is the *Delete* and/or *Backspace* key and the *ESC* is the *Escape* key.

| KEY | MEANING |
|---|---|
| **^D** | Move down one level |
| **^E** | Duplicate |
| **^I** | Make present level invisible |
| **^M** | Metal On/Off (toggle) |
| **^O** | Add Points |
| **^P** | Add Polygons |
| **^R** | Add Rectangle |
| **^T** | Reselect |
| **^U** | Move up one level |
| **^V** | Make present level visible |
| **^W** | Zoom out wider |
| **^Y** | Previous View |
| **^Z** | Full View |
| ***DEL*** | Cut |
| ***ESC*** | Select Single Layer |

In addition, clicking on the *Select* menu button is the same as the *Escape* key, (Select Single Layer). Also, on many computers, the *up arrow* and *down arrow* keys function the same as ^U and ^D.

# Menu Summary

| Objects | Edit | Select | View | Param | File |
|---|---|---|---|---|---|
| Polygons... | Cut | Single Layer | Zoom In | Box... | Save... |
| Add Rect. | Copy | Mult. Layer | Zoom Out | Dielectrics... | Load... |
| Add Points | Paste | All | Prev. View | Metallization... | Directory... |
| Ports... | Duplicate | Unselect | Full View | Length Units... | Comments... |
| Ref. Planes | Flip... | Reselect | Pan | Snap... | Clear |
| Vias... | Rotate... | | Metal | Cal. Length... | Quit |
| | Magnify... | | Grid | Parallel Subs... | |
| | Clip | | Level... | | |
| | Snap | | Visible... | | |
| | Undo | | Aspect Ratio... | | |
| | | | Ruler... | | |
| | | | Origin... | | |
| | | | Redraw | | |

**Figure 42** Chart of ***xgeom***'s menu options.

# Appendix I The *Xgeom* Command Line

Run ***xgeom*** by typing “xgeom <options> <file-name>”. Options may appear after the file name. A file name ending in “.geo” is recommended. If no file name is provided, “cir.geo” is assumed. If the file does not exist, a new circuit is started.

Most of the usual X Window System command line options are available. For example, to run ***xgeom*** on one computer while using the display, keyboard and mouse of another computer (node name, say, “galaxy”), type:

**xgeom -display galaxy:0**

***Xgeom*** also looks in all the usual places for the X Window System defaults.

***Xgeom*** options are as follows (associated resource keywords are in parentheses):

| | |
|---|---|
| **-a <x>** | (*aspect) Sets the aspect ratio (see section "Menu: View - Aspect Ratio" on page 81), x is a floating point number. |
| **-aspect <x>** | Same as -a. |
| **-autoSave <x>** | Changes the autosave delay time from the default of 5 minutes to x minutes. Setting x to 0 disables the autosave feature. |
| **-background <color>** | (*background) Sets the background color. |

| | |
|---|---|
| **-backing** | (*backing: yes) Uses backing store, if supported by display. This provides faster re-draw in exchange for larger memory requirements. Unless modified, default is no use of backing store. |
| **-bd <color>** | (*borderColor) Sets color of main window border. |
| **-bg <color>** | Same as -background. |
| **-borderwidth <x>** | (*borderWidth) Sets main window border width to x pixels if allowed by the window manager. |
| **-bordercolor <color>** | Same as -bd. |
| -**bw <x>** | Same as -borderwidth. |
| **-display <name>** | (*display) Sets display for input/output. For example: -display galaxy:0. |
| **-fg <color>** | *foreground) Sets color for foreground. |
| **-font <font_name>** | (*font) Selects a different font for ***xgeom*** displays. |
| **-fn <font_name>** | Same as -font. |
| **-foreground <color>** | Same as -fg. |
| **-geometry <str>** | (*geometry) Sets window size and position. “str” is in the format WIDTHxHEIGHT+XOFF+YOFF, where WIDTH and HEIGHT is the width and height of the ***xgeom*** window in pixels. +XOFF places the ***xgeom*** window XOFF pixels from the left edge of the screen. If you use -XOFF then the window is offset from the right edge of the screen. +YOFF places the ***xgeom*** window from the top edge of the screen and -YOFF places the ***xgeom*** window from the bottom edge of the screen.For example, use “xgeom -geometry 800x600-0+0” to make an ***xgeom*** window of size 800 by 600 in the top left hand corner of the screen. |
| **iconic** | (*iconic: yes)Starts ***xgeom*** up as an icon. |
| **-monochrome** | (*monochrome: yes) Uses only black and white even if display is color. |
| **-name <str>** | (.name) Used to select a set of special defaults. See X documentation for details. |
| **-reverse** | (*reverseVideo: yes) Works only if monochrome CRT or -monochrome is in effect. |
| **-rv** | Same as -reverse. |

**-stiplist <file_name>** (*stiplist) The file specified contains a list of file names which are stipple bitmaps. Each file name listed in the stiplist file may be optionally followed by a color to be used with that stipple. Each stipple (which can be created using the X Window System utility “bitmap”), is used as a pattern for different metallizations. The number of stipples is unlimited. The default stipple list file is “$SONNET_DIR/stiplist”. See section "Menu: Param - Metallization" on page 85.

**-textcolor <color>** (*textColor) Sets color of all text.

**-title <str>** (*title) Sets title displayed on main window (if window can display title). Be sure to enclose entire title in quotes if it contains white space.

**-ux** (*units) Sets default units, -ua is inches, -ub is mils, -uc is meters, -ud is cm, -ue is mm, -uf is microns. For all other units use -uu <string>, where string is “x,lab”, x is the number which, when multiplied by a length in the given units yields meters and lab is the label for the units. For example, “-ud” and “-uu 0.01,cm” are equivalent.

**-xrm <str>** Provides access to the resource manager, see X window documentation.

**-Ver** Prints out the current version of ***xgeom*** and exits. Must be the first option on the command line. All other options are ignored.

**+backing** (*backing: no) Makes sure the backing store is turned off, even if the default has been changed.

**+iconic** (*iconic: no) Makes sure window comes up, not icon, even if default has been changed.

**+monochrome** (*monochrome: no) Makes sure color is used (if available), even if default has been set to monochrome.

**-pasteFile <file>** (*pasteFile: $HOME/.xgeomcut) Specifies the name of the paste buffer file. Environment variable may be used including “$$” as process id.

**-removePasteFile** Normally, the paste file is not removed when ***xgeom*** is terminated so that cutting and pasting may be done across ***xgeom*** windows. If this option is specified, then the paste file is removed when ***xgeom*** is terminated.

**-origin <type>** May set the origin to either “TopLeft” or “BottomLeft”.

**-deleteKey <keysym>** (*deleteKey: Delete Key) Specifies the Keysym for the cut function as defined in <X11/keysymdef.h>. The format of <keysym> is “0xHHHH”. For example, use “0xFF08” to use the back space key for the cut function.

**-pointToObjects** (*pointToObjects: no) Cursor changes shape depending on object being pointed to.

**+rv** (*reverseVideo: no) Makes sure reverse video is not used, even if default has been changed.

There are several ways to specify the defaults to the ***xgeom*** program:

1. Command line argument.
2. File specified by $XENVIRONMENT or if not set, the file $HOME/.Xdefaults-<hostname> is used.
3. X11 Default values already set in the window manager or by the xrdb command or, if not set, by the file $HOME/.Xdefaults. Use $HOME/.Xdefaults to set defaults on a per user basis.
4. Reads the file $APPLRESDIR/Xgeom.
5. Reads the file /usr/lib/X11/app-defaults/Xgeom.
6. Reads the file $SONNET_DIR/data/Xdefaults. Use this file to set defaults for all ***xgeom*** users.

For example the following lines could be added to the $HOME/.Xdefaults file to

```
Xgeom*origin: BottomLeft
Xgeom*pasteFile: $HOME/xgeom.$$
Xgeom*removePasteFile: True
Xgeom*geometry: 980x680
```

The above file is read by ***xgeom*** and sets the origin to the bottom left. Also, the paste file (buffer file) is different for each copy of ***xgeom*** that is run. This may be useful if multiple users are using the same login. Also the ***xgeom*** window is started up at 980x680 size (in pixels). For other ways to control the defaults of the X Window System programs, consult the X Window System documentation.

# Appendix II Graphics Hardcopy

Since ***xgeom*** is an X Window System based program, graphics hard copy may be obtained using standard utilities provided by the X Window System. The commands of interest are “xwd” and “xpr”. For postscript output, use the following procedure:

- Bring up ***xgeom*** window. You may wish to use the “-mono” option in ***xgeom*** to display a monochrome window. This may give a better picture for black and white printers.
- In another window, type:

  **xwd -nobdrs -out tmp**

  You may also want to add the option “-xy” which converts color pictures to monochrome. However, some systems have been found to crash using this option.
- After pressing return, the cursor changes shape. Move the cursor to the desired window and click the left mouse button. Two beeps are heard. The first indicates xwd is getting the window, the second that the window has been saved to disk (in file “tmp”).
- Type:

  **xpr -portrait -device ps -scale 3 -out ptmp tmp**

- You may wish to add the “-rv” option to the above command to give reverse video. The above command converts tmp into a file ready for printing, ptmp. When complete, print ptmp at a postscript printer. Alternatively, the output device can be specified in the xpr command (“-device”) for output directly to the printer.
- To save disk space type

  **rm ptmp**

  **rm tmp**

- The bitmap files can become large.

Since there can be minor differences between systems, minor modifications of the above commands may be needed. Reference the X Window System documentation for details.

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