
Creating a Parameterized Cell

This chapter shows you how to create pcells (parameterized cells). A parameter is a setting that controls the size, shape, or contents of a cell instance. A pcell displays a list of parameters when you place an instance of the cell. You enter values for the parameters to control what that instance looks like. In this chapter, you will be:

- [Defining a Stretch Line for Gate Width](#) on page 5-4.
- [Creating a Repeat Group for Contacts](#) on page 5-9.
- [Creating a Repeat Group for Gates](#) on page 5-14.
- [Creating a Stretch Line for Gate Length](#) on page 5-16.
- [Correcting the Pcell](#) on page 5-22.
- [Summarizing and Saving the Pcell](#) on page 5-27.

The *ptran* and *ntran* cellviews that you used to create the inverter earlier in this tutorial are examples of pcells. They have parameters that let you control the number of gates, width, and length of each instance.

Using pcells, such as *ptran* and *ntran*, means you avoid having to create different cells with different numbers of gates, widths, and lengths. Instead, you create one *ntran* cell, then add parameters that change each *ntran* instance without changing the original cell.

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You create a pcell by doing the following:

- Defining parameters to be applied to shapes in your design.
For example, you can create a parameter that lets you stretch all the shapes in your design. You can create a parameter that lets you repeat shapes any number of times.
- Compiling the cell to create the pcell *supermaster*.
- Creating instances of the cell, supplying different values for the parameters. The system keeps track of these variations of the pcell in virtual memory.

In this chapter, you see how the *ptran* and *ntran* cells were created. When you finish this chapter, you will be able to

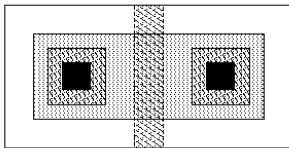
- Understand parameter definitions.
- Create stretch lines.
- Create repeat groups.
- Create dependent stretch lines.
- Compile pcells.
- Test and modify pcells.

The tutorial database contains a layout for a CMOS (complementary metal-oxide semiconductor) transistor. In this chapter, you add parameters to the transistor so you can place it with varying widths, lengths, numbers of contacts,

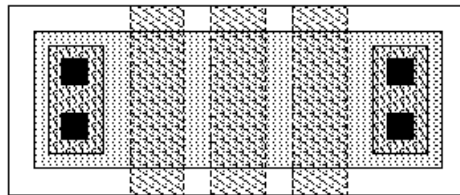
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and numbers of gates. The following figure shows the original cell and the modified cell, after the parameters have been changed.



Original layout



Instance of pcell with different values for gate, width, and length parameters

If You Have Not Completed the Previous Chapters

You can follow the steps in this chapter without completing the previous chapters. If you have not completed the previous chapters, all you need to do is start the software.

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

1. To check whether the layout editor is already running, type the following in an xterm window:

```
ps auxw | grep layout
```

2. If the layout editor is running, choose *File – Exit* in the CIW to exit the software.
3. To start the layout editor, type the following in an xterm window:

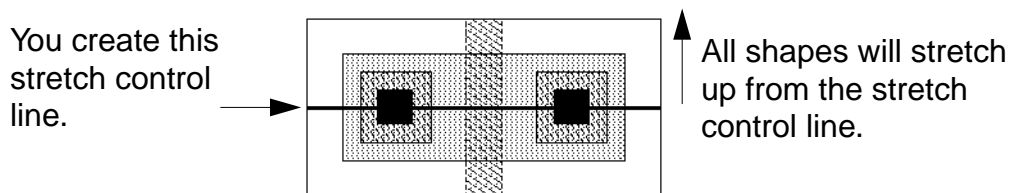
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```
cd ~/cell_design  
layoutPlus &
```

Defining a Stretch Line for Gate Width

In this section, you define a stretch parameter so you can stretch the transistor gate. To do so, you create a stretch line to control the stretch. When you create a stretch line, all intersected shapes stretch perpendicularly to the direction of the stretch line. You will create a horizontal stretch line to stretch shapes vertically from the line.

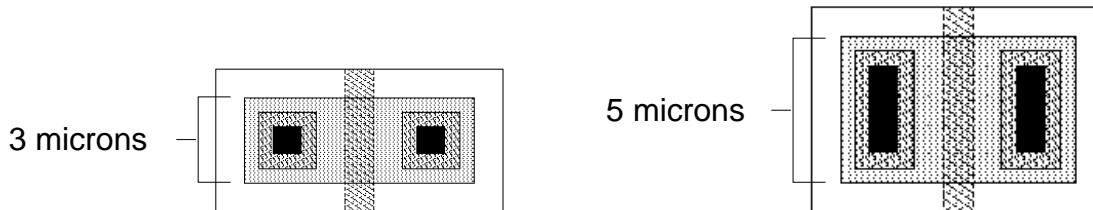


All stretch lines use a reference dimension that determines the amount to stretch. The reference dimension matches the size of a significant shape in the supermaster. When you place an instance of the pcell, the cell stretches by the value you enter for the stretch parameter minus the reference dimension (the starting dimension).

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In this section, you define the width of the p-diffusion as the reference dimension.



You enter the width of the p-diffusion as the reference dimension.

If you enter 5 for the parameter value in the instance, the cell stretches 2 microns (5 minus the reference dimension, 3).

Note: The figure shows what would happen if you were to compile and then place an instance of the pcell after following the steps in this section. However, in a later section, you add another parameter to make the contacts repeat, rather than stretch.

In this section, you learn to

- Open the layout view of the cell.
- Turn off repeat mode, so you don't inadvertently repeat commands.
- Create the stretch line and give it a parameter name.

Opening an Existing Layout

1. Choose *File – Open*.

The Open File form appears.

2. Set the library, cell, and view names as follows:

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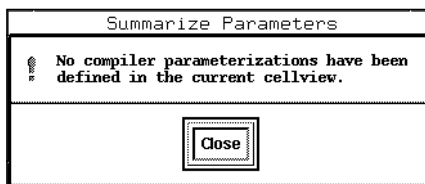
Library Name pCells
Cell Name mypcell
View Name layout

3. Click *OK*.

The mypcell layout window appears.

4. Choose *Pcell – Parameters – Summarize*.

There are no parameters defined for this cell. The system beeps twice and a dialog box appears telling you there are no parameters.



5. Click *Close* in the dialog box.

Turning Off Repeat Mode

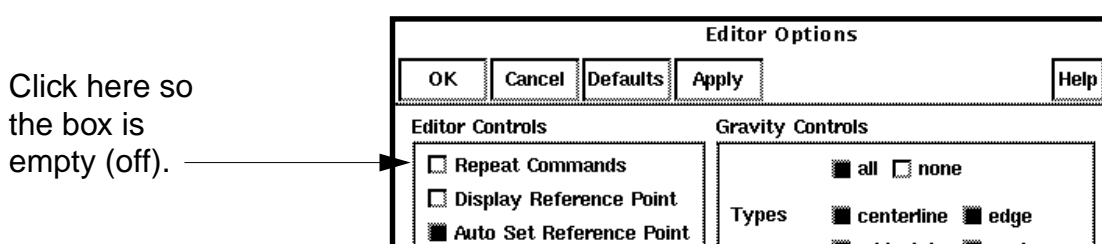
Repeat mode eliminates steps when you use the same command many times in a row. For this chapter, you turn repeat mode off so you don't accidentally create extra parameters. You set the Repeat Mode in the Layout Editor Options form.

1. In the mypcell window, press `Shift-e` to display the Layout Editor Options form in the *Repeat Commands* field.

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2. Click the button next to *Repeat Commands*.

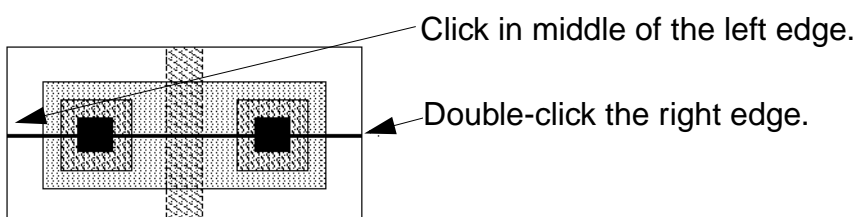


3. To turn off *Repeat Commands* and close the form, click *OK*.

Creating the Stretch Line

You use *Stretch in Y* to stretch an object along the Y axis.

1. Choose *Pcell – Stretch – Stretch in Y*.
2. To create a horizontal stretch line through the middle of the transistor, do the following.
 - Click in the middle of the left edge of the pcell.
 - Move the cursor to the right edge.
 - Double-click.



The Stretch in Y form appears.

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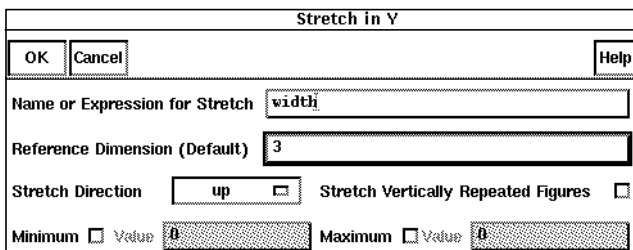
3. Type `width` in the *Name or Expression for Stretch* field.

You are defining `width` as a logical name (variable) for use within the pcell. Other parameter definitions can use this name in expressions.

When you place an instance of the pcell, the Instance form displays a prompt named `width` to let you enter a value for the parameter.

4. Change the *Reference Dimension (Default)* to 3.

The system picks a default reference dimension by looking at the shortest edge crossed by the stretch line. In this case, the shortest edge belongs to the contact shapes. But the contacts are not significant in determining the gate width. The p-diffusion should control the gate width. The p-diffusion measures 3 microns; so 3 is the correct reference dimension.



The screenshot shows a dialog box titled "Stretch in Y". At the top left are "OK" and "Cancel" buttons, and at the top right is a "Help" button. Below the buttons are four input fields: "Name or Expression for Stretch" containing "width", "Reference Dimension (Default)" containing "3", "Stretch Direction" set to "up" with a small square icon to its right, and "Stretch Vertically Repeated Figures" with an unchecked checkbox. At the bottom are two fields: "Minimum" with an unchecked checkbox and "Value" followed by "0", and "Maximum" with an unchecked checkbox and "Value" followed by "0".

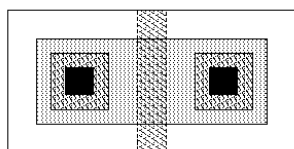
Notice that *Stretch Direction* is set to `up`. This means that all objects intersected by the stretch line will stretch up from the line.

5. Click *OK*.

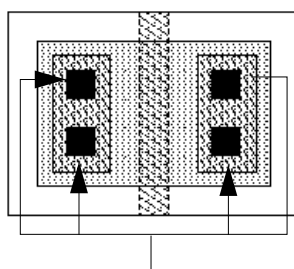
You have completed the first parameter.

Creating a Repeat Group for Contacts

In this section, you define a repetition parameter so you can repeat, rather than stretch, both contacts along the Y axis. To do so, you identify the contacts as a repeat group.



Original layout



Contacts in the stretched instance are repeated.

It is possible to both repeat and stretch objects. By default, repeating objects crossed by a stretch line are not stretched. The *Stretch Vertically Repeated Figures* option in the Stretch in Y form controls whether or not repeated objects stretch. In the previous section, you left this option off when you created the *width* stretch parameter. Any objects that repeat along the Y axis will not stretch.

← This setting controls whether repeated objects stretch.

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You create a repeat group by selecting the shapes to be included in the group, then specifying the number of repetitions and the stepping distance. The stepping distance controls the spacing between repeated objects or groups of objects.

The values for the stepping distance and number of repetitions are often defined as names (variables) or expressions so that they change based on the values of other parameters. For example, in this case, you use an expression for the number of repetitions. This lets you control the number of repeated contacts based on the width parameter you created earlier.

In this section, you learn to

- Create a repeat group.
- Use the CIW to look at the expression you enter to control the number of repetitions.

Creating the Repeat Group

You use *Repeat in Y* to repeat objects along the Y axis.

1. In the mypcell window, choose *Pcell – Repetition – Repeat in Y*.

The prompt in the CIW asks you to choose objects for the repeat group.

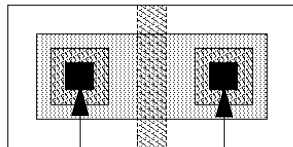
2. Click the edge of one of the contacts.

If you select the wrong shape, press `Control` and click the shape to deselect it.

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3. To finish selecting, double-click the other contact.



Select each contact.

Note: You usually press `Shift` and click to select more than one object. Pcell assumes you want to select multiple shapes; so you do not need to press `Shift`.

The Repeat in Y form appears.

4. Type 2 in the *Stepping Distance* field.

The stepping distance is equal to the width of the object you want to repeat plus the space you want between repeated objects. Leave a 1 micron space between each contact, and each contact is 1 micron wide; so the stepping distance should be 2.



Stepping distance is the width of the object to be repeated plus the distance between repeated objects.

Note: In the following steps, be careful with spaces around the minus operator (`-`). If you enter a space on one side and not the other, the pcell will not be created correctly.

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5. In the *Number of Repetitions* field, type
`fix(width-1)/pcStep`

You learn more about this expression in the next section, “Using Expressions.”

Repeat in Y		
OK	Cancel	Help
Stepping Distance	2	
Number of Repetitions	fix(width-1)/pcStep	
Dependent Stretch		
Adjustment to Stretch	((fix(pcRepeatY) - 1) * pcStepY)	

6. Click *OK*.

You have completed the second parameter.

Using Expressions

You just used a SKILL expression for the number of repetitions. You should examine it now so that you understand how expressions work. This expression is typical of the expressions used in parameterized cells.

The expression `fix(width-1)/pcStep` contains the following elements:

- `fix` is a SKILL function that converts nonintegers to integers. `fix` rounds down. The number of repetitions must be an integer because you want to repeat whole objects.
- `width-1` lets you control the area within which you want to fit the repeat group. You created the stretch parameter named `width` that defines the width of the p-diffusion. As the diffusion stretches up and the contacts

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repeat within it, you want the final contact to be spaced away from the edge of the diffusion by at least 1 micron. So the available space for the contacts is width minus 1.

- `pcStep` is a variable known to the Pcell Compiler, and it represents the stepping distance for this repetition parameter. You defined the stepping distance as 2.

The entire expression means that the number of repetitions will be an integer equal to 1 micron less than the value of `width` (the stretch parameter), divided by the stepping distance (2).

You can use the CIW to simulate how the Pcell program evaluates the expression. You are using the CIW only to test the expression; none of the pcell variables are affected.

1. In the CIW, type `width = 5.5` and press `Return`.

You see 5.5 in the output region.

2. In the CIW, type `pcStep = 2` and press `Return`.

3. In the CIW, type `(width-1)/pcStep` and press `Return`.

You see 2.25 in the output region. The number of repetitions must evaluate to an integer, however, so you need to add the `fix` function to round the value down to the nearest integer.

4. In the output region of the CIW, click `(width-1)/pcStep`.

The entire line is highlighted in black and appears in the input region of the CIW.

5. At the beginning of the line in the input region, click.

The blinking text insertion bar appears in front of the expression.

6. Type `fix`.

The CIW input region now contains the complete expression:

```
fix(width-1)/pcStep.
```

7. Press Return.

You see 2 in the output region. If the value of the stretch parameter were set to 5.5, the contacts would be repeated 2 times.

There is no decimal point because the number is now an integer.

Creating a Repeat Group for Gates

In this section, you create a second repetition parameter so you can repeat the poly1 gate along the X axis.

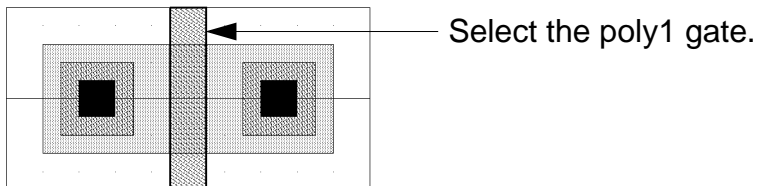
In the following steps, you will enter an expression that refers to a parameter named *length*. You will create that parameter in the next section, “Defining a Stretch Line for Gate Length.” It is quite common for stretch lines and repeat groups to refer to each other in this way. You can do this because the Pcell Compiler evaluates all the parameters when you compile, not before. Therefore, it does not matter which parameter you create first.

1. In the mypcell window, choose *Pcell – Repetition – Repeat in X*.

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2. To select the poly1 gate and open the Repeat in X form, double-click.



The Repeat in X form appears. The form contains the definitions you typed for the last repeat group.

3. Change *Stepping Distance* to `length+1`.

This time you use an expression to control the stepping distance. As noted, you later create the `length` parameter that stretches the transistor along its length, with the reference dimension set to the width of the poly1 gate.

The expression you enter here, `length+1`, defines the distance between the gates as the value of the poly1 gate (the stretch reference dimension) plus 1 micron. This way the gates will be spaced 1 micron apart no matter how much you stretch the poly1 gate with the `length` parameter.

4. Change *Number of Repetitions* to `gate`.

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The word `gate` is now a logical name (variable) for the number of repetitions. When you place an instance of the pcell, the Instance form includes a prompt named `gate` to let you type the number of gates.

Repeat in X		
OK	Cancel	Help
Stepping Distance	length+1	
Number of Repetitions	gate	
Dependent Stretch		
Adjustment to Stretch	((fix(pcRepeatX) - 1) * pcStepX)	

5. Click *OK*.

You have completed the third parameter.

Creating a Stretch Line for Gate Length

In this section, you use *Stretch in X* to create a stretch parameter to stretch the transistor along the X axis. Objects intersected by the stretch line (the poly1 gate, the p-diffusion, and the nwell surrounding the transistor) will stretch horizontally from the line.

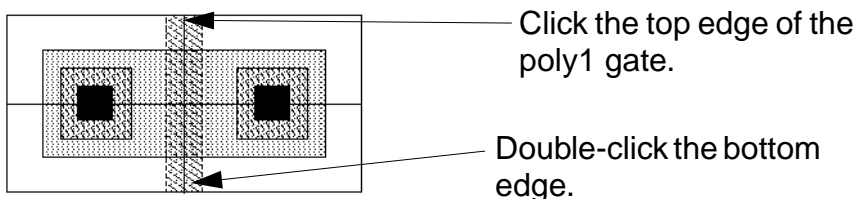
Unlike the repeating contacts you created previously, this time you want the poly1 shape to both repeat and stretch. So this time you set the Stretch form to allow any objects that repeat along the X axis (the poly1 gate) to stretch.

1. In the mypcell window, choose *Pcell – Stretch – Stretch in X*.
2. To create a vertical stretch line down the middle of the poly1 gate, do the following:

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- ❑ Click the top edge of the poly1 gate.
- ❑ Move the cursor to the bottom edge.
- ❑ Double-click.



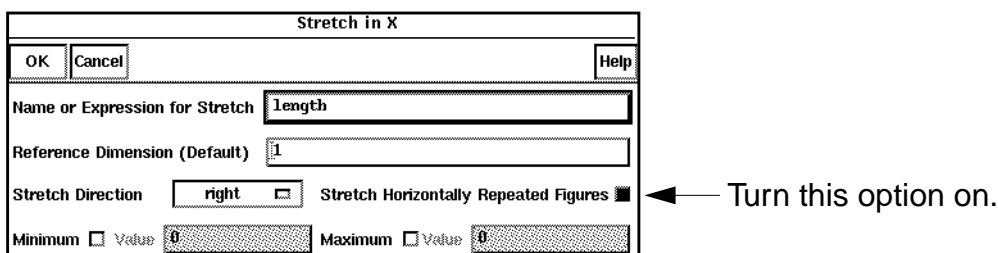
The Stretch in X form appears.

3. Type `length` in the *Name or Expression for Stretch* field.

The word `length` is now a logical name for the stretch. When you place an instance, you are prompted to enter a value for `length`.

4. Click the button next to *Stretch Horizontally Repeated Figures*.

Turning this field on lets you both stretch and repeat the poly1 gate.



Notice that *Stretch Direction* is set to *right*. Objects intersected by the stretch line will stretch to the right.

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Also, *Reference Dimension (Default)* is set to 1, by default. The value comes from the smallest dimension crossed by the stretch line, in this case the length of the poly1 gate.

5. To set the stretch parameter and close the form, click *OK*.

You have completed the fourth parameter.

Compiling and Testing the Pcell

Now you have completed enough parameters to test the pcell. You will find that not all the parameters are correct, but this is also typical. Creating pcells is often an iterative process. You compile, test, then modify. You can easily go back and add parameters or make corrections.

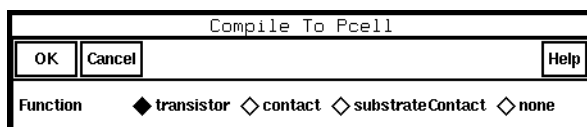
In this section, you learn to

- Compile the pcell.
- Place an instance of the pcell.
- Evaluate the resulting instance to see what parameters you need to add or change.

Compiling the Pcell

1. In the mypcell window, choose *Pcell – Compile – To Pcell*.

The Compile To Pcell form appears. The first time you compile a parameterized cell, you need to classify it as transistor, contact, substrate contact, or none. The Virtuoso® compactor uses these classifications.



2. Click *OK*.

You see the following messages in the CIW.

```
Compiling Parameterized Cell . . .
```

```
Compilation complete
```

If the output in the CIW shows you had any errors, use the *Modify* command on each parameter menu to modify the parameters so they are defined as described in the previous sections. Then recompile the pcell.

Testing the Pcell

1. In the CIW, choose *File – Open*.

The Open File form appears.

2. In the Open File form, choose *pcelltest* from the *Cell Names* browser list.

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3. Click *OK*.

The pcelltest cellview window is empty except for a large rectangle. The rectangle forces the window to be large enough to place several variations of the pcell as you test it.

4. To place the compiled pcell in the pcelltest window, open the Create Instance form by pressing *i* in the pcelltest window.

The Create Instance form appears.

The screenshot shows the 'Create Instance' dialog box with the following fields and values:

- Library: pCells
- Cell: mypcell
- View: layout
- Names: I1
- Rows: 1
- Columns: 1
- Delta X: 10
- Delta Y: 5
- Mag: 1

Buttons include: Hide, Cancel, Defaults, Help, Rotate, Sideways, Upsidedown, and Browse.

5. In the Create Instance form, type `mypcell` in the *Cell* field.

6. Press *Tab*.

The parameters of `mypcell` are displayed at the bottom of the Create Instance form. The values shown are the defaults.

Note: The parameters might appear in a different order than is shown in the following example. Make sure you check the parameter name to the left

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before typing in the values given in step 7 through step 9.

7. Change *length* to 2.
8. Change *width* to 5.
9. Change *gate* to 2.

Create Instance

Hide Cancel Defaults Help

Library pCells

Cell mypcell Browse

View layout

Names I1

Rows 1 Columns 1

Delta X 10 Delta Y 5 Mag 1

Rotate Sideways Upsidedown

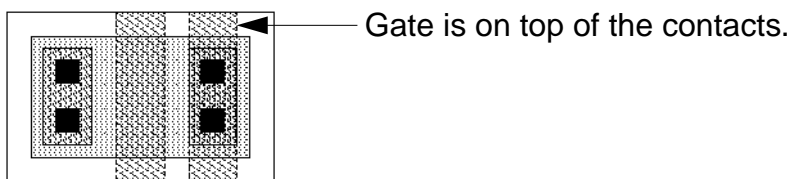
length 2

width 5

gate 2

10. To place the instance, click in the pcelltest window.

The instance appears. It is not correct; the gate is on top of the contacts.



Evaluating the Results

The pcell is not correct. First, review how you set the parameters when you placed the instance.

- The `width` parameter set the transistor width to 5 microns.
- The `repetition` parameter for the contacts repeated the contacts based on the width.
- The `length` parameter stretched the gate length to 2 microns.
- The `gate` parameter created two gates 1 micron apart.

The problem is that you haven't yet defined everything the pcell needs to create a correct design.

The `length` parameter stretched the `poly1` gate, the p-diffusion, and the nwell layer each by 1 micron, but that did not leave enough room for the extra `poly1` gate created by the `gate` parameter.

You need to find a way to do the following:

- Stretch the p-diffusion and nwell to make room for any extra gates.
- Move the contacts and metal on the right side out of the way.

Correcting the Pcell

You can correct the pcell by adding a parameter called a *dependent stretch line*. A dependent stretch line takes all its values from a repeat group. You can

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create a dependent stretch line to tell the p-diffusion and nwell shapes to stretch only if the repeat group controlled by the `gate` parameter adds extra gates.

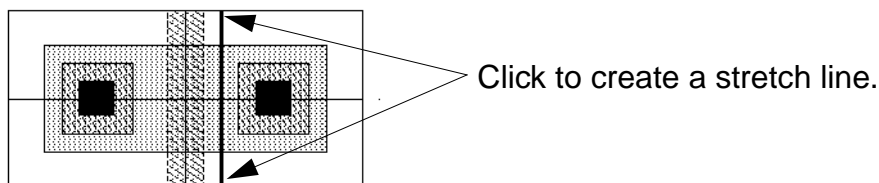
In this section, you learn to

- Create a new stretch line.
- Modify the repeat group to identify the new stretch line as dependent.
- Recompile the pcell.

Creating the Dependent Stretch Line

Return to the pcell supermaster to add a stretch line to stretch the p-diffusion and nwell rectangles.

1. To see the mypcell window, move the pcelltest window out of the way.
You can drag the pcelltest window partially off the screen, if necessary.
2. In the mypcell window, choose *Pcell – Stretch – Stretch in X*.
3. To create a second vertical stretch line, click as shown.



Because the line intersects only p-diffusion and nwell, only these objects will stretch. This means that the contact and metal1 shapes to the right of the stretch line will move to the right, rather than stretch.

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4. To complete the line, double-click.

The Stretch in X form appears.

5. Type `diff_stretch` in the *Name or Expression for Stretch* field.

Stretch Direction is set to *right*, so the objects will stretch to the right.

Reference Dimension (Default) is set to its default. This value is not used because in the next section you set this parameter to be a dependent stretch line. The layout editor calculates the amount to stretch based on the size of the repeat group.

Stretch in X

OK Cancel Help

Name or Expression for Stretch `diff_stretch`

Reference Dimension (Default) 8

Stretch Direction right Stretch Horizontally Repeated Figures

Minimum Value 0 Maximum Value 0

6. Click *OK*.

Modifying the Gate Repeat Group

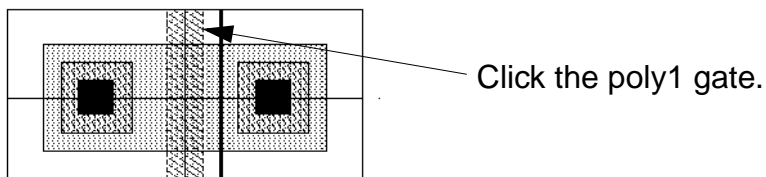
Now that you have created the stretch line, you must make it a dependent stretch line. To do so, you modify the repeat group to tell it that a stretch line depends on that repetition parameter. The amount to stretch the diffusion is determined by the number of gates, so you modify the *gate* repetition parameter.

1. In the mypcell window, choose *Pcell – Repetition – Modify*.

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2. To identify the repeat group, click the poly1 gate.



3. To indicate that you don't want to add shapes to the group, double-click anywhere in the window.

The Modify Repeat in X form appears.

4. Type `diff_stretch` in the *Dependent Stretch* field.

This makes the `diff_stretch` parameter dependent on the repetition parameter.

Modify Repeat in X		
OK	Cancel	Help
Stepping Distance	<input type="text" value="length+1"/>	
Number of Repetitions	<input type="text" value="gate"/>	
Dependent Stretch	<input type="text" value="diff_stretch"/>	
Adjustment to Stretch	<input type="text" value="((fix(pcRepeatX) - 1) * pcStepX)"/>	

5. Click *OK*.

Recompiling the Pcell

Recompile the pcell and see if your changes correct the error.

1. In the mypcell window, choose *Pcell – Compile – To Pcell*.

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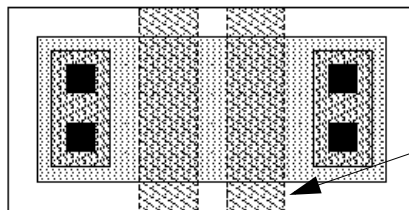
This time you are not asked for a classification.

2. Move the pcelltest window so you can see its contents.

The instance still looks wrong. Recompiling the pcell did not automatically redraw the pcelltest window.

3. To redraw pcelltest, press `Control-r`.

The instance now looks correct.

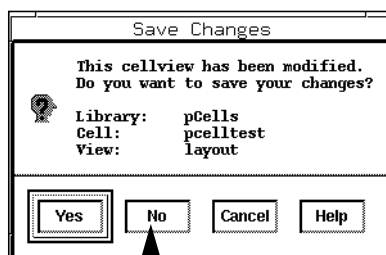


The gate no longer covers the contacts.

4. To close pcelltest, choose *Window – Close*.

The Save Changes form appears. You don't need to save the results of the test.

5. Click *No*.



Click *No*.

Summarizing and Saving the Pcell

You can use the *Summarize* command to display all the parameters you defined. You can do this after you have created all parameters, or as you create a pcell, to check syntax as you go.

In this section, you learn to

- Summarize the parameters.
- Save the parameters to a file for future reference.
- Save the pcell.

Summarizing Parameters

1. In the mypcell window, choose *Pcell – Parameters – Summarize*.

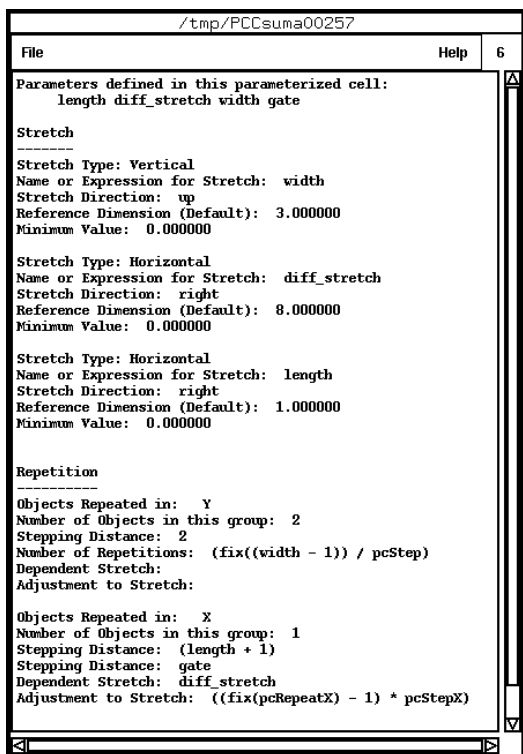
A text file window appears, showing all the parameters of the pcell. The file being displayed is a temporary file.

Note: The order in which the parameters are listed in the following

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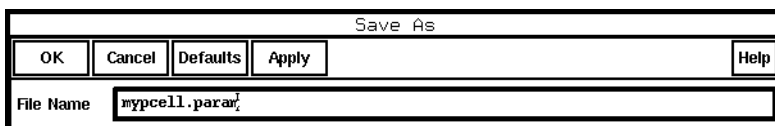
example might be different from what you see.



2. To save the file to disk, choose *File – Save As*.

The Save As form appears.

3. Type `mypcell.param`.



4. Click *OK*.

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The system creates a text file called `mypcell.param` in your current working directory (`cell_design`).

5. In the text file window, choose *File – Close Window*.

The text window closes.

Saving the Pcell

1. To save mypcell, choose *Design – Save*.
2. Choose *Window – Close*.

Summary

In this chapter you learned to create and modify pcells. Specifically, you

- Created stretch lines.
- Created repeat groups.
- Compiled and tested a pcell.
- Added new parameters.
- Modified parameters.
- Summarized parameters and saved them to a file.
- Saved the pcell.