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## Creating the Inverter Layout

This chapter introduces you to the Virtuoso® layout editor as you perform the following tasks:

- [Starting a New Layout Design](#) on page 2-2
- [Creating Instances for N- and P-Transistors](#) on page 2-6
- [Connecting the Inputs and Outputs](#) on page 2-11
- [Checking Design Rules](#) on page 2-32
- [Saving Your Design](#) on page 2-35

When you finish this chapter, you will be able to

- Create new cellviews
- Create instances of existing cellviews
- Create rectangles
- Use the Layer Selection Window to set entry layers
- Create paths
- Create polygons
- Copy and mirror objects

- Run the design rule checker
- Save your design

## If You Have Not Completed the Previous Chapter

You can follow the steps in this chapter without completing the previous chapter. However, you might want to read the previous chapter summary before starting this chapter, so you know what was covered.

It is possible to run out of resources, such as memory, if you run multiple layout editors. Before you start the software, check whether the software is already running.

To check whether the layout editor is already running,

1. Type the following in an xterm window:

```
ps auxw | grep layout
```

2. If the layout editor is listed in the standard output of the `ps` command, use *File – Exit* in the Command Interpreter Window (CIW) to exit the software.
3. Type the following in an xterm window to start the layout editor:

```
cd ~/cell_design  
layoutPlus &
```

## Starting a New Layout Design

In this section, you learn to

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- Create and open a new cellview
- Set your image and drawing grid

As introduced in the previous chapter, a design cell is stored in a library. The cell can have several views, such as schematic or layout, that are different representations of the design. Before you can open a new design, you must have a library and it must contain definitions of the types of views you use. For this tutorial, the library and views have already been created for you.

**Note:** You will be instructed to move the cursor to specific X and Y coordinates as you build your design. These coordinates may differ slightly from the coordinates on your system. This should not be a problem in building the design.

## Creating a New Cellview

1. In the CIW, choose *File – New – Cellview* to create a new file.

The Create New File form appears.

2. Set *Library Name* to *tutorial*.
3. Type `Inv` in the *Cell Name* field.
4. Press the `Tab` key and type `layout` in the *View Name* field.
5. Press the `Tab` key.

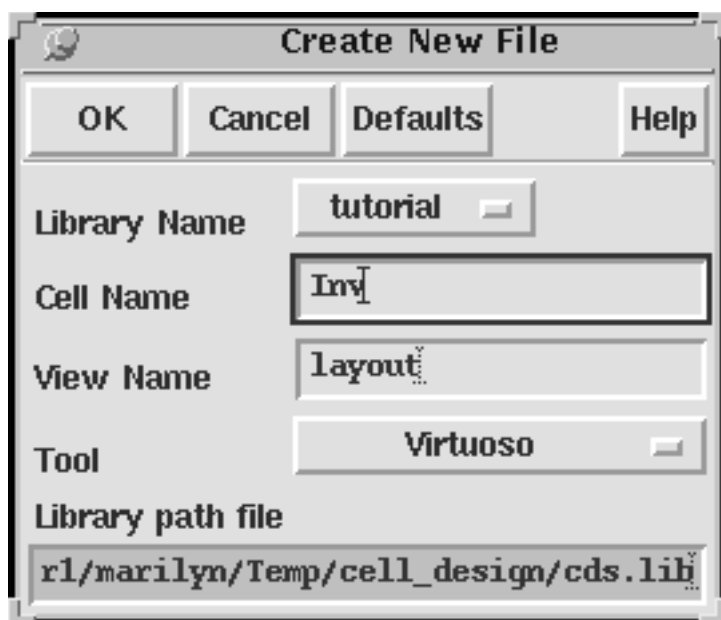
Because the view name `layout` is a recognized name for the layout editor, the *Tool* field changes to *Virtuoso*.

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The completed form should look like this:



6. Click *OK*, to create the new cellview and close the form.

After a few moments, the *Inv layout* cellview appears in a layout window. The window is empty, and you can see the axes and the grid points.

## Displaying the Grids

There are two grid displays: the minor (small) grid and the major (large) grid. Usually, you enter points using the minor grid. The tutorial library is set to show minor grid points at every micron and major grid points at every 5 microns. (For details about changing the grid point spacing with the *Display* command, refer to the [Virtuoso® Layout Editor User Guide](#).)

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The minor grid points are white. The major grid points are green. You might need to look closely to see the difference in color. Notice that a major grid point (green) appears in place of every fifth minor grid point (white).

To see the green, major grid points,

1. Press `Shift-z` in the cellview to zoom out by 2.

The green, major grid points become visible.

You can repeat the last command by clicking right.

The right mouse button information in the CIW reads

```
R: hiZoomRelativeScale(h ...
```

This is the SKILL command for *Zoom – Out by 2*. (The three dots mean you cannot see the rest of the line.)

**Note:** Once started, most layout editor create and edit commands repeat automatically; you do not have to click right.

2. Click right to repeat *Zoom – Out by 2*.

The spacing between grid points becomes larger instead of smaller.

The display shows only the major grid. This is because you are zoomed out too far to see the minor grid.

3. Choose *Window – Zoom – To Grid*.

*Zoom – To Grid* zooms out to the smallest magnification at which the minor grid points are visible. Again, you see all the grid points.

4. Choose *Window – Zoom – In by 2* or press `Control-z` to set the grid so it is easy to place instances.

## Using Pan to View the Positive Quadrant

Most designs are created in the positive (upper right) quadrant. You can pan the window so you can view just the positive quadrant.

To view the positive quadrant,

1. Choose *Window – Pan*.

The prompt in the layout window and CIW reads

`Point at the center of the desired display:`

2. Click in the upper right corner of the window.

The image changes so the axes are in the lower left corner.

## Creating Instances for N- and P-Transistors

Now you are ready to create objects in your design window. In this section, you learn to

- Place a copy of another cell into this cellview
- Use a layout editor options form
- Stop a layout editor command that automatically repeats

Placing a copy of a cell is commonly called placing an instance of that cell.

In this section, you place instances of two parameterized cells (pcells). A parameterized cell is designed to let you change some of its features whenever

you place an instance of the cell. You will learn how to create pcells later in this tutorial.

The pcells you place in this section are designed to change dimensions based on the length, width, and number of gates. These changeable dimensions are the parameters of each cell. You enter parameter values when you place the pcell instances.

## Creating the N-Transistor Instance

To create the n-transistor,

1. Choose *Create – Instance*.

The Create Instance form appears.

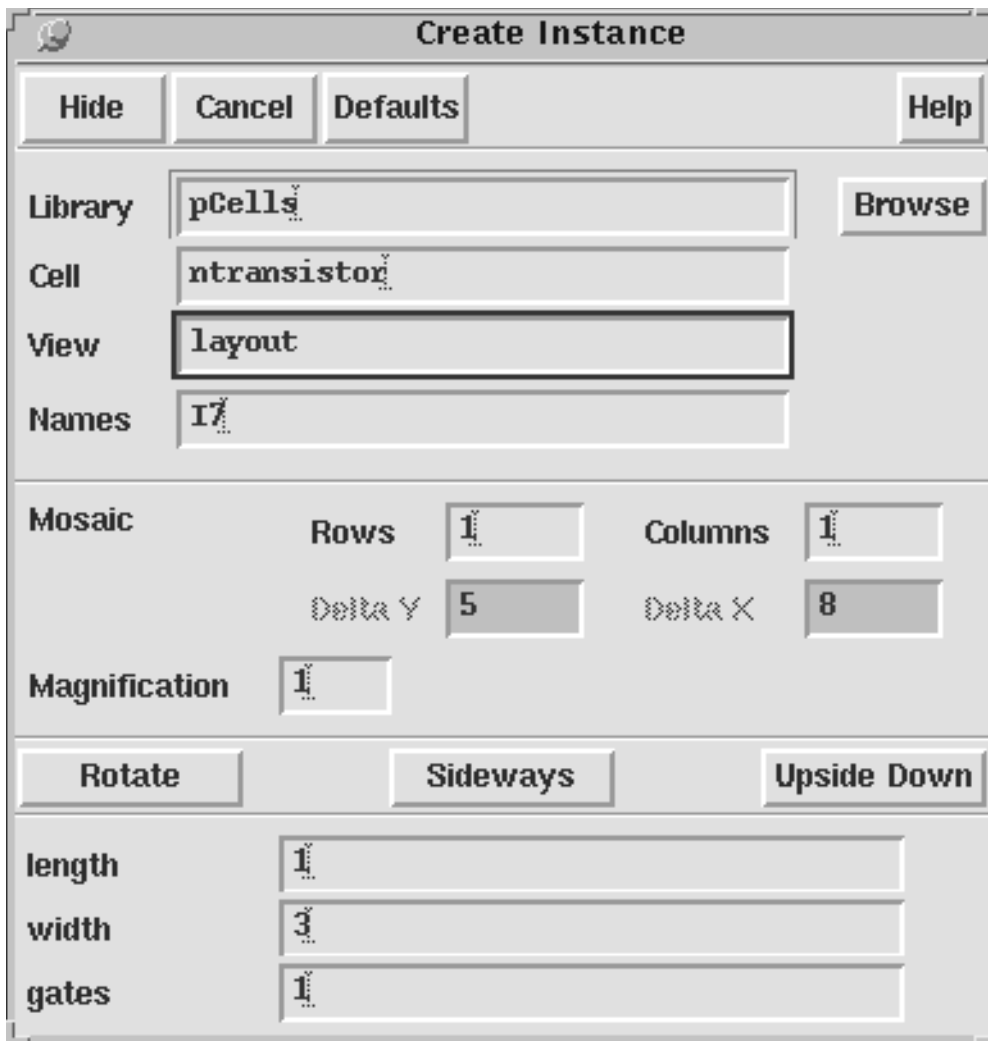
**Note:** This form is called a layout editor options form, which means it appears for the duration of the *Create Instance* command. Look at the buttons on the form; instead of *OK*, there is a *Hide* button. The *Hide* button lets you hide the form while you continue to use *Create Instance*.

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2. Type the library and cell names:



**Create Instance**

Hide Cancel Defaults Help

Library pCells Browse

Cell ntransistor

View layout

Names I7

Mosaic Rows 1 Columns 1

Delta Y 5 Delta X 8

Magnification 1

Rotate Sideways Upside Down

length 1

width 3

gates 1

You can double-click in a text field to highlight and type over a word. Press the **Tab** key to move to the next form field.

3. Press the **Tab** key to display the parameter fields.



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The parameter names and values appear at the bottom of the form. You are going to change these parameters for this exercise.

4. Move the cursor into the cellview window.

Outlines of the shapes in the n-transistor follow the cursor. The outlines help you align the cell as you place it.

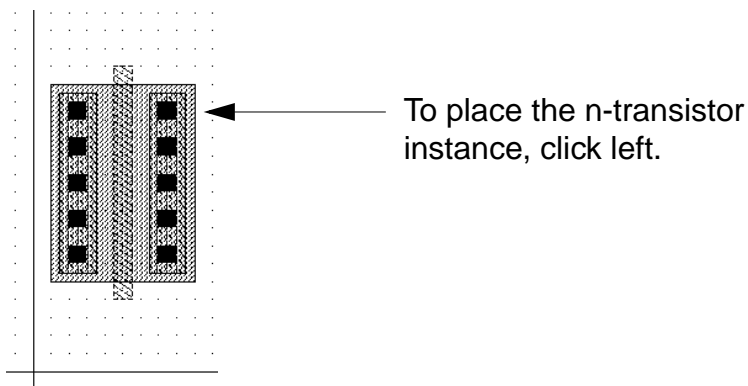
5. In the Create Instance form, change the *width* parameter to 11.
6. Move the cursor back into the cellview window.

The transistor is larger.

7. Move the cursor to X = 5, Y = 6.5, and click left to place the instance.

Remember to look in the window banner for the X and Y coordinates.

After you place the instance, the n-transistor appears with the layer colors filled in.



8. Move your cursor to the right.

The outline of another identical n-transistor follows the cursor because the *Create Instance* command is a repeating command.

## Stopping Repeating Commands

The Create Instance form is still open, ready to place another instance. By default, commands on the *Create* and *Edit* menus always repeat.

To stop the *Create Instance* command,

- Press the `Escape` key.

You can stop repeating commands whenever you want to ensure that you do not change your design by mistake.

**Note:** If a repeating command has an options form, you can also stop the command by clicking *Cancel* in the form. You already practiced this with the *Create Ruler* command in the previous chapter.

## Creating the P-Transistor Instance

Next, you place an instance for the p-transistor.

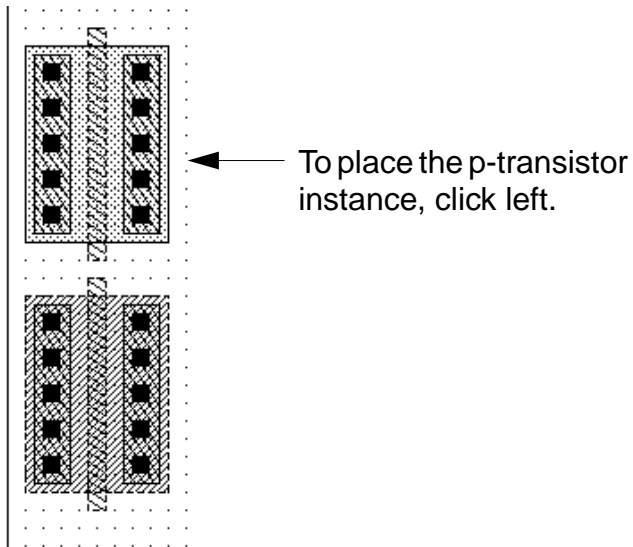
1. Choose *Create – Instance* or press the `i` key.
2. In the Create Instance form, change *Cell* to `ptransistor`.
3. Press the `Tab` key to see the p-transistor parameters you can change.
4. Change the *width* parameter to `11`.

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5. Click  $X = 5$ ,  $Y = 20.5$  to place the instance.



Your design now contains a p- and an n-transistor.

6. Press the `Escape` key to stop the *Create Instance* command.
7. Press the `f` key to see both transistors.

## Connecting the Inputs and Outputs

Now that you have placed the n- and p-transistors, you need to create connections to tie them together and create an inverter. In this section, you learn to

- Choose the correct layer for creating the connection
- Create a rectangle, a path, and a polygon

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- Correct an editing mistake
- Practice selecting objects
- Copy shapes
- Use infix mode to reduce the number of mouse clicks needed to create an object

## Selecting Layers in the LSW

Before you create the connections to build the inverter, you need to select the correct entry layer.

Every layer in your library is assigned a purpose, such as *net* or *drawing*. Most layouts use layers with purposes of *drawing*, so by default the Layer Selection Window (LSW) shows all the layers that are defined as *drawing* in your library technology file. The abbreviation *dg* after each layer name means *drawing*.



- Click the *metal1 dg* layer in the LSW.

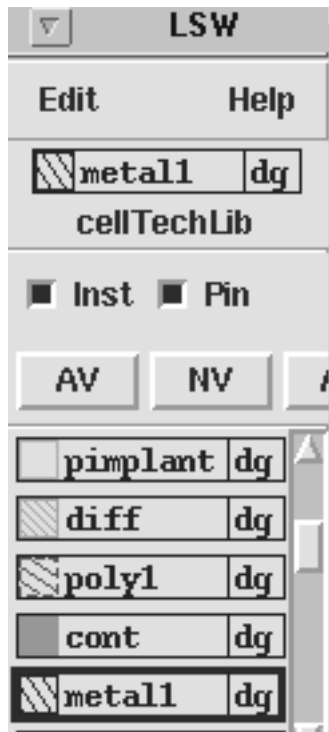
**Note:** Be sure to use the left mouse button to select the entry layer. If you click a different mouse button on a layer in the LSW, you will change the selectability or visibility of the layer.

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The *metal1* layer is outlined in bold and appears at the top of the LSW. This tells you *metal1 dg* is the current entry layer. The layout editor prompts refer to this as the entry layer.



## Connecting the Output

To connect the output of the two transistors,

1. Choose *Create – Rectangle*.

The Create Rectangle form appears.

The prompt in the layout window and CIW reads

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Point at the first corner of the rectangle:

2. Click X = 7.5, Y = 15.5 to create the first corner of the rectangle.

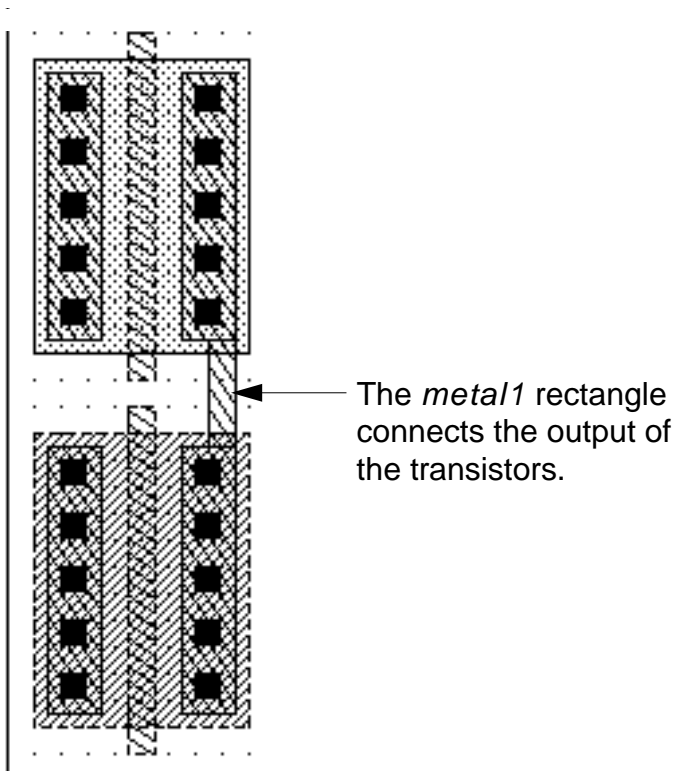
The prompt in the layout window and CIW reads

Point at the opposite corner of the rectangle:

A rectangle appears and stretches as you move the cursor.

3. Click X = 8.5, Y = 19.5 to create the opposite corner of the rectangle.

You have completed the rectangle that connects the output of the two transistors.



The layout window and CIW still display a prompt because repeat mode is on.

## Nesting a Command

Nesting means to run one command while another command is still running. For example, if you make a mistake while using the *Create Rectangle* command, you can use *Edit – Undo* to undo the previous command. This does not stop the *Create Rectangle* command but does nest the *Undo* command.

**Note:** You cannot nest repeating commands. For example, you cannot nest the *Copy* command while using the *Create Rectangle* command.

To nest a command,

1. Choose *Edit – Undo*.

The rectangle disappears.

2. Choose *Edit – Redo*.

The rectangle reappears.

You can undo up to 10 previous commands. Use *Redo* if you used *Undo* by mistake.

## Connecting the Input

You are ready to connect the inputs. Use the *Create Path* command to connect the inputs for the transistors on the *poly1* layer.

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Paths are shapes defined by a centerline and a width. You set the width in the Create Path form and create the path centerline.

1. In the LSW, click the *poly1 dg* layer.

The *poly1* layer appears at the top of the LSW.

The system still prompts you to create rectangles because repeat mode is on. You do not need to manually stop the *Create Rectangle* command. It stops automatically when you choose any other *Create* or *Edit* command.

2. Choose *Create – Path*.



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The Create Path form appears. The width is set to 1 micron, which is the minimum width for the *poly1* layer.

**Create Path**

Hide Cancel Defaults Help

Mode ☐ Guided ☒ Manual Change To Layer

Width

Fixed Width ☐

Offset

Justification

End Type

Begin Extension

End Extension  Snap Mode

Net Name

☐ As ROD Object

ROD Name

Contact Justification

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Rotate Sideways Upside Down

The prompt in the layout window and CIW reads

Point at the first point of the path:

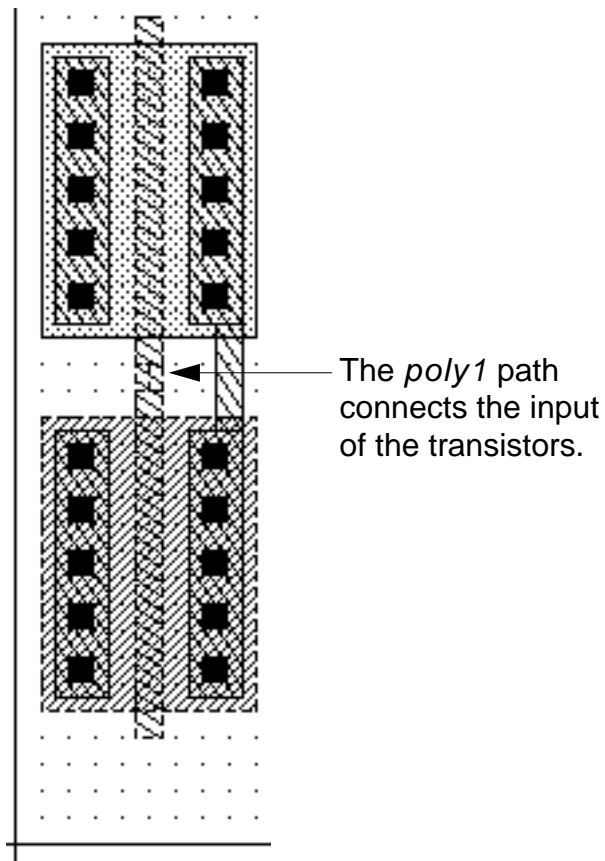
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3. Click X = 5.0, Y = 17.0.
4. Double-click X = 5.0, Y = 18.0.

The path appears. Double-clicking tells the system where to end the path.



## Adding the Power Connection

Use the *Create Polygon* command to create the power connection.

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Polygons are shapes defined by any number of points. Polygons must be closed; that is, the first point and the last point must be the same. The layout editor can close the polygon for you automatically.

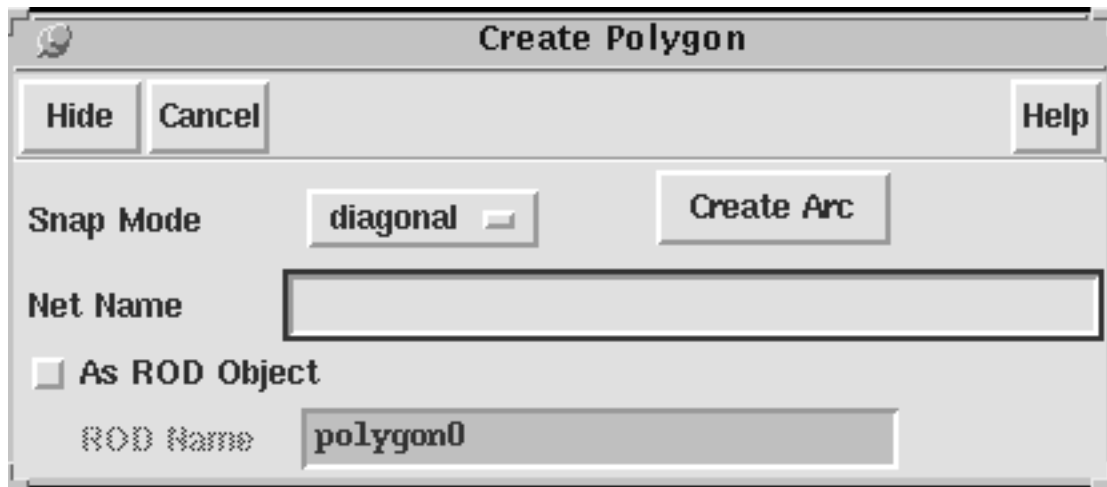
To add the power connection,

1. In the LSW, click the *metal1 dg* layer.

The *metal1* layer appears at the top of the LSW.

2. Choose *Create – Polygon*.

The Create Polygon form appears.



The prompt in the layout window and CIW reads

Point at the first point of the polygon:

3. In the Create Polygon form, set *Snap Mode* to *L90XFirst*.

The snap mode controls the way segments snap to the drawing grid as you create the polygon. *L90* creates two segments at right angles to each other

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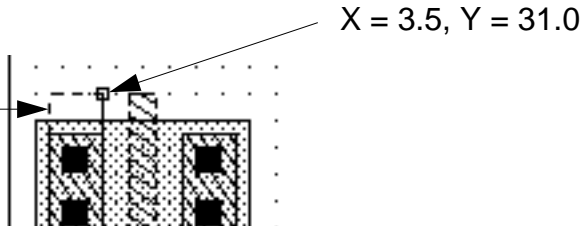
between every pair of points you enter. *XFirst* means the first segment is parallel to the X axis.

4. Press the **Tab** key to start the *Pan* command to view the area above the p-transistor.
5. Click  $X = 5.0$ ,  $Y = 28.0$  to complete the pan, and to display the area above the p-transistor.
6. Click  $X = 1.5$ ,  $Y = 29.5$  to create the first point of the polygon.
7. Click  $X = 3.5$ ,  $Y = 31.0$ .

The layout editor creates

- ❑ Two solid lines at right angles to each other between the points you entered
- ❑ Two dashed lines at right angles to each other attached to the two points you entered. The dashed lines show how the layout editor would close the polygon if you click twice on the second point you entered

The dotted line shows how the polygon would be closed.



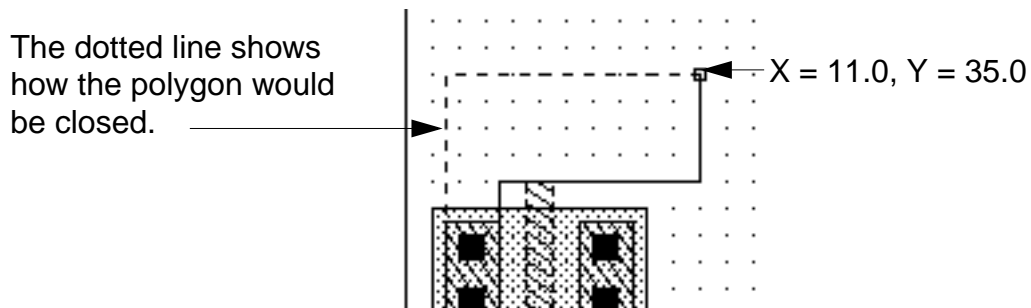
You do not want to complete the polygon at these points.

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- Click X = 11.0, Y = 35.0 to complete the polygon.



### Undoing Points

If you make a mistake while creating an object, you do not have to start over. You can back up any number of points by pressing the **Backspace** key.

The last point you entered is not correct. The *metal1* shape should be one micron outside the boundary of the p-transistor. Because you are using L90 snap mode, the system entered two points for you, so you must back up two points.

- Press the **Backspace** key.

The last point you entered is undone.

- To undo the other point, press **Backspace** again.

### Finishing the Polygon

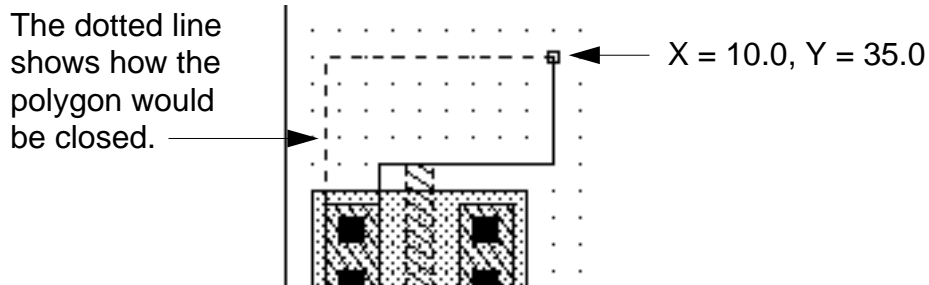
Now you can enter the correct point and finish the polygon.

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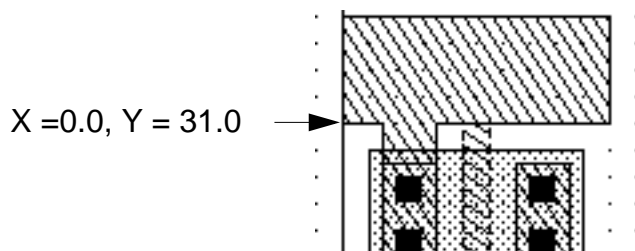
---

1. Click  $X = 10.0$ ,  $Y = 35.0$  to enter the correct point.



The polygon is 1 micron outside of the p-transistor.

2. Double-click  $X = 0.0$ ,  $Y = 31.0$ .



The polygon is complete. You clicked twice to tell the system to close the polygon.

3. Press the `Escape` key to stop the *Create Polygon* command.
4. Press the `f` key to fit the design in the window.

## Selecting Objects

After you create objects, you can edit them. To edit an object, first you need to select it. There are two selection modes: full and partial. In full mode you select the entire object. In partial mode, you can select an entire object or just an edge or corner of an object. You use the  $\mathbb{F}4$  key to toggle between selection modes. The selection mode is displayed in the status banner of the window.

Full mode:



(F) Select: 0

Partial mode:



(P) Select: 0

To select an object, set the selection mode and click the object. You also use the left mouse button to deselect objects by clicking in an empty part of the design. You can select one or several objects at a time. In this section, you practice selecting objects in the full mode (the default) before you go on to edit the inverter design.

**Note:** As you select and deselect objects in this section, notice how the pointer changes. When you select an object, then move the cursor within the selected object, you see the pointer change to four arrows ( $\updownarrow\leftarrow\rightarrow$ ), indicating you can move the object. When you select the edge or vertex (corner) of an object, you see the pointer change to an arrow ( $\rightarrow$  or  $\nwarrow$ ), indicating you can stretch the edge or corner. Refer to the [Virtuoso Layout Editor User Guide](#) for detailed descriptions about moving and stretching objects.

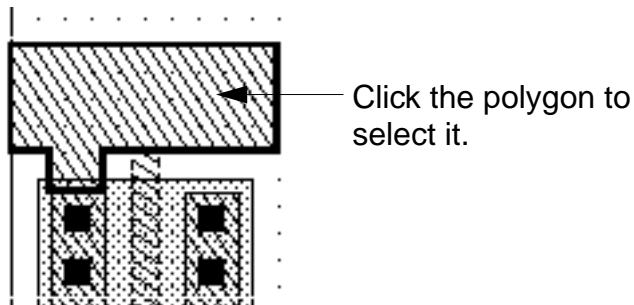
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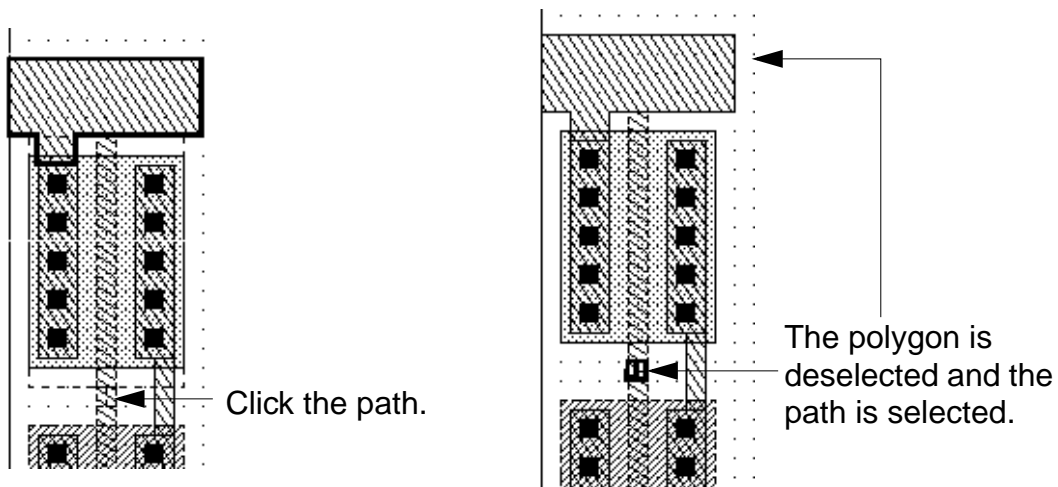
1. Click inside the polygon you just created to select it.

The polygon is highlighted in a white line, showing it is selected.



2. Click the path you created earlier.

To make it easier to click the path, you can zoom in. The polygon is deselected, and the path is selected.



3. Press **Shift** and click the polygon again.

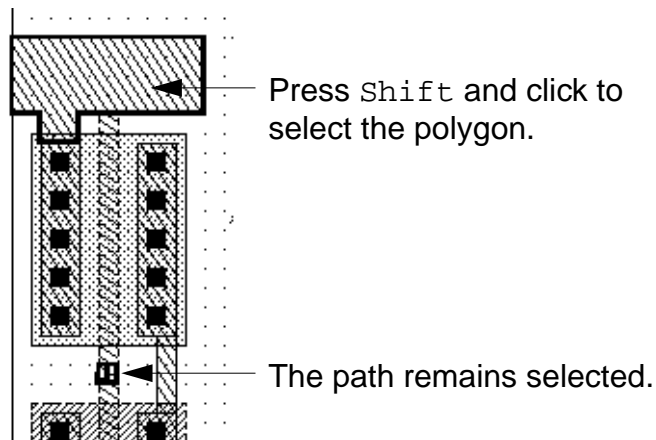


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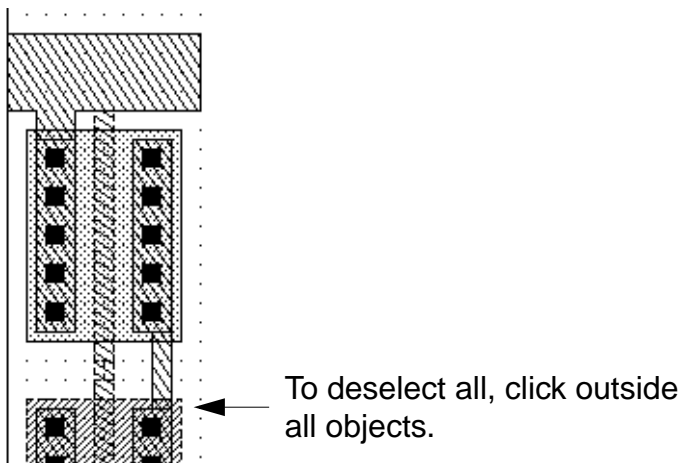
---

Both the polygon and the path are selected. Pressing `Shift` lets you add objects to the group of selected objects.



4. Click an empty part of the design.

Both the polygon and the path are deselected. Clicking outside all objects deselects any objects that are selected.



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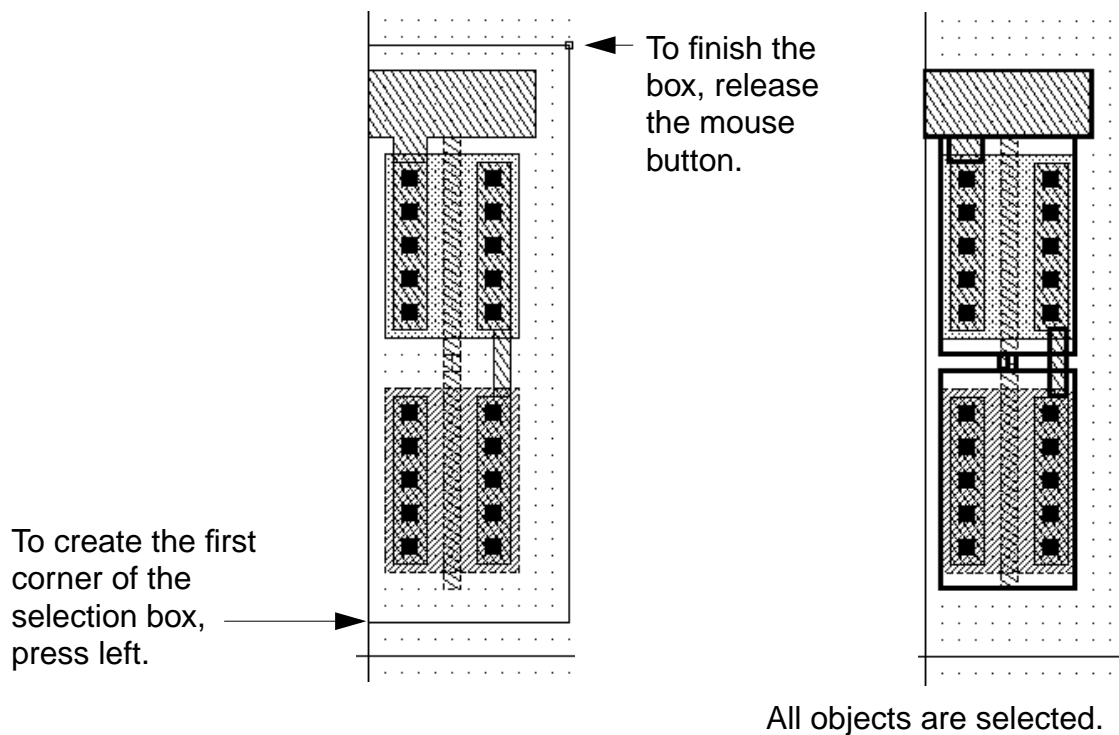
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5. Select a group of objects by doing the following:

- ❑ Move the cursor to the lower left corner of the image.
- ❑ Press and drag the cursor to create a box around all of the objects in the image.
- ❑ Release the mouse button.

All objects entirely inside the selection box are highlighted and selected.



The objects inside the n- and p-transistors are not highlighted. Because the transistors are cells, only their borders are highlighted.

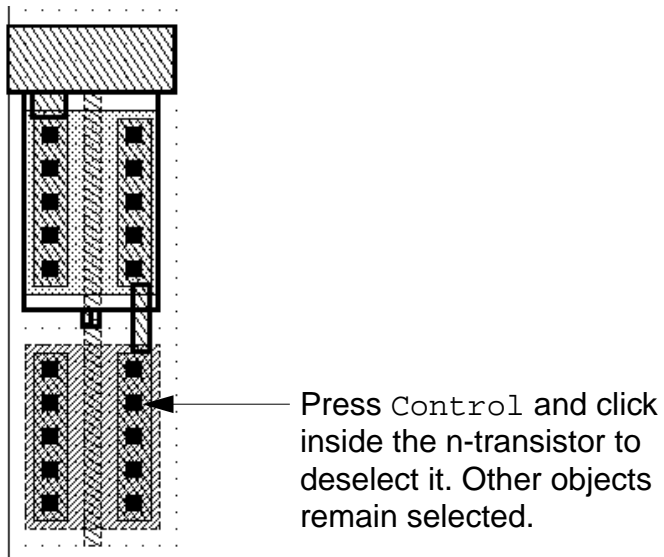
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#### 6. Press `Control` and click the n-transistor.

The n-transistor is deselected; all other objects remain selected. Pressing `Control` lets you deselect one object from a selected group.



#### 7. Click an empty part of the design.

All objects are deselected.

You can select objects either before or after you start any editing command. In this exercise, you practiced selecting before starting a command. In the rest of this tutorial, you usually select objects after starting a command because this is more typical for new users.

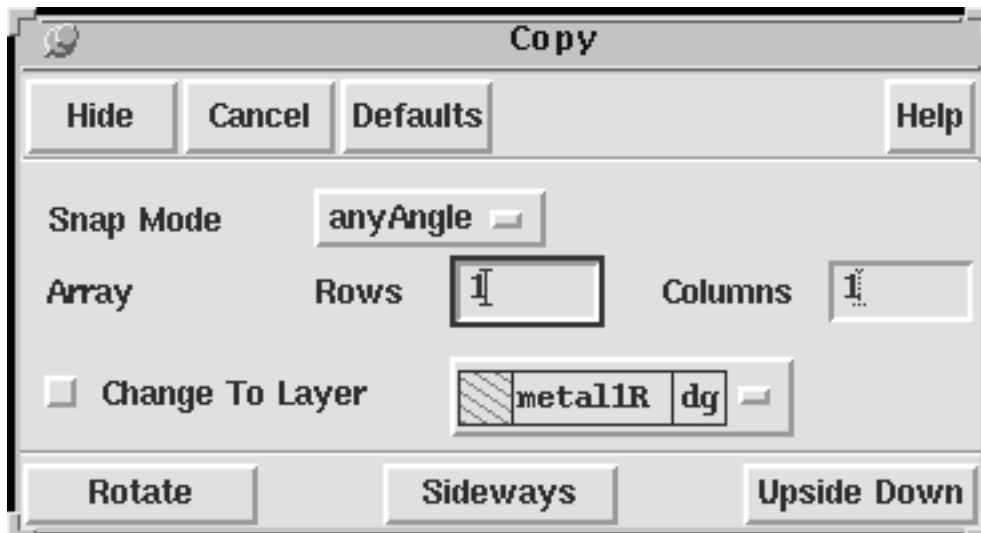
For detailed information about selecting and deselecting objects, refer to the [Virtuoso Layout Editor User Guide](#).

## Adding the Ground Connection

Use the *Copy* command to copy and mirror the shape you just created to build the ground connection.

1. Choose *Edit – Copy*.

The Copy form appears.



The prompt in the layout window and CIW reads

Select the figure to be copied

2. Click the *metal1* polygon you just created.

The polygon is selected.

3. Move the cursor slightly to the right.

A copy of the *metal1* polygon follows the cursor.

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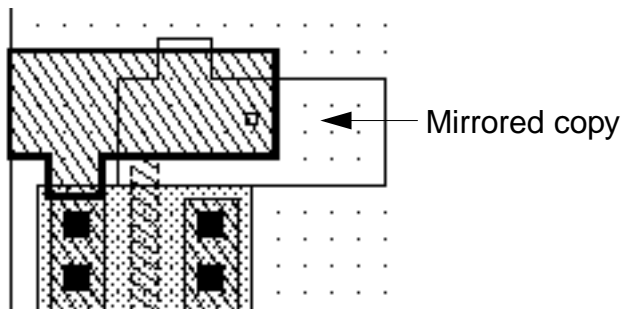
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You can mirror the copy of the polygon and use it for the ground wire at the bottom of the inverter.

1. In the Copy form, click *Upside Down*.

The copy of the polygon is mirrored around the X axis.



### Panning the Cellview

Before you move the mirrored copy of the polygon, you can pan the image to see the bottom of the design better.

1. Press the `Tab` key to pan.

The `Tab` key is the bindkey for the *Pan* command.

The prompt in the layout window and CIW reads

Point at the center of the desired display:

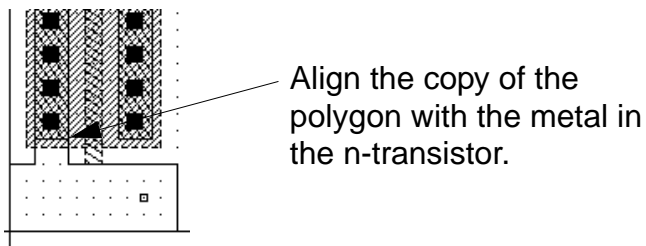
2. Click the top of the n-transistor.

The image changes so the top of the n-transistor is in the center. The *Pan* prompt disappears from the layout window and CIW, and the *Copy* prompt reappears.

## Completing the Copy

Now you can finish moving the mirrored copy of the polygon.

1. Move the mirrored copy of the polygon so it aligns with the metal in the n-transistor.



2. Click left to place the copy of the polygon.

The copy of the polygon appears on the *metal1* layer.

3. Press the `Escape` key to stop the *Copy* command.

## Adding the Well

Next, you create a rectangle on the *nwell* layer to create the well.

In this section, you use the bindkey to start creating the rectangle. You also use a special entry mode called infix, which reduces the number of mouse clicks needed to create shapes.

When infix is on, no click is necessary for the first point of a command. The cursor location at the start of the command is used as the first point. Infix works only with commands started from bindkeys or pop-up menus.

## Using Infix

To create the well using infix,

1. From the CIW, choose *Options – User Preferences*.

The User Preferences form appears.

2. Click the box next *Infix* to set infix on.
3. Click *OK* to apply the change and close the form.
4. Press the  $\text{f}$  key to fit the design in the window.
5. In the LSW, click *nwell dg*.

The *nwell* layer appears at the top of the LSW.

6. Move the cursor to  $X = 0.0$ ,  $Y = 31.0$ .

Because infix is on, this location will be the first corner of your rectangle.

7. Press the  $\text{r}$  key to start the *Create Rectangle* command.

The rectangle starts at  $X = 0.0$ ,  $Y = 31.0$ . Notice the prompt asks you for the second (opposite) corner of the rectangle:

Point at the opposite corner of the rectangle:

8. Move the cursor to  $X = 10.0$ ,  $Y = 18.0$ .

An outline of the rectangle stretches with the cursor.

9. Click to complete the rectangle.

The rectangle appears on the *nwell* layer.

The prompt in the layout window and CIW reads

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Point at the first corner of the rectangle:

Infix works only for the first rectangle you create after pressing the bindkey.

**10.** Press the `Escape` key to stop the *Create Rectangle* command.

### Turning Infix Off

The remainder of this tutorial does not use infix mode. (You can experiment with it on your own if you like.)

To turn infix off,

1. From the CIW, choose *Options – User Preferences*.
2. Click the box next to *Infix*.
3. Click *OK*.

## Checking Design Rules

Before saving the inverter, check the design against your design rules. Interactive design rule checking is part of Assura™ interactive verification products.

The interactive Design Rule Checker (DRC) uses rules defined in the `divaDRC.rul` file. For the tutorial, these rules have been defined for you. For details about the Cadence® SKILL functions used to write these rules, refer to the [Assura® Diva Verification Reference](#) manual.

DRC flags the errors it finds by creating polygons around the errors. The polygons are created on a layer reserved for markers. The marker layer usually



appears as a blinking layer and is not selectable. DRC removes the error-flag polygons automatically after you correct the errors and run DRC again.

## Finding Out if You Can Run DRC

You might not have a license to run interactive verification even if you can use the layout editor. To find out whether you have a license to run interactive verification,

- Click the *Verify* menu.

If the commands under *Verify* appear shaded, you do not have a license to run interactive verification. Go on to the [“Saving Your Design”](#) on page 2-35.

If the commands are not shaded, you have a license to run interactive verification. Go to the next section, [Running the Design Rule Checker](#).

## Running the Design Rule Checker

1. Choose *Verify – DRC*.

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The DRC form appears.

The DRC dialog box contains the following settings:

- Checking Method:** ☒ flat, ☐ hierarchical, ☐ hier w/o optimization
- Checking Limit:** ☒ full, ☐ incremental, ☐ by area
- Coordinate:** [Text Field]
- Sel by Cursor:** [Button]
- Switch Names:** [Text Field]
- Set Switches:** [Button]
- Run-Specific Command File:** ☐ [Text Field]
- Inclusion Limit:** [Text Field: 1000]
- Join Nets With Same Name:** ☐
- Echo Commands:** ☒
- Rules File:** [Text Field: divaDRC.rul]
- Rules Library:** ☒ [Text Field: cellTechLib]
- Machine:** ☒ local, ☐ remote, [Text Field]

2. Click **OK** to start the Design Rule Checker.

If you followed the previous steps exactly, there should be no errors. If you have errors, you see a blinking polygon marking the first error. Follow the next steps to fix any errors.

## Deleting Objects

The easiest way to correct errors is to delete the objects you created that were in error, and recreate them using the original instructions in this chapter.

To delete objects,

1. Click the object you want to delete.

When you want to delete an object, it is easier to select the object before starting the *Delete* command. If you select the wrong object, move the cursor and click again.

2. Press the `Delete` key.

Now you can recreate the object using the original instructions in this chapter.

## Saving Your Design

You have completed the inverter layout. However, the layout exists only in virtual memory. You need to save the design to disk.

To save the design,

1. Choose *Design – Save*.

Save copies the design in virtual memory to disk under the library directory specified when the design was created. This design is saved to the `tutorial` library. You use this design in the next chapter.

2. Choose *Window – Close*.

## Summary

In this chapter, you learned how to use the layout editor to create, select, and edit shapes. Specifically, you

- Set up an environment for entering points
  - ❑ Created a new cellview
  - ❑ Learned how to zoom the display
  - ❑ Learned about grid displays
  - ❑ Panned the image
- Created instances of n- and p-transistor parameterized cells (pcells)
  - ❑ Learned how to place cell instances
  - ❑ Learned how to assign parameter values to pcells
- Created and edited shapes
  - ❑ Set the entry layer using the LSW
  - ❑ Created a path
  - ❑ Created a rectangle
  - ❑ Created a polygon
  - ❑ Learned how to select shapes
  - ❑ Copied a polygon
- Learned how to correct mistakes

## Cell Design Tutorial

### Creating the Inverter Layout

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- ☐ Learned how to undo both *Create* and *Edit* commands
- ☐ Deleted a point you created
- Learned how to run the Design Rule Checker
- Learned how to save your design and close the window
- Used bindkeys for
  - ☐ Fit All [f]
  - ☐ Pan [Tab]